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INCREASING FODDER BEET PRODUCTIVITY BY INTERCROPPING WITH SOME FIELD CROPS

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ABSTRACT

A two-year study was carried out at Sids Agricultural Experiments and Research Station, A.R.C., Beni - Sweif Governorate, Egypt during 2009/2010 and 2010/2011 winter seasons to investigate the possibility of increasing fodder beet productivity and net return unit^{-1} area by intercropping fodder beet with some field crops for encouraging Egyptian farmers to grow fodder beet in their fields. Fodder beet plants were grown in one row on all ridges (60 cm width) with intercropping barley, wheat or faba bean plants on the other side of the first and third ridges. Also, fodder beet plants were grown in both sides of beds (120 cm width) with intercropping barley, wheat or faba bean plants in the middle of all fodder beet beds in addition to sole plantings of all the tested field crops. A split plot design in randomized complete block design in four replications was used. The results can be summarized as follows:

Intercropping barley, wheat and faba bean with fodder beet led to decrease in yields of all tested field crops in comparison with sole plantings of these crops. As a result of intercropping, root yield of fodder beet was decreased by 18.44, 17.10 and 17.78% in the 1st and 2nd seasons and the combined analysis, respectively, as compared with sole fodder beet. Growing fodder beet on ridges (60 cm width) under intercropping and sole cultures had higher values of all the studied traits of fodder beet than those gown on beds (120 cm width) , whereas, yields of barley, wheat and faba bean were not affected. All the studied traits of all the tested crops were not affected by the interaction between cropping systems and ridge width.

For competitive relationships, intercropping fodder beet with barley, wheat and faba bean increased land equivalent ratio (LER) as compared to sole fodder beet. LER ranged from 1.05 to 1.22 with an average of 1.11. All values of relative crowding coefficient (K) exceeded 1.00. K of barley, wheat or faba bean was higher than those of fodder beet. With respect to dominance analysis, barley, wheat or faba bean plants are dominant components and fodder beet plants are dominated components.

Intercropping fodder beet with barley, wheat and faba bean increased total and net returns as compared with sole fodder beet. Net return of intercropping fodder beet with barley, wheat and faba bean was 8903, 9015 and 10362 L.E. faddan^{-1} as compared with sole fodder beet (9605 L.E.). Growing fodder beet with faba bean plants on ridges (60 cm width) gave the highest financial return as compared with sole fodder beet. This study concluded that growing fodder beet plants in one row on all ridges (60 cm width) with intercropping faba bean plants on the other side of the first and third ridges gave high yield of fodder beet.

(Key words: Intercropping, fodder beet, barley, wheat, faba bean, competitive relationships, financial return)

It could be concluded that although intercropping pattern resulted in adverse effects on intercropped fodder beet yield and its attributes, however, Egyptian farmers could achieve an increase in their income by about 50% as compared to sole fodder beet when growing fodder beet with faba bean on ridges (60 cm width).This paper emphasizes there is a critical need for several scientific studies including morphological and physiological characteristics to increase the productivity of intercropped fodder beet wit minimizing the adverse effects of shading intercropped barley, wheat or faba bean crops which reflects positively on financial return of fodder beet's farmers.

INTRODUCTION

Egyptian forage crops production is very important for successful animal production which is severely limited by marked seasonal feed deficits. These crops mainly fresh berseem during winter and as hay during summer represents about 60% of available local feed. Summer forage crops such as Darawa, millet, sorghum, cowpea, Sudan grass, and corn silage represent about 5% of the available local feed. Alfalfa which provides feed all the year around represents about 5% of the available local feed (El-Nahrawy, 2011).

Accordingly, there is a shortage in green forage supply during the summer season. Fodder beet (*Beta vulgaris* L.) is cultivated as an annual winter crop. It is one of the promising forage crops which is recommended as a good source for energy for dairy cows (Gaivoronskii, 1981). It offers a higher yield potential than any other "arable" fodder crop.

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The above and below growth parts (leaves and roots) are used to feed the animals but, the main fodder is tuberous roots (Ibrahim, 2005).The roots have an excellent feed quality and they are very palatable to ruminant stock. The leaf can be utilized if required to boost the total fodder output even further (Turk, 2010). Consequently, its cultivation may help in overcoming the problem of animal feeding in summer season; but the cultivated area is very limited and expects to be devoted to the cultivation of strategic food crops such as wheat (*Triticum aestivum* L.) and faba bean (*Vicia faba* L.) during winter season.

Also, cultivated barley (*Hordeum vulgare* L.) ranks fourth among the cereals in worldwide production. It is commonly used for animal feed and malting production (Finocchiaro *et al*., 2008). It is mostly grown by resource-poor farmers in marginal environments, receiving modest or no inputs in Egypt. Moreover, Al-Karaki and Al-Hashimi (2012) mentioned that barley is the most commonly grown forage, because it usually gives the best yield of nutrients. They recorded the highest values in green fresh yields in cowpea followed by barley, alfalfa, sorghum, and wheat, respectively. However, the differences between the crops barley, cowpea, and alfalfa in green fresh fodder yields were not significant.

In view of the previous, it was necessary to find a modern agricultural technical practice in Egypt for the cultivation of this forage crop in the Nile Valley areas. Egyptian efforts are being focused on measures that lead to a significant increase in crop production unit^{-1} area. The successful implementation of two agricultural strategies in the 1980s and the 1990s had a positive economic impact at both macro and sector levels. Several different cropping patterns are followed in the Nile Valley and Delta areas, depending on the soil type and crops. Farmers are very responsive to technology transfer, extension activities and price incentives. Intercropping is recommended to increase total agriculture products in Egypt (Metwally, 1999). But fodder beet yield was reduced by intercropping (Abdel-Gwad *et al.*, 2008). However, intercropping can be used as a tool to improve competitive ability of a canopy with good suppressive characteristics (Rezvani *et al*., 2011).

The objective of this study was to investigate the possibility of increasing fodder beet productivity and net return unit^{-1} area by intercropping with wheat, faba bean or barley for encouraging Egyptian farmers to grow fodder beet.

MATERIALS AND METHODS

Two experiments were carried out at Sids Agricultural Experiments and Research Station, A.R.C., Beni - Sweif Governorate (Lat. 29° 12' N, Long. 31° 01' E, 32 m a.s.l.), Egypt during 2009/2010 and 2010/2011 winter seasons to investigate the possibility of increasing fodder beet productivity and net return unit^{-1} area by intercropping with some field crops for encouraging Egyptian farmers to grow fodder beet. Fodder beet variety 'Voroshenger' and three different field crops (barley variety 'Giza 29', wheat variety 'Beni – Sweif 1'and faba bean variety 'Misr 1') were used. Fig. 1 shows the treatments which were the combinations among cropping systems and ridge width as follows:

1. Planting fodder beet on one side of the ridges (60 cm width) and planting one barley row on the other side of the fodder beet on the first and third ridge (100% fodder beet : 25% barley)
2. Planting fodder beet on one side of the ridges (60 cm width) and planting one wheat row on the other side of the fodder beet on the first and third ridge (100% fodder beet : 25% wheat)
3. Planting fodder beet on one side of the ridges (60 cm width) and planting one faba bean row on the other side of the fodder beet first and third ridge (100% fodder beet: 25% faba bean)
4. Planting fodder beet on both sides of the beds (120 cm width) and planting one barley row on middle of all fodder beet beds (100% fodder beet : 25% barley)
5. Planting fodder beet on both sides of the beds (120 cm width) and planting one wheat row on middle of all fodder beet beds (100% fodder beet : 25% wheat)
6. Planting fodder beet on both sides of the beds (120 cm width) and planting one faba bean row on middle of all fodder beet beds (100% fodder beet: 25% faba bean)
7. Sole fodder beet: Planting fodder beet on one side of the ridges (60 cm width)
8. Sole barley: Planting two barley rows on both sides of the ridges (60 cm width)

9. Sole wheat: Planting two wheat rows on both sides of the ridges (60 cm width)

10. Sole faba bean: Planting two faba bean rows on both sides of the ridges (60 cm width)

Varieties of fodder beet, barley, wheat and faba bean provided by forage, barley, wheat and food legumes Res. Dept., Field Crops Res. Inst., ARC, respectively. The preceding summer crop was maize in both seasons. Normal cultural practices for growing all crops were used as recommended in the area. Fodder beet solid and in all intercropped crops was sown at the same date on 29th and 20th October at 2009/2010 and 2010/2011 seasons, respectively.

Fodder beet plants were thinned to one plant hill^{-1} at 20 cm between hills under intercropping and sole cultures. Barley and wheat grains were drilled in one row in intercropping cultures and in two rows in sole cultures.

Faba bean plants were thinned to two plants hill^{-1} at 25 cm between hills. Recommended solid cultures of all the tested crops were used to estimate the competitive relationships. A split plot design in randomized complete block design in four replications was used. Cropping systems (intercropping and sole) were randomly assigned to the main plots, ridge width was allocated in sub plots. The area of sub-plot was 14.4 m^2, it consisted of 8 ridges, and each ridge was 3.0 m in length and 0.6 m in width.

Yield and its attributes

At harvest, root length, diameter (cm) and root weight plant^{-1} were measured on ten guarded plants from each plot, whereas, root yields (ton faddan^{-1}) were recorded on the basis of experimental plot area by harvesting all fodder beet plants of each plot. Grain yields of barley and wheat (ardab faddan^{-1}), as well as, seed yield of faba bean (ardab faddan^{-1}) were recorded on the basis of experimental plot area.

Competitive relationships

Land equivalent ratio (LER)

LER defined as the ratio of area needed under sole cropping to one of intercropping at the same management level to produce an equivalent yield (Mead and Willey, 1980). It is calculated as follows:

$$LER = (Y_{ab} / Y_{aa}) + (Y_{ba} / Y_{bb})$$

Where Y_{aa} = Pure stand yield of crop a (fodder beet)
Y_{bb} = Pure stand yield of crop b (barley, wheat or faba bean)
Y_{ab} = Intercrop yield of crop a (fodder beet)
Y_{ba} = Intercrop yield of crop b (barley, wheat or faba bean)

Relative crowding coefficient (K)

Relative crowding coefficient estimates the relative dominance of one species over the other in the intercropping system (Banik *et al*., 2006).It is calculated as follows: $K = K_a \times K_b$

$$K_a = Y_{ab} \times Z_{ba} / [(Y_{aa} - Y_{ab}) \times Z_{ab}]$$
$$K_b = Y_{ba} \times Z_{ab} / [(Y_{bb} - Y_{ba}) \times Z_{ba}]$$

Where Y_{aa} = Pure stand yield of crop a (fodder beet)
Y_{bb} = Pure stand yield of crop b (barley, wheat or faba bean)
Y_{ab} = Intercrop yield of crop a (fodder beet)
Y_{ba} = Intercrop yield of crop b (barley, wheat or faba bean)
Z_{ab} = The respective proportion of crop a in the intercropping system (fodder beet)
Z_{ba} = The respective proportion of crop b in the intercropping system (barley, wheat or faba bean)

Aggressivity (Agg)

Aggressivity represents a simple measure of how much the relative yield increase in one crop is greater than the other in an intercropping system (Ghosh *et al*., 2006).

$$A_{ab} = [Y_{ab} / (Y_{aa} \times Z_{ab})] - [Y_{ba} / (Y_{bb} \times Z_{ba})]$$
$$A_{ba} = [Y_{ba} / (Y_{bb} \times Z_{ba})] - [Y_{ab} / (Y_{aa} \times Z_{ab})]$$

Where Y_{aa} = Pure stand yield of crop a (fodder beet)
Y_{bb} = Pure stand yield of crop b (barely, wheat or faba bean)
Y_{ab} = Intercrop yield of crop a (fodder beet)
Y_{ba} = Intercrop yield of crop b (barley, wheat or faba bean)
Z_{ab} = The respective proportion of crop a in the intercropping system (fodder beet)
Z_{ba} = The respective proportion of crop b in the intercropping system (barley, wheat or faba bean)

Farmer's benefit

It was calculated by determining the total costs and net return of intercropping culture as compared to recommended sole planting of fodder beet according to Metwally *et al.* (2009).

1. Total return of intercropping cultures = Price of fodder beet yield + price of barley, wheat or faba bean yield (L.E.)

To calculate the total return, the average of barley, wheat and faba bean prices presented by Anonymous (2013) Agricultural Statistics was used, while the average of fodder beet yield price presented by market price in 2011 season.

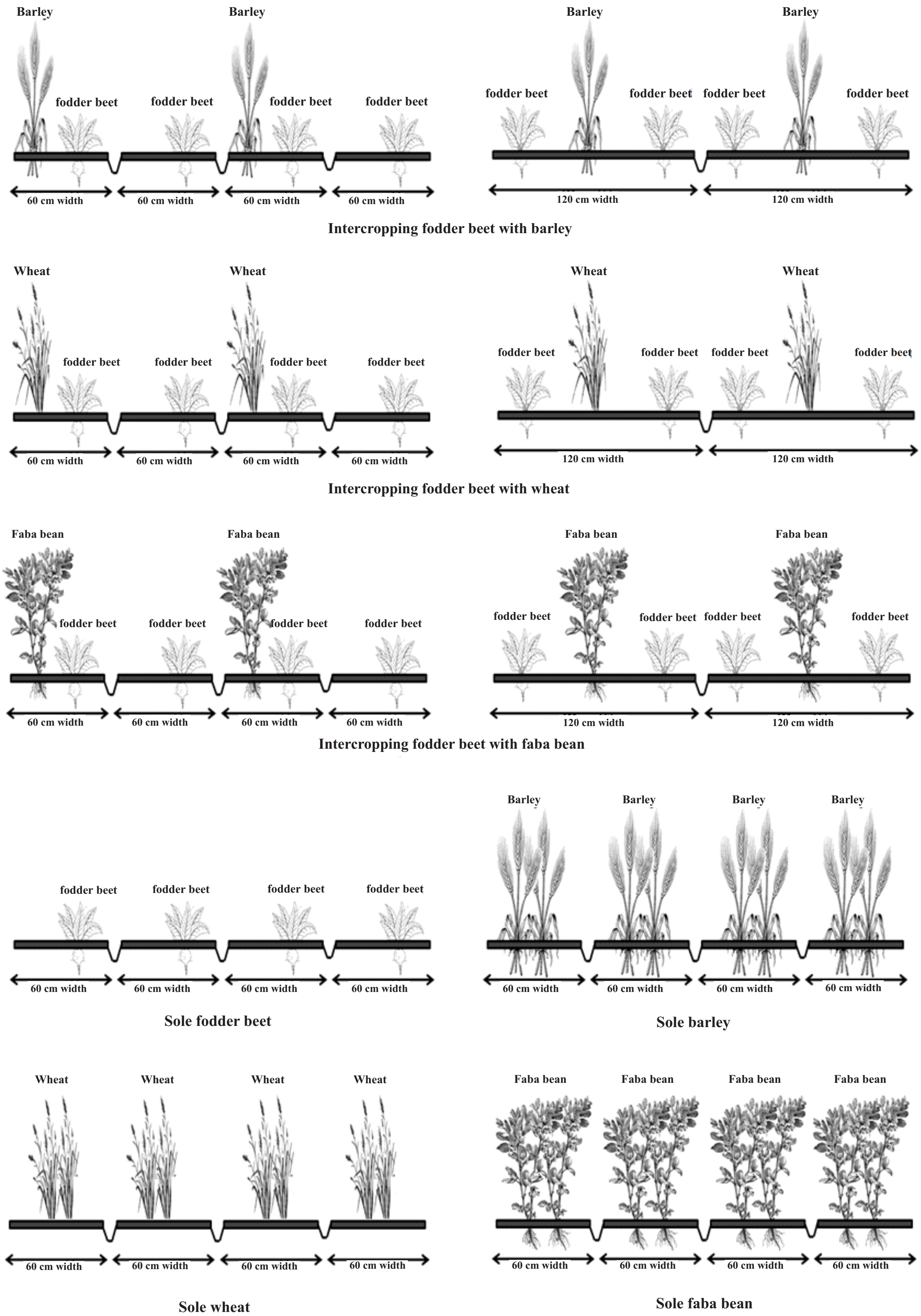

Fig. 1. Intercropping barley, wheat and faba bean with fodder beet and sole cultures

2. Net return/fad = Total return – (fixed cost of fodder beet + variable costs of barley, wheat and faba bean according to intercropping pattern).

Statistical manipulation

Analysis of variance of the obtained results of each season was performed. The homogeneity test was conducted of error mean squares and accordingly, the combined analysis of the two experimental seasons was carried out. The measured variables were analyzed by ANOVA using MSTATC statistical package (Freed, 1991). Mean comparisons were done using least significant differences (LSD) method at 5 % level of probability to compare differences between the means (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Yield and its attributes

Cropping systems

Intercropping fodder beet with barley, wheat or faba bean significantly affected root length and diameter, root weight plant^{-1} and root yield fad^{-1} in the two growing seasons and the combined analysis (Table 1). Intercropping barley, wheat or faba bean with fodder beet decreased root length and diameter, root weight plant^{-1} and root yield fad^{-1} in comparison with sole fodder beet. As a result of intercropping, root weight plant^{-1} and root yield fad^{-1} were decreased by 11.97 and 18.44% in the 1st season, 8.95 and 17.10% in the 2nd season, 10.86 and 17.78% in the combined analysis, respectively, as compared with sole fodder beet.

Data revealed that intercropping wheat or barley with fodder beet had a significant negative impact *($P \leqslant 0.05$)* on fodder beet plants as compared with those obtained by intercropping with faba bean. Obviously, intercropping legumes with fodder beet had lower adverse effects on yield of intercropped fodder beet than cereal crops under intercropping conditions. Legumes are plants that bear their seeds in pods. They differ markedly from grasses, cereals and other non-legume crops. Legumes in close association with nitrophilous crops have increased crop production (Waghmare and Singh, 1984). Because of their ability to biological nitrogen fixation, legumes are largely involved in nitrogen facilitation and nitrogen dynamic in the plant community and in agrosystems (Hauggaard-Nielsen and Jensen, 2005 and Fustec *et al*., 2010). These results are in accordance with those obtained by Abdel-Gwad *et al.* (2008) they showed that root yield of fodder beet were reduced significantly by intercropping with wheat as compared with sole fodder beet.

Also, intercropping barley, wheat or faba bean with fodder beet significantly affected grain yields of barley and wheat, as well as, seed yield of faba bean in the two growing seasons and the combined analysis (Table 1). Intercropping barley with fodder beet decreased grain yield fad^{-1} by 70.40% in the 1st season, 71.13% in the 2nd season and 70.81% in the combined analysis. Also, intercropping wheat with fodder beet decreased grain yield fad^{-1} by 69.56% in the 1st season, 70.12% in the 2nd season and 69.86% in the combined analysis. Moreover, intercropping faba bean with fodder beet decreased seed yield fad^{-1} by 67.76% in the 1st season, 68.47% in the 2nd season and 68.21% in the combined analysis.

It is clear that decreasing plant population density of barley, wheat and faba bean to 25% of sole plantings of these crops decreased *($P \leqslant 0.05$)* grain and seed yields unit^{-1} area for these crops. The reduction in grain yield of wheat fad^{-1} was quite expected as a result of decreasing stand of intercropped wheat as reported by Abdel-Gwad *et al.* (2008). Similar results were obtained by Abou-Elela and Gadallah (2012) they indicated that seed yield of faba bean faddan^{-1} was reduced significantly by intercropping with fodder beet as compared with sole faba bean.

Ridge width

All the studied traits of fodder beet were significantly affected by ridge width, except root length and diameter in the 1st season only, while, yields of barley, wheat and faba bean were not affected in both seasons (Table 1). Growing fodder beet on ridges (60 cm width) under intercropping and sole cultures had higher values of all the studied traits of fodder beet than those grown on beds (120 cm width), relatively. Growing fodder beet on ridges increased fodder beet weight plant^{-1} and fodder beet yield fad^{-1} by 0.75 and 1.16% in the 1st season, 0.78

and 1.26% in the 2nd season and 0.76 and 1.21% in the combined analysis, respectively, in comparison with that gown on beds under intercropping and sole cultures. Obviously, decreasing ridge width from 120 to 60 cm slightly increased *($P \leqslant 0.05$)* fodder beet productivity unit^{-1} area. These results may be due to competition for basic resources between fodder beet and barley, wheat or faba bean was not pronounced between both patterns.

Also, grain yields of barley and wheat, as well as, seed yield of faba bean were not affected by ridge width in the two growing seasons and the combined analysis (Table 1). These results are in harmony with those obtained by El-Shereif (2013) who demonstrated that intercropped barley, wheat or faba bean yields fad^{-1} were not affected by ridge width.

Interaction between cropping systems and ridge width

With respect to response of cropping systems to ridge width, all the studied traits of all the tested crops were not affected (Table1). Data showed that each of these two factors act independently on all the studied traits of all the tested crops meaning that cropping systems responded similarly *($P > 0.05$)* to ridge width. These results are in harmony with those obtained by Mack (1979) who compared 6, 12, 18, and 24-inch rows combined with three seeding rates of table beet. There was no interaction of row spacing and within-row seeding rate on yields.

Also, grain yields of barley and wheat, as well as, seed yield of faba bean were not affected by the interaction between cropping systems and ridge width in the two growing seasons and the combined analysis (Table 1). Obviously, the insignificant interaction between cropping systems and ridge width shows that cropping systems responded similarly ($P > 0.05$) to ridge width for these traits.

Competitive relationships
Land Equivalent Ratio (LER)

Relative yields of fodder beet and barley, wheat or faba bean were affected significantly by the cropping systems in the two growing seasons and the combined analysis (Table 2). Intercropping fodder beet with faba bean had higher values of relative yields of fodder beet and intercrops as compared with intercropping fodder beet with barley or wheat. These data may be due to faba bean plants (as legume crop) have ability to biological nitrogen fixation, legumes are largely involved in nitrogen facilitation and nitrogen dynamic in the plant community and in agrosystems.

Relative yield of fodder beet was significantly affected by ridge width, whereas, relative yield of intercrops was not affected in the two growing seasons and the combined analysis (Table 2) Growing fodder beet in ridges (60 cm width) had higher relative yield of fodder beet than growing fodder beet in beds (120 cm width) under both intercropping and sole. Relative yields of fodder beet and barley, wheat or faba bean were significantly affected by the interaction between cropping systems and ridge width in the two growing seasons and the combined analysis except relative yield of fodder beet in the 1st season only (Table 2). Intercropping fodder beet with faba bean on ridges (60 cm width) had higher values of relative yields of both crops, whereas, intercropping fodder beet with wheat had the lowest relative yield of both crops.

The values of land equivalent ratio (LER) were estimated by using data of recommended sole cultures of all crops. LER was affected significantly by the cropping systems in the two growing seasons and the combined analysis (Table 2). In general, intercropping fodder beet with barley, wheat and faba bean increased LER as compared to sole fodder beet (Table 2). It ranged from 1.05 (by intercropping fodder beet with wheat on beds, 120 cm width) to 1.22 (by intercropping fodder beet with faba bean on ridges, 60 cm width) with an average of 1.11. The advantage of the highest LER by intercropping fodder beet with faba bean over the others could be due to faba bean plants (as legume crop) have ability to biological nitrogen fixation, legumes are largely involved in nitrogen facilitation and nitrogen dynamic in the plant community and in agrosystems.

It is clear that plant population density of fodder beet and barley, wheat or faba bean played a major role in increasing productivity unit^{-1} area under intercropping culture where it reached 100 and 25% of sole plantings, respectively. Similar results were obtained by Abdel-Gwad *et al.* (2008), they found that intercropping fodder beet with wheat increased land equivalent ratio in the average of both seasons by 1.21, 1.07, 1.15 and 1.22, when adding 70, 90, 110 and 130 kg N fertilizer fad^{-1} respectively. Also, Abou-Elela and Gadallah (2012) reported that LER was higher by intercropping faba bean with fodder beet than those of sole plantings.

With respect to ridge width, LER was significantly affected by ridge width in the two growing seasons and the combined analysis (Table 2). Growing fodder beet on ridges (60 cm width) gave the highest LER than those grown on beds (120 cm width) under both intercropping and sole cultures. LER was significantly affected by the interaction between cropping systems and ridge width in the two growing seasons and the combined analysis (Table 2). Intercropping fodder beet with faba bean on ridges (60 cm width) gave the highest LER in the two growing seasons and the combined analysis, whereas, the lowest LER was obtained by growing fodder beet with wheat in the two growing seasons and the combined analysis.

Relative crowding coefficient (K)

The relative dominance of one species over the other in this intercropping study was estimated by the use of relative crowding coefficient (K). When the value of relative crowding coefficient (K) is greater than 1.00, there is intercrop advantage; when K is equal to 1.00, there is no yield advantage; when K is lesser than 1.00, there is a disadvantage. Table 3 and Fig. 2 shows that all values of the total relative crowding coefficient (K) were exceeded 1.00. Relative crowding coefficient of barley, wheat or faba bean was higher than those of fodder beet. The lowest K was obtained from intercropping fodder beet with wheat on beds (120 cm width), whereas, intercropping fodder beet with faba bean on ridges (60 cm width) gave the highest K in the combined data across 2009/2010 and 2010/2011 seasons. These data suggest that canopy structures of fodder beet and faba bean which grown together on ridges (60 cm width) were suitable for intercropping which led to low competitive pressure of component crops, indicating that these species are complementary and suitable in mixture. These results are in accordance with those obtained by Abou-Elela and Gadallah (2012), they demonstrated that relative crowding coefficient of faba bean was higher than those of fodder beet.

Aggressivity (Agg)

Aggressivity determines the difference in competitive ability of the component crops in intercropping association. The positive sign indicates the dominant component and the negative sign indicates the dominated component. Higher numerical values of aggressiveness denote greater difference in competitive ability, as well as, bigger difference between actual and expected yield in both crops. The results indicate that the value of aggressivity of barley, wheat and faba bean was positive for all treatments, whereas, the values of aggressivity was negative for all intercropped fodder beet in the combined data across 2009/2010 and 2010/2011 seasons (Table 3 and Fig. 3). These data show that barley, wheat or faba bean are dominant component and fodder beet plants are dominated component.

In general, the highest negative values were obtained by growing fodder beet with barley or wheat plants, whereas, intercropping fodder beet with faba bean had the lowest negative values. These results clear that intercropping fodder beet with barley or wheat is more aggressive than intercropping fodder beet with faba bean.

Economic evaluation

Intercropping fodder beet with barley, wheat and faba bean increased total and net returns as compared with sole fodder beet (Table 4). Net return of intercropping fodder beet with barley, wheat and faba bean was 8903, 9015 and 10362.E. faddan^{-1} as compared with sole fodder beet (9605 L.E.). Intercropping fodder beet with faba bean in ridges (60 cm width) gave the highest financial value when using high population densities of both crops which reached 100 and 25% of sole fodder beet and faba bean, respectively. The study indicated that

Table 1. Effect of cropping systems, ridge width and their interactions on fodder beet yield and its attributes, as well as, yields of barley, wheat and faba bean during two seasons and the combined analysis

Characters / Treatments	Root length (cm)			Root diameter (cm)			Root weight plant^{-1} (kg)			Root yield of fodder beet (ton faddan^{-1})			Grain yield of barley (ardab faddan^{-1})			Grain yield of wheat (ardab faddan^{-1})			Seed yield of faba bean (ardab faddan^{-1})		
	60 cm	120 cm	Mean	60 cm	120 cm	Mean	60 cm	120 cm	Mean	60 cm	120 cm	Mean	60 cm	120 cm	Mean	60 cm	120 cm	Mean	60 cm	120 cm	Mean
First season 2009/2010																					
Fodder beet + barley	27.75	26.00	26.87	13.25	12.75	13.00	1.25	1.22	1.23	38.41	37.28	37.84	4.85	5.03	4.94	--	--	--	--	--	--
Fodder beet + wheat	26.25	25.75	26.00	12.00	11.25	11.62	1.23	1.20	1.21	37.08	36.21	36.64	--	--	--	5.86	5.61	5.73	--	--	--
Fodder beet + faba bean	29.00	28.00	28.50	14.50	14.00	14.25	1.34	1.32	1.33	42.07	41.05	41.56	--	--	--	--	--	--	2.56	2.70	2.63
Average of intercropping	27.66	26.58	27.12	13.25	12.66	12.95	1.27	1.24	1.25	39.18	38.18	38.68	4.85	5.03	4.94	5.86	5.61	5.73	2.56	2.70	2.63
Sole planting	31.00	31.00	31.00	16.00	16.00	16.00	1.42	1.42	1.42	47.43	47.43	47.43	16.69	16.69	16.69	18.83	18.83	18.83	8.16	8.16	8.16
Average of ridge width	29.33	28.79	29.06	14.62	14.33	14.47	1.34	1.33	1.33	43.30	42.80	43.05	10.77	10.86	10.81	12.34	12.22	12.28	5.36	5.43	5.39
LSD at 0.05 Intercropping		1.93			3.13			0.03			2.17			3.26			3.16			0.70	
LSD at 0.05 Ridge width		-			-			0.01			0.58			-			-			-	
LSD at 0.05 Interaction		-			-			-			-			-			-			-	
Second season 2010/2011																					
Fodder beet + barley	26.25	25.50	25.87	13.40	12.60	13.00	1.21	1.19	1.20	38.25	37.50	37.87	4.60	4.96	4.78	--	--	--	--	--	--
Fodder beet + wheat	25.75	24.25	25.00	12.47	11.77	12.12	1.20	1.18	1.19	37.75	36.75	37.25	--	--	--	5.63	5.53	5.58	--	--	--
Fodder beet + faba bean	29.50	28.75	29.12	14.55	13.35	13.95	1.29	1.27	1.28	42.85	41.32	42.08	--	--	--	--	--	--	2.82	2.64	2.73
Average of intercropping	27.16	26.16	26.66	13.47	12.57	13.02	1.23	1.21	1.22	39.61	38.52	39.06	4.60	4.96	4.78	5.63	5.53	5.58	2.82	2.64	2.73
Sole planting	30.90	30.90	30.90	15.50	15.50	15.50	1.34	1.34	1.34	47.12	47.12	47.12	16.56	16.56	16.56	18.68	18.68	18.68	8.66	8.66	8.66
Average of ridge width	29.03	28.53	28.78	14.48	14.03	14.25	1.28	1.27	1.27	43.36	42.82	43.09	10.58	10.76	10.67	12.15	12.10	12.12	5.74	5.65	5.69
LSD at 0.05 Intercropping		2.60			1.75			0.01			1.53			1.66			0.69			1.30	
LSD at 0.05 Ridge width		0.59			0.58			0.01			0.49			-			-			-	
LSD at 0.05 Interaction		-			-			-			-			-			-			-	
Combined analysis																					
Fodder beet + barley	27.00	25.75	26.37	13.32	12.67	12.99	1.23	1.20	1.21	38.32	37.39	37.85	4.72	4.99	4.85	--	--	--	--	--	--
Fodder beet + wheat	26.00	25.00	25.50	12.23	11.51	11.87	1.21	1.19	1.20	37.41	36.48	36.94	--	--	--	5.74	5.57	5.65	--	--	--
Fodder beet + faba bean	29.25	28.37	28.81	14.52	13.67	14.09	1.31	1.29	1.30	42.46	41.18	41.82	--	--	--	--	--	--	2.68	2.66	2.67
Average of intercropping	27.41	26.37	26.89	13.35	12.61	12.98	1.25	1.22	1.23	39.39	38.35	38.87	4.72	4.99	4.85	5.74	5.57	5.65	2.68	2.66	2.67
Sole planting	30.95	30.95	30.95	15.75	15.75	15.75	1.38	1.38	1.38	47.28	47.28	47.28	16.62	16.62	16.62	18.75	18.75	18.75	8.40	8.40	8.40
Average of ridge width	29.18	28.66	28.92	14.55	14.18	14.36	1.31	1.30	1.30	43.33	42.81	43.07	10.67	10.80	10.73	12.24	12.16	12.20	5.54	5.53	5.53
LSD at 0.05 Intercropping		1.80			1.66			0.02			1.43			1.58			1.42			0.84	
LSD at 0.05 Ridge width		0.50			0.37			0.008			0.41			-			-			-	
LSD at 0.05 Interaction		-			-			-			-			-			-			-	

Table 2. Relative yields and land equivalent ratio as affected by cropping systems, ridge width and their interactions during the two seasons and the combined analysis

Characters / Treatments	Relative yield						LER		
	$L_{Fodder\ beet}$			$L_{intercrop}$					
	60 cm	120 cm	Mean	60 cm	120 cm	Mean	60 cm	120 cm	Mean
				First season 2009/2010					
Fodder beet + barley	0.80	0.78	**0.79**	0.29	0.30	**0.29**	1.09	1.08	**1.08**
Fodder beet + wheat	0.78	0.76	**0.77**	0.31	0.29	**0.30**	1.09	1.05	**1.07**
Fodder beet + faba bean	0.88	0.86	**0.87**	0.31	0.33	**0.32**	1.19	1.19	**1.19**
Average of intercropping	**0.82**	**0.80**	**0.81**	**0.30**	**0.30**	**0.30**	**1.12**	**1.10**	**1.11**
Sole planting	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
LSD at 0.05 Intercropping		**0.008**			**0.01**			**0.007**	
LSD at 0.05 Ridge width		**0.008**			**-**			**0.004**	
LSD at 0.05 Interaction		**-**			**0.01**			**0.010**	
				Second season 2010/2011					
Fodder beet + barley	0.81	0.79	**0.80**	0.27	0.29	**0.28**	1.08	1.08	**1.08**
Fodder beet + wheat	0.80	0.76	**0.78**	0.30	0.29	**0.29**	1.10	1.05	**1.07**
Fodder beet + faba bean	0.90	0.87	**0.88**	0.32	0.30	**0.31**	1.22	1.17	**1.19**
Average of intercropping	**0.82**	**0.80**	**0.81**	**0.29**	**0.29**	**0.29**	**1.13**	**1.10**	**1.11**
Sole planting	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
LSD at 0.05 Intercropping		**0.010**			**0.01**			**0.006**	
LSD at 0.05 Ridge width		**0.006**			**-**			**0.003**	
LSD at 0.05 Interaction		**0.010**			**0.01**			**0.008**	
				Combined analysis					
Fodder beet + barley	0.80	0.78	**0.79**	0.28	0.29	**0.28**	1.08	1.08	**1.08**
Fodder beet + wheat	0.79	0.76	**0.77**	0.30	0.29	**0.29**	1.09	1.05	**1.07**
Fodder beet + faba bean	0.89	0.86	**0.87**	0.31	0.31	**0.31**	1.20	1.18	**1.19**
Average of intercropping	**0.82**	**0.80**	**0.81**	**0.29**	**0.29**	**0.29**	**1.12**	**1.10**	**1.11**
Sole planting	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
LSD at 0.05 Intercropping		**0.007**			**0.003**			**0.006**	
LSD at 0.05 Ridge width		**0.004**			**-**			**0.003**	
LSD at 0.05 Interaction		**0.010**			**0.005**			**0.008**	

Table 3. Relative crowding coefficient (K) and Aggressivity (Agg) as affected by cropping systems, ridge width and their interactions, combined analysis

Characters / Treatments	RCC									Aggressivity			
	Ka			Kb			K			Agg+		Agg-	
	60 cm	120 cm	Mean	60 cm	120 cm	Mean	60 cm	120 cm	Mean	60 cm	120 cm	60 cm	120 cm
Fodder beet + barley	1.06	0.94	**1.00**	1.58	1.71	**1.64**	**1.67**	**1.60**	**1.63**	0.85	**0.41**	-0.85	**-0.41**
Fodder beet + wheat	0.94	0.84	**0.89**	1.76	1.69	**1.72**	**1.65**	**1.41**	**1.53**	0.43	**0.41**	-0.43	**-0.41**
Fodder beet + faba bean	2.20	1.68	**1.94**	1.87	1.85	**1.86**	**4.11**	**3.10**	**3.60**	0.38	**0.39**	-0.38	**-0.39**

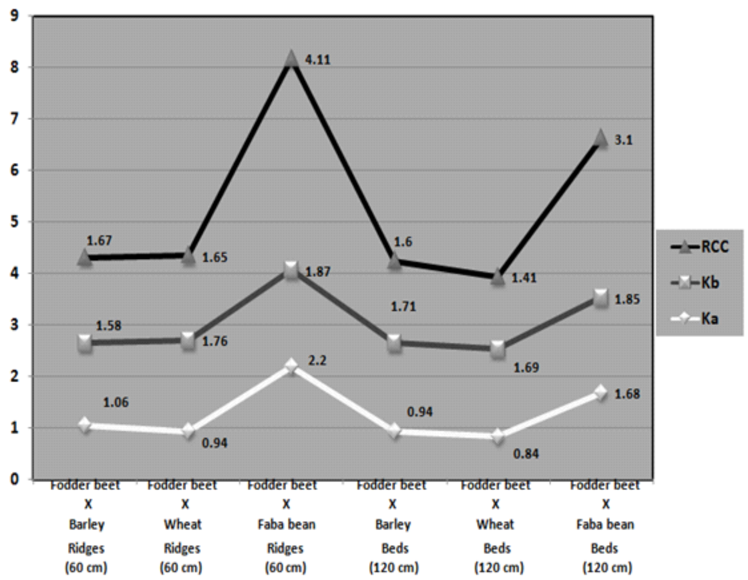

Fig. 2. Relative crowding coefficient (RCC) as affected by the intercropping system, ridge width and their interaction (combined data across 2009/2010 and 2010/2011 seasons)

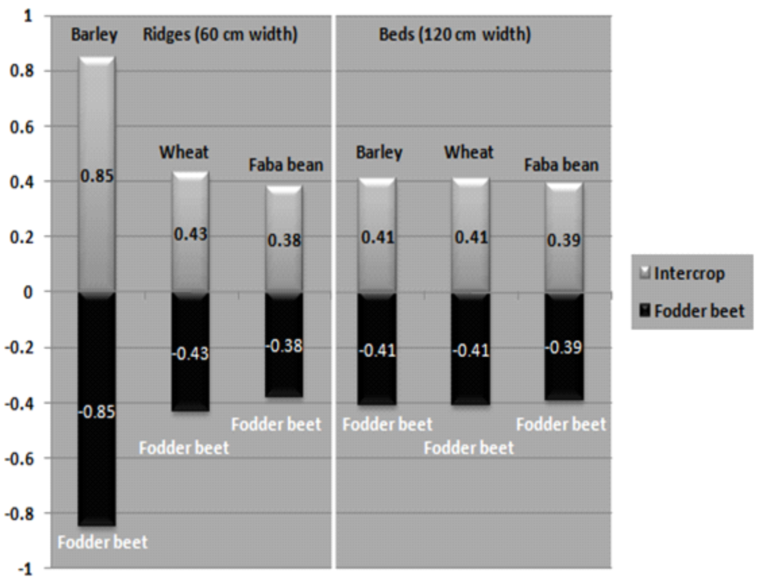

Fig. 3. Aggressivity as affected by the intercropping system, ridge width and their interaction (combined data across 2009/2010 and 2010/2011 seasons)

Table 4. Financial return as affected by cropping systems, ridge width and their interactions (combined data across 2009/2010 and 2010/2011 seasons)

Characters / Treatments	Financial return											
	Fodder beet			Intercrops			Total			Net		
	60 cm	120 cm	Mean	60 cm	120 cm	Mean	60 cm	120 cm	Mean	60 cm	120 cm	Mean
Fodder beet + barley	13412	13086	**13249**	1434	1516	**1475**	14846	14602	**14724**	9025	8781	**8903**
Fodder beet + wheat	13093	12768	**12930**	2020	1960	**1990**	15113	14728	**14920**	9208	8823	**9015**
Fodder beet + faba bean	14861	14413	**14637**	1597	1585	**1591**	16458	15998	**16228**	10592	10132	**10362**
Average of intercropping	**13788**	**13422**	**13605**	**1683**	**1689**	**1686**	**15472**	**15109**	**15290**	**9608**	**9245**	**9426**
Sole planting of fodder beet	15165	15165	**15165**	--	--	--	15165	15165	**15165**	9605	9605	**9605**

Prices of main products are that of 2011:
350 L.E.$^{-1}$ton of fodder beet
304 L.E.$^{-1}$ardab of barley
352 L.E.$^{-1}$ardab of wheat
596 L.E.$^{-1}$ardab of faba bean
Intercropping fodder beet with faba bean increased variable costs of intercropping culture 757 L.E. over those of sole fodder beet

intercropping fodder beet with faba bean is more profitable to farmers than sole fodder beet by using suitable intercropping pattern. These results are in harmony with those obtained by Abdel-Gwad *et al.* (2008), they reported that the highest return between growing fodder beet as sole crop and its growing with wheat was collected when adding 130 kg N fad^{-1} (2718.80 L.E.).

It could be concluded that although intercropping pattern resulted in adverse effects on intercropped fodder beet yield and its attributes, however, Egyptian farmers could achieve an increase in their income by about 50% as compared to sole fodder beet when growing fodder beet with faba bean on ridges (60 cm width).This paper emphasizes there is a critical need for several scientific studies including morphological and physiological characteristics to increase the productivity of intercropped fodder beet with minimizing the adverse effects of shading intercropped barley, wheat or faba bean crops which reflected positively on the financial return of fodder beet's farmer.

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THE MOLECULAR STRUCTURE OF GREEN FLUORESCENT PROTEIN

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ABSTRACT

The research was done in department of Biochemistry and Cell Biology and the Reddick center for computational Biology, Edinburg university, Edinburg during year 2013 .The crystal structure of recombinant wild-type green fluorescent protein (GFP) has been solved to a resolution of 1.9 Å by multi-wavelength anomalous dispersion (MAD) phasing methods. The protein is in the shape of a cylinder, comprising 11 strands of -sheet with an -helix inside and short helical segments on the ends of the cylinder. This motif with -structure on the outside and -helix on the inside, represents a new protein fold, which we have named the -can. Two promoters pack closely together to form a dimer in the crystal. The fluorophores are protected inside the cylinders, and their structures are consistent with the formation of aromatic systems made up of Tyr[66] with reduction of its C - C bond coupled with cyclization of the neighboring glycine and serine residues. The environment inside the cylinder explains the effects of many existing mutants of GFP and suggests which side chains could be modified to change the spectral properties of GFP. Furthermore, the identification of the dimer contacts may allow mutagenic control of the state of assembly of the protein. It is concluded that, the study of protein dimer indices will helpful in identifying the new era for rice research which will help in developing protein rich rice which can provide a dietary supplement for people.

(Key words: Protein, wavelength, flurophore, amino acids)

INTRODUCTION

Green fluorescent protein, GFP, is a spontaneously fluorescent protein isolated from coelenterates, such as the Pacific jellyfish, *Aequoria victoria*[1]. Its role is to transduce, by energy transfer, the blue chemiluminescence of another protein, aequorin, into green fluorescent light (Ward,1979). The molecular cloning of GFP cDNA (Prasher *et al*.,1992) and the demonstration by Chalfie that GFP can be expressed as a functional transgene (Chalfie *et al*.,1994) have opened exciting new avenues of investigation in cell, developmental and molecular biology. Fluorescent GFP has been expressed in bacteria (Chalfie *et al*.,1994), yeast (Kahana *et al*.,1995), slime mold (Moores *et al*.,1996), plants (Casper and Holt,1996 ; Epel *et al.,*1996) , drosophila (Wang and Hazelrigg,1994), zebrafish (Amsterdam *et al*.,1996), and in mammalian cells (Ludin *et al*.,1996 ; DeGiorgi *et al*.,1996) . GFP can function as a protein tag, as it tolerates N- and C-terminal fusion to a broad variety of proteins many of which have been shown to retain native function (Moores *et al*.,1996 ; Cubitt *et al*.,1995 ; *Olsen et al*.,1995). When expressed in mammalian cells fluorescence from wild type GFP is typically distributed throughout the cytoplasm and nucleus, but excluded from the nucleolus and vesicular organelles (reviewed by Cubitt *et al*., 1995, LG Moss unpublished observations). However, highly specific intracellular localization including the nucleus, mitochondria (Rizzuto *et al*.,1996), secretory pathway Kaether and Gerdes,1995), plasma membrane (Marshall *et al*., 1995) and cytoskeleton (Kahana *et al*.,1995) can be achieved via fusions both to whole proteins and individual targeting sequences. The enormous flexibility as a noninvasive marker in living cells allows for numerous other applications such as a cell lineage tracer, reporter of gene expression and as a potential measure of protein-protein interactions (Mitra *et al*.,1996). Green fluorescent protein is comprised of 238 amino acids. Its wild-type absorbance/ excitation peak is at 395 nm with a minor peak at 475 nm with extinction coefficients of roughly 30,000 and 7,000 M^{-1} cm^{-1}, respectively(Kahana and Silver,1996). The emission peak is at 508 nm. Interestingly, excitation at 395 nm leads to decrease over time of the 395 nm excitation peak and a reciprocal increase in the 475 nm excitation band (Cubitt *et al*.,1995). This presumed photoisomerization effect is especially evident with irradiation of GFP by UV light. Analysis of a hexapeptide derived by proteolysis of purified GFP led to the prediction that the fluorophore originates from an internal Ser-Tyr-Gly sequence which is post-translationally modified to 4(*p*hydroxybenzylidene)-imidazolidin-5-one, structure (Cody *et al*.,1993). Studies of recombinant GFP expression in *E. coli* led to a proposed sequential mechanism initiated by a rapid cyclization between set[65] and Gly[67] to form a imidazolin-5 one intermediate followed by a much slower (hours) rate-limiting oxygenation of the Tyr[66] side chain by O_2 (Heim et al., 1994). Combinatorial

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mutagenesis suggests that the Gly^{67} is required for formation of the fluorophore (Delagrave *et al*.,1995). While no known co-factors or enzymatic components are required for this apparently auto-catalytic process, it is rather thermosensitive with the yield of fluorescently active to total GFP protein decreasing at temperatures greater than 30 C(Lim *et al*.,1995). However, once produced GFP is quite thermostable.

Physical and chemical studies of purified GFP have identified several important characteristics. It is very resistant to denaturation requiring treatment with 6 M guanidine hydrochloride at 90 C or pH of <4.0 or >12.0. Partial to near total renaturation occurs within minutes following reversal of denaturing conditions by dialysis or neutralization (Ward and Bokman,1982). Circular dichroism predicts significant amounts of sheet structure that is subsequently lost on denaturation. (Ward and Bokman,1982) Over a non-denaturing range of pH, increasing pH leads to a reduction in fluorescence by 395 nm excitation and an increased sensitivity to 475 nm excitation (Ward *et al*., 1982). Reduction of purified GFP by sodium dithionite results in a rapid loss of fluorescence that slowly recovers in the presence of room air. While insensitive to sulfhydryl reagents such as 2-mercaptoethanol, treatment with the sulfhydral reagent di-thiobisnitrobenzoic acid (DTNB) irreversibly eliminates fluorescence(Inouye and Tsuji,1994).

The availability of *E. coli* clones expressing GFP has led to extensive mutational analysis of GFP function. Truncation of more than 7 amino acids from the C-terminus or more than the N-terminal Met lead to total loss of fluorescence (Dopf and Horiagan,1996). All non-fluorescent mutants also failed to exhibit absorption spectra characteristic of the intact fluorophore, implying a possible defect in post-translational processing. Screens of random and directed point mutations for changes in fluorescent behavior have uncovered a number of informative amino acid substitutions. Mutation of Tyr^{66} in the fluorophore to His results in a shift of the excitation maximum to the UV (383 nm) with emission now in the blue at 448 nm (Heim *et al*., 1994). A Tyr^{66}Trp mutant is blue-shifted albeit to a lesser degree. Both changes are associated with a severe weakening of fluorescence intensity compared to wild type GFP. Mutation of Ser^{65} to Thr, Ala, Cys or Leu causes a loss of the 395 nm excitation peak with a major increase in blue excitation (Delagrave *et al*.,1995 ; Heim *et al*.,1995). When combined with Ser^{65} mutants, mutations at other sites near the fluorophore such as Val^{68}Leu and Ser^{72}Ala can further enhance the intensity of green fluorescence produced by excitation at 488 nm (Delagrave *et al*.,1995 ; Cormack *et al*., 1996). However, amino acid substitutions significantly outside this region also affect the protein's spectral character. For example, Ser^{202}Phe and Thr^{203}Ile both cause the loss of excitation in the 475 nm region with preservation of 395 nm excitation (Chalfie *et al*.,1994 ; Heim *et al*., 1994 ; Ehrig *et al*., 1995). Ile^{167} Thr results in a reversed ratio of 395 to 475 nm sensitivity (Cubitt *et al*., 1995), while Glu^{222} Gly is associated with the elimination of only the 395 nm excitation (Ehrig *et al.,* 1995). Another change, Val^{163} Arg, not only enhances the magnitude of the Ser^{65} Thr mutant, but also increases the temperature tolerance for functional GFP expression (Kahana and Silver, 1996). Molecular evolution techniques have been reported to improve GFP fluorescence (Crameri *et al*., 1996). Unfortunately, a roster of substitutions associated with complete loss of function has not been published.

Because GFP *in crystallum* exhibits a nearly identical fluorescence spectrum and lifetime to that for GFP in aqueous solution (Perozzo *et al*., 1988) and fluorescence is not an inherent property of the isolated fluorophore, the elucidation of its three-dimensional structure will help provide an explanation for the generation of fluorescence in the mature protein, as well as the mechanism of autocatalytic fluorophore formation. Furthermore, the development of fluorescent proteins with additional emission and excitation characteristics would dramatically expand their biological applications. Color vision is based on the fact that spectral properties of a common fluorophore, cis-retinal, are altered as a function of protein environment within red, blue, or green opsins (Merbs and Nathans , 1992). The GFP from the sea pansy, *Renilla reniformis,* which exhibits a single major excitation peak at 498 nm, apparently utilizes an identical core fluorophore to that of *A. victoria* GFP . These findings taken together with the spectral changes exerted by substitutions in amino acids over

100 residues from the GFP fluorophore suggest that a rational strategy to modify and expand the fluorescence behavior of GFP based on protein structure may be possible. Here we report the X-ray diffraction structure derived from a crystal of wild-type, recombinant *A. victoria* green fluorescent protein.

MATERIALS AND METHODS

Green fluorescent protein was purified from *E. coli* strain BL21(DE3)pLysS (Novagen) containing plasmid pTu58, bearing the wild-type *Aequorea victoria* green fluorescent protein (Chalfie *et al.,1994*). For the seleniomethionine protein, the plasmid was moved to *E. coli* methionine auxotroph strain B834(DE3)pLysS (Novagen). The purification involved cell lysis, centrifugation of cell debris, and four column chromatography steps: DEAE anion exchange column (Sigma, CL-6B) with a zero to 1M NaCl gradient in 10 m M phosphate, 2 m M EDTA, 2 m M DTT, pH 7; a hydrophobic interaction column (Sigma, CL-4B) with a 0.1 to zero M phosphate gradient in 2 m M EDTA, 2 m M DTT, pH 7; an HPLC anion exchange column (Bio-Rad, Bio-Gel DEAE-5PW) with a zero to 1M NaCl gradient in 10 mM phosphate, 2 m M EDTA, 2 m M DTT, pH 7; and an HPLC gel filtration column (Bio-Rad, Bio-Gel SEC-125) with 0.1 M phosphate, 2 m M EDTA, 2 m M DTT, pH 7. Gel filtration columns run at 10 m M phosphate showed predominately a 2-fold higher molecular weight species. Matrix-assisted laser desorption ionization mass spectrometry was performed by the University of Texas Health Sciences Center analytical chemistry service.

The protein was crystallized in sitting drop vapor diffusion wells (Hampton Research) at room temperature using 58% 2-methyl-2,4-pentanediol (Aldrich), 50mM morpholino ethane sulfonic acid, 0.1% sodium azide at pH 6.8. The protein concentration varied, but was typically 20-30 mg ml^{-1}. Crystals grew as green fluorescent square bipyramids up to 0.5 mm on a side. The space group was determined to be $P4_12_12$ or its enantiomorph, with a=b=87.15 Å and c=119.85 Å at cryogenic temperatures, and a=b= 89.23 Å and c= 119.78 Å at room temperature. The unit cell also varies with changes in ionic strength, and this effect thwarted solution by multiple isomorphous replacement. Packing density calculations suggested that there were probably two molecules per asymmetric unit.

Multi-wavelength anomalous dispersion (MAD) data were taken at Brookhaven beam line X4A at four wavelengths. The wavelengths to be used were determined by reference and crystal absorption scans. The data were taken at liquid nitrogen temperature using inverse-beam geometry in wedges of four degrees and processed using DENZO (Otwinowski, 1993). Native and selenio-methionine data sets were also taken in the laboratory on an R-AXIS IIC detector with CuK radiation. The native data set used in the refinement had a R_{merge} of 7.7% to 1.9 Å resolution (99+% complete in all shells with 5-fold average redundancy). Selenium atoms were located initially by standard difference Patterson maps between selenium-substituted and native protein using SHELX96 (Sheldrick *et al*.,1993) and HEAVY (Terwilliger *et al*.,1987) and confirmed by Patterson maps using the MAD data. MADSYS software (Yang *et al.,*1990) was used to give the anomalous diffraction differences shown in table 2 and to extract Fa, Ft, and phase information.

The resulting MAD-phased map was solvent flattened and two-fold averaged based on the selenium sites using CCP4 (Anonymous,1994), skeletonized using the program O (Jones *et al*.,1991), and immediately revealed two 11-stranded cylindrical -barrels. The polypeptide chain was traced for one of the barrels beginning from the seleniomethionines and extending the structure in each direction, helped by the recognition of the modified tyrosine in the middle of the barrel as Tyr^{66}, the nucleus of the fluorophore. The correct enantiomorph is space group $P4_12_12$, as confirmed by the handedness of the -barrel and the -helices. Refinement has been started using the program X-Plor (Brunger,1992) using the native data collected at room temperature; the current R-factor at 1.9 Å is 0.21 with an R-free of 0.26, with good geometry (rms) bond and angle deviations from ideality of 0.013 Å and 1.8, respectively) and tight restraint of the non-crystallographic symmetry. All measured data were included in the refinement. Coordinates and structure factors have been deposited at the Brookhaven Protein Data Bank under accession numbers 1GFL and R1GFLSF, respectively.

RESULTS AND DISCUSSION

The structure of GFP has been solved using seleniomethionyl-substituted protein and multi-wavelength anomalous dispersion (MAD) phasing methods. The electron density maps produced by the MAD phasing were very clear, revealing a dimer comprised of two quite regular -barrels with 11 strands on the outside of cylinders (Figure 1,2,3). These cylinders have a diameter of about 30 Å and a length of about 40 Å. Inspection of the density within the cylinders reveals modified tyrosine side chains as a part of an irregular -helical segment (Figure 4). Small sections of -helix also form caps on the ends of the cylinders. This motif, with a single -helix inside a very uniform cylinder of -sheet structure, represents a new protein class, as it is not similar to any other known protein structure.

The fluorophore is highly protected, located on the central helix within a couple of Ångstroms of the geometric center of the cylinder. The pocket containing the fluorophore has a surprising number of charged residues in the immediate environment (Figure 5 and Table 1). The environment around the fluorophore includes both apolar and polar amino acid side chains. Phe^{64} and Phe^{46} are near the fluorophore and separate the single tryptophan, Trp^{63} from direct contact with fluorophore (closest distance of 13 Å). A table of all atoms that come in contact with the fluorophore and their distances to the fluorophore is provided (Table 1).

The crystallographic contacts are all rather tenuous, consisting of a few amino acids side chains for each. The non-crystallographic symmetry is maintained by extensive contacts and thus is likely to be the source of the dimerization seen in solution studies (Figure 6). The dimer contacts are fairly tight and consist of a core of hydrophobic side chains from Ala^{206}, Leu^{221}, and Phe^{223} from each of the two monomers and a wealth of hydrophilic contacts (Figure 5), including Tyr^{39}, Glu^{142}, Asn^{144}, Asn^{146}, Ser^{147}, Asn^{149}, Tyr^{151}, Arg^{168}, Asn^{170}, Glu^{172}, Tyr^{200}, Ser^{202}, Gln^{204}, and Ser^{208}. Contacts with other crystallographic molecules are not extensive, and the salt-dependence of this dimer interface and/or the loose contacts with neighboring molecules may explain the difficulties with isomorphism in initial heavy atom phasing studies.

Mass spectrometry studies of the bacterially expressed wild-type and selenio- methionyl protein show masses of 26836.1 (±0.9) and 27069.3 (±1.4) g mole^{-1}, respectively. The masses calculated for the known pTu58 gene sequence, including the original inadvertent Gln^{80}Arg PCR error during the cloning of the gene for GFP (Chalfie *et al*.,1994) and the cyclization and oxidation of the tyrosine are 26835.5 and 27070.0 for the seleniomethionine, respectively. The differences of 0.6 and -0.7 g mole^{-1} are small and the results are therefore consistent with essentially complete fluorophore formation, including the loss of water after cyclization. The error limits do not allow accurate determination of the degree of oxidation of the dehydrotyrosine, however. These results indicate the starting material for the crystallization was essentially fully formed GFP and the lack of difference density in Fo-Fc maps in this region shows that the crystal contains fully cyclized GFP.

The remarkable cylindrical fold of the protein seems ideally suited for the function of the protein. The strands of -sheet are tightly fitted to each other like staves in a barrel, and form a regular pattern of hydrogen bonds. Together with the short -helices and loops on the ends, the 'can' structure forms a single compact domain and does not have obvious clefts for easy access of diffusable ligands to the fluorophore. This fold, taken with the observation that the fluorophore is near the geometric center of the molecule explains the observed protection of the fluorophore from collisional quenching by oxygen (K_{bm} < 0.004 $M^{-1}s^{-1}$)[34] and hence reduction of the quantum yield. Perhaps more seriously, photochemical damage by the formation of singlet oxygen through intersystem crossing is reduced by the structure. The tightly constructed -can would appear to serve this role nicely, as well as provide overall stability and resistance to unfolding by heat and denaturants.

The location of certain amino acid side chains in the vicinity of the fluorophore also begins to explain the fluorescence and the behavior of certain mutants of the protein. At least two resonant forms of the fluorophore can be drawn, one with a partial negative charge on the benzyl oxygen of Tyr^{66}, and one with the charge on the carbonyl oxygen of the imidazolidone ring. Interestingly, basic residues appear to form hydrogen bonds with each of these oxygen atoms, His[148] with Tyr[66] and Gln[94] and Arg[96] with the imidazolidone. These bases presumably act to stabilize and possibly further delocalize the charge on the fluorophore. Most of the other polar residues in the pocket form an apparent hydrogen-bonding network on the side of Tyr[66] that requires abstraction of protons in the oxidation process. It is tempting to speculate that these residues help abstract the protons. As for the mutants, atoms in the side chains of Thr[203], Glu[222], and Ile[167] are in van der Waals contact with Tyr[66], so their mutation would have direct steric effects on the fluorophore and would also change its electrostatic environment if the charge were changed, as suggested previously (Ehrig *et al*.,1995). A quantitative explanation will require further examination. It seems likely that other mutations of the residues identified to be near the fluorophore would also have effects on the absorption and/or emission spectra, and such experiments to change the electrostatic environment around the fluorophore are in progress. By virtue of their varied fluorophore environments and hence altered spectra, these mutants should lead to expanded uses of green fluorescent protein as gene markers, cell lineage markers, and encourage other uses in biotechnology.

Mutations in regions of the sequence adjacent to the fluorophore, i.e. in the range of positions 65-67, have been systematically explored (Delagrave *et al*.,1995), some having significant wavelength shifts and most suffer a loss of fluorescence intensity. For example, mutation of the central Tyr to Phe or His shifts the excitation bands but there is an overall loss of intensity. Secondary mutations to compensate for the deleterious intensity effects should also now be possible. The Ser[65]Thr mutant is particularly interesting because of its reported increase in fluorescence intensity (Heim *et al*.,1994; Heim *et al*.,1995). The mechanism for increased fluorescence may be reduced collisional quenching, as the additional methyl group may make for better packing in the interior of the protein. On the other hand, the effect has been suggested to be through improved conversion of the tyrosine to dehydrotyrosine. However, the fact that we see significantly altered structure relative to standard protein conformations in the wild-type argues against a dramatic increase in cyclization and/or oxidation. This effect is most likely produced by increased expression and/or folding of the protein. The crystal structure of the Ser[65]Thr mutant has also been solved (Ormo *et al*.,1996), and it will be interesting to compare the two structures for clues about the fluorescence and other differences. The report of improvements in GFP by DNA shuffling (Crameri *et al*.,1996), comprising mutations Phe[100]Ser, Met[154]Thr and Val[164]Ala are difficult to explain based on the structure. Positions 154 and 164 are on the surface of the protein and may exert their effects through improved solubility and/or reduced aggregation. The Phe-Ser mutation at first glance would appear to destabilize the core of the protein and we have no idea how it would improve the system.

The mechanism of activation of the fluorophore from ordinary protein structure is consistent with a non-enzymatic cyclization mechanism like that of Asn-Gly deamidation (Wright,1991) followed by oxidation of the tyrosine to dehydrotyrosine, as previously suggested. The role of molecular oxygen in this mechanism and in GFP fluorescence is paradoxical, however. Molecular oxygen is proposed to be needed for formation of the double bond between C and C on the tyrosine to form an extended aromatic system, but oxygen must also be excluded from regular interactions with the fluorophore or else collisional quenching of the fluorescence or damaging photochemistry will occur. The low bimolecular quenching rate suggests that the protein's design sacrifices efficient fluorophore formation for stability and higher quantum yields once fully formed.

The excited state dynamics of GFP have been studied using Stark, steady state, and time-resolved fluorescence spectroscopies (Chattoraj *et al*.,1996) (and Youvan and Michel-Beyerle, personal communication) . The results suggest that proton transfer is involved in interconversions within two ground and two excited states. The extended set of polar interactions around the flourophore could easily accomodate proton rearrangements, with the most likely direct effects being associated with the His[148] with the hydroxyl of Tyr[66], Arg[96] interactions with the imidazolidone, or Glu[222] interactions with the hydroxyl of Ser[65]. Since the Ser[65]/Glu[222] mutants have both lost their native interactions together with their ~400 nm absorption bands, one possibility is that the 400nm band arises from the abstraction of the Ser[65] hydroxyl proton by Glu[222]. This is speculation however, but similar spectroscopic studies on mutants at these positions may be able to differentiate the roles of these sites in excited state dynamics.

The N- and C-termini truncation studies(Dopf and Horiagan,1996) and the fluorescent fusion products(Moores *et al*.,1996;Cubitt *et al*.,1995;Olsen *et al*.,1995) are now understandable, given the structure of the protein. Since the C-terminus loops back outside the cylinder and the last seven or so amino acids are disordered it shouldn't be critical to have them present and further addition would seem to be easily tolerated. These residues do not form a stave of the barrel. The role of the N-terminus is a little less clear, as the first strand in the barrel does not begin until amino acid 10 or 11. Thus barrel formation does not require the N-terminal region. The N-terminal segment, is however, an integral part of the 'cap' on one end of the protein, and may be essential in folding events or in protecting the fluorophore. Again, extensions at the N-terminus would not disrupt the motif structure of the protein.

The chemical modification studies (Inouye and Tsuji,1994) using sulfhydral reagents can be partially explained. Reaction of one of the cysteines near one end of the cylinder, Cys[70], would appear to disrupt the packing of the cap on that end, and hence allow quenching of the fluorophore. Significant fluorescence intensity effects by the modification of Cys[48] on the exterior of the protein would not be expected, *a priori*. The structure determination of the dithionite-reduced, non-fluorescent species has not yet been studied, but should provide additional data on the nature of the fluorophore. The pH dependence of the excitation bands at 395 nm and 475 nm (Ward *et al*.,1982) is almost certainly due to His[148], whose N atom is 3.3 Å from the Tyr[66] hydroxyl oxygen atom of the fluorophore, although NMR pKa measurements or mutagenesis studies would be needed for confirmation.

The dimer we see as the asymmetric unit in the crystal is likely to be the same one formed in solution, since the ionic strength of the crystallization buffer is low, and we see dimers at low (<100 mM) ionic strengths in solution. Thus, it is not surprising to us to see the large number of hydrophilic dimer contacts. The smaller hydrophobic patch could conceivably be involved in physiological interactions with aequorin, as there would be a natural advantage to close proximity for efficient energy transfer. It is not known at present whether dimers form in physiological circumstances, or what the effect of dimerization is on energy transfer, aside from the circumstantial inferences on the excitation spectra previously reported on the native protein(Ward *et al*.,1982) . The dimer contacts should now be able to be modified in such a way to disrupt the formation of dimers without affecting stability and folding. Other nearby residues could also be converted to hydrophobic residues to enhance dimer stability if desired. Control of the dimerization will be important for fluorescence resonance energy transfer (FRET) studies of protein-protein interactions using GFP, as one would not want to induce association and hence resonance energy transfer between the differently colored GFP proteins by mechanisms other that of the target protein interactions. Mutants may also be developed for reduction of aggregation during expression and hence fewer problems with inclusion bodies.

Thus, the three-dimensional structure of GFP has provided a physico-chemical basis of many observed features of the protein, including its stability, protection of it fluorophore, behavior of mutants, and dimerization properties. The structure will also allow directed mutation studies to complement random and combinatorial approaches.

From above research it is concluded that, the study of protein dimer indices will helpful in identifying the new era for rice research which will help in developing protein rich rice which can provide a dietary supplement for people.

Table 1. List of amino acid side chains with close contacts (less than 5 Å) to the fluorophore. The fluorophore is defined as the 7 atoms of the phenol of Tyr[66], the 6 atoms of the imidazolidone, and the bridging methylene between the rings. The following amino acid side chains would be expected to have the most direct effects on fluorescence and perhaps fluorophore formation. The atom names are taken from the Brookhaven Protein Data Bank nomenclature

Protein		**Fluorophore**		**Distance**
Residue	**Atom**	**Residue**	**Atom**	**(Å)**
Arg 96	NH2	Tyr 66	O	2.7
Gln 94	NE2	Tyr 66	O	3.0
His 148	ND1	Tyr 66	OH	3.3
Gln 69	CD	Tyr 66	O	3.4
Glu 222	OE2	Tyr 66	CE2	3.5
Val 150	CG2	Tyr 66	CE1	3.6
Phe 165	CE1	Tyr 66	CD1	3.6
Thr 203	CG2	Tyr 66	CE2	3.6
Ile 167	CD1	Tyr 66	OH	3.7
Thr 62	CG2	Tyr 66	CG	3.7
Tyr 145	CE2	Tyr 66	OH	3.7
Ser 205	OG	Tyr 66	CE2	4.0
Val 61	CG1	Tyr 66	CE2	4.4
Gln 183	NE2	Tyr 66	O	4.8
Val 68	CG2	Ser 65	C	4.9

Table 2. Anomalous diffraction differences and scattering factors for seleniomethionyl GFP at the four wavelengths used. Following the format used by Yang *et al*. (!990), Bijvoet differences ratios are given in diagonal elements with centric values in parentheses, and dispersive differences are given in off-diagonal elements. Scattering factors were chosen to minimize the cumulative errors in Bijvoet and dispersive terms

Wave-length	**30 > d > 3.4 (Å)**				**3.4 > d > 2.7 (Å)**				**2.7 > d > 2.2 (Å)**				**scattering**	
(Å)	0.9879	0.9794	0.9792	0.9686	0.9879	0.9794	0.9792	0.9686	0.9879	0.9794	0.9792	0.9686	f'	f''
0.9879	0.026 (0.026)	0.042	0.030	0.020	0.037 (0.035)	0.046	0.037	0.032	0.064 (0.052)	0.071	0.068	0.064	4.0	1.1
0.9794		0.050 (0.029)	0.026	0.045		0.058 (0.039)	0.035	0.049		0.088 (0.060)	0.065	0.077	-10.5	3.9
0.9792			0.067 (0.031)	0.032			0.074 (0.042)	0.040			0.101 (0.062)	0.071	7.9	5.5
0.9686				0.049 (0.027)				0.059 (0.039)				0.089 (0.064)	3.4	3.9

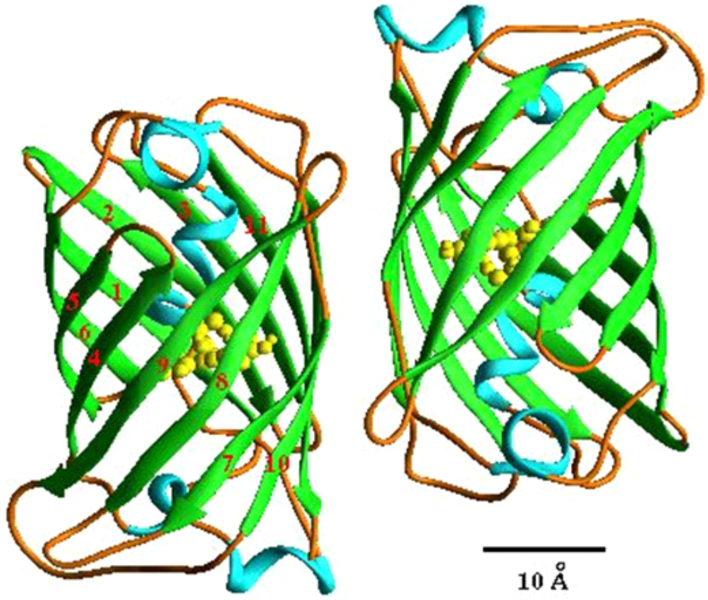

Figure 1. The overall shape of the protein and its association into dimers. Eleven strands of -sheet (green) form the walls of a cylinder. Short segments of -helices (blue) cap the top and bottom of the '? -can' and also provide a scaffold for the fluorophore which is near geometric center of the can. This folding motif, with -sheet outside and helix inside, represents a new class of proteins. Two monomers are associated into a dimer in the crystal and in solution at low ionic strengths. This view is directly down the two-fold axis of the non-crystallographic symmetry. Figures 1 and 6 were produced with Ribbons (Carson, 1987).

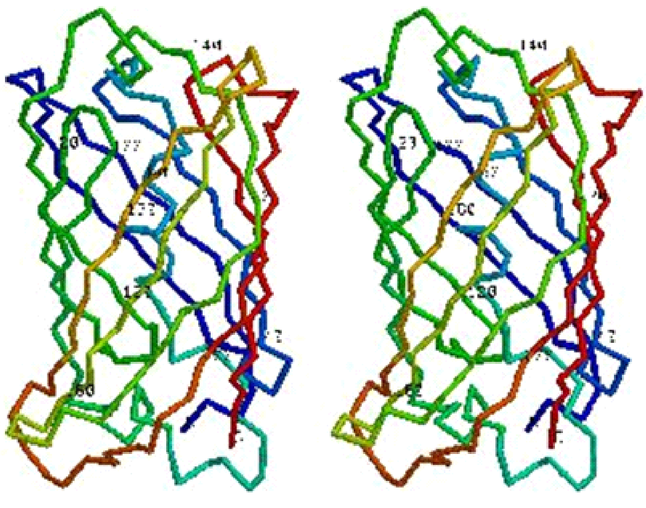

Figure 2. Stereo view of a monomer, with colors that vary slowly as a function of the distance along the polypeptide chain. The termini and C atoms of every 20th amino acid are marked just to the upper right of each atom. Figure produced by RasMol (Sayle and Milner-White, 1995).

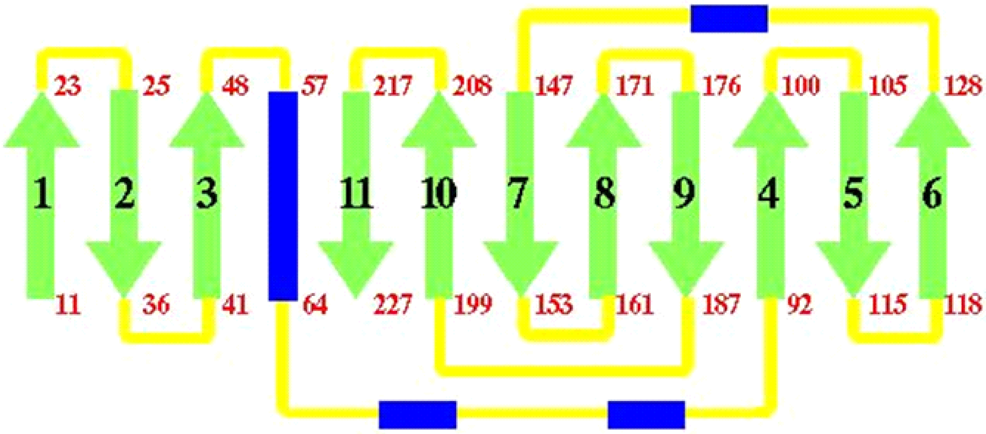

Figure 3. A topology diagram of the folding pattern in GFP. The -sheet strands are shown in light green, ? -helices in blue, and connecting loops in yellow. The positions in the sequence that begin and end each major secondary structure element are also given. The anti-parallel strands (except for the interactions between stands 1 and 6) make a tightly formed barrel

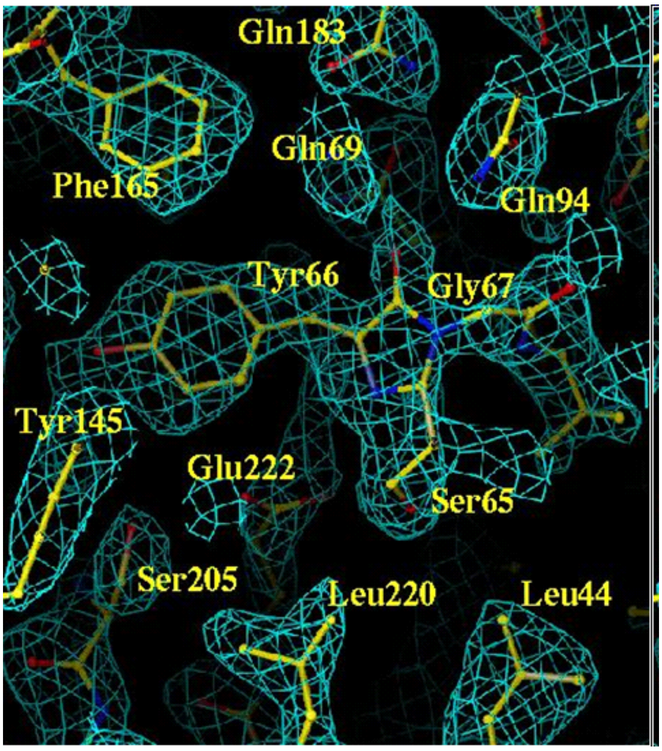

Figure 4. Model of the fluorophore and its environment superposed on the MAD-phased electron density map at 2.2 Å resolution. The clear definition throughout the map allowed the chain to be traced and side chains to be well placed. The density for Ser[65], Tyr[66] and Gly[67] is quite consistent with the dehydrotyrosine - imidazolidone structure proposed for the fluorophore. Many of the side chains adjacent to the fluorophore are labeled. Figures 4 and 5 were produced with O[43]

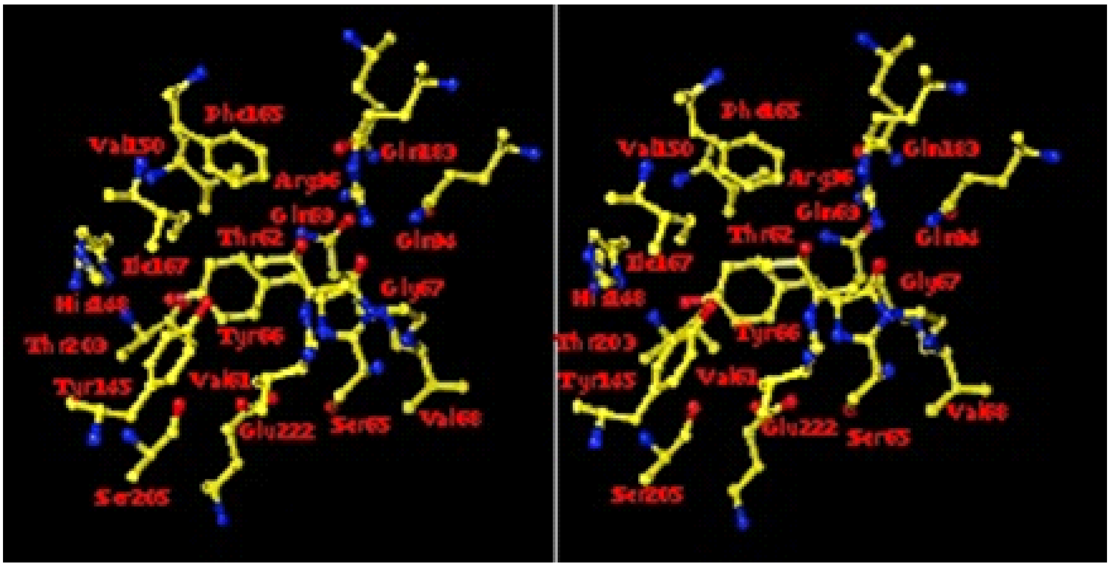

Figure 5. Stereo view of the fluorophore and its environment. His[148], Gln[94] and Arg[96] can be seen on opposite ends of the fluorophore and probably stabilize resonant forms of the fluorophore. Charged, polar, and non-polar side chains all contact the fluorophore in some way.

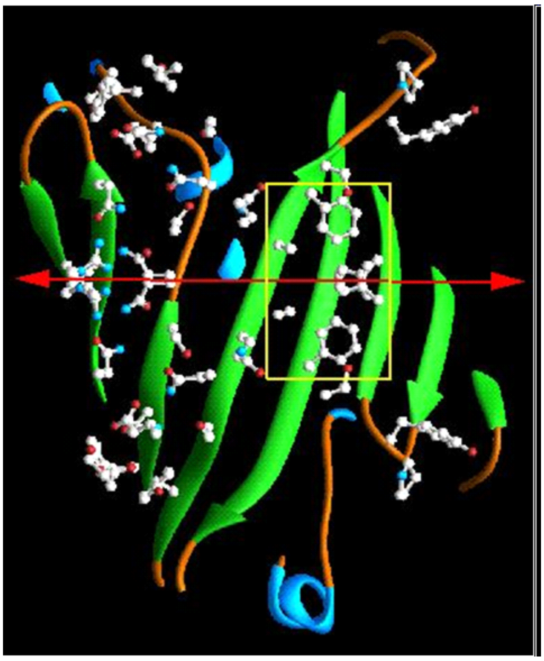

Figure 6. The dimer contact region. The two polypeptide chains associate over a broad area, with a small hydrophobic patch (in the yellow box) and numerous hydrophilic contacts. The two-fold symmetry axis is in the plane of the page, and is marked by the red arrow. The polar residues are marked with red atoms for oxygen and blue for nitrogen.

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SUGAR BEET PRODUCTIVITY AND PROFITABILITY AS AFFECTED BY THREE CROPPING SYSTEMS AND MINERAL NITROGEN FERTILIZER RATES

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ABSTRACT

Agriculture occupies a dominant position in the Egyptian economy. The sugar industry is a main strategic industry in Egypt. A two-year study was carried out at El-Serw Agricultural Experiments and Research Station, A.R.C., Domiatte governorate, Egypt during 2012-2013 and 2013-2014 winter seasons to determine the effect of intercropping wheat and faba bean on sugar beet yield and its attributes and agro - feasibility under different mineral nitrogen (N) fertilizer rates of sugar beet. The treatments were the combinations between three cropping systems (intercropping wheat with sugar beet, intercropping faba bean with sugar beet and sugar beet solid culture) and three mineral N fertilizer rates of sugar beet under intercropping and solid cultures (125.0, 166.6 and 208.2 kg N ha^{-1}). Sugar beet plants were grown in both sides of beds (120 cm width) with intercropping wheat or faba bean plants in the middle of all sugar beet beds in addition to solid cultures of all the tested crops. A split plot design in three replicates was used. The results showed that sugar beet solid culture had maximum root length and diameter, root weight plant^{-1}, root yield ha^{-1} yield and sugar quality traits. Root weight plant^{-1} and root yield ha^{-1} were decreased by 27.48 and 18.97 per cent, respectively, as compared with sugar beet solid culture. Increasing mineral N fertilizer rates from 125.0 to 166.6 kg N ha^{-1} increased sugar beet yield by 5.17 and 6.34% under intercropping and solid cultures, respectively. All the studied traits of sugar beet were affected significantly by the interaction between cropping systems and mineral N fertilizer rates. Land equivalent ratio (LER) ranged from 0.98 to 1.26 with an average of 1.14. All values of relative crowding coefficient (RCC) were exceeded 1.00 except at intercropping wheat with sugar beet that fertilized by 125.0 kg N ha^{-1}. Wheat or faba bean plants are dominant components and sugar beet plants are dominated components. Maximum financial return $410 ha^{-1} was recorded by intercropping faba bean with sugar beet was fertilized by 75% of the recommended mineral N fertilizer rate (125.0kg N ha^{-1}).

(Key words: Intercropping, sugar beet, wheat, faba bean, competitive relationships, financial return)

INTRODUCTION

Egypt is bridging the gap between sugar consumption and production through imports. After sugarcane, sugar beet (*Beta vulgaris* L.) is considered the second important sugar crop in Egypt and also in many countries in the world. By 1880, sugar beet had replaced sugarcane as the main source of sugar in continental Europe (Anonymous, 2009). Although demand for sugar in the Egyptian market is intensively increasing but sugarcane production and area are stable with no expectations for change due to scarce land and water resources in Egypt, in addition to sugar beet area is not expanding. Always, there is a severely competition between sugarcane and the other winter field crops for land, water, light and nutrients according to production costs and lower net returns. Sugar beet cultivated area reached about 193,482 ha in 2012 season with an average yield of 51.91 tons ha^{-1}, while the other strategic winter food crops such as wheat and faba bean (*Vicia faba*) which their cultivated area reached about 1,419,275 and 44,082 with an average yield of 6.66 and 3.53 tons ha^{-1} in 2012 season, respectively, (Anonymous, 2012).

Accordingly, one of the main problems associated with the Egyptian agricultural system is the low size of cultivated land farmer^{-1}. This led to an increase need to maximize land usage to enhance farmer's income. In view of the previous, it was necessary to find a modern agricultural technical practice in Egypt for increasing sugar yield unit^{-1} area without any significant change in crop structure. Intercropping is the best agricultural practice to maximize land usage without negative change for the sugar beet cultivated area. However, crop species in intercropping pattern must be carefully chosen to minimize competition and enhance the efficient use of water, light and nutrients (Sayed Galal *et al*., 1983). There are some socio-economic advantages of intercropping over monoculture system (Ofori and Stern, 1987). Increased productivity, optimal use of available resources and increasing the efficiency of land use (Dhima *et al*., 2007) are considered the benefits of cereals or legumes intercropping compared to their solid cultures.

On the other hand, output improvement in a crop production system is related to the better use of

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resources. Among the plant nutrients, N plays a very important role in crop productivity (Zapata and Cleenput, 1986). It is considering as balance wheel of sugar beet nutrition due to the fact that the efficiency of other nutrients and productivity of sugar beet are depended on N availability. In this concern, Jahedi and Noroozi (2010) revealed that increasing N fertilizer levels substantially improved root, top and sugar yields, as well as, its components, whereas quality parameters were decreased. So, the present study was conducted to determine the effect of intercropping wheat and faba bean on sugar beet yield and its attributes and agro - feasibility under different mineral N fertilizer rates.

MATERIALS AND METHODS

A two-year study was carried out at El-Serw Agricultural Experiments and Research Station, A.R.C., Domiatte governorate (Lat. 31° 24' 59" N, Long. 31° 48' 47" E, 16 m a.s.l.), Egypt during 2012-203 and 2013-2014 winter seasons to determine the effect of intercropping wheat and faba bean on sugar beet yield and its attributes and agro - feasibility under different mineral N fertilizer rates. Sugar beet variety Cleopatra and two field crops (wheat variety Misr 1 and faba bean variety Giza 716) were used. The treatments were the combinations between three cropping systems (intercropping wheat with sugar beet, intercropping faba bean with sugar beet and sugar beet solid culture) and three mineral N fertilizer rates of sugar beet (75%, 100% and 125% of the recommended mineral N fertilizer rates of sugar beet as expressed by 125.0, 166.6 and 208.2 kg N ha^{-1}, respectively). Cropping systems were illustrated in Figure 1 as follows:

1. Planting sugar beet on both sides of the beds (120 cm width) and planting one wheat row on middle of all sugar beet beds. This pattern resulted in 83,300 plants of sugar beet ha^{-1} (100% sugar beet : 25% wheat).

2. Planting sugar beet on both sides of the beds (120 cm width) and planting one faba bean row on middle of all sugar beet beds. This pattern resulted in 83,300 and 66,640 plants of sugar beet and faba bean ha^{-1}, respectively (100% sugar beet: 25% faba bean).

3. Sugar beet solid culture by planting sugar beet on one side of the ridges (60 cm width). This pattern resulted in 83,300 plants of sugar beet.

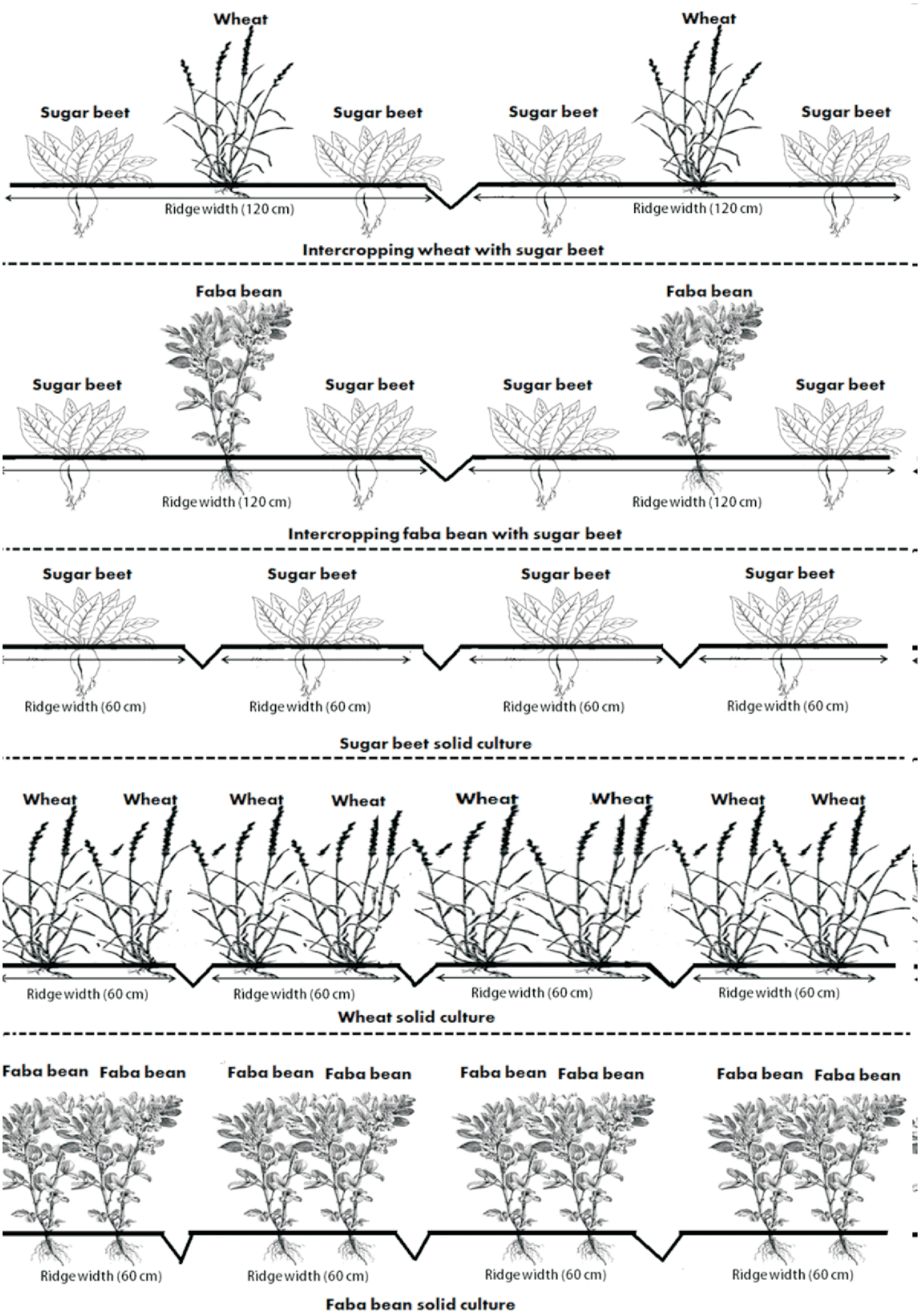
4. Wheat solid culture by planting two wheat rows on both sides of the ridges (60 cm width).

5. Faba bean solid culture by planting two faba bean rows on both sides of the ridges (60 cm width). This pattern resulted in 266,560 plants of faba bean.

Sugar beet variety kindly provided by Sugar Crops Res. Institute, ARC. Varieties of wheat and faba bean kindly provided by Wheat and Food Legumes Res. Depts., Field Crops Res. Inst., ARC, respectively. The preceding summer crop was rice in both seasons. Normal cultural practices for growing all crops were used as recommended in the area. Faba bean seeds were inoculated with *Rhizobium leguminosarum* and gum arabic was used as a sticking agent. Mineral N fertilizer was applied at rates of 44.6 and 8.9 kg N ha^{-1} for wheat and faba bean, respectively, under intercropping systems. The previous rates were applied by 178.5 and 35.7 kg N ha^{-1} for wheat and faba bean, respectively, under solid culture. All the tested crops were sown at the same date on 21st and 10th October at 2012 and 2013 seasons, respectively. Sugar beet plants were thinned to one plant $hill^{-1}$ at 20 cm between hills under intercropping and solid cultures. Wheat grains were drilled in one row in intercropping culture and in two rows in solid culture. Faba bean plants were thinned to two plants $hill^{-1}$ at 25 cm between hills. Recommended solid cultures of all the tested crops were used to estimate the competitive relationships. A split plot design with three replicates was used. Cropping systems (intercropping and solid) were randomly assigned to the main plots, mineral N fertilizer rates were allotted in sub plots. The area of sub-plot was 14.4 m^2, it consisted of 8 ridges, and each ridge was 3.0 m in length and 0.6 m in width.

Yield and its attributes

At harvest, root length and diameter (cm) and plant root weight (g) were measured on ten guarded plants from each plot, whereas, root yield ha^{-1} (ton) were recorded on the basis of experimental plot area by harvesting all sugar beet plants of each plot. Grain yields of wheat ha^{-1} (ton) and seed yield of faba bean ha^{-1} (ton) were recorded on the basis of experimental plot area.


Wheat
Wheat
Sugar beet
Sugar beet
Sugar beet
Sugar beet
Ridge width (120 cm)
Ridge width (120 cm)
Intercropping wheat with sugar beet
Faba bean
Faba bean
Sugar beet
Sugar beet
Sugar beet
Sugar beet
Ridge width (120 cm)
Ridge width (120 cm)
Intercropping faba bean with sugar beet
Sugar beet
Sugar beet
Sugar beet
Sugar beet
Ridge width (60 cm)
Ridge width (60 cm)
Ridge width (60 cm)
Ridge width (60 cm)
Sugar beet solid culture
Wheat
Wheat
Wheat
Wheat
Wheat
Wheat
Wheat
Wheat
Ridge width (60 cm)
Ridge width (60 cm)
Ridge width (60 cm)
Ridge width (60 cm)
Wheat solid culture
Faba bean
Faba bean
Faba bean
Faba bean
Faba bean
Faba bean
Faba bean
Faba bean
Ridge width (60 cm)
Ridge width (60 cm)
Ridge width (60 cm)
Ridge width (60 cm)
Faba bean solid culture

Competitive relationships

Land equivalent ratio (LER)

LER defined as the ratio of area needed under sole cropping to one of intercropping at the same management level to produce an equivalent yield (Mead and Willey, 1980). It is calculated as follows:

$LER = (Y_{ab} / Y_{aa}) + (Y_{ba}/ Y_{bb})$

Where Y_{aa} = Pure stand yield of crop a (sugar beet), Y_{bb} = Pure stand yield of crop b (wheat or faba bean), Y_{ab} = Intercrop yield of crop a (sugar beet), Y_{ba} = Intercrop yield of crop b (wheat or faba bean)

Land equivalent coefficient (LEC)

LEC is a measure of interaction concerned with the strength of relationship (Adetiloye *et al*., 1983). It is calculated as follows: $LEC = L_a \times L_b$

Where L_a = LER of crop a (sugar beet), L_b = LER of crop b (wheat or faba bean)

Relative crowding coefficient (RCC)

RCC estimates the relative dominance of one species over the other in the intercropping system (Banik *et al*., 2006). It is calculated as follows: $K = K_a \times K_b$

$K_a = Y_{ab} \times Z_{ba} / [(Y_{aa} - Y_{ab}) \times Z_{ab}]$ $K_b = Y_{ba} \times Z_{ab} / [(Y_{bb} - Y_{ba}) \times Z_{ba}]$

Where Y_{aa} = Pure stand yield of crop a (sugar beet), Y_{bb} = Pure stand yield of crop b (wheat or faba bean), Y_{ab} = Intercrop yield of crop a (sugar beet), Y_{ba} = Intercrop yield of crop b (wheat or faba bean), Z_{ab} = The respective proportion of crop a in the intercropping system (sugar beet), Z_{ba} = The respective proportion of crop b in the intercropping system (wheat or faba bean)

Aggressivity

Aggressivity represents a simple measure of how much the relative yield increase in one crop is greater than the otherin an intercropping system (Willey, 1979).

$A_{ab} = [Y_{ab} / (Y_{aa} \times Z_{ab})] - [Y_{ba} / (Y_{bb} \times Z_{ba})]$ $A_{ba} = [Y_{ba}/ (Y_{bb} \times Z_{ba})] - [Y_{ab}/ (Y_{aa} \times Z_{ab})]$

Where Y_{aa} = Pure stand yield of crop a (sugar beet), Y_{bb} = Pure stand yield of crop b (wheat or faba bean), Y_{ab} = Intercrop yield of crop a (sugar beet), Y_{ba} = Intercrop yield of crop b (wheat or faba bean), Z_{ab} = The respective proportion of crop a in the intercropping system (sugar beet), Z_{ba} = The respective proportion of crop b in the intercropping system (wheat or faba bean)

Farmer's benefit

It was calculated by determining the total costs and net return of intercropping culture as compared to recommended solid planting of sugar beet according to Metwally *et al.* (2009).

Total return of intercropping cultures = Price of sugar beet yield + price of wheat or faba bean yield (American dollars $).

To calculate the total return, the average of sugar beet, wheat and faba bean prices presented by Anonymous (2014) was used.

Net return ha^{-1} = Total return – (fixed cost of sugar beet + variable costs of wheat or faba bean according to intercropping pattern).

Statistical Manipulation

Analysis of variance of the obtained results of each season was performed. The homogeneity test was conducted of error mean squares and accordingly, the combined analysis of the two experimental seasons was carried out. The measured variables were analyzed by ANOVA using MSTATC statistical package (Freed, 1991). Mean comparisons were done using least significant differences (L.S.D) method at 5 % level of probability to compare differences between the means (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Yield and its attributes

Cropping systems

Intercropping sugar beet with wheat or faba bean affected significantly root length and diameter, root weight $plant^{-1}$, root yield ha^{-1}, total soluble solids (T.S.S.) and sucrose percentages in the combined analysis of the two seasons (Table 1). Intercropping wheat or faba bean with sugar beet decreased root length and diameter, root weight plant^{-1}, root yield ha^{-1} in comparison with sugar beet solid culture, meanwhile, the opposite trend was recorded for T.S.S. and sucrose percentages. As a result of intercropping, root weight plant^{-1} and root yield ha^{-1} were decreased by 27.48 and 18.97 per cent, respectively, as compared with sugar beet solid culture. These data reveal that intercropping wheat with sugar beet had a significant negative impact *($P \leqslant 0.05$)* on sugar beet crop as compared with those intercropped with faba bean. Obviously, intercropping legume crops with sugar beet had lower adverse effects on yield of intercropped sugar beet than cereal crops under intercropping conditions. Grain legumes help maintain and improve soil fertility due to their ability to biologically fix atmospheric nitrogen (Sanginga and Woomer, 2009) than cereal crops.

On the other hand, intercropping wheat or faba bean with sugar beet affected significantly grain yield of wheat or seed yield of faba bean in the combined analysis of the two seasons (Table 1). Intercropping wheat with sugar beet decreased grain yield ha^{-1} by 73.00 per cent in the combined analysis of the two seasons. Also, intercropping faba bean with sugar beet decreased seed yield ha^{-1} by 68.65 per cent in the combined analysis of the two seasons. It is clear that decreasing plant population density of wheat or faba bean plants to 25% of those grown under solid culture decreased *($P \leqslant 0.05$)* grain or seed yield unit^{-1} area. The reduction in seed yield of faba bean ha^{-1} was quite expected as a result of decreasing stand of intercropped faba bean as reported by Abou-Elela and Gadallah (2012) who indicated that seed yield of faba bean unit^{-1} area was reduced significantly by intercropping with fodder beet as compared with faba bean solid culture.

Mineral N fertilizer rates of sugar beet

All the studied traits of sugar beet were affected significantly by mineral N fertilizer rates in the combined analysis of the two seasons (Table 1). Increasing mineral N fertilizer rates from 125.0 to 208.2 kg N ha^{-1} increased root length and diameter, root weight plant^{-1} and root yield plant^{-1} under intercropping and solid cultures, meanwhile, the opposite trend was recorded for T.S.S. and sucrose percentages. There were no significant differences between the medium mineral N fertilizer rate (166.6 kg N ha^{-1}) and the highest mineral N fertilizer rate (208.2 kg N ha^{-1}) on root length and diameter, root weight plant^{-1} and root yield ha^{-1}. These results are in agreement with those obtained by López-Bellido *et al*. (1994) who showed that sugar yield response to N fertilizer rates depended on the N available in the soil and on the total water input to the crop. The amount of N required to produce 1 ton of root and of sugar ranged between 1.5 and 3.8 kg N and between 11.1 and 22.4 kg N respectively, and varied according to the N fertilizer rates applied.

On the other hand, increasing mineral N fertilizer rates from 125.0 to 208.2 kg N ha^{-1} did not effect on wheat or faba bean yield ha^{-1} under intercropping and solid cultures in the combined analysis of the two seasons (Table 1). It is clear that there is no direct impact for mineral N fertilizer rates of sugar beet on wheat or faba bean crops under intercropping and solid cultures.

Interaction between cropping systems and mineral N fertilizer rates of sugar beet

All the studied traits of sugar beet were affected significantly by the interaction between cropping systems and mineral N fertilizer rates of sugar beet in the combined analysis of the two seasons (Table1). The highest values of root length and diameter, root weight plant^{-1} and root yield ha^{-1} were obtained under solid culture that fertilized by 166.6 kg N ha^{-1}, meanwhile, the lowest values of root length and diameter, root weight plant^{-1} and root yield ha^{-1} were obtained by intercropping wheat with sugar beet that fertilized by 125.0 kg N ha^{-1}. Because of their ability to biological N fixation, legumes are largely involved in N facilitation and N dynamic in the plant community and in agrosystems (Hauggaard-Nielsen and Jensen, 2005 and Fustec *et al*., 2010).

On the other hand, wheat or faba bean yield ha^{-1} were not affected by the interaction between cropping systems and mineral N fertilizer rates of sugar beet in the combined analysis of the two seasons (Table 1). These data reveal that each of these two factors act independently on all the studied traits of wheat or faba bean yield where cropping systems responded similarly *($P > 0.05$)* to mineral N fertilizer rates for either wheat or faba bean yield.

Competitive relationships

Relative yields of sugar beet and wheat or faba bean were affected significantly by the cropping systems in the combined data across 2012/2013 and 2013/2014 seasons (Table 2). Intercropping faba bean with sugar beet had higher values of relative yields of sugar beet and intercrops as compared with intercropping wheat with sugar beet. These data may be due to faba bean plants (as legume crop) have ability to biological N fixation, legumes are largely involved in N facilitation and N dynamic in the plant community and in agrosystems.

Relative yield of sugar beet was affected significantly by mineral N fertilizer rates, meanwhile, relative yield of intercrops was not affected in the combined data across 2012/2013 and 2013/2014 seasons (Table 2). Adding the lowest mineral N fertilizer rate (125.0 kg N ha^{-1}) resulted in decrease in relative yield of sugar beet as compared to those that received the other mineral N fertilizer rates.

Relative yield of sugar beet was affected significantly by the interaction between cropping systems and mineral N fertilizer rates, meanwhile, relative yield of intercrops were not affected in the combined data across 2012/2013 and 2013/2014 seasons (Table 2). Intercropping faba bean with sugar beet had higher values of relative yield of sugar beet with different mineral N fertilizer rates in comparison with intercropping wheat with sugar beet that received the lowest mineral N fertilizer rate (125.0 kg N ha^{-1}).

Land equivalent ratio (LER)

The values of LERs were estimated by using data of recommended solid cultures of all the tested crops. LER was affected significantly by the cropping systems in the combined analysis of the two seasons (Table 2). In general, intercropping wheat or faba bean with sugar beet increased LER as compared to sugar beet solid culture in the combined data across 2012/2013 and 2013/2014 seasons (Table 2). It ranged from 0.98 (by intercropping wheat with sugar beet that fertilized by 125.0 kg N ha^{-1} to 1.26 by intercropping faba bean with sugar beet that fertilized by 166.6 kg N ha^{-1} with an average of 1.14. The advantage of the highest LER by intercropping faba bean with sugar beet over the others could be due to faba bean plants (as legume crop) have ability to biological N fixation, legumes are largely involved in N facilitation and N dynamic in the plant community and in agrosystems. It is clear that plant population density of sugar beet and wheat or faba bean played a major role in increasing productivity $unit^{-1}$ area under intercropping culture where it reached 100 and 25% of solid cultures, respectively. Similar results were obtained by Abdel-Gwad *et al.* (2008) who found that intercropping fodder beet with wheat increased land equivalent ratio in the average of both seasons by 1.21, 1.07, 1.15 and 1.22, when adding 70, 90, 110 and 130 kg N fertilizer fad^{-1}., respectively. Also, Abou-Elela and Gadallah (2012) reported that LER was higher by intercropping faba bean with fodder beet than those of sole plantings.

With respect to mineral N fertilizer rates, LER was affected significantly by mineral N fertilizer rates in the combined data across 2012/2013 and 2013/2014 seasons (Table 2). Increasing mineral N fertilizer rates from 125.0 to 166.6 or 208.2 kg N ha^{-1} increased LER in the combined analysis of the two seasons. LER was affected significantly by the interaction between cropping systems and mineral N fertilizer rates in the combined data across 2012/2013 and 2013/2014 seasons (Table 2). Intercropping wheat with sugar beet that received 125.0 kg N ha^{-1} gave the lowest LER, meanwhile, the highest LER was obtained by intercropping faba bean with sugar beet that received 166.6 or 208.2 kg N ha^{-1}.

Land equivalent coefficient (LEC)

LEC is a measure of interaction concerned with the strength of relationship. LEC is used for a two- crop mixture the minimum expected productivity coefficient (PC) is 25 per cent, that is, a yield advantage is obtained if LEC value was exceeded 0.25. LEC was affected by the cropping systems, meanwhile, mineral N fertilizer rates or the interaction between cropping systems and mineral N fertilizer rates did not affect LEC in the combined data across 2012/2013 and 2013/2014 seasons (Table 2). Mean LEC of intercropped wheat with sugar beet was not reached 0.25 and consequently the wheat – sugar beet intercropping had yield disadvantage. On contrary, mean LEC of intercropped faba bean with sugar beet was exceeded 0.25 and consequently the faba bean – sugar beet intercropping had yield advantage.

Relative crowding coefficient (RCC)

The relative dominance of one species over the other in this intercropping study was estimated by the use of relative crowding coefficient (k). When the value of relative crowding coefficient (k) is greater than 1.00, there is intercrop advantage; when k is equal to 1.00, there is no yield advantage; when k is lesser than 1.00, there is a disadvantage. Figure 2 shows that all values of the total relative crowding coefficient (RCC) were exceeded 1.00 except intercropping wheat with sugar beet that fertilized by 125.0 kg N ha^{-1} in the combined data across 2012/2013 and 2013/2014 seasons. The lowest k was obtained from intercropping wheat with sugar beet that fertilized by 125.0 kg N ha^{-1}, whereas, intercropping faba bean with sugar beet that fertilized by 166.6 kg N ha^{-1} had the highest k. These data suggest that canopy structures of faba bean and sugar beet that fertilized by 166.6 kg N ha^{-1} formed better performance to decrease competitive pressure of component crops under intercropping conditions, indicating that these species are complementary and suitable in mixture with adding 166.6 kg N ha^{-1} for intercropped sugar beet. These results are in accordance with those obtained by Abou-Elela and Gadallah (2012) who demonstrated that relative crowding coefficient of faba bean was higher than those of fodder beet.

Aggressivity

Aggressivity determines the difference in competitive ability of the component crops in intercropping association. The positive sign indicates the dominant component and the negative sign indicates the dominated component. Higher numerical values of aggressiveness denote greater difference in competitive ability, as well as, bigger difference between actual and expected yield in both crops. The results indicate that the value of aggressivity of wheat and faba bean was positive for all treatments, whereas, the values of aggressivity was negative for all intercropped sugar beet in the combined data across 2012/2013 and 2013/2014 seasons (Figure 3).

These data show that wheat or faba bean are dominant component and sugar beet plants are dominated component.

In general, the highest negative values were obtained by growing wheat with sugar beet that fertilized by 125.0 kg N ha^{-1}, whereas, intercropping faba bean with sugar beet that fertilized by the previous mineral N rate had the lowest negative values. These results clear that intercropping wheat with sugar beet is more aggressive than intercropping faba bean with sugar beet especially under the lowest mineral N fertilizer rate (125.0 kg N ha^{-1}).

Financial evaluation

Net return of intercropping sugar beet with wheat and faba bean was $ 3729 and 4766 ha^{-1} as compared with sugar beet solid culture ($ 4362 ha^{-1}) in the combined data across 2012/2013 and 2013/2014 seasons (Table 3). Intercropping faba bean with sugar beet increased total and net returns by 7.63 and 9.26%, respectively, as compared with sugar beet solid culture. The study indicated that intercropping faba bean with sugar beet is more profitable to farmers than sugar beet solid culture by using suitable intercropping pattern. On the contrary, intercropping wheat with sugar beet that fertilized by different mineral N fertilizer rates is not profitable to farmers than sugar beet solid culture. Although increasing mineral N fertilizer rate (208.2 kg N ha^{-1}) above 25% of the recommended mineral N fertilizer rate (166.6 kg N ha^{-1}), however, intercropping wheat with sugar beet caused financial loss (11.27%) than sugar beet solid culture. These results are in harmony with those obtained by Abdel-Gwad *et al.* (2008) who reported that the highest return between growing fodder beet as sole crop and its growing with wheat was collected when adding 130 kg N fad^{-1} (2718.80 L.E.). Also, Usmanikhail *et al.* (2012) concluded that sugar beet yields and monetary benefits were maximum in lentil intercropping compared to cereals and oilseeds intercropping.

It could be concluded that growing one row of faba bean on middle of all sugar beet beds with fertilizing sugar beet plant by 75% of the recommended mineral N fertilizer rate (125.0 kg N ha^{-1}) achieved $ 410 ha^{-1} over than sugar beet solid culture.

Table 1. Effect of cropping systems, mineral nitrogen fertilizer rates and their interactions on sugar beet yield and its attributes, as well as, yields of wheat and faba bean (combined analysis of the two seasons)

Treatments	Root length (cm)				Root diameter (cm)				Root weight plant $^{-1}$ (kg)				Root yield ha^{-1} (ton)			
	125.0 kg N ha^{-1}	166.6 kg N ha^{-1}	208.2 kg N ha^{-1}	Mean	125.0 kg N ha^{-1}	166.6 kg N ha^{-1}	208.2 kg N ha^{-1}	Mean	125.0 kg N ha^{-1}	166.8 kg N ha^{-1}	208.2 kg N ha^{-1}	Mean	125.0 kg N ha^{-1}	166.6 kg N ha^{-1}	208.2 kg N ha^{-1}	Mean
Sugarbeet + wheat	25.95	26.22	26.33	26.16	11.31	11.50	11.68	11.50	0.73	0.84	0.92	0.83	62.28	69.77	70.18	67.41
Sugarbeet + faba bean	28.49	28.51	28.51	28.50	13.19	13.19	13.22	13.20	1.08	1.07	1.10	1.08	83.31	83.36	83.27	83.31
Average of intercropping	27.22	27.36	27.42	27.33	12.25	12.34	12.45	12.34	0.90	0.95	1.01	0.95	72.79	76.56	77.62	75.22
Solid culture	30.81	30.99	31.01	30.94	15.61	15.77	15.78	15.72	1.15	1.37	1.33	1.28	84.78	90.41	90.29	88.49
Averageof nitrogen fertilizer rates	28.41	28.57	28.62	28.53	13.37	13.49	13.56	13.47	0.99	1.09	1.11	1.06	76.79	81.18	81.25	79.74
L.S.D. 0.05 Cropping systems		0.18				0.10				0.15				0.12		
L.S.D. 0.05 Nitrogen fertilizer rates		0.06				0.08				0.07				0.10		
L.S.D. 0.05 Interaction		0.18				0.12				0.16				0.13		

Treatments	T.S.S. (%)				Sucrose (%)				Grain yield of wheat (ton ha^{-1})				Seedyield offaba bean (ton ha^{-1})			
	125.0 kg N ha^{-1}	166.6 kg N ha^{-1}	208.2 kg N ha^{-1}	Mean	125.0 kg N ha^{-1}	166.6 kg N ha^{-1}	208.2 kg N ha^{-1}	Mean	125.0 kg N ha^{-1}	166.6 kg N ha^{-1}		Mean	125.0 kg N ha^{-1}	166.6 kg N ha^{-1}	208.2 kg N ha^{-1}	Mean
Sugarbeet + wheat	20.53	19.66	18.33	19.51	18.86	17.96	17.16	18.00	2.04	2.03	2.05	2.04	---	---	---	---
Sugarbeet + faba bean	20.70	20.76	20.56	20.67	18.66	18.86	18.56	18.70	---	---	---	---	1.14	1.16	1.15	1.15
Average of intercropping	20.61	20.21	19.44	20.08	18.76	18.41	17.86	18.34	2.04	2.03	2.05	2.04	1.14	1.16	1.15	1.15
Solid culture	21.86	21.96	20.66	21.50	20.80	20.43	19.46	20.23	6.77	6.80	6.78	6.78	3.35	3.36	3.34	3.35
Average of nitrogen fertilizer rates	21.03	20.80	19.85	20.52	19.44	19.08	18.40	18.97	4.40	4.41	4.42	4.41	2.24	2.26	2.24	2.25
L.S.D. 0.05 Cropping systems		0.59				0.59				0.06				0.02		
L.S.D. 0.05 Nitrogen fertilizer rates		0.46				0.39				N.S.				N.S.		
L.S.D. 0.05 Interaction		0.77				0.69				N.S.				N.S.		

Table 2. Relative yields, land equivalent ratio and land equivalent coefficient as affected by cropping systems, mineral nitrogen fertilizer rates and their interactions (combined analysis of the two seasons)

Treatments	Relative yield								LER				LEC			
	$L_{sugar\ beet}$				$L_{intercrop}$											
	125.0 kg N ha^{-1}	166.6 kg N ha^{-1}	208.2 kg N ha^{-1}	Mean	125.0 kg N ha^{-1}	166.6 kg N ha^{-1}	208.2 kg N ha^{-1}	Mean	125.0 kg N ha^{-1}	166.6 kg N ha^{-1}	208.2 kg N ha^{-1}	Mean	125.0 kg N ha^{-1}	166.6 kg N ha^{-1}	208.2 kg N ha^{-1}	Mean
Sugar beet + wheat	0.68	0.77	0.77	**0.74**	0.30	0.29	0.30	**0.29**	0.98	1.06	1.07	**1.03**	0.20	0.22	0.23	**0.21**
Sugar beet + faba bean	0.92	0.92	0.92	**0.92**	0.33	0.34	0.34	**0.33**	1.25	1.26	1.26	**1.25**	0.30	0.31	0.31	**0.30**
Average of intercropping	**0.80**	**0.84**	**0.84**	**0.82**	**0.31**	**0.31**	**0.32**	**0.31**	**1.11**	**1.16**	**1.16**	**1.14**	**0.25**	**0.26**	**0.27**	**0.26**
Solid culture	1.00	1.00	1.00	**1.00**	1.00	1.00	1.00	**1.00**	1.00	1.00	1.00	**1.00**	1.00	1.00	1.00	**1.00**
L.S.D. 0.05 Cropping systems		**0.04**				**0.04**				**0.03**				**0.04**		
L.S.D. 0.05 Nitrogen fertilizer rates		**0.01**				**N.S.**				**0.02**				**N.S.**		
L.S.D. 0.05 Interaction		**0.04**				**N.S.**				**0.03**				**N.S.**		

Table 3. Financial return as affected by cropping systems, mineral nitrogen fertilizer rates and their interactions (combined of the two seasons)

Treatments	Financial return															
	Sugar beet				Intercrop				Total				Net			
	125.0 kg N ha^{-1}	166.6 kg N ha^{-1}	208.2 kg N ha^{-1}	Mean	125.0 kg N ha^{-1}	166.6 kg N ha^{-1}	208.2 kg N ha^{-1}	Mean	125.0 kg N ha^{-1}	166.6 kg N ha^{-1}	208.2 kg N ha^{-1}	Mean	125.0 kg N ha^{-1}	166.6 kg N ha^{-1}	208.2 kg N ha^{-1}	Mean
Sugar beet + wheat	3437	3851	3873	**3720**	750	747	754	**750**	4187	4598	4627	**4470**	3461	3856	3870	**3729**
Sugar beet + faba bean	4598	4601	4596	**4598**	766	779	773	**772**	5364	5380	5369	**5371**	4772	4776	4752	**4766**
Average of intercropping	**4017**	**4226**	**4234**	**4159**	**758**	**763**	**763**	**761**	**4775**	**4989**	**4998**	**4920**	**4116**	**4316**	**4311**	**4247**
Sugar beet solid culture				**4990**				**---**				**4990**				**4362**

Prices of main products are that of 2013: $ 55.2 for ton of sugar beet; $ 368.0 for ton of wheat; $ 672.2 for ton of faba bean; intercropping faba bean with sugar beet increased variable costs of intercropping culture $ 404 over those of sugar beet solid culture.

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EFFECT OF MULTICOTE™ AGRI SLOW RELEASE FERTILIZERS ON A NEW ISRAEL MANDARIAN VARIETY

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ABSTRACT

A field experiment was conducted for three years during 2010-11 to 2012-13 on commercial plot located at Kibuzt Naan, where new Israel mandarin variety of Citrus was planted. In this experiment slow release fertilizers (SRF) Multicote™ 50% and Multicote™70% formulated by Haifa chemicals ltd. were tested along with farm nutrition regime with KCl as a source of potassium and KNO_3 as other source of potassium. The SRF nutrient treatments were applied only once in March every year by placing adequate quantity into 4 holes around the tree. Other two treatments with different sources of potassium were supplied continuously through drip irrigation system. Three years data on fruit yield ha^{-1} revealed that the yield was low during the first year. However, fruit yield considerably increased multifold during subsequent two years. During the second and the third year of study, Multicote™50% and Multicote™70% produced significantly higher fruit yield than from control treatment with KCL without exhibiting significant differences in these two treatments and KNO_3. The data on fruit weight and fruit size revealed that significantly more fruit weight and fruit size was observed in Multicote™70% and Multicote™50% and was significantly higher than farm control treatment with KCl. So far as number of fruits $tree^{-1}$ is concerned, during 2011-12 the number ranged between 98 and 113 without any significant difference amongst treatments. There was multifold increase in number of fruits $tree^{-1}$ from March 2009 during subsequent two years i.e. 2011-12 and 2012-13 in all the treatments. The number of fruits $tree^{-1}$ was significantly higher in farm control or KNO_3 treatment than Multicote™ 50% and Multicote™70% during 2011-12. Whereas during 2012-13 the number of fruits in the treatment Multicote™ 50% and Multicote™70% were slightly higher than from control treatment. There were no significant differences between treatments so far as percentage of NPK content in leaves and the values were almost equal or more than the normal standards. However, the mg content in leaves was less than 0.23% which is less than the standard level of 0.25 to 0.30 %. So far as the trunk diameter and sour root stock diameter are concerned there was steady increase in diameter from March 2009 to March 2012 without any significant difference between treatments. Root stock diameter was slightly more than the trunk diameter of the tree. In general, it can be inferred that slow release fertilizers Multicote™ 50% and Multicote™ 70% were superior over farm control treatment of KCl.

(Key words : Mandarian, slow release fertilizers, multicote™, KCl, KNO_3)

INTRODUCTION

It is necessary to supply optimum doses of organic manures alongwith chemical fertilizer for maintaining desired crop growth and for initiating flowering and achieving desired fruit yield in perennial fruit crops including mandarins. The organic manures have long residual effects and hence they are required to be applied only once in a year at the beginning of rainy season. However, chemical fertilizers are applied through various sources like urea, DAP, murriate of potash and other branded complex fertilizers. Amongst the three major nutrients, phosphorus and potassium are applied at the beginning of the season whereas N is applied in split doses depending upon crop growth period. Because main source of N (urea) is soluble in water and gets easily drained or leached, attempts are being made to avoid leaching by providing sustain or slow release chemical fertilizers so that they can be applied only once in a season. Various types of slow release fertilizers extend the availability of nutrients especially N for the plant for longer durations (Maynard and Lorenz, 1979) and reduce N leaching losses from soil (Wang and Alva, 1996). Khah and Arvanitoyannis (2003) reported that slow release fertilizers can produce yields at least equal to those observed with split applications of soluble fertilizers in Lettuce(*Lactuca sativa*). Similar results were also reported Senthil-Valavan and Kumaresan (2006) in tomato.

In Israel, Haifa chemicals Ltd. have developed Multicote™AGRI (Multigro) a family of controlled (slow) release fertilizer products for Agriculture and Horticulture. Multicote™AGRI products contain polymer coated sources of nitrogen, phosphorus and potassium with release longevity of 2-8 months.Multicote™AGRI products are recommended for single application per season-which results in a drastic reduction of field

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labor and application costs, as well as considerably less soil compaction. SRF minimize losses through leaching, volatilization or fixation in the soil and availability of nutrients throughout the growth cycle is ensured. It ensures more efficient use of fertilizers without wastage, allowing for reduced application rates. Ecologically superior (no soil or air pollution) and salt accumulation in the soil is prevented. Fertilization is totally independent of irrigation, no need to maintain sophisticated dosing systems and no need for technical irrigations.

Multicote™ AGRI products are highly recommended on light soils in rainy areas to avoid nutrient leaching due to rains, to the crops with shallow root system and to the crops with high nutritional requirements. It is also useful where mid season application is not feasible eg. when the crop covers the soil surface or where mulching is done or when the fields are muddy. Figure 1 and 2 explains how the slow release fertilizers (SRF) like Multicote™ work in the field after they are applied through fertilization.

Considering the advantage of single time application of slow release fertilizers (SRF) like Muticote™ in one season, studies were undertaken to judge the performance of Multicote™ 50% and 70% on citrus in comparison to farm control regime on various aspects of fruits, fruit yield etc. of new Israel mandarin variety.

MATERIALS AND METHODS

A field experiment was conducted during 3 years i.e., 2010-11, 2011-12 and 2012-13 on sandy loam soil at commercial plot located at Kibuzt Naan on new Israeli citrus (mandarin) variety. There were 4 treatments of nutrients application with four replicates of each treatment. Each treatment plot consisted of 5 citrus trees. There was one border tree between the treatment plots (replicates). The treatment details are as follows (i) Farm nutrition regime (control) with KCl as source of K (ii) KNO_3 as the only source of K (iii) Multicote™50% and (iv) Multicote™ 70%. As per farm nutrition regime (control), NPK were applied .Fertilizer formula was 24-0-24 (N-P-K) in the beginning or other formulas depending on needs along the experiment. The K was applied through KCL or KNO_3.

The fertilizers in Multicote™ 50% and 70% were N in the form of KNO_3 or Urea. The Multicote™ 50% and 70% were coated with polymer with a view to releasing the plant nutrients slowly and continuously throughout the growth cycle. The SRF nutrient treatments were applied only once in March every year by placing the right amounts into 4 holes around the tree. The other two treatments with different sources of potassium were supplied continuously through drip irrigation system. The water source was effluent water second grade pure.

Date generation

From every 5 trees, 2 trees were chosen for recording various observations. (i) The leaves samples for nutrient analysis were taken in October every year. (ii) The fruits were picked up from every 2 trees in the middle of five trees replicated.

Fifty fruits were randomly selected from sample trees for measuring size and weight of fruits and the weight of 50 fruits was further considered for calculating the weight of total number of fruits on one tree.

Harvesting of citrus fruits at maturity was done on 17-2-1011, 23-1-2012 and 13-2-2013 for the year 2010-11, 2011-12 and 2012-13 respectively. Data on fruit weight fruit^{-1}, fruit size, number of fruits tree^{-1} and yield of fruits tree^{-1} (in kg) and ha^{-1} (ton) were recorded. Mineral levels for N.P.K. and Mg were analyzed for two seasons by sampling the leaves on 17-11-2011 and 12-11-2012 respectively. Trunk diameter and sour root stock diameter in mm were recorded between 2009 and March 2012 and data are graphically presented for each treatment during March 2009, Oct.2009, March 2010, Oct.2010, March 2011, Oct.2011 and March 2012 and data are presented in table 7 and 8.

RESULTS AND DISCUSSION

The data on fruit weight and size, number of fruits tree^{-1} and fruit yield tree^{-1} and ha^{-1} for 2010-11, 2011-12 and 2012-13 are presented in table 1, 2 and 3. Graphical presentation for the data recorded during 2012-13 on fruit yield in tones ha^{-1}, fruit weight, fruit size and number of fruits tree^{-1} are given in graphs 1, 2, 3 and 4 respectively.

The data on yield (tones ha^{-1}) revealed that during 2010-11 the yield ranged between 11.7 to 17.8 tones ha^{-1} whereas during 2011-12 it ranged between 43.4 and 50.7 tones ha^{-1} and during 2012-13 it ranged from 36.5 to 45.2 tones ha^{-1}. The data clearly indicated

Table 1. First yield, picked at 17-2-11- Any statistical significance was not found

Treatments	Yield ($t\ ha^{-1}$)	Fruit weight of I fruit (g)	Fruit size (mm)	Yield ($kg\ tree^{-1}$)	Fruit no. $tree^{-1}$
Farm Control Kcl	11.7	161	67	17.6	110
KNO_3	11.7	179	69.5	17.5	98
Multicote^{Tm} 50 %	17.8	189	71.6	21.4	113
Multicote^{Tm} 70 %	13.1	198	73	19.6	99
Treatments Average	14.0	182	70	19	105

Table 2. First yield, picked at 23-1-12- Statistical significance was found

Treatments	Yield ($t\ ha^{-1}$)	Fruit weight of I fruit (g)	Fruit size (mm)	Yield ($kg\ tree^{-1}$)	Fruit no. $tree^{-1}$
Farm Control Kcl	43.4 B	161 B	62 B	89.5 B	787 B
KNO_3	50.7 A	179 B	68 A	104 A	803 B
Multicote^{Tm} 50 %	48.4 A	189 A	66 A	99.7 A	647 A
Multicote^{Tm} 70 %	47.5 A	198 A	68 A	97.9 A	682 A
Treatments Average	47	135	66	98	730

Table 3. First yield, picked at 13-2-13- Statistical significance was found

Treatments	Yield ($t\ ha^{-1}$)	Fruit weight of I fruit (g)	Fruit size (mm)	Yield ($kg\ tree^{-1}$)	Fruit no. $tree^{-1}$
Farm Control Kcl	36.5 B	115 B	61.7 B	75.3 B	654 AB
KNO_3	40 AB	136 A	65.9 A	83.3 A	615 B
Multicote^{Tm} 50 %	43.4 A	127 A	63.8 A	89.6 A	705 A
Multicote^{Tm} 70 %	45.2 A	130 A	64.6 A	93.3 A	715 A
Treatments Average	41	127	64	85.4	672

Table 4. Comparison of the yields tones ha^{-1} of three years 2010-2011-2012

Treatments	2010-11	2011-12	2012-13	Accumulation of yields	Accumulation difference against control
Farm Control Kcl	11.7	43.4 B	36.5 B	91.4	0
KNO_3	11.7	50.7 A	40.0 AB	102.8	10.8
Multicote^{Tm} 50 %	17.8	48.4 A	43.4 A	109.6	18.2
Multicote^{Tm} 70 %	13.1	47.5 A	45.2 A	105.8	14.4
Treatments Average	13.6	47.5	41.3	102.4	

Table 5.Mineral levels of leaves sampled date 17-11-2011- Not significance

Treatments	N %	P %	K %	Mg %
Farm Control Kcl	2.91	0.13	0.78	0.23
KNO_3	2.62	0.14	0.65	0.24
Multicote^{Tm} 50 %	2.85	0.14	0.72	0.23
Multicote^{Tm} 70 %	2.71	0.14	0.66	0.23
Treatments Average	2.773	0.139	0.700	0.231

Table 6.Mineral levels of leaves sampled date 12-11-2012- Not significance

Treatments	N %	P %	K %	Mg %
Farm Control Kcl	2.42	0.13	0.78	0.23
KNO_3	2.34	0.14	0.65	0.24
Multicote^{Tm} 50 %	2.38	0.14	0.72	0.23
Multicote^{Tm} 70 %	2.46	0.14	0.66	0.23
Treatments Average	2.398	0.151	0.668	0.159

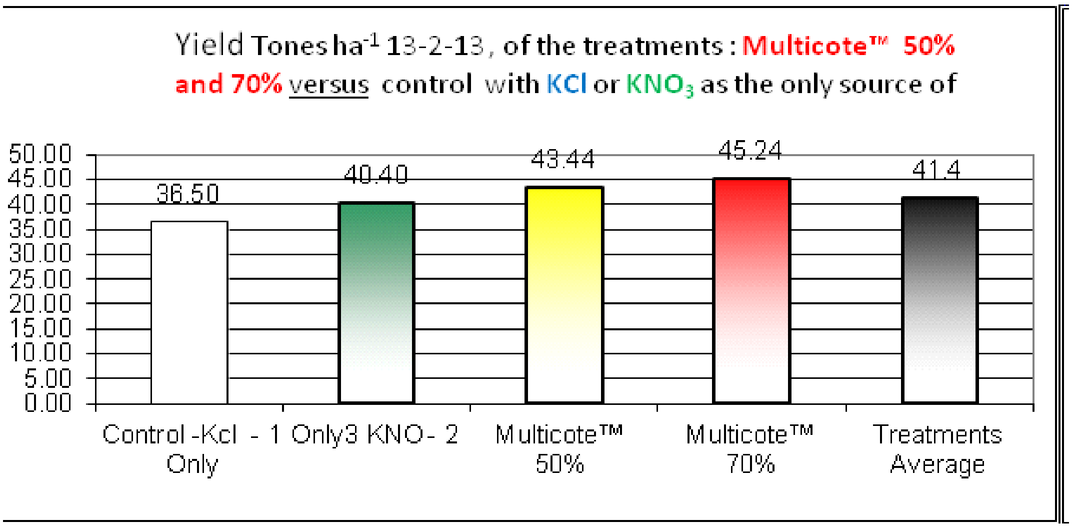
Table 7. Trunk diameter (mm) of the new Israel mandarin variety from March 2009 - March 2012

Period	Nutritional Treatments				
	Control KCl only	Only KNO_3	Multicote^{TM} 50%	Multicote^{TM} 70%	Average
March 09	43	45	44	45	44.2
Oct. 09	57	58	59	60	58.5
March 10	65	65	66	68	65.8
Oct. 10	73	74	75	77	74.8
March 11	79	84	83	86	83.2
Oct.11	91	92	92	92	91.9
March 12	95	96	98	100	97.2

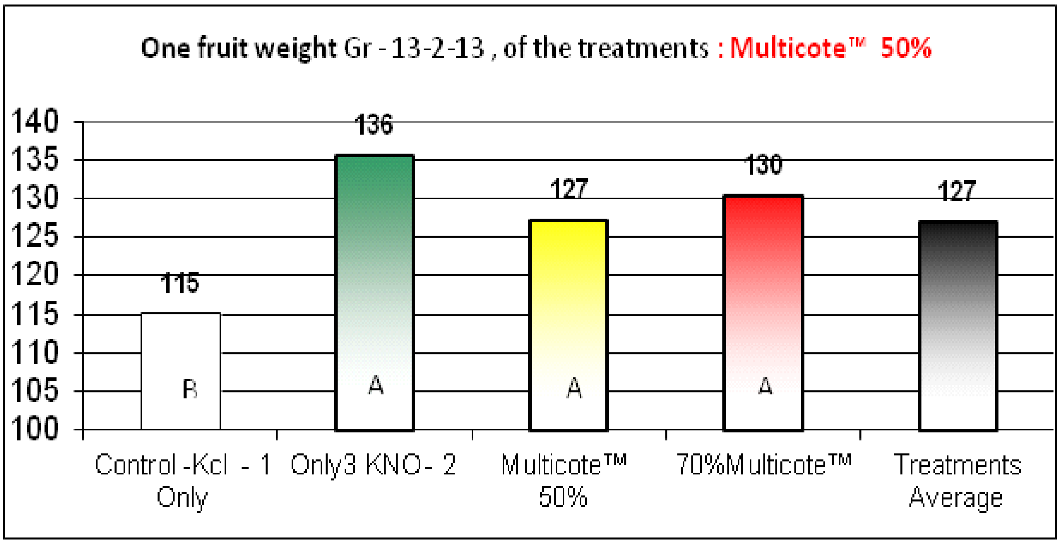
Table 8. Trunk diameter (mm) of sour orange root stock from March 09 to March 2012

Period	Treatments				
	Control KCl only	Only KNO_3	Multicote™ 50%	Multicote™ 70%	Average
March 09	50	54	52	54	52.5
Oct. 09	65	70	71	74	69.9
March 10	74	75	76	77	75.7
Oct. 10	83	84	85	86	84.7
March 11	93	96	97	99	96.6
Oct.11	104	105	105	106	105.00
March 12	108	113	113	114	112.00

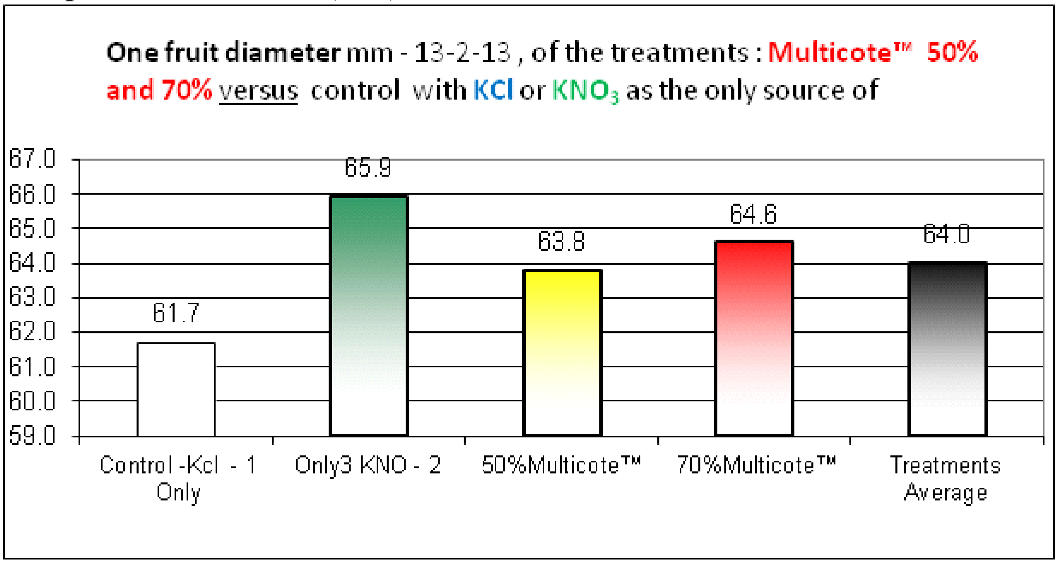
Graph 1 .Yield Tones ha^{-1}- 13-2-13- Values with different letter means Significant difference



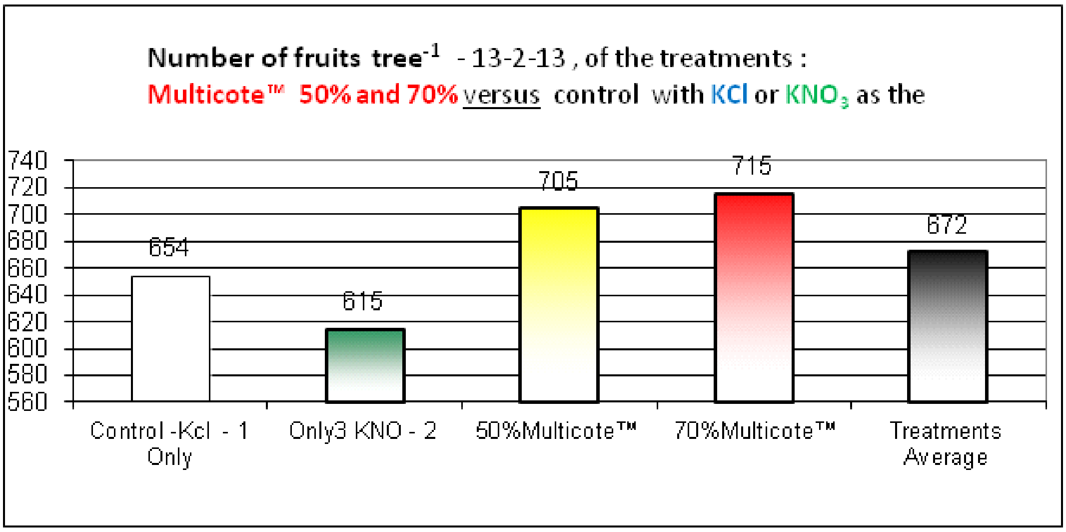
Graph 2.One fruit weight (Gr) - 13-2-13

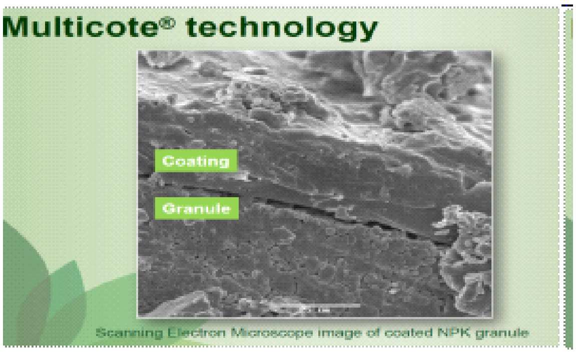


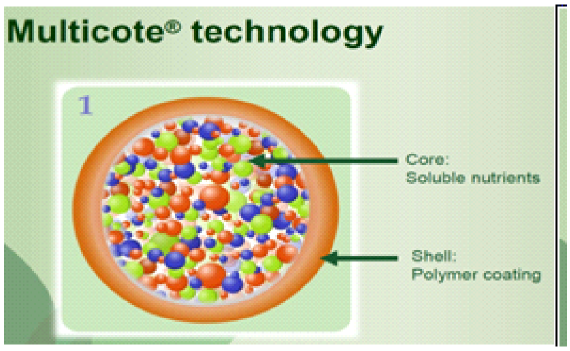
Graph 3.One fruit size (mm)

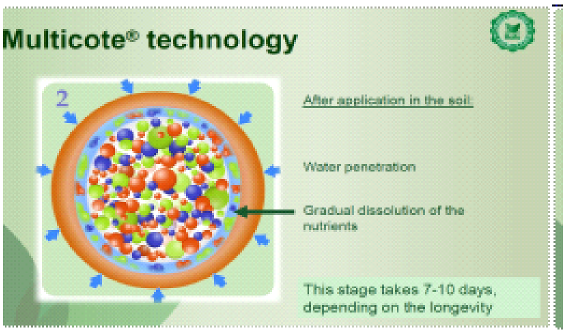


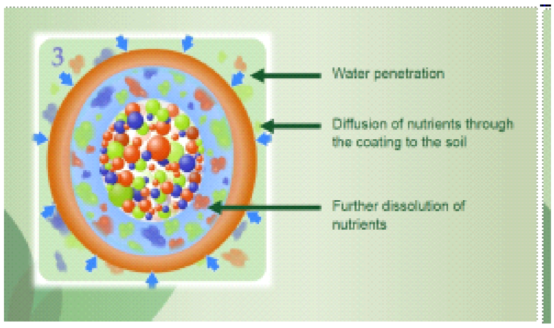
Graph 4.Number of fruits tree^{-1} - 13-2-13

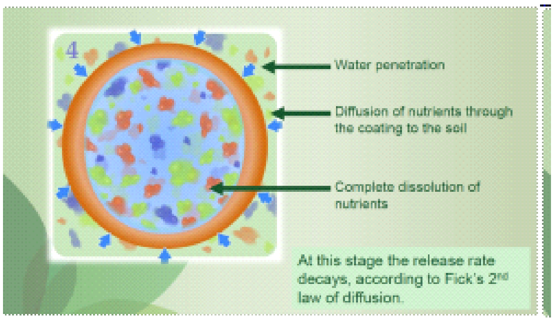


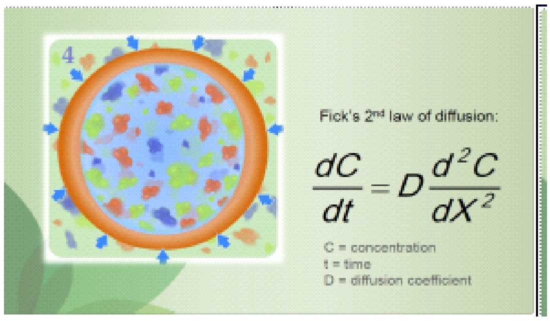


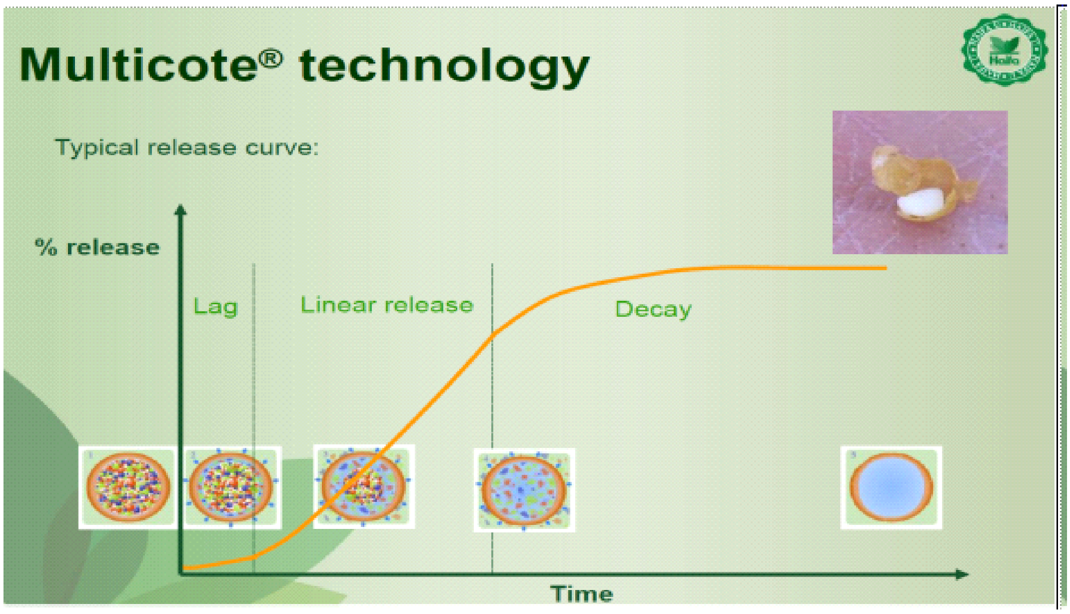












<u>Release is complete</u> , After the release is complete, the coating will degrade gradually, leaving no residues in the soil

that the least yields were recorded in farm control practice with KCl. Multicote™ 50% recorded the highest yield of 17.8 tones ha^{-1} during 2010-11 followed by Multicote™ 70% (13.1tones ha^{-1}). The fruit yield was considerably increased during subsequent two years, however, the maximum yield (50.7 ha^{-1}) was recorded in KNO_3 treatment followed by Multicote™ 50% (48.4 t ha^{-1}) and Multicote™ 70% (47.5 t ha^{-1}) without executing any significant difference. However, during 2012-13 the yield of 45.2 t ha^{-1} was obtained in Multicote™ 70% followed by Multicote™ 50% (43.4 t ha^{-1}) and KNO_3 (40 t ha^{-1}) without exhibiting any significant difference, but KNO_3 treatment was also at par with farm control with KCl.

Considering the data of three years, nutritional supply through Multicote™ 50% and 70% appeared superior over remaining treatments. Hutchinson *et al.* (2003) on potato and Koivunen and Horwath (2005) on tomato reported that more N was made available by slow release fertilizer to meet the needs of growth and fruit production. The present results also justify the advantage of slow release fertilizers. Khah and Arvanitoyannis (2003) reported that slow release fertilizers can produce yields at least equal to those observed with split applications of soluble fertilizers in lettuce (*Lactuca sativa*).

So far as fruit weight $fruit^{-1}$ is concerned it ranged between 161 and 198 g during 2010-11 and 2011-12. However, the fruit weight was less and it ranged between 115 to 136 g. The fruit size in KNO_3, Multicote™ 50% and Multicote™ 70% was significantly higher during all the three years over farm practice (control).

The fruit size ranged between 67 to 73 mm in diameter during 2010-11, 62 to 68 mm diameter during 2011-12 and 61.7 to 65.9 mm diameter during 2012-13. In this respect also, farm control treatment with KCl was significantly inferior over the best treatments. The fruit size during 2010-11 appears to be larger than 2011-12 and 2012-13, because of bearing of less number of fruits $tree^{1}$ recorded during 2010-11.

The data on number of fruits $tree^{-1}$ were found non-significant, but the number of fruits during 2010-11 ranged between 98 and 113.There was considerable increase in number of fruits during 2011-12 and 2012-13 ranging from 647 to 803 fruits $tree^{-1}$ and 615 to 715 fruits $tree^{-1}$ respectively. The number of fruits was significantly less in Multicote™ 50% and 70% compared to KNO_3 and farm control with KCL during 2011-12 but during 2012-13 the fruits numbers were significantly higher in Multicot™ 70% and 50% than remaining treatments.

The data from table 5 and 6 pertaining to mineral levels of nutrients revealed that the content of N was in general higher during 2011-12 compared to 2012-13. It ranged from 2.62% to 2.91% during 2011-12 and 2.34% to 2.46 % during 2012-13. However, there were no significant differences. The content of P in leaves for both the years ranged between 0.13% and 0.14% without exhibiting significant difference. This level is considered satisfactory. K levels during both the years ranged between 0.65 and 0.78% without any significant difference. This level is also considered as normal level. The mg content in leaves ranged between 0.23 to 0.24% without any significant difference. Normal range of mg content in leaves is 0.3 to 0.4% .Thus, the Mg level was less than the normal levels in the present study

The trunk diameter (Table 7) recorded during March 2009 ranged between 43 to 45 mm. The trunk size gradually increased subsequently up to the last observation recorded during March 2012. During this period the trunk diameter ranged between 95 and 100 mm. However, there was no considerable increase in trunk diameter in test treatments. Similarly, sour orange root stock (Table 8) diameter did not show any significant difference between these treatments. The sour orange root stock diameter was slightly more than the trunk diameter. The root stock diameter ranged between 52 to 54 mm during March 2009 and 108 to 114 mm during March 2012.

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EFFICIENCY OF INTERCROPPING SOYBEAN WITH CORN UNDER TWO CORN PLANT DISTRIBUTIONS AND THREE MINERAL NITROGEN FERTILIZER RATES

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ABSTRACT

A two-year study was carried out at Sakha Agricultural Experiments and Research Station, A.R.C., Kafr El-Sheikh governorate, Egypt during 2012 and 2013 seasons to evaluate the productivity and profitability of soybean under two corn plant distributions and three mineral N fertilizer rates. Corn variety T.W.C. 310 was distributed in one and two plants hill^{-1} (one row ridge^{-1}) at 30 and 60 cm between corn hills under intercropping and solid cultures, respectively, which received three nitrogen fertilizer rates (4.00, 5.00 and 6.00 g N plant^{-1}), meanwhile soybean variety Giza 82 was drilled in two rows ridge^{-1} under intercropping and solid cultures. A split split plot design with three replications was used. The results indicated that intercropping soybean with corn had more severely negative effects on soybean yield plant^{-1} and its attributes, except plant height, in mixed stand than those grown in alternating ridges 2:2. Intercropping corn with soybean decreased seed yields plant^{-1} and ha^{-1} by 19.97 and 43.89 per cent as compared to soybean solid culture. Seed yield of intercropped soybean reached 62.04 % of that obtained from the recommended soybean solid culture in addition to 7.27 tons ha^{-1} of corn grains. Increasing distance between corn plants from 30 to 60 cm increased significantly soybean yield and its attributes except plant height. Increasing mineral nitrogen (N) fertilizer rates of corn from 4.00 to 6.00 g N plant^{-1} did not affect soybean plants. The interaction between cropping systems and corn plant distributions affected significantly soybean yield and its attributes. Yield advantages were achieved because of LER and LEC values were exceeded 1.00 and 0.25, respectively. Dominance analysis proved that soybean is dominated component. The highest net return was obtained by growing soybean with corn was distributed in two plants hill^{-1} (60 cm apart) and fertilized by 5.00 g N plant^{-1} in mixed stand.

(Key words: Intercropping, soybean, mineral N fertilizer rates, corn plant distributions, competitive relationships, financial return)

INTRODUCTION

Intercropping acts as a key factor in crop intensification field. It has been practiced by farmers for many years in various ways and most areas, and has played a very important role in Egypt. It has since been recommended as a practical alternative solution for increasing national production of soybean (Sayed Galal and Metwally, 1986), where soybean (*Glycine max* L.) is an important source of protein for man and animals globally (Singh, 2011). Despite its importance, soybean is not a common crop in the Egyptian farming systems in the summer season. There is a decline in soybean acreage due to increased production costs and lower net returns as compared with the other strategic summer crops such as corn where corn cultivated area reached about 906,334 ha in 2012 with an average yield of 4.05 tons ha^{-1}, while, the soybean acreage reached about 7,187 ha in 2012 with an average yield of 3.60 tons ha^{-1} (Anonymous, 2013).

The growth of two crops together in the same field during a growing season may result in inter-specific competition or facilitation between the plants (Zhang and Li, 2003). Intercropping legumes with cereals is an attractive strategy to smallholder farmers for increasing productivity and land labour utilization unit^{-1} area of available land though intensification of land use (Seran and Brintha, 2010) and spatial arrangement has an important influence on the degree of competition between crops (Addo-Quaye *et al*., 2011).

Obviously, selection of crop species with applying some cultural practices can decrease inter-specific competition between crop species under intercropping conditions. Plant distributions with actually its fertilizer needs can play an important role in augmenting yields of crop species. Soybean increases cereal yield in addition to improving soil fertility when crop residues are incorporated (Andrew, 1979). On the other hand, doubling corn number from two to four plants hill^{-1} with increasing distance between corn hills from 30 to 60 cm resulted in significant increments in soybean yield and its attributes under mixed intercropping pattern (Metwally *et al*., 2009).

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Accordingly, the objective of the study was to evaluate the productivity and profitability of soybean under two corn plant distributions and three mineral N fertilizer rates.

MATERIALS AND METHODS

A two – year study was carried out at Sakha Agricultural Experiments and Research Station, A.R.C., Kafr El-Sheikh governorate (Lat. 31°06'42" N, Long. 30°56'45" E, 17 m a.s.l.), Egypt during 2012 and 2013 seasons to evaluate the productivity and profitability of soybean under two corn plant distributions and three mineral N fertilizer rates of corn. Wheat was the preceding winter crop in both seasons. The experimental soil texture was clay. Chemical analysis of the soil (0 – 20 cm), pH value (7.95), available N (28.5 ppm), available phosphorus (7.77 ppm) and available potassium (392.5 ppm) were analyzed by Water and Soil Research Institute, ARC. Normal cultural practices for growing corn and soybean crops were used as recommended in the area. Surface irrigation was the irrigation system in the area. Corn variety (T.W.C. 310) and soybean variety (Giza 82) were used. Soybean seeds were inoculated with *Bradyrhizobium japonicum* and gum arabic was used as a sticking agent. Soybean seeds were sown on 9th and 13th May at 2012 and 2013 seasons, respectively, while, corn grains were sown fifteen days later. Soybean was thinned to 2 plants at 15 cm between hills. Mineral N fertilizer was applied at rate of 35.7 kg N ha^{-1} for soybean under intercropping and solid cultures. The experiment included three cropping systems (two intercroppings and one soybean solid culture), two corn plant distributions (one corn plant hill^{-1} at 30 cm between hills and two corn plants hill^{-1} at 60 cm between hills) and three mineral N (ammonium nitrate, 33.5% N unit) fertilizer rates corn^{-1} plant (285.6, 238.0 and 190.4 kg N ha^{-1} was expressed as 4.00, 5.00 and 6.00 g N plant^{-1}). This experiment included eighteen treatments which were the combinations of cropping systems (intercropping and solid), two corn plant distributions and three mineral N fertilizer rates of corn. Figure 1 shows the intercropping and solid cultures of soybean as follows:

1. Two corn ridges alternating with another two of soybean. Soybean was grown in two drillings ridge^{-1}. This pattern resulted in 23,800 and 190,400 plants of corn and soybean ha^{-1}, respectively (designated as 2:2 pattern).

2. Mixed intercropping pattern, corn was planted in middle of the ridge and soybean was planted in both sides of ridge. This pattern resulted in 47,600 and 380,800 plants of corn and soybean ha^{-1}, respectively.

3. Solid culture of soybean: pure stand of soybean ridges. Soybean was grown in two drillings ridge^{-1}. This pattern resulted in 380 800 soybean plants ha^{-1}.

4. Solid culture of corn: pure stand of corn ridges. This pattern resulted in 47,600 corn plants ha^{-1} (This pattern was used only to estimate the competitive relationships).

A split split plot distribution in randomized complete block design replicated thrice was used. Cropping systems (intercropping and solid) were randomly assigned to the main plots, distributions of corn plants were allotted in subplots and mineral N fertilizer rates of corn were devoted to sub sub-plots. The area of sub-sub-plot was 16.8 m^2, it consisted of 4 ridges, and each ridge was 6.0 m in length and 0.7 m in width.

Soybean yield and its attributes

At harvest, the following traits were measured on ten guarded plants from each plot: plant height (cm), numbers of pods and seeds plant^{-1}, 100 – seed weight (g), seed yield plant^{-1} (g). Soybean seed and corn grain yields ha^{-1} (ton) were recorded on the basis of experimental plot area by harvesting all plants of each plot.

Competitive relationships

Land equivalent ratio (LER): defines as the ratio of area needed under sole cropping to one of intercropping at the same management level to produce an equivalent yield (Mead and Willey, 1980). It is calculated as follows: LER = $(Y_{ab} / Y_{aa}) + (Y_{ba} / Y_{bb})$, Where Y_{aa} = Pure stand yield of crop a (corn), Y_{bb} = Pure stand yield of crop b (soybean), Y_{ab} = Intercrop yield of crop a (corn), Y_{ba} = Intercrop yield of crop b (soybean).

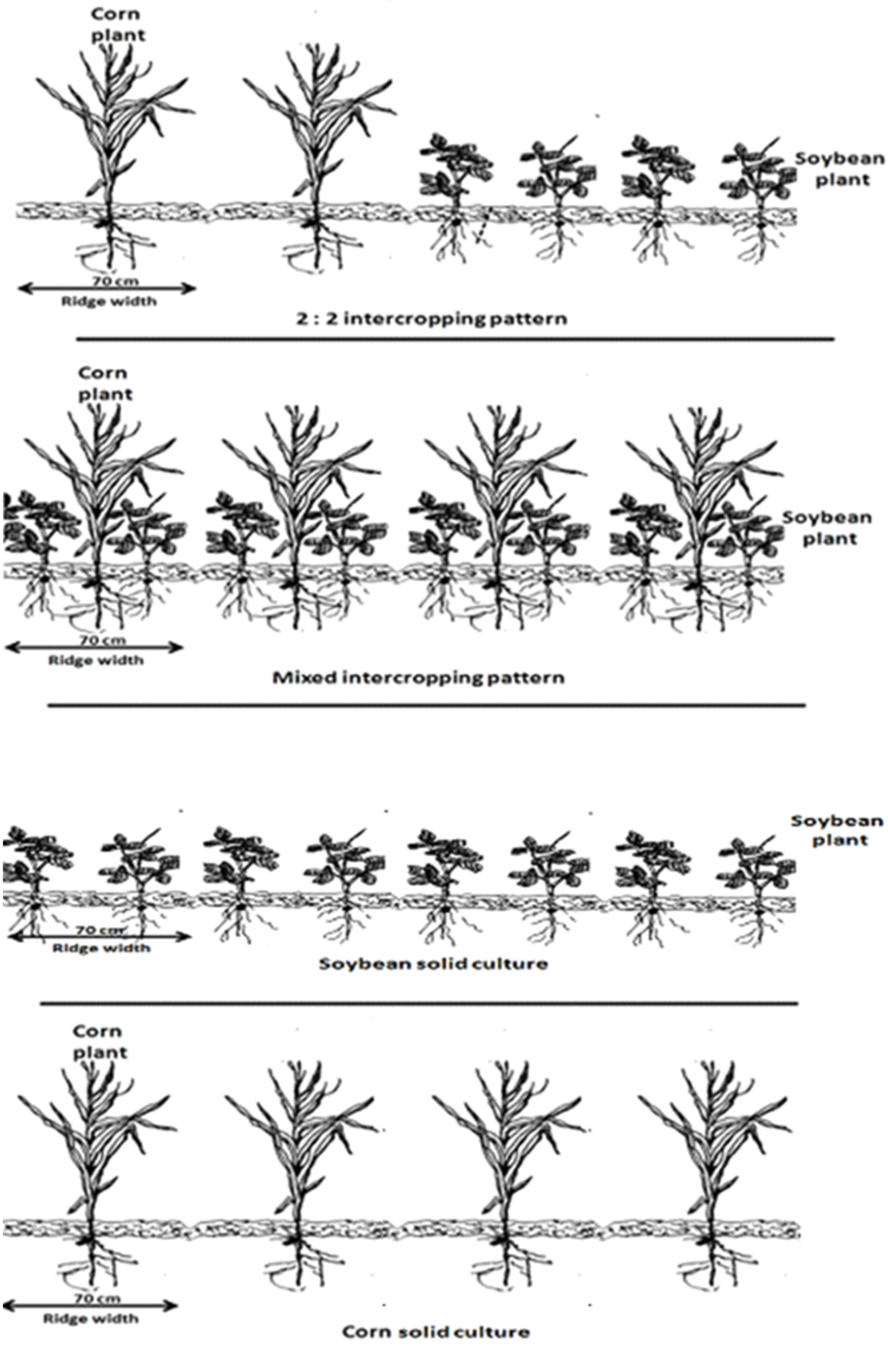

Figure 1. Intercropping soybean with corn and solid cultures of both crops

Land equivalent coefficient (LEC): is a measure of interaction concerned with the strength of relationship (Adetiloye *et al*., 1983). It is calculated as follows: LEC = L_a x L_b, Where L_a = LER of crop a (corn), L_b = LER of crop b (soybean)

Aggressivity: represents a simple measure of how much the relative yield increase in one crop is greater than the other in an intercropping system (Willey, 1979). It is calculated as follows:

$A_{ab} = [Y_{ab} / (Y_{aa} \times Z_{ab})] – [Y_{ba} / (Y_{bb} \times Z_{ba})]$ $A_{ba} = [Y_{ba} / (Y_{bb} \times Z_{ba})] – [Y_{ab} / (Y_{aa} \times Z_{ab})]$, Where Y_{aa} = Pure stand yield of crop a (corn), Y_{bb} = Pure stand yield of crop b (soybean), Y_{ab} = Intercrop yield of crop a (corn), Y_{ba} = Intercrop yield of crop b (soybean), Z_{ab} = The respective proportion of crop a in the intercropping system (corn), Z_{ba} = The respective proportion of crop b in the intercropping system (soybean).

Financial return

It was calculated by determining the total costs and net return of intercropping culture as compared to recommended solid planting of sugar beet according to Metwally *et al.* (2009).

1. Total return of intercropping cultures = Price of sugar beet yield + price of wheat or faba bean yield (American dollars $).

To calculate the total return, the average of sugar beet, wheat and faba bean prices presented by Anonymous (2013) was used.

2.. Net return ha^{-1} = Total return – (fixed cost of sugar beet + variable costs of wheat or faba bean according to intercropping pattern).

Analysis of variance of the obtained results of each season was performed. The homogeneity test was conducted of error mean squares and accordingly, the combined analysis of the two experimental seasons was carried out. The measured variables were analyzed by ANOVA using MSTATC statistical package (Freed, 1991). Mean comparisons were done using least significant differences (L.S.D) method at 5 % level of probability to compare differences between the means (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Soybean yield and its attributes cropping systems

Plant height, numbers of pods and seeds $plant^{-1}$, 100 – seed weight, seed yields $plant^{-1}$ and ha^{-1} were affected significantly by cropping systems in the combined data across 2012 and 2013 seasons (Table 1). Intercropping soybean with corn decreased significantly ($P \leqslant 0.05$) numbers of pods and seeds $plant^{-1}$, 100 – seed weight, seed yields $plant^{-1}$ and ha^{-1} in comparison with those grown in solid culture, meanwhile the reverse was true for plant height. As a result of intercropping, intercropping corn with soybean decreased seed yields $plant^{-1}$ and ha^{-1} by 19.97 and 43.89 per cent as compared to soybean solid culture.

The observed response in plant height of soybean may be primarily attributed to an increase of internode elongation of shaded soybean plant as a result of increasing plant hormones. Is clear that mixed pattern increased inter-specific competition between soybean and corn for basic growth resources (Olufajo, 1992) during soybean growth and development that reflected on more amounts of plant hormones as compared with soybean solid culture (Abdel-Galil *et al*., 2014a).

With regarding to intercropping systems, alternating ridges of corn and soybean (2:2) had little negative effect on soybean traits; numbers of pods and seeds $plant^{-1}$, 100 – seed weight and seed yield $plant^{-1}$ than those grown in mixed stand, meanwhile, the reverse was true for seed yield ha^{-1} in the combined data across 2012 and 2013 seasons. These results may be due to spatial arrangement of mixed pattern formed unfavorable conditions for growth and development soybean plant that reflected on numbers of pods and seeds $plant^{-1}$, 100 seed weight and seed yield $plant^{-1}$ as compared with the other pattern. Therefore, maize yield was not affected by the presence of soybean, while, soybean yield was reduced significantly under maize, that reduction being higher with increasing maize population (Putnam *et al*., 1985 and Weil and McFadden, 1991). There is potential for higher productivity of intercrops when intra-specific competition is less than inter-specific competition for a limiting resource (Banik and Sharma, 2009).

Obviously, spatial arrangement of mixed pattern had the recommended ratio of occupied area by soybean plants (100% of the recommended soybean solid culture), whereas, 2:2 pattern had only 50 % of the recommended soybean solid culture. Consequently, mixed stand led to increase in soybean yield ha^{-1} despite the severe negative impact on the other soybean traits. These results are in the same context of those obtained by Board and Harville (1992) who revealed that spatial arrangement of intercropping culture resulted in shading effects of adjacent corn plants on soybean plant, where, environmental conditions prevailing during growth period, especially intensity and quality of intercepted solar radiation by canopy, are important determinants of yield components and hence yield of soybean. Also, Egbe (2010) investigated that intercropped soybean produced lower seed yield than their sole crop counterparts. Moreover, Metwally *et al.* (2012) showed that intercropping corn with soybean affected negatively on seed yield $plant^{-1}$ and consequently seed yield ha^{-1}.

Corn plant distributions

Plant height, numbers of pods and seeds $plant^{-1}$, 100 – seed weight, seed yields $plant^{-1}$ and ha^{-1} were affected significantly by corn plant distributions in the combined data across 2012 and 2013 seasons (Table 1). Increasing distance between corn hills from 30 to 60 cm increased significantly ($P \leqslant 0.05$) numbers of pods and seeds $plant^{-1}$, 100 seed weight, seed yields $plant^{-1}$ and ha^{-1}, meanwhile, the reverse was true for plant height. Increasing number of corn plants from one o two plants $hill^{-1}$ increased seed yields $plant^{-1}$ and ha^{-1} by 3.43 and 4.78%, respectively.

These results may be attributed to wide space between corn hills formed a good chance for intercropped soybean plants to greatly benefit from environmental resources than the other one (30 cm apart). Therefore, there were decrease in internode elongation of soybean plant as a result of decreasing plant hormones and significant increments in number of pods and seeds $plant^{-1}$, 100 seed weight and seed yield $plant^{-1}$ that reflected on the yield of soybean ha^{-1} as compared with the other one. It is observed that growing two corn plants $hill^{-1}$ encouraged soybean growth and development through decreasing inter-specific competition between corn and soybean plants for basic growth resources as compared with the other one. These results are in agreement with those reported by Metwally *et al.* (2012) who concluded that increasing maize plant population densities to 47,600 plants ha^{-1} (100% of the recommended solid culture) and distributed corn plant at wide distance between hills, as well as, increasing densities of soybean plants to 380,800 plants ha^{-1} (100% of the recommended solid culture) in intercropping culture could be recommended to increase intercropped maize and soybean yields. In the same trend, Abdel-Galil *et al.* (2014a) showed that corn plant geometry which was distributed at wide distance (90 cm apart) increased soybean seed yields $plant^{-1}$ and ha^{-1} as compared to the other distributions (30 and 60 cm).

Mineral N fertilizer rates

Plant height, number of pods and seeds $plant^{-1}$, 100 seed weight, seed yields $plant^{-1}$ and ha^{-1} were not affected by mineral N fertilizer rates in the combined data across 2012 and 2013 seasons (Table 1). Increasing mineral N fertilizer rates of corn from 4.00 to 6.00 g N $corn^{-1}$ plant did not affect soybean yield and its attributes. These data show that mineral N fertilizer rates had not any relationship *($P > 0.05$)* with all the studied traits of soybean. These results may be due to grain legumes help maintain and improve soil fertility due to their ability to biologically fix atmospheric N (Sanginga and Woomer, 2009) than cereal crops. These results are in the same context of those obtained by Chui (1984) who studied two fertility levels of N and various spatial arrangements of maize (*Zea mays* L.) in an attempt to assess the feasibility of applying N fertilizer to a maize-soybean (*Glycine max* (L.) Merr.) mixture. He found N fertilizer did not affect growth and yield components of soybean.

Response of cropping systems to corn plant distributions

Plant height, number of pods and seeds $plant^{-1}$, 100 seed weight, seed yields $plant^{-1}$ and ha^{-1} were affected significantly by the interaction between cropping systems and corn plant distributions in the combined data across 2012 and 2013 seasons (Table 1). The lowest values of number of pods and seeds $plant^{-1}$ and seed yield $plant^{-1}$ were obtained by intercropping soybean with corn that distributed at 30 cm between hills (one plant hill^{-1}) under mixed stand, meanwhile, soybean solid culture produced the highest values of numbers of pods and seeds plant^{-1} and seed yield plant^{-1}. Although wide distance between corn hills (60 cm apart) played a major role to minimize the adverse effects of intercropping conditions for all the studied soybean traits, however, soybean growth and development severely suffered ($P \leqslant 0.05$) from adjacent corn shading effects under intercropping conditions and reflected on all the studied traits of soybean in comparison with soybean solid culture. These results are confirmed with those obtained by Abou-Elela *et al.* (2012) who showed that seed yield plant^{-1} and unit^{-1} area was affected significantly by the interaction between cropping systems and distributions of corn plants. Also, Abdel-Galil *et al*. (2014a) indicated that cropping systems x corn plant geometry affected significantly plant height, seed yields plant^{-1} and ha^{-1}.

Soybean yield and its attributes were not affected by the other interactions among cropping systems, corn plant distributions and mineral N fertilizer rates in the combined data across 2012 and 2013 seasons (Table 1). These data show that each of these three factors act independently on all the studied traits of soybean meaning that there was no effect *($P >$ 0.05)* of cropping systems x corn plant distributions x mineral N fertilizer rates on all the studied traits of soybean.

Competitive relationships

Relative yields of soybean and corn were affected significantly by the cropping systems in the combined data across 2012 and 2013 seasons (Table 2). Mixed intercropping soybean with corn increased relative yields of both crops as compared with those grown in alternating ridges (2:2). These data may be due to plant population density of soybean and corn reached 100 % of solid cultures of both crops. These results are in accordance with those obtained by Metwally *et al*. (2009) who revealed that mixed intercropping soybean with corn increased relative yields of both crops as compared with those grown in alternating ridges.

Relative yields of soybean and corn were affected significantly by corn plant distributions in the combined data across 2012 and 2013 seasons (Table 2). Increasing distance between corn hills from 30 to 60 cm increased relative yields of both crops. These results may be due to growing two corn plants hill^{-1} encouraged soybean growth and development through decreasing inter-specific competition between corn and soybean plants for basic growth resources that increased relative yields of both crops as compared with the other one.

Relative yields of soybean and corn were not affected by increasing mineral N fertilizer rate from 4.00 to 6.00 g N plant^{-1} in the combined data across 2012 and 2013 seasons (Table 2). These results may be due to grain legumes help maintain and improve soil fertility due to their ability to biologically fix atmospheric N **(**Sanginga and Woomer, 2009) than cereal crops.

Relative yields of soybean and corn were affected significantly by the interaction between cropping systems and corn plant distributions in the combined data across 2012 and 2013 seasons (Table 2). Mixed intercropping soybean with corn which distributed in wide distance between corn hills (60 cm apart) had higher relative yields of both crops than growing soybean with corn which distributed in narrow distance between corn hills (30 cm apart) under alternating ridges (2:2). Relative yields of corn and soybean were not affected by the other interactions among cropping systems, corn plant distributions and mineral N fertilizer rates in the combined data across 2012 and 2013 seasons (Table 2).

Land equivalent ratio (LER)

The values of LERs were estimated by using data of recommended solid cultures of both crops. LER was affected significantly by the cropping systems in the combined analysis of the two seasons. In general, intercropping soybean with corn increased LER as compared to corn solid culture in the combined data across 2012 and 2013 seasons (Table 2). It ranged from 1.12 (by intercropping soybean with corn in alternating ridges '2:2' which grown in narrow distance between corn hills and received the medium mineral N fertilizer rate (5.00 g N plant^{-1}) to 1.68 (by mixed intercropping soybean with corn which grown in wide distance between corn hills and received the medium mineral N fertilizer rate (5.00 g N plant^{-1}) with an average of 1.38. The advantage of the highest LER by mixed intercropping soybean with corn over the others could be due to plant population density of soybean and corn where it reached 100 % of solid cultures of both crops. These results are in parallel with those obtained by Metwally *et al*. (2009) and Abdel-Galil *et al.* (2014 a and b) who concluded that LER was increased by intercropping soybean with corn.

With respect to corn plant distributions, LER was affected significantly by corn plant distributions in the combined data across 2012 and 2013 seasons (Table 2). Increasing distance between corn hills from 30 to 60 cm increased LER. These results may be due to growing two corn plants hill^{-1} encouraged soybean growth and development through decreasing inter-specific competition between corn and soybean plants for basic growth resources that increased LER as compared with the other one. These results are in parallel with those obtained by Metwally *et al*. (2009) and Abdel-Galil *et al.* (2014a) who concluded that LER was increased by increasing distance between corn hills.

With respect to mineral N fertilizer rates, LER was not affected by increasing mineral N fertilizer rate from 4.00 to 6.00 g N plant^{-1} in the combined data across 2012 and 2013 seasons (Table 2). LER was affected significantly by the interaction between cropping systems and corn plant distributions in the combined data across 2012 and 2013 seasons (Table 2). Intercropping soybean with corn which grown in narrow distance between corn hills (30 cm apart) had the lowest LER, meanwhile, the highest LER was obtained by intercropping soybean with corn which distributed in wide distance between corn hills (60 cm apart). LER was not affected by the other interactions among cropping systems, corn plant distributions and mineral N fertilizer rates in the combined data across 2012 and 2013 seasons (Table 2).

Land equivalent coefficient (LEC)

LEC is a measure of interaction concerned with the strength of relationship. LEC is used for a two- crop mixture the minimum expected productivity coefficient (PC) is 25 per cent, that is, a yield advantage is obtained if LEC value was exceeded 0.25. LEC was affected significantly by the cropping systems in the combined data across 2012 and 2013 seasons (Table 2). Mean LEC of intercropped soybean with corn was exceeded 0.25 and consequently the soybean – corn intercropping had yield advantage. Mixed intercropping soybean and corn had the highest LEC than those grown in alternating ridges (2:2). The advantage of the highest LEC by mixed intercropping soybean with corn over the others could be due to plant population density of soybean and corn where it reached 100 % of solid cultures of both crops. Similar results were obtained by Abdel-Galil *et al.* (2014a) who found there is a yield advantage of intercropping soybean with corn because of means LEC value was exceeded 0.25.

With respect to corn plant distributions, increasing distance between corn hills from 30 to 60 cm increased LEC in the combined data across 2012 and 2013 seasons (Table 2). These results may be due to growing two corn plants hill^{-1} encouraged soybean growth and development through decreasing inter-specific competition between corn and soybean plants for basic growth resources that increased LEC as compared with the other one. These results are in harmony with those obtained by Abdel-Galil *et al.* (2014a) who demonstrated that Mean LEC values varied from 0.39 by growing corn at narrow distance between corn hills (30 cm) with soybean variety Giza 111 to 0.60 by growing corn at 90 cm between corn hills with soybean variety Giza 22.

With respect to mineral N fertilizer rates, LEC was not affected by increasing mineral N fertilizer rate from 4.00 to 6.00 g N plant^{-1} in the combined data across 2012 and 2013 seasons (Table 2). LEC was affected significantly by the interaction between cropping systems and corn plant distributions in the combined data across 2012 and 2013 seasons (Table 2). Intercropping soybean with corn which grown in narrow distance between corn hills (30 cm apart) had the lowest LEC, meanwhile, the highest LEC was obtained by intercropping soybean with corn which distributed in wide distance between corn hills (60 cm apart). LEC was not affected by the other interactions among cropping systems, corn plant distributions and mineral N fertilizer rates in the combined data across 2012 and 2013 seasons (Table 2).

Aggressivity

Aggressivity determines the difference in competitive ability of the component crops in intercropping association. The positive sign indicates the dominant component and the negative sign indicates the dominated component. Higher numerical values of aggressiveness denote greater difference in competitive ability, as well as, bigger difference between actual and expected yield in both crops. The results indicate that the value of aggressivity of corn was positive for all treatments, whereas, the values of aggressivity was negative for all intercropped soybean in the combined data across 2012 and 2013 seasons (Figure 2). These data show that corn plants are dominant component and soybean plants are dominated component. In general, the highest negative values were obtained by growing soybean with corn in mixed stand which grown in narrow distance between corn hills (30 cm apart) and received the medium mineral N fertilizer rate (5.00 g N plant^{-1}), whereas, intercropping soybean with corn which grown in alternating ridges (2:2) and received the previous mineral nitrogen fertilizer rate had the lowest negative values. These results clear that mixed intercropping soybean with corn is more aggressive than intercropped soybean with corn in alternating ridges 2:2 especially under fertilizer rate 5.00 g N plant^{-1}. Similar results were obtained by Abdel-Galil *et al.* (2014b) who showed that corn plants are dominant component and soybean plants are dominated component.

Financial evaluation

The data regarding financial return of intercropped soybean with corn plants as compared with corn solid culture are shown in Table 3. Intercropping cultures increased total and net returns by about 30.51 and 94.09 per cent, respectively, as compared with the recommended corn solid culture. Net return of intercropping soybean with corn was varied between treatments from 966 to \$ 1573 ha^{-1} as compared with recommended corn solid culture (\$ 644 ha^{-1}). Mixed intercropping pattern gave the highest financial value when using high population densities of both crops and distributing the corn plants at wide distance between corn hills (60 cm apart) and received the medium mineral N fertilizer rate (5.00 g N plant^{-1}). The financial return showed that the mixed intercropping pattern has higher values than alternating ridges (2:2). These results suggest that intercropping soybean with corn is more profitable to farmers than corn solid culture for farmers by using suitable intercropping pattern. These findings are parallel with those obtained by Metwally *et al*. (2009) and Abdel-Galil *et al*. (2014a) who found that intercropping soybean with corn is more profitable than corn solid culture.

It could be concluded that growing soybean on both sides of all corn ridges with distributing two corn plants hill^{-1} at 60 cm between corn hills and fertilizing corn plant by 238.0 kg N ha^{-1} that expressed as 5.00 g N plant^{-1} (80% of the recommended mineral N fertilizer rate for corn under Egyptian conditions) achieved \$ 929 ha^{-1} over than corn solid culture.

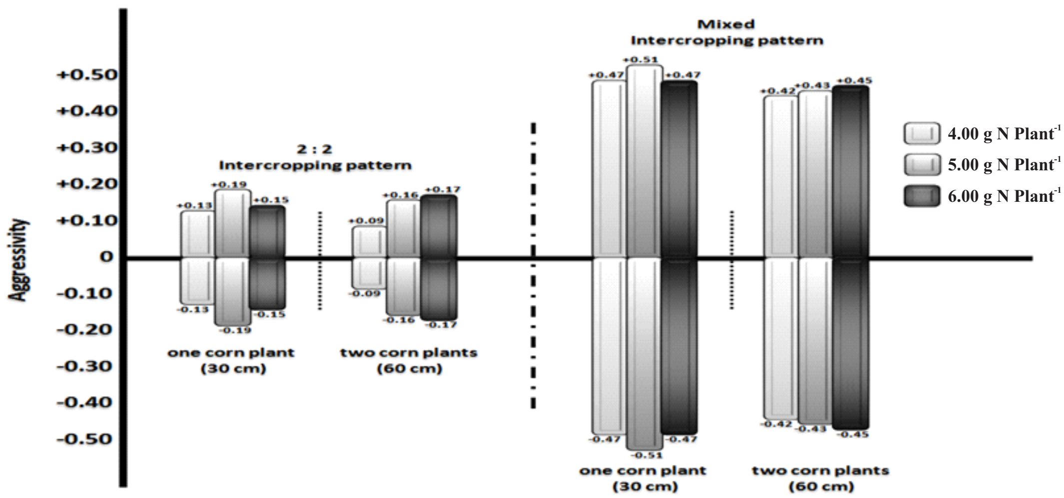

Figure 2. Aggressivity as affected by the cropping systems, corn plant distributions, mineral N fertilizer rates and their interactions, combined data across 2012 and 2013 seasons.

Table 1. Effect of cropping systems, corn plant distributions, mineral N fertilizer rates and their interactions on soybean yield and its attributes, combined data across 2012 and 2013 seasons

Traits / Cropping systems	Corn plant distributions	Plant height (cm) 4.00 g N plant^{-1}	5.00 g N plant^{-1}	6.00 g N plant^{-1}	Mean	Number of pods plant^{-1} 4.00 g N plant^{-1}	5.00 g N plant^{-1}	6.00 g N plant^{-1}	Mean	Number of seeds plant^{-1} 4.00 g N plant^{-1}	5.00 g N plant^{-1}	6.00 g N plant^{-1}	Mean
2 :2	1P/ 30 cm	77.53	77.76	77.80	77.69	31.86	32.03	31.96	31.95	87.93	87.76	88.06	87.91
	2P / 60 cm	73.73	73.80	73.90	73.81	35.50	35.73	35.80	35.67	90.46	90.63	90.76	90.61
Mean		75.63	75.78	75.85	75.75	33.68	33.88	33.88	33.81	89.19	89.19	89.41	89.26
Mixed	1P/ 30 cm	87.86	87.73	88.20	87.93	23.60	23.70	23.90	23.73	71.66	71.43	71.96	71.68
	2P / 60 cm	82.33	81.96	82.10	82.13	26.63	26.86	26.70	26.73	76.16	75.93	75.83	75.97
Mean		85.09	84.84	85.15	85.02	25.11	25.28	25.30	25.23	73.91	73.68	73.89	73.82
Average of intercropping		80.36	80.31	80.50	80.39	29.39	29.58	29.59	29.52	81.55	81.43	81.65	81.54
Recommended solid culture			69.26		69.26		40.83		40.83		106.30		106.30
Average of corn plant distributions	1P/ 30 cm	78.21	78.25	78.42	78.29	32.09	32.18	32.23	32.16	88.63	88.49	88.77	88.63
	2P / 60 cm	75.10	75.00	75.08	75.06	34.32	34.47	34.44	34.41	90.97	90.95	90.96	90.96
Average of nitrogen fertilizer rates		76.65	76.62	76.75	76.67	33.20	33.32	33.33	33.28	89.80	89.72	89.86	89.79
L.S.D. 0.05 Cropping systems (C)					0.85				0.96				1.03
L.S.D. 0.05 Corn plant distributions (D)					0.21				0.27				0.13
L.S.D. 0.05 Mineral N fertilizer rates (N)					N.S.				--				--
L.S.D. 0.05 C x D					0.81				0.94				1.06
L.S.D. 0.05 C x N					N.S.				--				--
L.S.D. 0.05 N x D					N.S.				--				--
L.S.D. 0.05 C x D x N					N.S.				--				--

Table 1 continued..

Traits / Cropping systems	Corn plant distributions	100 seed weight (g) 4.00 g N plant^{-1}	5.00 g N plant^{-1}	6.00 g N plant^{-1}	Mean	Seed yield plant^{-1} (g) 4.00 g N plant^{-1}	5.00 g N plant^{-1}	6.00 g N plant^{-1}	Mean	Soybean seed yield ha^{-1} (ton) 4.00 g N plant^{-1}	5.00 g N plant^{-1}	6.00 g N plant^{-1}	Mean	Corn grain yield ha^{-1} (ton) 4.00 g N plant^{-1}	5.00 g N plant^{-1}	6.00 g N plant^{-1}	Mean
2 :2	1P/ 30 cm	9.02	9.03	9.04	9.03	8.72	8.75	8.67	8.71	1.62	1.57	1.66	1.61	4.11	4.20	4.27	4.19
	2P / 60 cm	9.32	9.33	9.28	9.31	9.09	9.07	9.14	9.10	1.76	1.71	1.73	1.73	4.30	4.40	4.50	4.40
Mean		9.17	9.18	9.16	9.17	8.90	8.91	8.90	8.90	1.69	1.64	1.69	1.67	4.20	4.30	4.38	4.29
Mixed	1P/ 30 cm	8.46	8.44	8.48	8.46	6.72	6.74	6.71	6.72	1.66	1.61	1.68	1.65	6.94	7.18	7.06	7.06
	2P / 60 cm	8.75	8.78	8.75	8.76	7.15	7.24	7.23	7.20	1.84	1.88	1.80	1.84	7.01	7.27	7.18	7.15
Mean		8.60	8.61	8.61	8.60	6.93	6.99	6.97	6.96	1.75	1.74	1.74	1.74	6.97	7.22	7.12	7.10
Average of intercropping		8.88	8.89	8.88	8.88	7.91	7.95	7.93	7.93	1.72	1.69	1.71	1.70	5.58	5.76	5.75	5.69
Recommended solid culture			10.09		10.09		9.91		9.91		3.03		3.03	6.56	6.75	6.86	6.72
Average of corn plant distributions	1P/ 30 cm	9.19	9.18	9.20	9.19	8.45	8.46	8.43	8.44	2.10	2.07	2.12	2.09	5.87	6.04	6.06	5.99
	2P / 60 cm	9.38	9.40	9.37	9.38	8.71	8.74	8.76	8.73	2.21	2.20	2.18	2.19	6.01	6.17	6.22	6.13
Average of nitrogen fertilizer rates		9.28	9.29	9.28	9.28	8.58	8.60	8.59	8.59	2.16	2.14	2.15	2.15	5.94	6.10	6.14	6.06
L.S.D. 0.05 Cropping systems (C)					0.45				0.10				0.12				0.06
L.S.D. 0.05 Corn plant distributions (D)					0.02				0.04				0.05				0.02
L.S.D. 0.05 Mineral N fertilizer rates (N)					--				--				--				0.04
L.S.D. 0.05 C x D					0.45				0.10				0.13				0.06
L.S.D. 0.05 C x N					--				--				--				0.07
L.S.D. 0.05 N x D					--				--				--				N.S.
L.S.D. 0.05 C x D x N					--				--				--				N.S.

Table 2. Relative yields of corn and soybean, land equivalent ratio (LER) and land equivalent coefficient (LEC) as affected by cropping systems, corn plant distributions, mineral N fertilizer rates and their interactions, combined data across 2012 and 2013 seasons

Cropping systems (Traits)	Corn plant distributions	Relative yield (RY)								LER				LEC			
		RY_m				RY_s											
		4.00 g N plant^{-1}	5.00 g N plant^{-1}	6.00 g N plant^{-1}	Mean	4.00 g N plant^{-1}	5.00 g N plant^{-1}	6.00 g N plant^{-1}	Mean	4.00 g N plant^{-1}	5.00 g N plant^{-1}	6.00 g N plant^{-1}	Mean	4.00 g N plant^{-1}	5.00 g N plant^{-1}	6.00 g N plant^{-1}	Mean
2 :2	1P/ 30 cm	0.60	0.61	0.62	**0.61**	0.53	0.51	0.54	**0.52**	1.13	1.12	1.16	**1.13**	0.31	0.31	0.33	**0.31**
	2P / 60 cm	0.63	0.64	0.65	**0.64**	0.58	0.56	0.57	**0.57**	1.21	1.20	1.22	**1.21**	0.36	0.35	0.37	**0.36**
Mean		**0.61**	**0.62**	**0.63**	**0.62**	**0.55**	**0.53**	**0.55**	**0.54**	**1.17**	**1.16**	**1.19**	**1.17**	**0.33**	**0.33**	**0.35**	**0.33**
Mixed	1P/ 30 cm	1.01	1.04	1.03	**1.02**	0.54	0.53	0.55	**0.54**	1.55	1.57	1.58	**1.56**	0.54	0.55	0.56	**0.55**
	2P / 60 cm	1.02	1.06	1.04	**1.04**	0.60	0.62	0.59	**0.60**	1.62	1.68	1.63	**1.64**	0.61	0.65	0.61	**0.62**
Mean		**1.01**	**1.05**	**1.03**	**1.03**	**0.57**	**0.57**	**0.57**	**0.57**	**1.58**	**1.62**	**1.60**	**1.60**	**0.57**	**0.60**	**0.58**	**0.58**
Average of intercropping		**0.81**	**0.83**	**0.83**	**0.82**	**0.56**	**0.55**	**0.56**	**0.55**	**1.37**	**1.39**	**1.39**	**1.38**	**0.45**	**0.46**	**0.46**	**0.45**
Average of corn plant distributions	1P/ 30 cm	**0.80**	**0.82**	**0.82**	**0.81**	**0.53**	**0.52**	**0.54**	**0.53**	**1.34**	**1.34**	**1.37**	**1.35**	**0.42**	**0.43**	**0.44**	**0.43**
	2P / 60 cm	**0.82**	**0.85**	**0.84**	**0.83**	**0.59**	**0.59**	**0.58**	**0.58**	**1.41**	**1.44**	**1.42**	**1.42**	**0.48**	**0.50**	**0.49**	**0.49**
Solid culture		**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
L.S.D. 0.05 Cropping systems (C)					**0.029**				**0.002**				**0.014**				**0.018**
L.S.D. 0.05 Corn plant distributions (D)					**0.008**				**0.011**				**0.009**				**0.006**
L.S.D. 0.05 Mineral N fertilizer rates (N)					**--**				**--**				**--**				**--**
L.S.D. 0.05 C x D					**0.028**				**0.017**				**0.017**				**0.018**
L.S.D. 0.05 C x N					**--**				**--**				**--**				**--**
L.S.D. 0.05 N x D					**--**				**--**				**--**				**--**
L.S.D. 0.05 C x D x N					**--.**				**--**				**--**				**--**

Table 3. Financial return as affected by cropping systems, corn plant distributions, mineral N fertilizer rates and their interactions, combined data across 2012 and 2013 seasons

Cropping systems (Traits)	Corn plant distributions	Financial return ha^{-1} (American dollars $)															
		Corn				Soybean				Total				Net			
		4.00 g N plant^{-1}	5.00 g N plant^{-1}	6.00 g N plant^{-1}	Mean	4.00 g N plant^{-1}	5.00 g N plant^{-1}	6.00 g N plant^{-1}	Mean	4.00 g N plant^{-1}	5.00 g N plant^{-1}	6.00 g N plant^{-1}	Mean	4.00 g N plant^{-1}	5.00 g N plant^{-1}	6.00 g N plant^{-1}	Mean
2 :2	1P/ 30 cm	1270	1298	1320	**1296**	952	923	976	**950**	2222	2221	2296	**2246**	981	966	1027	**991**
	2P / 60 cm	1329	1360	1391	**1360**	1035	1005	1017	**1019**	2364	2365	2408	**2379**	1123	1110	1139	**1124**
Mean		**1299**	**1329**	**1355**	**1327**	**993**	**964**	**996**	**984**	**2293**	**2293**	**2352**	**2312**	**1052**	**1038**	**1083**	**1057**
Mixed	1P/ 30 cm	2145	2219	2182	**2182**	976	946	988	**970**	3121	3165	3170	**3152**	1370	1386	1363	**1373**
	2P / 60 cm	2167	2247	2219	**2211**	1082	1105	1058	**1081**	3249	3352	3277	**3292**	1498	1573	1470	**1513**
Mean		**2156**	**2233**	**2200**	**2196**	**1029**	**1025**	**1023**	**1025**	**3185**	**3258**	**3223**	**3222**	**1434**	**1479**	**1416**	**1443**
Average of intercropping		**1727**	**1781**	**1777**	**1761**	**1011**	**994**	**1009**	**1004**	**2739**	**2775**	**2787**	**2767**	**1243**	**1258**	**1249**	**1250**
Corn solid culture					**2120**				**---**				**2120**				**644**

Prices of main products are that of 2012: $ 309.1 for ton of corn; $ 588.1 for ton of soybean; intercropping corn with soybean increased variable costs of intercropping culture from $ 347 – 869 over those of corn solid culture.

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INTEGRATED EFFECT OF ORGANIC MANURES AND INORGANIC FERTILIZERS ON SOIL AVAILABLE NUTRIENT STATUS AND YIELD OF MAIZE-SPINACH CROPPING SYSTEM

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ABSTRACT

A field experiment was conducted on a sandy loam soil during *rabi* (maize) and summer (spinach) seasons of 2009-2010 with a view to study the effect of organic manures and inorganic fertilizers on soil available nutrient status and yield of maize-spinach cropping system. Among the different combinations application of 75% RDF + 25% through vermicompost recorded significantly highest grain and stover yield (52.38, 60.77 q ha^{-1}) at harvest but, on par with75% RDF + 25% through poultry manure and 75% RDF + 25% through FYM. The spinach crop was grown during summer responded favourably to the residual and cumulative treatments and the highest fresh leaf yield (14.68 t ha^{-1}) was recorded in cumulative treatments. Application of 75% RDF + 25% through VC, PM and FYM to the maize crop showed highest available nitrogen at vegetative and tasseling stages (264.5 and 248.6 kg ha^{-1}) and highest phosphorus and potassium was recorded with 100% poultry manure. The highest available N (240.3 kg ha^{-1}) and K_2O (335.8 kg ha^{-1}) in soil at the end of maize-spinach cropping system showed significantly highest values at 100% vermicompost whereas available P_2O_5 (40.43 kg ha^{-1}) was highest under 100% poultry manure treated plots under cumulative treatments. These changes in soil available nutrients from initial status to harvest of maize-spinach cropping system gives an indication that growing heavy feeders like maize cannot sustain the soil fertility for next crop. Even if any nutrients are left, they cannot meet the nutrient requirement of the crop. Some amount of inorganic fertilizers need to be applied *viz.,* 75% RDF to a short duration crop like spinach to obtain economic yields.

(Key words: Organic manures, inorganic fertilizers, available nutrients, maize, spinach)

INTRODUCTION

Integrated use of organic manures and chemical fertilizers generally produce higher crop yields than their sole application. This increase in crop productivity may be due to combined effect of nutrient supply, synergism and improvement in soil physical and biological properties (Sarawad *et al.,* 2005). Thus, Integrated Nutrient Management (INM) system envisages the use of inorganic fertilizers, organic manures, crop residues and biofertilizers besides taking into account the fertility status of the soils. Organic manures such as Farm Yard Manure (FYM), Poultry Manure (PM), Vermicompost (VC) are few among the important components of integrated nutrient management.

In recent years emphasis has been shifted from individual crops to cropping system as a whole since the responses of the component crops in the cropping system are influenced by the preceding crops and inputs applied to them. Therefore, the concept of integrated nutrient management (INM) is more effective for cropping systems rather than individual crops as it takes care of residual effect of nutrients particularly of nitrogenous and phosphatic fertilizers and organic sources of nutrients (Randhawa and Brar, 2004). About less than 30 per cent of nitrogen and small fractions of phosphorus and potassium in organic manure may become available to immediate crop while the rest may be utilized by the subsequent crop.

Keeping in view the significance of integrated nutrient management in maintaining the soil health and improvement in the productivity of crops, an experiment was conducted to study the effect of organic manures and inorganic fertilizers on soil nutrient status in maize-spinach cropping system.

MATERIALS AND METHODS

A field experiment was conducted on a sandy loam soil at College Farm, College of Agriculture, Rajendranagar, Hyderabad during *rabi* (maize) and summer (spinach) seasons of 2009-2010. During *rabi,* an experiment was laid out in randomized block design with 12 treatments, replicated thrice. The treatments included T_1 (Control), T_2 (50% RDNF through inorganic fertilizer + 50% RDNF through vermicompost), T_3 (75% RDNF through inorganic fertilizer + 25% RDNF through vermicompost), T_5 (100% RDNF through inorganic fertilizer), T_6 (50% RDNF through inorganic fertilizer + 50% RDNF through poultry manure), T_7 (75% RDNF through inorganic fertilizer + 25% RDNF through poultry manure), T_8 (100% RDNF through poultry manure),

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T_9 (50% RDNF through inorganic fertilizer + 50% RDNF through farm yard manure), T_{10} (75% RDNF through inorganic fertilizer + 25% RDNF through farm yard manure), T_{11} (100% RDNF through farm yard manure), and T_{12} (25% RDNF through inorganic fertilizer + 25% RDNF through vermicompost + 25% RDNF through poultry manure + 25% RDNF through farm yard manure). Maize was test crop during *rabi* season with RDF applied as N : P_2O5 : K_2O @120:60:60 kg ha^{-1}. In summer season, spinach was taken up as a test crop to that 75 per cent of recommended dose of N, P and K were applied in half of the plot pertaining to each treatment. No fertilizers were applied to another half of the plot to know the residual effects. Entire quantity of phosphorus, half of nitrogen and potassium were applied as basal in the form of single super phosphate, urea and muriate of potash. Remaining half of nitrogen and potassium were applied in two equal splits at 15 and 30 DAS. Soil samples collected from the surface layers to a depth of 0-15 cm. Soil of the experimental field is a sandy loam, slightly alkaline in reaction (pH: 7.21, non saline (EC: 0.19 dS m^{-1}), medium in organic carbon (0.46%) and available nitrogen (217.8 kg ha^{-1}), medium in available P_2O_5 (28.7 kg ha^{-1}) and K_2O (285.6 kg ha^{-1}). Apart from the initial soil analysis, the organic manures used for the study *viz.,* FYM, poultry manure and vermicompost also analyzed for their nutrient contents. Among all the organic manures, poultry manure found to have highest nitrogen (1.84%), phosphorus (0.82%) and potassium (1.12%) followed by vermicompost (1.18, 1.07 and 0.85%) and FYM (0.50, 0.75 and 0.75%). Available nitrogen was estimated by alkaline potassium permanganate method (Subbaiah and Asija, 1956). Available phosphorus content was estimated by Olsen's method (Olsen *et al.,* 1954), available potassium was extracted by using neutral normal ammonium acetate method (Jackson, 1973) and determined by flame photometer. Observations on fresh leaf yield (t ha^{-1}) of spinach was recorded at 45DAS and 60DAS. Grain and stover yield (q ha^{-1}) of maize were also recorded.

RESULTS AND DISCUSSION

Grain and stover yield of maize

The grain and stover yield of maize was significantly influenced by different levels of organic manures and inorganic fertilizers (Table 1). The lowest and highest grain and stover yields were recorded at control (21.52, 29.94 q ha^{-1}) and 75% RDNF + 25% VC (52.38, 60.77 q ha^{-1}) respectively. However, the yield recorded at 75% RDNF + 25% VC was on par with that recorded at 75% RDNF + 25% PM (51.28, 59.53 q ha^{-1}), 75% RDNF + 25% FYM (50.46, 58.49 q ha^{-1}) and 100% RDNF (49.26, 57.23 q ha^{-1}) and significantly superior over all other treatments. The per cent increase in grain yield of 75% RDNF + 25% VC over the control, 100% RDNF, 100% VC, 100% PM and 100% FYM was 143.4, 6.33, 18.9, 20.5, and 22.0, respectively. Conjunctive use of different levels of chemical fertilizers with any one of the organics produced higher yields as compared to their individual applications. This was due to the direct availability of nutrients from inorganic fertilizers and also the vermicompost containing higher available N, P and K contents. The enrichment of biological activity and release of organic acids might have degraded and mobilized the occluded soil nutrients to available form (Reddy and Reddy, 1998). Thus, favorable effect of poultry manure and vermicompost in the root zone resulted in increased availability and uptake of nutrients by the plants which in turn was reflected through increase in maize grain and stover yield.

Fresh leaf yield of spinach

The spinach crop grown during summer responded favourably to the residual and cumulative treatments after harvest of maize crop and the highest leaf yield (t ha^{-1}) were recorded in cumulative treatments than their respective residual treatments (Table 1).

Among the cumulative and residual effects, the green leaf yield of spinach ranged from 6.71 to 14.68 t ha^{-1} and 4.89 to 12.37 t ha^{-1}, respectively. In both cumulative and residual effects, the treatments which received 100% organic manures (VC/PM/FYM) during preceding maize crop showed higher leaf yields of spinach than those with combined application of organic manures and inorganic fertilizers.

Among the cumulative treatments, the lowest green leaf yield was observed in control **(**6.71 t ha^{-1}) and highest was recorded in the treatment (14.68 t ha^{-1}) which received, 100% VC during previous *rabi* and 75% RDF to spinach recorded highest fresh leaf yield but was on par with 100% poultry manure and 100% farm yard manure.

Table 1. Effect of INM on grain and stover yield (q ha^{-1}) of maize and fresh leaf yield of spinach (t ha^{-1})

Treatments	Grain yield	Stover yield	Fresh leaf yield (t ha^{-1})	
			Cumulative	Residual
T_1 Control	21.52	29.94	6.71	4.89
T_2 50% N + 50% VC	48.16	55.47	12.82	10.78
T_3 75% N + 25% VC	52.38	60.77	9.85	8.57
T_4 100% VC	44.04	48.13	14.68	12.37
T_5 100% RDNF	49.26	57.23	8.84	7.24
T_6 50% N + 50% PM	47.34	53.48	12.24	10.39
T_7 75% N + 25% PM	51.28	59.53	9.73	8.42
T_8 100% PM	43.46	47.41	14.55	12.14
T_9 50% N + 50% FYM	46.84	53.02	12.79	10.47
T_{10} 75% N + 25% FYM	50.46	58.49	9.46	8.27
T_{11} 100% FYM	42.90	46.89	14.30	12.04
T_{12} 25% N + 25% VC + 25% PM +25% FYM	44.64	50.15	13.38	11.68
SE(m) ±	1.70	1.90	0.60	0.57
CD at 5%	3.53	3.94	1.25	1.19

Table 2. Change in content of available nutrients in control plots after harvest of crops in maize-spinach cropping system

Particulars	Available nutrients		
	Nitrogen	Phosphorus	Potassium
After maize			
Initial content (mg kg^{-1})	217.80	28.70	285.60
Content after maize (mg kg^{-1})	175.50	26.30	248.50
Changes in content (%)	-19.42	-8.36	-12.99
After spinach (Cumulative effect)			
Content after spinach (mg kg^{-1})	182.4	27.76	255.70
Changes in content (%)	3.93	5.55	2.90
Changes in content after the sequence (%)	-16.25	-3.28	-10.47
After spinach (Residual effect)			
Content after spinach (mg kg^{-1})	165.70	23.57	245.80
Changes in content (%)	-5.58	-10.38	-1.09
Changes in content after the sequence (%)	-23.92	-17.87	-13.94

Table 3. Effect of INM on available N, P_2O_5 and K_2O (kg ha^{-1}) in soil at different growth stages of maize and at final harvest of spinach

Treatments	Vegetative stage			Tasseling stage			Harvest			N		P_2O_5		K_2O	
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	Cumulative	Residual	Cumulative	Residual	Cumulative	Residual
T_1	203.6	34.6	279.6	187.4	29.5	265.4	175.5	26.3	248.5	182.4	165.7	27.76	23.57	255.7	245.8
T_2	246.4	38.5	308.4	232.5	33.5	298.5	227.3	31.7	286.3	232.2	208.3	32.26	29.56	292.5	292.5
T_3	264.5	37.2	300.5	248.6	31.6	287.6	223.4	28.4	281.4	228.6	204.2	29.46	26.72	287.7	276.2
T_4	225.2	45.8	349.2	203.7	41.6	345.7	238.6	39.5	329.1	240.3	215.6	40.43	37.26	335.8	322.7
T_5	256.5	35.7	288.5	241.4	30.5	275.4	216.3	27.3	258.3	211.2	189.1	28.53	25.74	264.8	253.3
T_6	245.4	40.4	310.4	230.6	35.2	299.6	225.2	32.1	286.2	230.8	206.4	33.26	30.43	291.8	291.5
T_7	263.7	36.7	301.7	247.3	32.4	289.3	221.4	29.6	282.4	226.9	202.3	30.61	27.34	286.5	275.5
T_8	224.7	47.2	355.7	202.2	42.5	346.2	236.1	41.3	329.6	239.6	213.2	42.37	38.16	334.9	321.6
T_9	243.8	37.4	305.8	229.9	33.9	295.9	224.3	30.2	285.3	228.7	205.1	31.23	28.53	291.2	290.7
T_{10}	262.6	36.6	298.6	245.8	31.8	284.8	220.6	28.5	279.6	224.2	201.5	28.54	26.15	285.9	274.8
T_{11}	223.6	44.3	347.6	201.5	40.8	342.5	235.4	38.5	327.4	236.4	212.5	41.03	36.67	332.8	320.9
T_{12}	236.3	42.5	345.3	228.9	37.7	340.9	230.6	36.2	325.6	234.5	211.6	38.26	34.26	330.6	318.3
SE(m) ±	5.77	2.92	5.77	4.56	1.58	4.56	5.09	1.61	5.09	3.46	3.14	2.97	2.53	6.96	5.80
CD at 5%	11.96	6.04	11.97	9.46	3.28	9.46	10.56	3.34	10.56	7.18	6.51	6.18	5.26	-	-

Among the residual effects, the green leaf yield of spinach varied from 4.89 to 12.37 t ha^{-1}. The lowest green leaf yield (4.89 t ha^{-1}) was recorded in control where no fertilizers were applied. Though application of 100% VC to *rabi* maize resulted in highest green leaf yield of 12.37 t ha^{-1}, it was on par with 100% PM and 100% FYM. But it was significantly superior to all the other combined treatments.

The results clearly indicated that application of 75% RDF to spinach apart from the application of inorganic and organic manures to maize crop was sufficient as it ensured ample supply of nutrients and favoured better growth. The additional fresh green leaf yield under cumulative effects might be due to the fact that an adequate and balanced supply of nutrients with 75% RDF application had favourable effect on leaf and root growth resulting in improvement in the yield attributes. Similar observations were made by Reddy (2007). He reported that use of 75% RDF along with application of vermicompost resulted in better growth of maize crop in maize-groundnut cropping sequence.

Soil available nutrient status in maize

The soil samples collected at different growth stages of maize and at final harvest of spinach were analyzed for available N, P_2O_5 and K_2O to study the effect of organic manures and inorganic fertilizers on nutrient availability.

Available nitrogen

The data pertaining to available nitrogen are given in table 3. The available nitrogen in soil decreased from vegetative to harvesting stage of maize in all the treatments. The highest available nitrogen *viz.,* 264.5 and 248.6 kg ha^{-1} was recorded at vegetative and tasseling stages in 75% RDNF + 25% VC, but was on par with 100% RDNF, 75% RDNF + 25% PM and 75% RDNF + 25% FYM. In these treatments where organic and inorganic fertilizers were applied, inorganic fertilizers contributed to nutrient uptake by plants in early stages. The available nitrogen content in the treatments receiving only organic manures increased at harvest compared to integrated application of organic and inorganic fertilizers. This might be due to slow release of nitrogen due to decomposition of organic matter by increased microbial activity and reduction in N loss through formation of organo mineral complexes. Further, addition of mineral N along with organic sources will narrow down the C:N ratio of organic manures and this enhances the rate of mineralization and result in rapid release of nutrients. Hence, to meet the crop requirement during entire growth period, integrated use of both organic and inorganic fertilizers is ideal (Rathod *et al*., 2010).

Available phosphorus and potassium

With regard to available phosphorus and potassium (Table 3) the values decreased from vegetative to harvesting stages in all the treatments. The highest values of available P_2O_5 (47.2, 42.5 and 41.3 kg ha^{-1}) and K_2O (355.7, 346.2and 329.6 kg ha^{-1}) were recorded in the treatment which received 100% PM at vegetative, tasseling and harvesting stage of the crop, respectively. However, the values were on par with 100% VC and 100% FYM and was significantly differed from all other treatments at all growth stages. Organic manures during the decomposition release a large number of organic acids like vanillic acid, protocatecholic acid, which react with the insoluble iron, aluminium and calcium phosphates and release phosphates slowly into the solution, resulting in higher phosphate availability in plots treated with organic manures. Further the organic matter acts as a coating over iron and aluminium oxides and reduces phosphate fixing capacity of the soil (Parmar and Sharma, 2002). Increase in available P might be due to the decomposition of organic matter accompanied by the release of appreciable quantities of CO_2. The CO_2 released during decomposition of organic matter forms carbonic acid which solublizes certain primary minerals too (Anup Das *et al.,* 2010).

The buildup of available K in soil was due to beneficial effect of organic manures on the reduction of potassium fixation, releasing K due to interaction of organic matter with clay, and direct addition of K to the available pool of soil.

The lower values of available N, P_2O_5 and K_2O (216.3, 27.3 and 258.4 kg ha^{-1}) in 100% RDNF treatment at the time of harvest may be attributed to the maximum utilization of applied nutrients by the crop, which are in most available form.

From the results it was also clear that the N, P and K availability to maize crop was there throughout the growth period. The increase in nutrient contents and uptake by crop from vegetative to harvest gives and uptake by crop from vegetative to harvest gives an indication that integrated use of inorganic fertilizers and organic manures (75% RDNF+ 25% organic manures) is ideal for effective supply and utilization by crops.

Soil available nutrient status in spinach

Available nitrogen (kg ha^{-1})

Among the cumulative treatments, the available nitrogen contents after final cutting of spinach ranged from 182.4 to 240.3 kg ha^{-1}.The treatment which received 100% RDF applied to maize and 75% RDF to spinach recorded significantly lower available N content (211.2 kg ha^{-1}) than other organic and integrated treatments. The treatment which received 100% VC during maize and 75% RDF during spinach showed highest available nitrogen content (240.3 kg ha^{-1}).

Among the residual treatments, the treatment which received 100% VC during maize showed highest available nitrogen content (215.6 kg ha^{-1}). But it was significantly superior to all the other treatments. In residual treatments, the available nitrogen content varied from 165.7 to 215.6 kg ha^{-1}.

Available phosphorus (kg ha^{-1})

Among the cumulative treatments, after final harvest of spinach, the lowest available phosphorus was recorded in control (27.76 kg ha^{-1}) and the highest available phosphorus was observed in the treatment (42.37 P_2O_5 kg ha^{-1}), which received 100% PM during previous *rabi* and 75% RDF to spinach but was on par with 100% VC and 100% farm yard manure and it was significantly superior to other treatments.

Among the residual treatments, the available P_2O_5 content ranged from 23.57 to 38.16 kg ha^{-1}. The treatment which received 100%PM for first crop (maize) showed highest available P content (38.16 P_2O_5 kg ha^{-1}). However, the values were on par with 100% VC and 100% farm yard manure.

Available potassium (kg ha^{-1})

There was no significant differences observed in case of available K content both in cumulative and residual treatments. Prativa and Bhattarai (2011) revealed that the integration of organic manures in combination with inorganic fertilizers was found significant in improving the overall plant growth, yield and soil macro nutrient status than the sole application of either of these nutrients.

With regard to changes in available nutrient status of the soil, taking control plot as a check, it was found that the available N, P_2O_5 and K_2O depleted to an extent of 19.42, 8.36 and 12.99 per cent, respectively after harvest of maize crop (Table 2).

The cumulative and residual effects of INM treatments on spinach indicated that there was negative balance in available nutrient status by the end of maize-spinach cropping system. The N, P_2O_5 and K_2O depletion was more under residual treatments where no fertilizers were applied to spinach (23.92, 17.87 and 13.94 per cent). While there was decrease in available nutrients in soil by 16.25, 3.28 and 10.47 per cent under cumulative effects.

These changes in soil available nutrients from initial status to harvest of maize-spinach cropping system gives an indication that growing heavy feeders like maize cannot sustain the soil fertility for next crop. Even if any nutrients are left, they cannot meet the nutrient requirement of the crop. Some amount of inorganic fertilizers needs to be applied *viz.,* 75% RDF to a short duration crop like spinach to obtain economic yields.

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EFFECT OF DIFFERENT DOSES OF NPK FERTILIZERS ON LOCAL RICE (*Oryza sativa* L.) UNDER DIRECT-SEEDED UPLAND CONDITION

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ABSTRACT

A field study was conducted during rainy (*kharif*) season of 2013 to assess the response of local rice (*Oryza sativa* L.) cultivars to different levels of NPK doses under direct-seeded upland condition at the experimental research farm of School of Agricultural Sciences, Nagaland University, Medziphema campus. The treatments consisted of factorial combination of five local rice cultivars *viz.,* Haccha, Inglongkiri, Dehangi, Maizu Biron and Dimroo and three doses of NPK *viz.,* 0 NPK kg ha^{-1}, 60:30:30 NPK kg ha^{-1} and 90:45:45 NPK kg ha^{-1} laid out in a randomized block design and replicated three times. The results showed that 90:45:45 NPK kg ha^{-1} fertilizer dose significantly increased plant height, number of green leaves plant^{-1}, number of tillers hill^{-1} and plant population. The NPK doses at 90:45:45 kg ha^{-1} recorded maximum number of panicles m^{-2}, length of panicle, number of grains panicle^{-1} and the overall grain yield. Among the cultivars, Dehangi produced the highest grain yield (2338.42 kg ha^{-1}) followed by Dimroo (2186.39 kg ha^{-1}). The interaction effects between rice cultivars and fertilizer doses were found to be non-significant. From the present experiment it was revealed that cultivar 'Dehangi' was found to be the most suitable rice cultivar under direct-seeded upland condition of Nagaland followed by Dimroo, Haccha and Inglongkiri. Increase in the doses of NPK fertilizer significantly enhanced growth characteristics and increased yields attributes of the upland rice cultivars. The result showed that among the different local rice cultivars Dehangi recorded highest grain yield followed by Dimroo. Yield increased due to NPK doses at 90:45:45 found to be 51 per cent compared to no fertilizer application.

(Key words: Cultivars, nutrient management, growth and yield attributes)

INTRODUCTION

Rice is the most consumed cereals grain in the world, constituting the dietary staple food for more than half of human population of the planet. India is the second largest producer after China and has an area of over 42.2 million ha and production of 104.32 million tonnes with productivity of 2.37 t ha^{-1} (Anonymous, 2013). Even then rice self-sufficiency in India is precarious. The country's population of more than a billion is growing at 1.8% year^{-1}, outpacing the 1.4% annual growth rate of rice production. India's population is expected to be 1.4 billion by the year 2025 and 300 million tonnes of food grains will be required by 2025. India need to raise its foodgrains targets at a rate of more than 4 million tonnes annum^{-1} and to maintain self-sufficiency, annual production need to increase by two million tonnes every year. The annual consumption of fertilizers, in nutrient terms (N, P and K), has increased from 0.07 million tonnes in 1951-52 to more than 28 million tonnes in 2010-11 and hectare^{-1} consumption has increased from less than 1 kg in 1951-52 to the level of 135 kg in 2010-11 (Anonymous, 2012). An adequate and balanced supply of plant nutrients is a prerequisite to maximize crop production. Judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice (Alam *et al.,* 2009). Chemical fertilizer offers nutrients which are readily soluble in soil solution and thereby instantly available to plants. So, the appropriate fertilizer input that is not only for getting high grain yield but also for attaining maximum profitability (Khuang *et al.*, 2008). The major nutrients required by rice are nitrogen, phosphorus and potassium. There are several factors responsible for low productivity of rice in Nagaland. These can be enumerated as use of local varieties of low genetic potential, leaching loss of N, unfavourable growth conditions, low inputs and heavy infestation of weeds, insects and pests attack clubbed with inefficient resources management practices. Almost negligible use of fertilizers also limits the productivity. Keeping this idea in view and realising the importance of the needs and problems, an investigation was undertaken to study the effects of different doses of NPK fertilizers on local rice cultivars on their growth, productivity and economics of the rice cultivars under study.

MATERIALS AND METHODS

The experiment was carried out during *kharif* season of 2013 at research farm of School of Agricultural Sciences, Nagaland University, Medziphema. The soil of the experimental plot was sandy loam, having pH 4.5 with electrical

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conductivity 0.227 dSm^{-1}, organic carbon 1.25 per cent and available N, P_2O_5 and K_2O 36.27, 248.40 and 9.22 kg ha^{-1} respectively. The experiment comprised of five different local rice cultivars *viz*., Haccha, Inglongkiri, Dehangi, Maizu Biron and Dimroo as identified by RRS, Karbi Anlong, Diphu, Assam Agricultural University and three different NPK doses F_1-$N_0P_0K_0$, F_2-$N_{60}P_{30}K_{30}$ and F_3-$N_{90}P_{45}K_{45}$ respectively. The experiment with these treatments was laid out in factorial randomized block design with three replications. Treated seeds of rice were dibbled at proper spacing 20 cm x 10 cm in the second week of June 2013, after basal application of fertilizer as per treatments. The soil samples were collected before sowing and after the harvest of rice crop with the help of tube auger (stainless steel) from each plot at 0-15cm soil depth. Soil pH was determined by glass electrode pH meter (Pipper, 1966). Organic carbon was determined by Walkey and Black Method as outlined by Jackson (1976). For available N by Alkaline potassium permanganate method (Subbiah and Asija, 1956), available P was extracted with 0.03 N, NH_4F in 0.025 N HCL solutions. Available K was extracted from 5g of soil by shaking with 25 ml of neutral ammonium acetate (pH 7) solution for half an hour and the extract was filtered immediately through the filter paper (Whatman no. 1) and then potassium concentration in the extract was determined by Flame Photometer (Hanway and Heidal, 1952). Weeds were controlled by manually at 20 DAS and 45 DAS respectively. Observations on growth attributes *viz*., plant height, number of leaves, plant population, tillering and yield attributes *viz*., number of panicles m^{-2}, number of grains $panicles^{-1}$, test weight, grain yield and straw yield were recorded. The observations were recorded on randomly selected 5 samples and their mean were taken for analysis 90 days after sowing. Observations on yield attributing characters were recorded at harvest stage and thereafter. The oven-dried plant samples were ground to powder and analysed for N, P and K (%). Uptakes of nutrient were calculated multiplying total biomass (dry wt. kg ha^{-1} basis) with respective nutrient content in per cent. The data related to each character were analysed statistically by applying the technique on analysis of variance and the significance of different sources of variation was tested by F test (Panse and Sukhatme, 1967).

RESULTS AND DISCUSSION

Growth parameters

It was observed from the table 1, that significant variations were observed in growth attributes at various stages. Plant height differed significantly among the different rice cultivars. It was observed that the cultivar 'Dehangi' was significantly superior over other varieties in terms of plant height (109.77cm) followed by Inglongkiri (108.09cm) and Dimroo (107.98cm). Maximum number of functional leaves (5.73) were recorded by cultivar Dehangi followed by Inglongkiri (5.6) and Dimroo (5.6). Maximum number of plant population ($304m^{-2}$) were recorded in cultivar Dehangi followed by Haccha (283 m^{-2}) and Dimroo (283 m^{-2}) and the lowest in Maizu Biron (262 m^{-2}). There were significant differences on number of tillers $hill^{-1}$ and the maximum tillers $hill^{-1}$ (8.41) were associated with cultivar 'Haccha'. The significant difference observed in the number of tillers $hill^{-1}$ can be ascribed to differences in the ability of the cultivars to utilize the fertilizer as well as partition their photosynthates and accumulation dry matter. The present findings were in agreement with the results of Sheela and Thomas Alexander (1995) who reported that growth parameters showed significant variations due to varieties. Different doses of NPK fertilizers recorded significant differences in growth parameters. However, treatment F_3 ($N_{90}P_{45}K_{45}$) recorded maximum value in all growth parameters. Interaction effect of cultivars and fertilizer doses could not record any significant variations in different growth parameters, however, leaf area index found to be significant due to cultivars and fertilizer doses. Highest LAI (2.10) was recorded by the cultivar 'Dimroo' at fertilizer dose of $N_{90}P_{45}K_{45}$.

Yield attributes

Data from table 2 indicated that Cultivar 'Dehangi' recorded highest number of grains $panicle^{-1}$ (195.68), longest panicle length (25.38 cm), filled grains percentage (72.52 %) and test weight (25.65 g). Test weight showed significant difference among the five different cultivars. These present findings are being supported by Satapathy and Nanda (1978) and Chavan *et al.* (2014), who reported that 1000-grains weight significantly varied with different varieties. The poorest performance was recorded in cultivar 'Maizu Biron' in terms of panicle length, number of grains panicle^{-1}, filled grains percentage and test weight. The reason might be poor adaptability and less vigour. The results regarding yield of five cultivars, showed significant differences. The cultivar 'Dehangi' out classed four other varieties by yielding 2338.42 kg ha^{-1} followed by Dimroo, Haccha, Inglongkiri and Maizu Biron with the production of 2186.39 kg ha^{-1}, 1839.50 kg ha^{-1}, 1843.87 kg ha^{-1} and 1692.59 kg ha^{-1}, respectively. The findings of present investigation were in close conformity with Dwivedi and Meshram (2014), who also reported that grain yield was found to be positively correlated with number of productive tillers, a number of grains panicle^{-1} both at genotypic and phenotypic levels. The grain yields varied from 1292.38 kg ha^{-1} in the control plot (F_1) to 2020.88 kg ha^{-1} in F_2 (60:30:30 NPK kg ha^{-1}) to 2627.27 kg ha^{-1} in F_3 (90:45:45 NPK kg ha^{-1}). This is in consonance with Purushotham *et al.* (1993) who reported that grain yield was highest with the highest NPK dose. Highest value of harvest index (40.03 %) was noticed under highest NPK dose as compared to control (F_1) and F_2. Murali and Setty (2000) also reported that application of higher NPK dose recorded significantly higher growth, yield attributes and yield compared to lower NPK doses.

Soil nutrient status

A significant variation could be observed on pH, organic carbon, available nitrogen, available phosphorus and available potassium due to cultivars (Table 3). Cultivar 'Maizu Biron' reported the highest pH (4.72). Cultivar 'Dimroo' recorded the highest value of organic carbon (2.04 %) and available potassium (208 kg ha^{-1}). While, the highest value of available nitrogen was reported in cultivar 'Inglongkiri' and cultivar 'Dehangi' recorded the highest value of available phosphorus. The highest value of available NPK, pH and organic carbon was associated with highest NPK dose (90:45:45 NPK kg ha^{-1}). Masthana *et al.* (2005) reported that application of NPK significantly improved the soil P and K status and increased the N content of the soil. This was also in close conformity with Naing Oo *et al.* (2010) who reported that application of FYM together with inorganic fertilizers significantly increased soil organic matter, CEC and available NPK in the soil.

The interaction effect of cultivars and different levels of NPK were found to be significant on soil available nitrogen, phosphorus and potash. Higher levels of NPK (F_3) recorded maximum soil available NPK irrespective of rice cultivars, however V_2F_3 (Inglongkiri x NPK dose 90:45:45) recorded maximum soil available N (370.48kg ha^{-1}), V_4F_3 (Maizu biron x NPK dose 90:45:45) recorded maximum P_2O_5 (35.48) and V_5F_3 (Dimroo x NPK dose 90:45:45) recorded maximum K_2O (225.02 kg ha^{-1}) respectively.

Nutrient uptake

There was a significant difference in NPK uptake due to different cultivars (Table 4). Cultivar Dehangi recorded the highest uptake of N, P and K. This type of variability may be attributed to genetic variability and varied capacity of different cultivars to utilize the applied fertilizers. The effect of fertilizer doses on NPK uptake was found to be significant. The highest value of NPK uptake was associated with high rate of NPK *i.e.,* 90:45:45 kg NPK ha^{-1}. The interaction effects of cultivars x fertilizer doses on NPK uptake of plant were found to be significant. Cultivar Inglongkiri recorded maximum uptake of N (71.72 kg ha^{-1}) and P (23.88 kg ha^{-1}) at F_3 level of NPK and cultivar Dimroo recorded highest uptake of K (123.02 kg ha^{-1}) when applied highest level (F_3) of K_2O. The variations might be due to genetic factors, better adaptability to the present climatic condition or high responsive character of cultivars to the applied fertilizers.

The result showed that among the different local rice cultivars Dehangi recorded highest grain yield followed by Dimroo. Yield increased due to NPK doses at 90:45:45 found to be 51 per cent compared to no fertilizer application.

Table 1. Growth of rice cultivars as influenced by different does of NPK fertilizer

Treatments	Plant height (cm)	Number of functional leaves plant^{-1}	Plant population (m^2)	Tillers hill^{-1}	Leaf area index
Cultivars					
Haccha	55.32	4.98	283.52	8.59	1.29
Inglongkiri	108.09	5.60	278.64	3.34	1.78
Dehangi	109.77	5.73	304.00	3.57	1.77
Maizu Biron	87.08	4.91	262.64	4.12	1.45
Dimroo	107.98	5.60	283.08	2.86	1.89
SEm$\pm$	1.90	0.13	7.72	0.18	0.02
CD (P=0.05)	5.51	0.39	22.44	0.53	0.07
Fertilizer doses (NPK kg ha^{-1})					
0:0:0	85.79	4.94	261.84	3.79	1.20
60:30:30	93.84	5.39	283.72	4.48	1.51
90:45:45	101.33	5.77	301.60	5.26	1.78
SEm$\pm$	1.48	0.10	6.00	0.14	0.01
CD(P=0.05)	5.51	0.30	17.36	0.41	0.05
Interaction (V x F)					
V_1F_1	48.72	4.63	254.64	7.27	0.91
V_1F_2	57.78	4.93	286.64	8.33	1.32
V_1F_3	59.46	5.40	309.32	10.19	1.66
V_2F_1	94.37	5.07	276.00	2.67	1.46
V_2F_2	111.94	5.67	270.64	3.27	1.83
V_2F_3	117.96	6.06	289.32	4.10	1.95
V_3F_1	101.59	5.33	278.64	3.16	1.60
V_3F_2	108.34	5.80	316.00	3.63	1.76
V_3F_3	119.37	6.07	317.32	3.90	1.96
V_4F_1	81.93	4.60	240.08	3.43	1.10
V_4F_2	83.68	5.04	261.32	4.36	1.41
V_4F_3	95.65	5.13	286.68	4.56	1.84
V_5F_1	102.31	5.07	260.08	2.40	1.69
V_5F_2	107.44	5.53	287.12	2.80	1.89
V_5F_3	114.20	6.20	305.32	3.36	2.10
SEm$\pm$	3.29	0.23	3.35	0.32	0.03
CD (P=0.05)	---	---	---	---	0.12

Table 2. Yield attributes of rice cultivars as influenced by different doses of NPK fertilizer

Treatments	Length of panicle (cm)	Grains panicle^{-1}	Fertility (%)	Test weight (g)	Grain yield (kg ha^{-1})	Harvest index (%)
Cultivars						
Haccha	23.12	141.34	59.98	21.41	1843.87	28.64
Inglongkiri	25.24	192.59	69.04	25.57	1839.50	24.64
Dehangi	24.72	195.68	72.52	25.65	2338.42	29.82
Maizu Biron	22.36	139.09	54.88	15.64	1692.59	28.20
Dimroo	24.47	187.32	67.38	19.73	2186.39	29.80
SEm±	0.50	8.00	1.05	0.42	78.94	0.87
CD (P=0.05)	1.45	23.18	3.05	1.23	228.68	2.54
Fertilizer doses (NPK kg ha^{-1})						
0:0:0	21.52	144.04	53.45	20.14	1292.38	22.45
60:30:30	23.90	159.48	67.14	21.81	2020.88	28.86
90:45:45	26.53	210.08	73.70	22.84	2627.27	33.95
SEm±	0.38	6.20	0.81	0.32	61.14	0.67
CD(P=0.05)	1.12	17.96	2.36	0.95	177.13	1.96
Interaction (V x F)						
V_1F_1	20.88	112.34	48.66	20.24	1197.49	22.88
V_1F_2	23.32	131.87	62.94	21.55	1883.59	30.83
V_1F_3	24.97	179.79	68.35	22.46	2450.54	35.22
V_2F_1	21.83	145.84	59.81	24.56	1112.49	20.19
V_2F_2	25.29	162.57	69.38	25.92	1960.82	25.41
V_2F_3	28.61	269.36	77.93	26.45	2445.19	28.32
V_3F_1	22.53	165.65	56.61	22.49	1378.05	22.23
V_3F_2	24.94	184.21	75.55	26.45	2360.32	28.99
V_3F_3	26.69	237.19	85.41	28.00	3276.90	38.24
V_4F_1	20.63	120.64	44.33	14.68	1259.43	23.74
V_4F_2	21.60	133.81	56.93	15.76	1758.62	28.04
V_4F_3	24.85	162.83	63.41	16.50	2059.71	32.83
V_5F_1	21.72	175.76	57.85	18.77	1514.43	23.20
V_5F_2	24.16	184.97	70.94	19.38	2141.06	31.03
V_5F_3	27.55	201.24	73.36	21.03	2903.68	35.16
SEm±	0.86	13.86	1.82	0.73	136.73	1.52
CD (P=0.05)	---	---	---	---	---	---

Table 3. Effect of different doses of NPK fertilizer on soil nutrient status after harvest

Treatments	Soil pH	Organic carbon (%)	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
Cultivars					
Haccha	4.66	1.91	326.75	22.47	192.70
Inglongkiri	4.71	1.94	337.89	22.84	195.61
Dehangi	4.67	1.83	310.72	28.71	197.43
Maizu Biron	4.72	1.72	315.31	28.61	194.42
Dimroo	4.68	2.04	326.39	23.47	208.55
SEm±	0.02	0.03	4.93	0.24	2.04
CD (P=0.05)	0.07	0.09	14.29	0.71	5.93
Fertilizer doses (NPK kg ha^{-1})					
0:0:0	4.63	1.68	287.92	20.11	178.68
60:30:30	4.68	1.87	323.06	25.97	195.48
90:45:45	4.74	2.12	359.25	29.58	219.07
SEm±	0.02	0.02	3.82	0.19	1.58
CD(P=0.05)	0.05	0.07	11.06	0.55	4.59
Interaction (V x F)					
V_1F_1	4.63	1.77	296.99	19.76	163.12
V_1F_2	4.65	1.86	329.41	22.85	189.96
V_1F_3	4.71	2.10	353.85	24.82	225.02
V_2F_1	4.63	1.72	308.02	19.21	180.19
V_2F_2	4.70	1.92	335.17	22.96	194.04
V_2F_3	4.76	2.18	370.48	26.33	212.61
V_3F_1	4.66	1.62	287.66	20.27	180.94
V_3F_2	4.70	1.77	302.72	31.84	194.70
V_3F_3	4.66	2.12	341.78	34.02	216.66
V_4F_1	4.63	1.53	256.08	22.12	181.99
V_4F_2	4.73	1.74	320.08	28.22	191.63
V_4F_3	4.80	1.89	369.76	35.48	209.65
V_5F_1	4.60	1.75	290.85	19.18	187.17
V_5F_2	4.63	2.05	327.93	23.99	207.06
V_5F_3	4.80	2.31	360.33	27.25	231.41
SEm±	0.04	0.05	8.54	0.42	3.50
CD (P=0.05)	---	---	24.75	1.23	10.28

Table 4. Effect of fertilizer doses on nitrogen (N), phosphorus (P) and potassium (K) uptake by the rice cultivars

Treatments	Nitrogen uptake (kg ha^{-1})	Phosphorus uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})
Cultivars (V)			
Haccha	41.49	14.06	86.52
Inglongkiri	50.98	16.64	92.33
Dehangi	49.98	13.18	76.24
Maizu Biron	48.94	11.96	77.45
Dimroo	47.03	13.64	89.15
SEm±	1.03	0.44	1.11
CD (P=0.05)	3.00	1.29	3.24
Fertilizer doses (F) (NPK kg ha^{-1})			
0:0:0	30.23	8.42	66.06
60:30:30	49.16	15.63	81.55
90:45:45	63.66	19.26	105.40
SEm±	0.80	0.46	0.86
CD(P=0.05)	2.32	1.03	2.51
Interaction (V x F)			
V_1F_1	26.77	9.25	77.67
V_1F_2	40.57	16.88	84.41
V_1F_3	57.12	19.72	97.48
V_2F_1	27.79	8.03	75.89
V_2F_2	53.45	19.34	94.47
V_2F_3	71.72	23.88	106.63
V_3F_1	32.68	8.44	55.82
V_3F_2	51.52	15.75	67.74
V_3F_3	65.74	17.29	105.16
V_4F_1	36.82	6.53	57.80
V_4F_2	46.41	13.07	79.82
V_4F_3	63.60	16.29	94.74
V_5F_1	27.10	9.85	63.12
V_5F_2	53.84	13.10	81.31
V_5F_3	60.14	19.15	123.02
SEm±	1.79	0.77	1.93
CD (P=0.05)	5.20	2.24	5.61

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YIELD, NUTRIENT UPTAKE BY JAPANESE MINT AND SOIL FERTILITY STATUS UNDER DRIP FERTIGATION

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ABSTRACT

An experiment was conducted for two years during *rabi* seasons of 2005-06 and 2006-07 to study the effect of fertigation on yield and net return of Japanese mint. The treatments consist of three irrigation regimes (Drip irrigation I_1 at 100% PE, I_2- at 80% PE and I_3-60% PE) and three fertility levels(F_1 -100%, F_2 – 75% and F_3 - 50% of recommended dose of NPK) with an extra (control) treatment having surface irrigation and soil application of fertilizer @150-60-60 kg N, P_2O_5 and K_2O ha^{-1} . Irrigating the crop at 100% PE with 100% RDF produced the highest herb and oil yield than other treatment combinations. Drip irrigation at 100% PE produced more herbage (32034 kg ha^{-1}) and oil yield (236 kg ha^{-1}) of mint. Application of irrigation at 100% PE and 100% RDF recorded the highest herbage yield of 35798 kg and oil yield of 260 kg ha^{-1}. Application of irrigation at 100% PE helped the plant to absorb maximum amount of nutrients, which was at par with that of 80% PE. NPK uptake increased with an increase in the level of fertilizer. Application of irrigation at 100% PE and full fertilizer dose (100% RDF) absorbed maximum amount of NPK (306 kg ha^{-1}) consisting of 125 kg N, 37 kg P and 144 kg K. In post harvested soil N, P and K depletion were noticed in the soil at lower levels of irrigation and fertilizer.

(Key words: Herbage yield, Japanese mint, nutrient uptake, pan evaporation)

INTRODUCTION

Menthol mint (*Mentha arvensis* L.) is an important cash crop in India. It has become increasingly popular among small holders. In India, it is a potential source of natural menthol and other ingredients viz., mint terpenes, menthone, isomenthone, menthyl acetate etc., which are extensively used in pharmaceutical, cosmetic, food and flavour industries. Essential oil and their valuable commercial constituents obtained from menthol mint have great export potential. Presently India is the largest producer of Mentha oil in world contributing about 85% of total production, and rest is contributed by China followed by Brazil and US (Chainani, 2010). Today , India is the major global producer and supplier of mint oil and its derivatives . Regarding productivity on an average, 20-25 tonnes of green herb $hectare^{-1}$ can be obtained in three cutting yields to 125-200 kg of Mentha oil , $annum^{-1}$ and its derivatives, valued at Rs. 6000–8000 millions are exported from India (Anonymous, 2010). Mint is a shallow rooted and high water demanding crop. The water requirement of this crop varies from location to location depending upon soil and climatic factors. Both, high soil moisture content and water potential decrease the oil yield (Shormin *et al.,* 2009). Similarly, moisture stress during the growing season severely reduces its productivity. So, to harvest good yield of this crop irrigation should be scheduled at 35% depletion of available soil moisture (Mitchell *et al*., 1993). Mint has a high nutrient demand. Singh (1994) calculated the N, P and K removal to the extent of 150, 25 and 100 kg ha^{-1}, respectively. Mint crop responds well to high levels of N fertilizer (150 to 250 kg N ha^{-1}) depending on agro-climatic conditions (Saxena and Singh, 1996; Patra *et al*., 2000 and Shormin *et al*., 2009). For harvesting good crop yield, water and nitrogen are the important factors, which influence the essential oil production in mint. The studies on fertilizer management on other crops, whose economic part is leaf, revealed that optimum availability of nutrients throughout the growing period increases leaf production when applied through fertigation due to placement of fertilizer in effective crop root zone and less leaching loss. Keeping this in view, the present investigation was carried out to assess the effect of fertigation on herbage, oil yield, and nutrient removal by mint crop.

MATERIALS AND METHODS

The field experiment was conducted in the Central Experimental Farm of the Directorate of Water Management (Formerly known as Water Technology Centre for Eastern Region), Bhubaneswar during regimes and fertigation levels on mint (*Mentha arvensis,* L.) grown in the rice

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fallow. It was laid out in Factorial Randomized Block Design with three replications. The treatments consist of three irrigation regimes (I_1- drip irrigation at 100% PE, I_2- drip irrigation at 80% PE and I_3- drip irrigation at 60% PE) and three fertility levels (F_1 -100%, F_2 – 75% and F_3 - 50% of the recommended dose of NPK) with an extra (control) treatment having surface irrigation and soil application of fertilizer (150-60-60 kg N, P_2O_5 and K_2O ha^{-1}). The experimental soil was sandy loam in texture with pH 5.7, low in organic carbon (0.46%), available nitrogen (159 kg ha^{-1}); medium in phosphorus (21 kg ha^{-1}) and potassium (183 kg ha^{-1}). The suckers of variety "Koshi" were transplanted at a spacing of 60 cm x 10 cm on 10 December 2005 and 11 December 2006. The total amount of rainfall received during the cropping season was 464 mm in 2005-06 and 359 mm in 2006-07 in 42 and 23 rainy days, respectively. Mint received 105 mm more rainfall in 2005-06 than 2006-07. Full dose of phosphorus was applied basally at the time of planting. It was placed in open furrows about 2.5 cm below the suckers and mixed well with the soil by a small stick. Fertigation was given in equal splits at fortnightly interval from 15 days after planting (DAP) upto 30 days before final harvest as per treatment. Required amount of urea and potash was dissolved in water and fed to the drip system through a ventury. The weighed amount of 35 g Urea and 11 g MOP $plot^{-1}$ (net plot size-4.60 m x 2.40 m) was applied through drip irrigation in one split. Fertigation was made by regulating the taps of the laterals by allowing the solution to the specified plots as per fertilizer levels (In F_1-150-60-60, F_2-112.5-45-45 and F_3-75-30-30 kg N, P_2O_5 and K_2O ha^{-1}). As per treatment, differential amount of water was supplied on the basis of two days cumulative pan evaporation (CPE) through meteorological approach (Pruitt, 1966 and Jenson*, et al.* 1961). Cumulative pan evaporation for different treatments was computed using data from a standard US Weather Bureau Class A open pan evaporimeter. The depth of irrigation water was 60 mm in case of surface irrigation. The water was drawn from the secondary reservoir. First irrigation was given one day prior to planting. Subsequent irrigations were given at two days interval in drip irrigation and at 60 mm CPE value in case of surface irrigation method. If rainfall event occurred between irrigation cycles, then the rainfall amount was deducted and irrigation water was applied accordingly.

The crop was harvested by taking the first cut at 115 days after planting and the second cut at 75 days after the first cut during both the years. It was done in bright sunny weather with the help of a sickle from 2 to 3 cm above the ground level when the lower leaves start yellowing. The fresh harvested herbage from net plot was weighed by an electronic balance and the data were converted to kg ha^{-1}. Similar procedure was also followed in second harvest. Both the yields were added to obtain the total herbage yield. The herbage was dried for two days. The essential oil was extracted from the fresh herbage through steam distillation method using Clevenger`s type extracting apparatus made of glass (Clevenger, 1928). The volume of oil was recorded and oil per cent was computed by the following formula.

$$\text{Oil content (w/w \%) on fresh weight basis} = \frac{\text{Weight of oil}}{\text{Weight of fresh herb}} \times 100$$

The oil per cent was multiplied with corresponding fresh herbage yield of each treatment to get the oil yield. Total NPK uptake by plant was worked out by adding the uptake in different plant parts. The oven-dried samples were grounded using Willey Mill and analysed for nitrogen, phosphorus and potassium content. Plant samples were wet digested in di-acid mixture ($3HNO_3$:1HCl) for determination of P and K. Phosphorus was determined by the Vanadomolybdo-phosphoric acid yellow colour method and neutral normal NH_4OAc extractable K by flame photometer. N was determined by modified micro Kjeldahl method (Jackson, 1973). Uptake in a particular plant was determined by multiplying the NPK concentration with corresponding dry matter and expressed in kg ha^{-1}.

RESULTS AND DISCUSSION

Herbage yield

The Herbage yield was higher in 2006-07 than 2005-06 except that of drip irrigation @ 100% PE and drip irrigation @ 80% PE (Table1). It was more (39% to 53%) in the second harvest than the first one. The yield was reduced by 1.0% to 3.0% in 2006 as compared to 2007 due to drainage congestion. The method of irrigation significantly affected the herbage yield. The yield declined from 12.4% to 12.6% during the first and from 14.2% to 14.6%

during the second harvest under surface irrigation as compared to drip irrigation at 100% PE. Maximum yield of 32034 kg ha^{-1} was recorded with drip irrigation which increased the yield by 15.8% as compared to surface irrigation (control). The herbage yield was affected by different irrigation levels during both the seasons (Table 1). Maximum herbage yield (35132 to 34463 kg ha^{-1}) was obtained from irrigation at 100% PE. The minimum yield of 28079 to 29010 kg ha^{-1} was recorded with 60% PE (I_3). Application of irrigation at 100% PE increased the total yield from 6.7% to 21.9%. Shormin *et al*. (2009) in Bangladesh conducted pot experiment with five levels of nitrogen (0,60,120,180 and 240 kg ha^{-1}) and four levels of irrigation water (100, 75, 50 and 25 % field capacity) in mint crop and reported maximum herb yield of 103.54 g pot^{-1} and very low yield of 31.67 g pot^{-1}. They further suggested that highest dose of nitrogen and irrigation level is quite beneficial to harvest potential yield of mint. In semi-arid sub -tropical climate at Lucknow (India), application of irrigation at 1.2 IW:CPE ratio in combination 200 kg N ha^{-1} and sugarcane trash mulch @7 t ha^{-1} produced highest benefit as compared to 0.9 IW:CPE ratio with same amount of nitrogen and mulch material tested in mint crop (Ram *et al*., 1995 and 2006). Saxena and Singh (1998) conducted field experiment at Pantnagar for two years (1989 and 1990)with irrigation regimes , nitrogen levels and mulches on yield of Japanese mint (cv. MAS 1). They found that frequent irrigations (1.0 IW:CPE ratio) increased the herb yield by 46.8% compared with that of 0.3 IW:CPE ratio.

Variation in fertilizer level affected the herbage yield during both the years except in case of second harvest in 2007 (Table1). Application of 100% RDF (F_1) produced maximum yield (32558 kg to 32586 kg ha^{-1}) with a mean yield of 32572 kg ha^{-1}. On an average, the mean yield decreased by 1.9% to 3.4% due to reduction in fertilizer dose by 25% to 50% from 100% RDF. The total herbage yield decreased only by 1.4% to 1.7% by further reduction of 25% fertilizer from 75% RDF (F_2). Adequate supply of nutrients increased herbage yield due to production of taller plants, more branches and leaves $plant^{-1}$, superior leaf- stem ratio and increased dry matter accumulation and crop growth rate. High yield of menthol mint with high rate of NPK has been reported on soils with low N content by Kumar and Sood (2011). They reported that application of N, P and K (120:50:40 kg ha^{-1}) fertilizer gave maximum herb yield (204.42 q ha^{-1}). Rahman *et al*. (2003) conducted field experiment at Chittongang(Bangladesh) to assess the effect of three levels each of nitrogen (0, 100 and 200 kg ha^{-1}) , phosphorus(0, 60, 120 kg ha^{-1}) and potassium (0,40, and 80 kg ha^{-1}) on herbage and oil yield of menthal mint(*M. arvensis*). The treatment combination of N 200, P 60 and K 40 kg ha^{-1} produced highest dry matter of 7.1 t ha^{-1} . The interaction effect was not significant during both the seasons.

Oil content

Higher oil content was recorded with the first harvest than the second one (Table 2). In present study application of more water decreased the oil content, whereas high fertilizer dose increased it. Drip irrigation increased the oil content due to optimum supply of nutrients throughout the crop growth period. Oil content was maximum (0.70% to 0.83%) with drip irrigation at 60% PE(I_3). It decreased by 0.01% to 0.03% in case of irrigation at 100% PE($I_{1)}$ and 80 % PE ($I_{2)}$ as compared to irrigation at 60% PE(I_3).Different doses of fertilizer affected oil content in plants. The oil content was maximum (0.70% to 0.83%) with the application of 100% RDF (F_1) as compared to 75% and 50% RDF due to more vegetative growth resulting in accumulation of more metabolites to form more oil. An increase in leaf number increased the photosynthetic area. It facilitated the crop for more vegetative growth and accumulation of secondary metabolites to develop more oil.

Oil yield

Drip fertigation at 100% RDF produced maximum oil of 236 kg ha^{-1} (Table 2). Balanced application of water and fertilizer through drip irrigation increased the oil yield by 34 kg ha^{-1} (16.7%). Singh *et al.* (1989) and Ram *et al*. (2006) recorded significant increase in herbage and oil yields due to N application in Japanese mint under optimum moisture conditions. Application of adequate amount of phosphorus helps in ramification of the root system, which increased the number of suckers in the plant. More sucker production resulted in higher herbage and oil yield.

The highest quantity of oil (253 kg ha^{-1}) was recorded in higher irrigation regime (100% PE) due to adequate availability of soil moisture to the crop. Ram *et al.* (1995 and 2006) reported increase in oil yield by 23.5 % and 15.5 % when irrigation to mint was provided at IW/CPE ratio 1.5 and 1.l2 as compared to 0.9 when significant degree of water stress was created during each irrigation cycle. Oil yield decreased by 5.5% with irrigation at 80% PE and 15% at 60% PE due to inadequate moisture availability under reduced irrigation frequency (Shormin *et al.,* 2009).

The crop showed positive response to N, P and K application. N plays an important role on plant growth and development. It promotes vegetative growth through cell enlargement, multiplication and increase in the rate of photosynthesis. Application of 100% RDF (F_1) produced maximum oil yield (246 kg ha^{-1}) followed by F_2 (236 kg ha^{-1}) and F_3 (226 kg ha^{-1}). The total oil yield was reduced by 3.9 % with 75% of the recommended does of fertilizer (F_2) and by 7.8% with 50% RDF (F_3). Anwar *et al.* (2010) reported favourable effect of graded levels of NPK fertilizers (150 kg N, 60 kg P and 60 kg K) on oil yield of mint. Zheljazkov *et al.*(2010) studied the effect of three levels of nitrogen (0, 80 and 160 kg ha^{-1}) on herbage yield and oil yield of two cultivars (Arvensis 2 and Arvensis 3) of Japanese corn mint at North Mississippi Research Station and Extension Centre for two years during 2007 and 2008 . They found that under different nitrogen levels oil content in fresh herbage varied from 0.25 to 0.37 %. Nitrogen application increased oil yield from 46 kg ha^{-1} in control to 136 kg ha^{-1} in 80 kg N ha^{-1} dose. With further addition of nitrogen dose to 160 kg ha^{-1} , the oil yield was not improved substantially. Hence the nitrogen dose of 80 kg ha^{-1} was sufficient under Mississippi condition. In a two years fertilizer study of Japanese cornmint (*M. arvensis*), Zheljazkov and Margina (1996) reported oil yields of Mentolna-18' of M. arvensis between 67 (N at 0 kg ha^{-1}) and 111 kg ha^{-1} (N at 151 kg ha^{-1}) . The interaction effect of irrigation and fertilizer was found significant in case of total oil yield. Application of irrigation at 100% PE(I_1) with 100% RDF(F_1) produced 259.51 kg oil ha^{-1} because of optimum supply of moisture and nutrients (Table 3).

Nutrient uptake

Nitrogen

The nitrogen uptake was more in 2006-07 than 2005-06 (Table 4). Drip irrigation increased the nitrogen uptake (115.46 kg ha^{-1}) as compared to surface irrigation (95.39 kg ha^{-1}) by 21.0%. Application of irrigation water at high frequency increased the uptake. Maximum amount (119.67 kg ha^{-1}) was taken up by plants through irrigation at 100% PE followed by 80% PE (119.43 kg ha^{-1}) and 60% PE (107.29 kg ha^{-1}). There was no conspicuous difference in uptake between 100% PE and 80% PE. The uptake increased by 11.5% (100% PE) due to the former as compared to 60% PE. Application of water at 80% PE increased N uptake by 11.3% more than that of 60% PE. High moisture regimes maintained during summer months proved significantly better for efficient utilization of water and nutrient by the crop (Ram *et al.,* 1995).

Maximum nitrogen was taken up by plants, which received 100% RD (119.57 kg ha^{-1}). It increased from 2.6% to 8.4% as compared to 75% and 50% RDF. Reduction of 25% fertilizer from 100% RDF decreased the uptake by 2.6% and that of 50% fertilizer by 7.7%. Application of 75% RDF (F_2) increased the nitrogen uptake by 5.6% more than 50% RDF (F_3). The interaction effect was not significant. Ram *et al.* (2006) reported the higher N uptake under different water and N treatments. Application of N at 200 kg ha^{-1} in the sugarcane trash @ 7 t ha^{-1} mulched plots significantly enhanced the N uptake by the crop (Ram *et al.*, 2006). Under water stress condition, the N-uptake by mint plant was considerably low (Shormin *et al.,* 2009).

Phosphorus (P)

Drip irrigation increased the phosphorus uptake (29.14 kg ha^{-1}) by 48.75% more than the surface irrigation (Table 4). Decrease in irrigation water decreased the uptake and highest uptake was recorded with 100% PE (32.04 kg ha^{-1}) followed by I_2 (30.93 kg ha^{-1}) and I_3 (24.45 kg ha^{-1}). Phosphorus uptake decreased from 3.5% to 23.7% in case of I_2 and I_3 as compared to I_1. Application of irrigation at 80% PE had higher uptake (30.93 kg ha^{-1}) than that of 60% PE (24.45 kg ha^{-1}).

Application of 100 % RDF (F_1) increased the phosphorus uptake from 13.7% to 25.2% more than 75% and 50% RDF. Reduction of 25% and 50% fertilizer from recommended dose decreased the uptake by 12.1% and 20.2%, respectively. Application of 75% RDF helped the plants to take up 10.1% more P than that of 50% RDF. The interaction effect was not significant

Potassium (K)

Drip irrigation had the highest uptake of 132.70 kg ha^{-1}, which was 16.3% higher than the surface irrigation (Table 4). Reduction in irrigation level by 40% PE decreased the potassium uptake by 10.8% as compared to that of 100% PE. I_2 remained at par with I_1. Application of irrigation at 80% PE increased the potassium uptake by 11.9% more than that of 60% PE.

An increase in fertilizer dose increased the uptake of potassium. Application of 100% RDF increased the uptake by 2.4% to 9.3% and had maximum value of 137.67 kg ha^{-1} as compared to F_2 and F_3.By reducing the RDF by 25% decreased the uptake by 2.3% and that of 50% RDF by 8.5% in comparison with 100% RDF. The uptake was 6.8% more in case of F_2 than F_3. The interaction effect was not significant.

Nutrient status in post harvested soil
Nitrogen content

Irrigation methods significantly influenced the nitrogen content in soil in both the years (Table 5). Irrigation levels significantly influenced the N content in soil at both the harvests. The maximum soil N content was observed with irrigation at 60% PE in both the years. With increase in irrigation frequency up to 100% PE, the reduction in soil N content was 2.5% and 1.5% in 2006 and 2007, respectively over 60% PE. The application of 100% NPK fertilizer in the soil had higher N content than 75% and 50% NPK. On an average, of two years about 1.5% and 1% less N content was estimated in 50% and 75% NPK, respectively over 100% NPK treatment. The interaction was not significant.

Phosphorus content

The effect of irrigation regimes on soil P content was significant only in 2006-07 (Table 5). The application of 100% PE and 80% PE irrigation had statistically similar effect on P content. The maximum P content was observed with 60% PE irrigation and the magnitude of depletion was 5.1% over 100% PE. Different amount of fertilizers significantly influenced P content in soil during both the years. The maximum P content in soil was estimated with 100% NPK fertilizer rate. On an average, the reduction in soil P content was 5.2% and 9.5% due to 75% and 50% NPK application over 100% NPK.

Potassium content

The significant effect of drip fertigation on soil K content in soil was found only in second year (Table 5). Irrigation and fertilizer levels significantly affected the K content in soil during both the years. The maximum K content was recorded with irrigation at 60% PE followed by 80% and 100% PE. It indicated that under moisture conditions, K was not utilized efficiently by mint plants. Among various fertilizer rates, 100% NPK observed the highest amount of K content in soil than other treatments.

Table 1. Effect of irrigation and fertility on herbage yield of mint (kg ha^{-1})

Treatments	2006			2007			Mean
	1st Harvest	2nd Harvest	Total	1st Harvest	2nd Harvest	Total	
Method of irrigation							
Control	11319	16227	27546	11501	16297	27798	27672
DF	12921	19004	31925	13156	18986	32142	32034
SE(m)±	61.7	57.3	108.0	102.1	293.7	485.4	127.2
CD(0.05)	183.3	170.3	320.9	303.3	880.0	1455.2	378.0
Irrigation (I)							
I_1 = 100% PE	14530	20602	35132	14165	20298	34463	34798
I_2 = 80% PE	12895	19731	32626	13002	19586	32588	32607
I_3 = 60% PE	11300	16779	28079	12138	16872	29010	28545
SE(m)±	106.9	99.3	187.1	176.9	171.3	283.0	220.4
CD(0.05)	317.5	294.9	555.8	525.4	508.8	840.7	654.7
Fertility (F)							
F_1 = 100% RDF	13244	19314	32558	13548	19038	32586	32572
F_2 = 75% RDF	12845	19025	31870	13050	19004	32054	31962
F_3 = 50% RDF	12662	18664	31326	12955	18641	31596	31461
SE(m)±	106.9	99.3	187.1	176.9	171.3	283.0	220.4
CD(0.05)	317.5	294.9	555.8	525.4	-	840.7	654.7

NS = Not significant

Table 2. Effect of irrigation and fertility on oil yields of mint in 2005-06 and 2006-07

Treatments	Oil yield (kg ha $^{-1}$)	
	2005-06	2006-07
Methods of irrigation		
control	202	203
DF	232	240
SE (m)±	0.6 1	0.64
CD (0.05)	1.8 1	1.9 1
Irrigation (I)		
I_1 = 100% PE	250	257
I_2 = 80% PE	237	242
I_3 = 60% PE	211	220
SE (m) ±	1.05	1.11
CD (0.05)	3.13	3.30
Fertility (F)		
F_1 = 100%RDF	242	250
F_2 = 75% RDF	232	240
F_3 = 50% RDF	22 4	229
SE (m) ±	1.05	1.11
CD (0.05)	3.13	3.30

Table 3. Interaction effect of irrigation and fertilizer on mean (2006 and 2007) oil yield (kg ha^{-1}) of mint

Irrigation	Fertilizer			
	F_1	**F_2**	**F_3**	**I Mean**
I_1	259.51	253.52	246.43	253.15
I_2	247.63	239.73	230.64	239.23
I_3	229.26	215.37	201.93	215.52
F mean	245.47	236.10	226.33	

SE (m) =1.72, CD (0.05)= 5.10

Table 4. Effect of irrigation and fertility on NPK uptake by mint (kg ha^{-1})

Treatments	Nitrogen uptake (kg ha^{-1})			Phosphorous uptake (kg ha^{-1})			Potassium uptake (kg ha^{-1})		
	2005-06	2006-07	Mean	2005-06	2006-07	Mean	2005-06	2006-07	Mean
Method of irrigation									
Control	92.31	98.47	95.39	16.44	22.75	19.60	109.97	118.31	114.14
DF	112.32	118.61	115.46	25.92	32.37	29.14	128.87	136.53	132.70
SE(m) ±	0.35	0.525	0.394	0.354	0.326	0.336	0.533	0.552	0.530
CD(0.05)	1.050	1.560	1.172	1.054	0.969	1.000	1.584	1.642	1.575
Irrigation									
I_1= 100% PE	116.60	122.74	119.67	28.92	35.17	32.04	133.94	141.62	137.78
I_2= 80% PE	116.40	122.45	119.43	27.71	34.15	[illegible]	133.37	141.57	137.47
I_3= 60% PE	103.95	110.64	107.29	21.13	27.77	24.45	119.31	126.34	122.85
SE(m) ±	0.612	0.910	0.683	0.614	0.565	0.583	0.923	0.957	0.918
CD(0.05)	1.819	2.703	2.030	1.825	1.678	1.732	2.744	2.845	2.728
Fertility									
F_1= 100% RDF	116.90	122.24	119.57	29.28	36.02	32.65	133.98	141.35	137.67
F_2=75%RDF	113.23	119.77	116.50	25.46	31.96	28.71	130.74	138.21	134.47
F_3=50%RDF	106.82	113.82	110.32	23.02	29.11	26.07	121.90	130.02	125.96
SE(m) ±	0.612	0.910	0.683	0.614	0.565	0.583	0.923	0.957	0.918
CD(0.05)	1.819	2.703	2.030	1.825	1.678	1.732	2.744	2.845	2.728

NS = Not significant

Table 5. Effect of irrigation and fertility on nutrient availability of post harvested soil by mint

Treatments	Available nutrients (kg ha^{-1})					
	2005-06			2006-07		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Method of irrigation						
Control	164.9	22.1	185.2	166.4	21.0	185.3
DF	166.4	22.3	185.5	167.0	21.8	187.3
SE(m) ±	0.42	0.13	0.23	0.16	0.16	0.22
CD(0.05)	1.27	--	--	0.47	0.47	0.65
Irrigation (I)						
I_1 = 100% PE	164.0	22.0	183.9	165.9	165.9	186.1
I_2 = 80% PE	166.9	22.3	186.0	166.8	166.8	187.2
I_3 = 60% PE	168.2	22.6	186.7	168.4	168.4	188.6
SE(m) ±	0.72	0.23	0.40	0.28	0.28	0.38
CD(0.05)	2.14	--	1.18	0.84	0.83	1.12
Fertility (F)						
F_1 = 100% RDF	167.9	23.2	186.6	168.3	168.3	188.7
F_2 = 75% RDF	165.9	22.3	185.3	166.9	166.9	187.1
F_3 = 50% RDF	165.4	21.4	184.5	166.0	166.0	186.2
SE(m) ±	0.72	0.23	0.40	0.28	0.28	0.38
CD(0.05)	--	0.69	1.18	0.84	0.84	1.12
Initial	159	21	183	161	22	184

NS= Not significant

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EVALUATION OF *IN-SITU* RAIN WATER RETAINING CAPACITY OF CULTIVATED LAND IN CENTRAL VINDHYAN PLATEAU OF BARKACHHA, MIRZAPUR DISTRICT, UTTAR PRADESH

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ABSTRACT

Barkachha, a part of central Vindhyan plateau of Mirzapur district is rocky and undulating and thus the underground water resources are uncertain, unpredictable and inadequate to meet the requirement of agriculture. The present study was undertaken to evaluate the *in-situ* rain water retention capacity of the soil from Barkachha under rainfed farming system during the rainy season of 2012. Soil samples from six profile layers were collected in pre and post monsoon period, represented different cultivated and uncultivated lands of Barkachha. The soil moisture retention is ranged from 2.22-6.91 % in surface layers and 2.89-11.33 % in subsurface layers. Moisture retention in surface layer was negatively and significantly correlated (r = -0.95[*]) with the bulk density of the soils in cultivated land. In sub-surface layer, the soil moisture retention was positively and significantly correlated with the porosity and organic matter content (r = 0.47[*] and 0.45[*], respectively) in cultivated land. The order of moisture retention after rainfall in both surface and subsurface soil were as fallow: mustard > guava > wheat > jatropha > fallow > pasture land.

(Key words: Rain water, soil moisture retention, Vindhyan plateau)

INTRODUCTION

Rainfall is the principal source of water, which augment soil moisture, ground water and surface flow. Agriculture and several of the other economic activities in sub-tropical to dry areas depend on rains. Rainfall in dry areas is of convective nature and usually occurs at a very high intensity for shorter duration generating high runoff in response of even little rainfall. Rainfall is partitioned in two categories of fresh water resource: a *green water* resource, i.e. the soil moisture generated from infiltrated rainfall that is available for root water uptake by plants, and which constitutes the main water resource in rainfed agriculture; and a *blue water* resource, i.e. the stored runoff in dams, lakes and aquifers, which is the main water source for irrigated agriculture (Falkenmark, 1995). These *green* and *blue* water resources generate flows in the hydrological cycle. Of the 1.5 billion ha (11 % of the world's land surface of 13.4 billion ha) of crop land world wide, 1.223 billion ha (82 %) is rainfed (Anonymous, 2005). Farmers' yields in rainfed regions in the developing countries are low largely due to low rainwater use efficiency. Lack of clear and sound water policy in rainfed agriculture is among the reasons for the low yield and water productivity in these areas (Rockstrom *et al.*, 2007 and Wani *et al.*, 2008). Other reasons for low yields in the stressed environments of rainfed areas (Kerr, 1996) is soil deficiency (Chen *et al.*, 2010) in terms of infiltration and water holding capacity (Abdel-Nasser, 2007); all the rainfall does not infiltrate and /or not all that infiltrates is beneficially utilized.

Barkachha (Fig. 1) in Mirzapur district is situated about 8 km South-West of Mirzapur town on Robertsganj highway. Physiographically and climatologically, the area represents the entire Vindhyan tract covering parts of Uttar Pradesh, which is mainly inhabited by tribes. The area being rocky and undulating, the underground water resources are uncertain, unpredictable and inadequate to meet the requirement of agriculture. Due to undulating topography many small rivulets and channels intersecting the area, quickly wash away the bounties of rainfall. Due to dry conditions setting after the rains, the few wells and other water bodies that are present in the area start drying after November. The area comes under the grip of drought and scarcity of water after March every year.

The land of Barkachha farm, Rajiv Gandhi South Campus (RGSC) was classified (ICAR, 1971) in five soil series (Fig. 2). According to their survey report of ICAR (1971) through NBSS & LUP, Regional Center, New Delhi, nearly 40 % land of this

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farm is rocky, *i.e.* surface with bed-rock exposure (1 to 25 % slope). Approximately 60 % farm land is low to moderate depth soil, mostly 1-5 % slope with slight to moderate surface erosion. Rainfed farming system is developed at Barkachha through the development of rain water harvesting project (Tripathi and Raha, 2014), *viz*., check dam reservoirs (Tripathi *et al*., 2014) and river water lifting project. Thus, the objective of the present work was the assessment of *in-situ* rain water retaining capacity of the cultivated/uncultivated soils at Barkachha for the management of water of check dam reservoirs and river water lifting project as a supplementary irrigation.

MATERIALS AND METHODS

Description of location

A field experiment was conducted during the rainy season of 2012 at the Barkachha farm (Fig. 1) popularly known as Rajiv Gandhi South Campus (RGSC), Mirzapur, India, and lies between $25^0 00'$ to $25^0 15'$ Northern latitude, $82^0 05'$ to $83^0 11'$ Eastern longitude and altitude 180.59 m above mean sea level. The Barkachha farm is situated in the central Vindhyan plateau region. The topography of the farm is undulating and surface is rough. The Barkachha farm has an area of 1010 ha and is situated from 8 km South-West of Mirzapur - Robertsganj highway. The river Khjuri flow on the eastern border of the farm, many streamlets flow across the area resulting in excessive runoff during rainy season. The climate is semi-arid and sub-tropical. Normal annual rainfall is 1060 mm, 90% of it received during South-West monsoon (June to September). Rainfall is highly variable, erratic and unpredictable, at times causing drought spells of varying degree and duration. May is the hottest and January is the coldest month with a normal mean temperature value ranging from 13.5 to 34.0 °C. The atmospheric mean temperature begin to rise towards the end of February and reach to maximum during May. The mean relative humidity is 62%.

Soil properties analysis

Soil samples from 6 depths (0-15, 15-30, 30-45, 45-60, 60-75 and 75-100 cm) were collected from Barkachha farm locations represented different cultivated and uncultivated lands. Different cereals (wheat, maize, rice etc.), pulse and oil seed crops (bengal gram, black gram, red gram, mustard etc.), vegetables (cauliflower, cabbage, tomato, bottle gourd etc.), fruit crops (guava, ber, sapota etc.), biofuel crop (jatropha) are cultivated in Barkachha farm, Mirzapur. There is a vast land used for pasture land for grazing of livestock animal, other part of land are low density forest and barren. The layer wise soil samples were air-dried, ground and passed through 2 mm sieve for laboratory analysis. Their properties *viz.,* pH, electrical conductivity, organic matter, calcium carbonate, particle distribution, bulk density, particle density, porosity and water holding capacity were then determined following the standard procedures (Jackson, 1973; Bouyoucos, 1962 and Walkley and Black, 1934).

Soil moisture determination

The moisture recharging in cultivated (*viz*., wheat, mustard, guava and jatropha) and uncultivated land (*viz*., pasture, and fallow) of Barkachha farm was determined in post monsoon for the assessment of rainwater retaining capacity of the soil. Soil samples were collected during pre and post monsoon from 0-15, 15-30, 30-45, 45-60, 60-75 and 75-100 cm depths with the help of core sampler. The sample was transferred to a previously weighed aluminum box and dried in a hot air oven at 105 °C for 24 hours till the constant weight was assured. The weight of oven dry soil was then determined. The loss of weight of the soil sample on drying accounts for the water present in it. The moisture content was estimated gravimetrically using the equation suggested by Gardner (1965),

$$m \quad \sum_{i\;0}^{n} \frac{\quad _1 \qquad _2}{_2} \quad 100$$

Where,

m = Soil moisture content in peercentage

$_1$ = Weight of moist soil, (g)

$_2$ = Weight of dry soil, (g)

= indicates summation of moisture for different soil layers.

The percentage moisture was then converted to depth of soil moisture by using the equation.

$$d \qquad \frac{m}{100} \; bd \;\; D$$

Where,

d = Depth of soil moisture in cm

m = Soil moisture content in percentage

bd = Bulk density mg m^{-3}

D = Depth of soil in cm.

= indicates summation of moisture for different soil depths.

Statistical analysis

Data on mean, standard deviation (S.D.) and coefficient of variation (C.V.) of the soil properties and soil moisture at different depths of the farm land were statistically analyzed (Gomez and Gomez, 1984). The correlations of soil properties (physical and chemical properties) with the rain water retaining capacity in soil were statistically calculated. Evaluation of moisture recharging in different probability distribution (Sharma and Singh, 2010) like Beta, Cauchy, Laplace, Weibull and Gamma has been calculated.

RESULTS AND DISCUSSION

Soil properties

The soil and climate sets the parameters for agro-ecosystems. Thus, the soils at different depths of the cultivated and uncultivated lands in Barkachha farm were characterized thoroughly. The particle distribution of the surface soils, both in cultivated (*viz*., wheat, mustard, guava and jatropha) and uncultivated lands (*viz*., pasture and fallow land) of Barkachha farm are presented in table 1. According to broad textural classes of soil, all the soils were loam and the subdivision was found as sandy loam, loam and sandy clay loam. Bulk density, particle density as well as porosity of the cultivated and uncultivated soils showed in table 2. There is a wide variation of the bulk and particle density of cultivated and uncultivated soils at different soil depths (0-15, 15-30, 30-45, 45-60, 60-75 and 75-100 cm). The mean bulk and particle density of the surface soil of cultivated soils ranged from 1.27 to 1.46 Mg m^{-3} and 2.40 to 2.45 Mg m^{-3}, respectively, whereas these values in uncultivated soils ranged from 1.33 to 1.43 Mg m^{-3} and 2.40 to 2.50 Mg m^{-3}, respectively. Bulk density and particle density of sub-surface soil of cultivated soils ranged from 1.20 to 1.28 Mg m^{-3}, respectively, while uncultivated soils ranged from 1.21 to 1.22 Mg m^{-3} and 2.43 to 2.46 Mg m^{-3}, respectively. Perusal of the data revealed that the bulk density of the surface soil of all the pedons, both cultivated and uncultivated lands was comparatively lower than sub-surface layers. The bulk density is generally higher in lower profile layers. But due to undulating plateau geomorpholly in Barkachha farm, the clays are deposited from the higher sloppy elevation to lower region. Therefore, bulk density was comparatively higher in surface soil than in the sub-surface soil. The average porosity of cultivated lands of the surface and sub-surface soils ranged from 39.31 to 48.61 and 47.03 to 49.46 %, respectively, whereas porosity of uncultivated lands of the surface and sub-surface soils ranged 40.41 to 46.80 and 50.27 to 50.68 %, respectively. The mean water holding capacity (WHC) of the surface and sub-surface soils of cultivated lands ranged from 31.18 to 36.15 and 37.01 to 41.86 %, respectively, the WHC also found lower value in surface layer than sub-surface layer. It was revealed from the data that the pH of the surface soils were very strongly acid to slightly acid in nature except the pasture land (6.9). It was also observed that the soil reaction (pH) of the sub-surface layers of all profiles was gradually increased. Alkalinity in sub-surface soil profile particularly in pasture land was due to the presence of carbonates of calcium. The mean EC of all the studied soils at different depths ranged from 0.26 to 0.96 dSm^{-1}. The surface soils are more exposed to the atmosphere that enhances the weathering of rocks and minerals, which releases soluble salts in soil solution. But, EC of the soils were below 1 dSm^{-1}, thus soil salinity problem was not observed in Barkachha farm. The mean range of calcium carbonate in different soils of Barkachha farm was 4.0 to 11.2 %. Calcium carbonate content in the wheat cultivated field was found comparatively higher than other cultivated and uncultivated field. Parent materials in these regions are also rich in lime. Thus, through the calcification process, calcium ions are converted into insoluble calcium carbonate in soil. Organic carbon in surface and subsurface soils (Table 2) were very low ranged from 6.46 to 12.4 g kg^{-1} throughout the soil profile in all the soils under studied; consequently mean organic matter content was very low i.e. below 10 g kg^{-1} regardless of cultivated and uncultivated lands. For the enhancement of the productivity of land and moisture retention, organic matter can be improved by adopting conservation agriculture technology and addition of organic matter, such as animal and plant wastes.

Rainfall pattern and rainfall index

Perusal of data from table 3 revealed that, period of onset of monsoon in this region was 4th week of April which lasted upto 1st week of October. More than 90 % of the annual rainfall was received during monsoon period (i.e. June to September), but it was erratic and unpredictable i.e. not uniform distribution. Out of 365 days, only 40 days were rainy days in 2012 and total rainfall was 1380.6 mm. Maximum rainfall occurred in the month of August, i.e. 38.16 % of the total annual rainfall. The intensity of rainfall (monthly average) was high (58.53 mm day^{-1}) in the month of August (Fig. 3) followed by the month of September (30.5 mm day^{-1}). Most of the rainfall events have a short duration but a high intensity in this period. There was a light shower during the month of April and May and it helped summer ploughing of the field. The month of January, February, March, November and December in experimental year 2012 were practically rainless. Thus, precipitation received for approximately six months (except 1 day in April) and the peak was August to September. This trend of monsoon rains coupled with existing toposequence of the central Vindhyan plateau of Mirzapur, Barkachha leads to imbalance between rain received and vegetation water demand. In order to classify the annual rainfall amounts, the rainfall index (Schiettecatte *et al*., 2005) can be used. In this way, the year 2012 was classified (Table 4) as wet year. But, considering the annual average rainfall (i.e. 1060 mm), Barkachha in Mirzapur district should fall under the medium rainfall area (semi-arid). According to rainfall criteria (Kerr, 1996), the rainfed areas are subdivided into three categories; a low rainfall area (> 750 mm per annum), medium rainfall area (750-1125 mm) and high rainfall area (> 1125 mm), sometimes described as the arid, semi-arid and humid areas. Considering the monthly average (Table 3) data on temperature, humidity, sunshine and evaporation of Mirzapur, the climate in the region of Barkachha is warm and semi-arid. The average relative humidity varied from 20.2 to 84.2 % and the lowest humidity was showed in the month of April and the highest in month of August. The monthly average temperature was the highest in the month of May and the lowest in the month of January and the variation of temperature was very wide. The annual average sunshine and evaporation were 7.3 hour and 4.4 mm day^{-1}, respectively in the year 2012.

Rain water retention capacity of soil

The soil moisture recharging in soil was determined in cultivated (*viz*., wheat, mustard, guava and jatropha) and uncultivated (*viz*., pasture and fallow) lands by gravimetric method. Rain water retention capacity by the soils of the respective lands was assessed by subtracting the soil moisture content, from post-monsoon period to pre-monsoon period. The data regarding the soil moisture content in wheat, mustard, guava, jatropha, pasture and fallow lands are presented in table 5. Comparative soil moisture conserved after the monsoon period in surface and subsurface (0-100 cm) soil of different lands in rainfed farm of Barkachha was estimated. Considering the mean soil moisture content in pre and post monsoon period of different cultivated and uncultivated lands of Barkachha farm and the total volume of moisture conserved in different layers of soil profiles, the order of moisture retention (Fig. 4) after rainfall was as follows: mustard > guava > wheat > Jatropha > fallow > pasture land. The moisture retention by the soils at different depths was controlled by soil organic matter and the crop canopy of the cultivated plants. The organic matter was comparatively very low (10.0 g kg^{-1}) in pasture land. The soil moisture retention at surface layer (Table 5) was observed the highest in mustard field (6.91 %) and the lowest in the field of jatropha (2.23 %). The conserved soil moisture at sub-surface layer (upto 60 cm) was comparatively higher in guava planted field. Thus, rhizosphere influenced the moisture retention in cropped land. The sub-surface soil moisture retention was noticed highest in rhizosphere zone of mustard (11.34 %) in the depth of 30-45 cm. The sub-surface soil moisture retention from 30-100 cm depth was very low in pasture land due to limited root growth of grasses (uptp 30 cm). The moisture retention at sub-surface layers (30-100 cm) was observed to be the lowest in pasture land. In fallow land, due to higher organic matter (10.4 g kg^{-1}), conserved moisture was found higher than pasture and jatropha plantation lands.

Correlation of the rain water retention with different soil properties

Correlation of the soil properties with rain water retention capacity by the soil in different profiles of Barkachha farm was studied. The soil moisture retention in surface layer was negatively and significantly correlated with the bulk density of the soils in cultivated land and particle density of the soils in uncultivated land with the value ($r = -0.95^{*}$) in the different layers of the soil profile. In sub-surface layer, the soil moisture retention was positively and significantly correlated with the porosity and organic matter content ($r = 0.47^{*}$ and 0.45^{*}), respectively in cultivated land and calcium carbonate and organic matter ($r = 0.75^{*}$ and 0.71^{*}), respectively in uncultivated land in the different layers of the profile. The diurnal and seasonal variations of soil temperature were also quite high in the Vindhyan plateau of Barkachha farm. Thus, for the improvement of soil bulk density, organic matter content in soil and consequently the significant amount of rain water retention by soil, crop cultivation under agroforestry system will be most suitable in Barkachha farm. The agroforestry system of crop cultivation would improve the micro-climate by reducing soil temperature and enhancing soil organic matter. The rain water will be retained more amount in this condition.

The distributions for each data set were computed for different probability distribution (Sharma and Singh, 2010). First rank probability distributions of moisture recharging (%) capacity of cultivated and uncultivated soils are presented in table 6. Statistical goodness of fit, Kolmogorov–Smirnov test was carried out in order to select the best fit probability distribution on the basis of highest rank with minimum value of test statistic. The highest value (0.2507) was obtained in mustard cultivated lands at Barkachha with Laplace distribution. The lowest value (0.1629) was attained with Cauchy distribution in wheat-cultivated land at Barkachha. In guava and jatropha best fitted probability distributions are respectively Weibull and beta. On the basis of minimum value of test statistics Gamma (0.2110) and Cauchy (0.1643) distribution were found best on pasture and fallow respectively.

The moisture retention capacity in the surface soils of farm land varied from 2.22-6.91 %, whereas in subsurface soils, it varied from 2.89-11.33 %. The variation of moisture retention was depended on crop coverage in the respective land. The order of rainwater retention in different soil profiles was as follow: mustard > guava > wheat > jatropha > fallow > pasture land. The moisture retention by soils at different depths was controlled by soil organic matter. The diurnal and seasonal variations of soil temperature are quite high in the Vidhyan plateau of Barkachha farm, which also governed the moisture retention in soil. Thus, for the enhancement of soil moisture retention in surface and subsurface soil profile in farm land and consequently the improvement of the productivity of land, organic matter in soil could be improved. In this situation and considering the agroclimatic condition, agroforestry system of crop cultivation will be most suitable cultivation practices in rainfed farm of Barkachha farm, rather than typical food grain (rice, wheat, pulse, oil seeds etc.) production techniques in plain land.

Table 1. Soil texture of the surface and sub-surface soils of Barkachha farm, Mirzapur district, Uttar Pradesh

Sr.No.	Cropped land	Sand (%)		Silt (%)		Clay (%)	
		Surface soil (0-15 cm)	Sub-surface soil (15-100 cm)	Surface soil (0-15 cm)	Sub-surface soil (15-100 cm)	Surface soil (0-15 cm)	Sub-surface soil (15-100 cm)
1	Wheat	51.68	56.70	16.56	22.98	31.76	20.32
2	Mustard	48.24	55.80	21.00	27.50	30.76	16.70
3	Guava	34.84	46.20	33.40	26.85	31.76	26.95
4	Jatropha	54.12	57.70	21.28	25.68	24.60	16.62
5	Pasture	44.24	46.23	23.00	24.17	32.76	29.60
6	Fallow	42.96	46.11	25.00	23.72	32.04	30.17

Table 2. Properties of soil profile* in cultivated lands of Barkachha farm, Mirzapur district, Uttar Pradesh

Sr.No.	Cropped land	Bulk density (Mg m^{-3})		Particle density (Mg m^{-3})		Porosity (%)		WHC (%)		Organic matter (g kg^{-1})		$CaCO_3$ (%)		pH		EC (dSm^{-1})	
		Surface soil (0-15 cm)	Sub-surface soil (15-100 cm)	Surface soil (0-15 cm)	Sub-surface soil (15-100 cm)	Surface soil (0-15 cm)	Sub-surface soil (15-100 cm)	Surface soil (0-15 cm)	Sub-surface soil (15-100 cm)	Surface soil (0-15 cm)	Sub-surface soil (15-100 cm)	Surface soil (0-15 cm)	Sub-surface soil (15-100 cm)	Surface soil (0-15 cm)	Sub-surface soil (15-100 cm)	Surface soil (0-15 cm)	Sub-surface soil (15-100 cm)
1	Wheat	1.46	1.24	2.43	2.46	41.97	49.46	34.41	41.86	12.4	9.12	11.25	9.36	4.80	6.52	0.96	0.57
2	Mustard	1.27	1.20	2.40	2.39	48.61	48.85	36.15	37.01	10.7	7.76	4.00	4.4	6.00	6.52	0.27	0.26
3	Guava	1.42	1.28	2.34	2.42	39.31	47.03	33.79	40.53	10.7	7.88	5.50	5.35	5.50	6.46	0.76	0.49
4	Jatropha	1.44	1.25	2.45	2.45	41.22	48.66	31.18	37.91	10.4	8.94	4.50	4.65	6.20	6.70	0.60	0.29
5	Pasture	1.33	1.21	2.50	2.46	46.80	50.68	34.16	39.97	10.0	6.46	4.75	4.90	6.90	8.14	0.53	0.45
6	Fallow	1.43	1.21	2.40	2.43	40.41	50.27	40.79	38.83	10.4	9.70	5.75	5.95	5.50	6.4	0.63	0.56

*Mean values of the surface and sub-surface soils

Table 3. Monthly average meteorological data (2012) of Mirzapur, Uttar Pradesh

Month	Total rainfall (mm)	Rainy day	Temperature (°C)		Relative humidity (%)		Wind velocity (km hr^{-1})	Sunshine (hr)	Evaporation (mm day^{-1})
			Max.	Min.	Max.	Min.			
January'12	0.0	0	19.64	7.40	83.54	47.52	3.2	6.05	2.2
February'12	0.0	0	27.20	12.10	80.57	45.58	3.5	8.01	3.1
March'12	0.0	0	34.78	16.10	65.2	32.10	3.4	8.89	4.9
April'12	23.40	1	40.02	22.61	50.42	20.24	4.3	9.64	7.6
May'12	44.20	2	42.12	26.01	55.65	30.43	4.8	9.21	8.1
June'12	319.80	11	39.68	27.35	67.63	45.60	5.5	7.31	7.4
July'12	82.30	5	34.28	25.41	76.85	69.81	5.3	4.9	4.7
August'12	526.80	9	33.21	26.1	84.82	70.3	4.5	5.6	3.9
September'12	335.60	11	32.88	25.8	84.01	70.1	3.9	6.5	3.7
October'12	48.50	2	31.04	20.83	83.51	54.85	2.6	7.5	3.1
November'12	0.0	0	28.78	14.51	82.61	42.12	2.1	8.0	2.5
December'12	0.0	0	23.61	10.12	84.7	43.12	1.9	6.5	1.7

Table 4. Classification of rainfall index

Rainfall index value[a]	Interpretation
x < -0.4	Extremely dry
x < x < -0.1	Dry
0.1< x < 0.1	Normal
0.1< x < 0.4	Wet
0.4< x	Very wet

$$x^{a} = \frac{\text{Annual precipitation - Average annual precipitation}}{\text{Average annual precipitation}}$$

Average annual precipitation of Mirzapur = 1060 mm[*]

[*]Indian Meteorological Department, Pune

Table 5. Moisture recharging of different land use in Barkachha, Mirzapur district through rain water

Sr. No.	Soil profile depth (cm)	Moisture recharging (%) in cultivated and uncultivated soil					
		Wheat	**Mustard**	**Guava**	**Jatropha**	**Pasture**	**Fallow**
1	0-15	2.54	6.91	5.33	2.23	3.32	3.45
2	15-30	5.52	7.59	8.37	3.84	4.18	5.01
3	30-45	6.28	11.34	5.68	5.53	2.55	4.96
4	45-60	4.88	6.76	8.77	5.13	2.90	4.75
5	60-75	5.90	4.67	5.05	6.11	3.80	6.64
6	75-100	5.34	3.51	4.82	4.74	2.96	4.47
	Range	2.54-6.28	3.51-11.34	4.81-8.77	2.22-6.11	2.55-4.18	3.45-5.01
	Mean	**5.07**	**6.79**	**6.34**	**4.59**	**3.28**	**4.88**
	± S.D.	1.32	2.78	1.76	1.515	0.732	1.03
	C.V. %	26.03	40.89	27.76	32.96	22.31	21.16

Table 6. First ranked probability distribution of moisture recharging (%) in cultivated and uncultivated lands

Different land use	Distribution	Value
Wheat	Cauchy	0.1629
Mustard	Laplace	0.2507
Guava	Weibull	0.1666
Jatropha	Beta	0.2276
Pasture	Gamma	0.2110
Fallow	Cauchy	0.1643

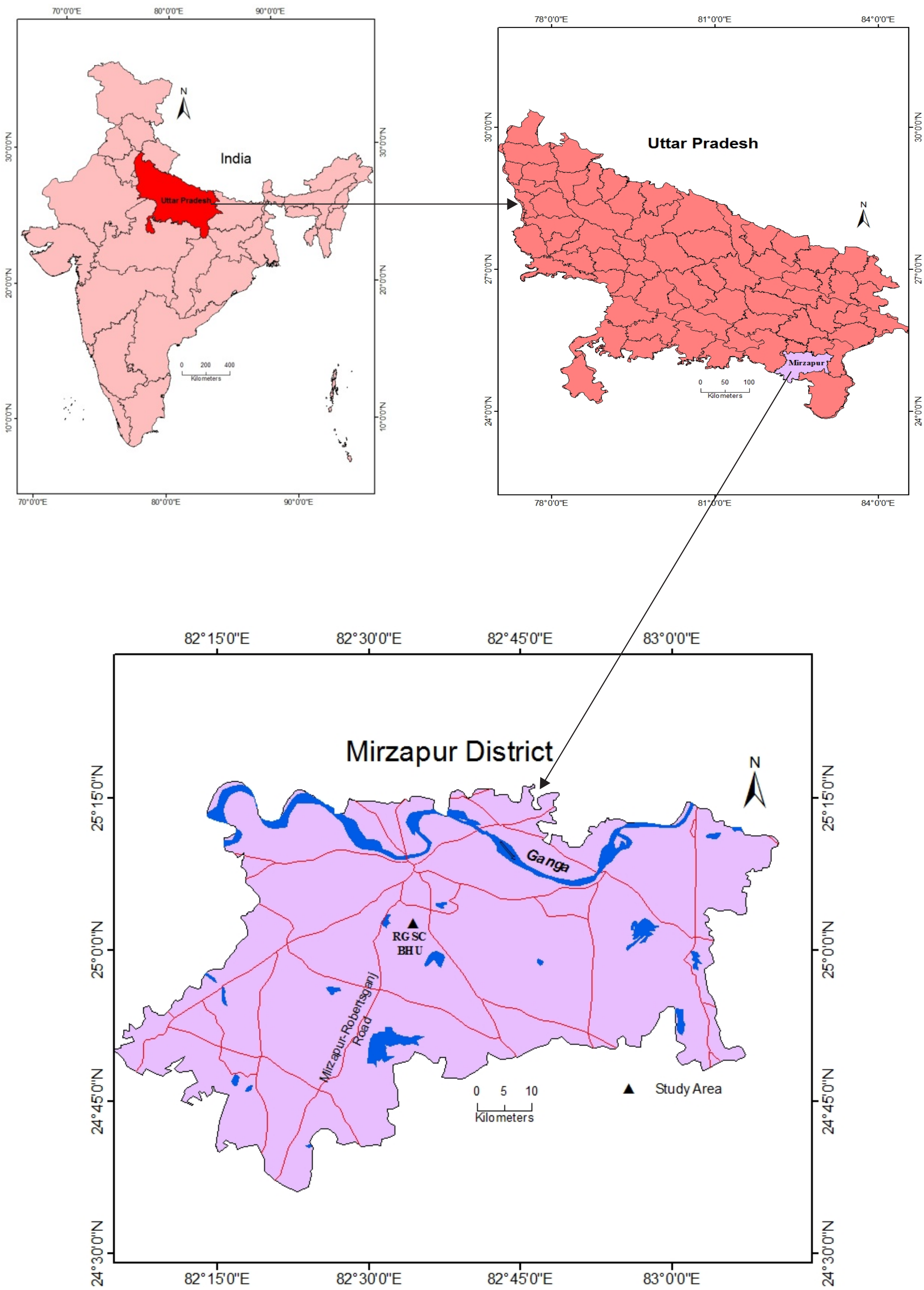


Fig. 1. Location map of study area

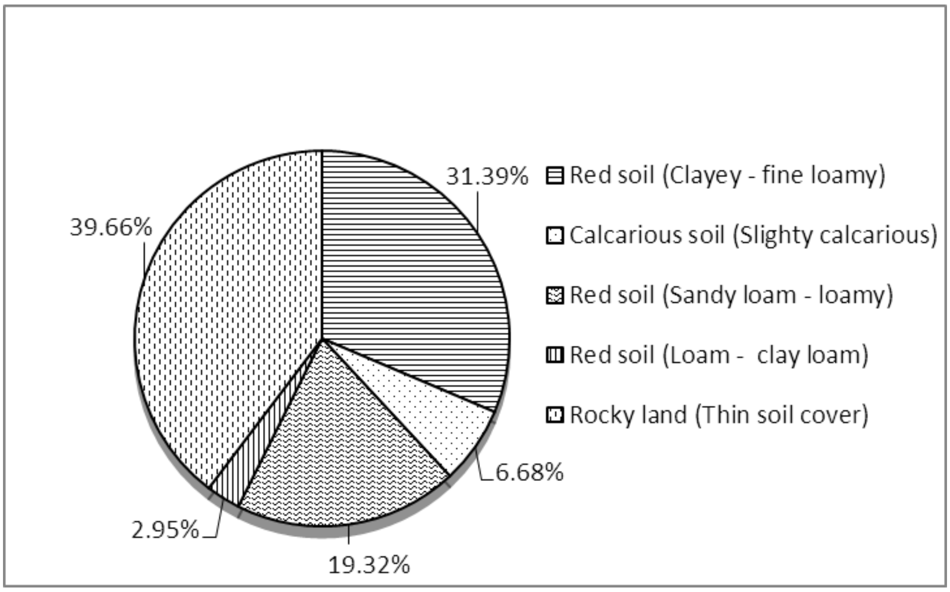


Fig. 2. Major soil series identified in Barkachha farm, Mirzapur (Soil Survey Report No. 423, ICAR, March, 1971)

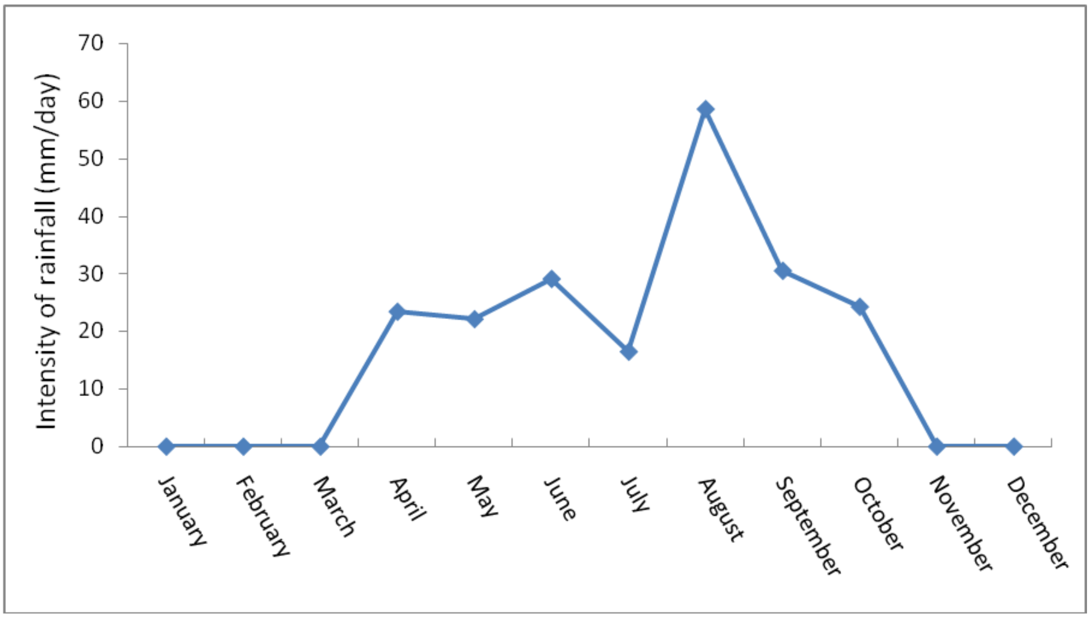
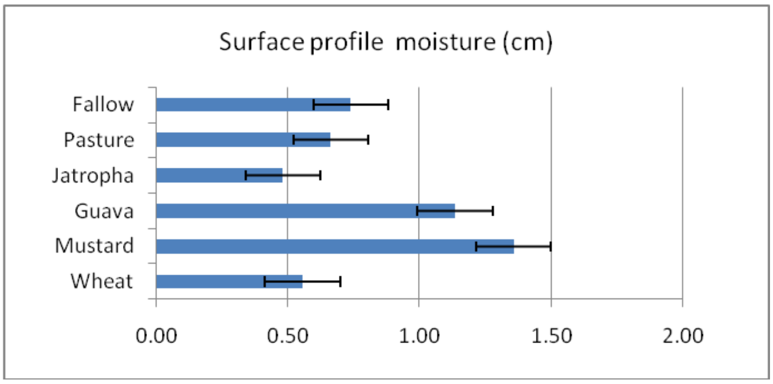


Fig. 3. Monthly average rainfall intensity (2012) in Barkachha, Mirzapur district



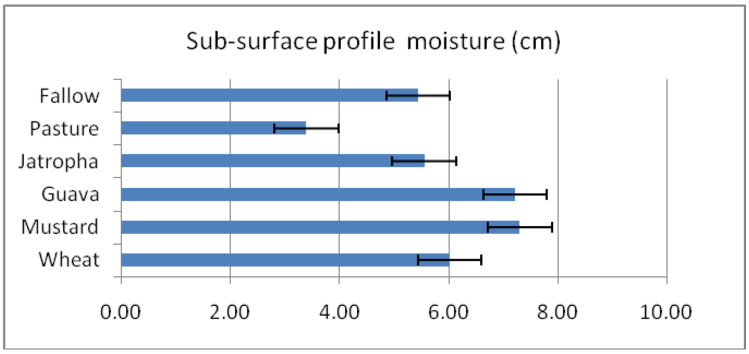


Fig. 4. Moisture content in surface and sub-surface profiles of different land use

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COMBINING ABILITY ANALYSIS FOR SEED YIELD AND ITS COMPONENT QUANTITATIVE TRAITS IN INDIAN MUSTARD [*Brassica juncea* (L.) Czern and Coss.]

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ABSTRACT

The experiment was conducted at Main Castor – Mustard Research Station, S.D. Agricultural University, Sardarkrushinagar-385 506 Gujarat (India) during *rabi* 2011-12 and *rabi* 2012-13 to identify the best parents and hybrids for gca and sca effects in Indian mustard by using diallel analysis without reciprocals involving ten parents. The study revealed the importance of non-additive gene effects reflected by high value of sca variance than gca variance for all the characters. Parents GM1 and Pusa Bold were good general combiners for seed yield and its related attributes. Three cross combinations namely, GM1 X BIO902, GM3 x GDM4 and Pusa bold X Kranti were observed to be promising as these possessed significant and positive sca effects for seed yield and its related component quantitative traits.

(Keywords: Combining ability, GCA, SCA, seed yield, component characters, Indian mustard)

INTRODUCTION

Indian mustard *[Brassica juncea* (L.) Czern & Coss] is the second important oilseed crop at national level after groundnut and contributes nearly 27% to edible oil pool of the country. For faster advances and getting tangible results in plant breeding, it is necessary to know the existing genetic variability and combining abilities of the breeding materials. In quantitative genetics, the study of different type of gene actions helps in the identification and selection of suitable parental lines to be included in hybridization to develop superior F1 hybrids. This technique can also be exploited for the choice of appropriate breeding procedures (Hayman, 1954 and Griffing, 1956). Keeping this background in view, the present investigation was undertaken in Indian mustard.

MATERIALS AND METHODS

The experimental materials comprised of 10 parents which were crossed in diallel mating fashion and 45 F_1 hybrids were developed. The research was carried out at Main Castor-mustard research station, Sardarkrushinagar, S.D. Agricultural University, Sardarkrushinagar (Gujarat). All the F_1S along with parents were grown in a randomized block design with three replications during *rabi* 2012-2013. Five plants were randomly selected for each genotype and the average value plant^{-1} was computed for recording observations for eight quantitative traits. Analysis of variance was followed as per method suggested by Panse and Sukhatme (1978) to test the differences between genotypes for all the characters under study. The Analysis of variance for combining ability for partitioning the total genetic variance into general combining ability, representing additive type of gene action and specific combining ability as a measure of non additive gene action was carried out by the procedure suggested by Griffing (1956) method 2 and model-I.

RESULTS AND DISCUSSION

The analysis of variance for combining ability indicated that the mean squares due to general combining ability and specific combining ability were significant for days to 50 per cent flowering, days to maturity, plant height, number of branches plant^{-1}, number of siliquae plant^{-1}, seed yield plant^{-1} and 1000 seed weight. The variance due to sca was higher than that of due to gca for all the characters under study indicated the predominant role of non-additive gene action, which would be necessitate the maintenance of heterozygosity in the population.

The preponderance of non-additive gene effects were reported for days to maturity (Rahman *et al.,* 2011), number of branches plant^{-1} (Gupta *et al.,* 2006) and seeds siliquae^{-1} (Azizinia., 2012). Similarly preponderance of additive genetic effects were observed in the inheritance of days to 50% flowering and plant hight (Gupta *et al.,* 2006), number of siliquae plant^{-1} (Dar *et al.,* 2011), seed yield plant^{-1} (Rahman *et al.,* 2011 and Dar *et al.,* 2011) and 1000 seed weight (Azizinia, 2012).

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Table 1. Analysis of combining ability and variance components

Source of d.f.variation	d.f.	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	No. of branches plant^{-1}	No. of siliquae plant^{-1}	No of seeds siliquae^{-1} (g)	Seed yield plant^{-1} (g)	1000 Seed weight (g)
GCA	9	32.01 **	27.42 **	94.25 **	8.44 **	2673.63 **	1.00	80.13**	0.42 **
SCA	45	20.03 **	19.00**	38.95	30.30 **	920.59 **	1.74	53.02 **	0.18
Error	108	4.75	2.52	26.97	1.39	182.10	0.42	0.79	0.13

*.** indicate level of significance at 5% and 1%, respectively

Table 2. Estimation of general combining ability effect associated with each parent for various characters

Parents	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	No. of branches plant^{-1}	No . of siliquae plant^{-1}	No. of seeds siliquae^{-1}	Seed yield plant^{-1} (g)	1000 seed weight (g)
CM 1	-0.71	0.07	-0.77	1.14**	22.99 **	0.11	3.92**	0.28 **
CM 3	0.94	1.52**	2.52	-0.22	9.06*	0.18	0.03	0.11
COM4	1.38*	1.43 **	3.06*	-0.82*	-19.47**	0.28	0.47	-0.05
PUSA BOLD	3.71 **	2.96 **	-1.85	1.50**	20.37 **	-0.12	4.13**	0.16
BIO 902	-0.48	-0.34	-6.46 **	-1.06**	-20.39 **	-0.42 *	-0.84 **	-0.34**
PVM 7	-0.557	-0.79	-0.50	-0.55	3.17	0.13	-1.36**	-0.20 *
PCR7	-1.80**	-1.79**	-0.92	-0.03	0.08	-0.44*	-2.41 **	0.09
PSR48	-1.48 *	-1.37**	1.39	-0.07	-4.65	0.31	-4.31 **	-0.15
KRANT1	-0.99	-0.54	1.74	-0.50	-12.32**	0.25	0.64*	0.05
SKM 9825	-0.01	-1.15 **	1.79	0.62	1.16	-0.27	-0.26	0.05
S E (gi)	2.01 **	1.47**	4.80 **	1.09**	12.46 **	0.60 **	0.82 **	0.33 **
Range	-1.80 to 3.71	-1.79 to 2.96	-6.46 to 3.06	-1.06 to 1.50	-20.40 to 22.99	-0.44 to 0.31	-4.31 to 4.13	-0.34 to 0.28

***, ** indicate level of significance at 5% and 1%, respectively**

Table 3. Estimates of specific combining ability effects associated with each hybrid for various characters

Hybrids	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	No. of branches plant^{-1}	No of siliquae plant^{-1}	No of seeds siliquae $^{-1}$	Seed yield plant^{-1}	1000 seed weight (g)
GM 1 X GM 3	-2.99	-2.72	1.17	-4.55**	-8.44	-1.12	4.08**	0.50
GM 1 X GDM 4	-4.40*	-0.97	-10.79	-7.62**	17.02	-0.95	-14.39**	-0.12
GM 1 X PUSA BOLD	-3.99	-2.17	0.44	-7.20**	-19.69	-1.22*	-3.64**	-0.46
GM 1 X BIO 902	0.18	-2.19	1.15	7.02**	17.61	-0.06	21.57**	1.07**
GM 1 X PYM 7	1.91	0.583	-7.13	-2.69*	-16.76	0.52	6.14**	0.13
GM 1 X PCR 7	4.37*	6.58**	8.53	3.88**	0.07	1.77**	1.30	0.27
GM 1 X PSR 48	0.93	4.17**	2.87	2.37*	-7.27	0.14	-1.43	-0.15
GM 1 X KRANTI	0.82	0.33	-0.05	-3.14**	42.57	0.37	-11.45***-	0.06
GM 1 X SKM 9825	1.11	0.94	3.79	0.41	-2.68	0.86	5.42**	-0.21
GM 3 X GDM 4	-9.49**	-7.42**	1.50	3.81**	33.98	-0.22	15.44**	-0.21
GM3 X PUSA BOLD	-5.22*	-5.61**	4.98	-4.78**	23.14	-0.69	9.77**	-0.32
GM 3 X BIO 902	1.10	1.03	13.10**	1.45	8.47	3.28**	-3.69**	-0.25
GM 3 X PYM 7	6.48**	7.14**	-8.95	5.27**	-2.96	-0.75	-6.62**	0.34
GM 3 X PCR 7	-0.22	0.14	-10.78*	10.82**	-3.54	1.30*	-10.523**	0.25
GM 3 X PSR 48	3.589	1.72	2.65	-1.01	-23.44	1.06	-2.451**	0.259
GM 3 X KRANTI	3.78	1.89	2.32	-0.98	-39.67	0.74	1.09	-0.14
GM 3 X SKM 9825	13.42**	12.17**	2.21	-8.83**	-43.27	-3.64**	-10.58**	0.50
GDM 4 X PUSA BOLD	-0.09	-0.53	5.88	7.23**	-36.60	0.58	-0.56	-0.47
GDM 4 X BIO 902	1.70	1.44	4.25	0.99	0.10	-0.26	-3.01**	0.84*
GDM 4 X PYM 7	5.96**	6.22**	8.22	-4.26**	-16.26	-0.75	-0.14	0.36
GDM 4 X PCR 7	-0.33	0.22	-2.30	-1.84	-14.74	0.73	-4.11**	-0.19
GDM 4 X PSR 48	4.35*	3.14*	-6.67	-0.20	2.35	-0.19	4.52**	-0.18
GDM 4 X KRANTI	-1.34	0.64	-6.02	-2.24*	8.29	0.84	-0.32	-0.05
GDM 4 X SKM 9825	-1.54	-2.75	-7.66	3.44**	-4.08	0.39	-4.04**	-0.01
PUSA BOLD X BIO 902	6.59**	7.92**	-4.08	2.20*	36.39**	-1.16	-8.25**	0.53
PUSA BOLD X PYM 7	4.82*	5.69**	-0.70	-0.44	12.47	3.35**	-1.83*	0.02
PUSA BOLD X PCR 7	1.81	2.36	-2.45	-6.63**	-13.32	-1.74**	11.31**	0.26
PUSA BOLD X PSR 48	5.18*	6.61**	-1.82	-2.05	26.62*	0.24	-5.02**	-0.43
PUSA BOLD X KRANTI	1.28	-1.22	-3.17	6.24**	59.954*	1.37*	10.82**	0.03
PUSA BOLD X SKM 9825	-5.33*	-4.94**	-7.12	6.92**	50.98**	1.52*	3.37***	0.14
BIO 902 X PYM 7	1.25	-2	-4.99	-7.52**	26.36*	1.62**	-1.77*	0.29
BIO 902 X PCR 7	1.03	0	4.91	-5.87**	-39.99	-1.01	1.33	-1.44
BIO 902 X PSR 48	-4.33*	-4.08**	-6.55	11.47**	-26.42*	0.34	2.10*	-0.29
BIO 902 X KRANTI	2.36	2.75	-9.08	-2.47	-38.42	-0.87	0.67	-0.36
BIO 902 X SKM 9825	-3.46	-3.97**	-5.53	0.08	-7.16	-0.35	2.76**	-0.26
PYM 7 X PCR 7	-3.27	-2.22	-1.47	-3.48**	-13.45	-0.39	2.70**	-0.18
PYM 7 X PSR 48	-4.85*	-6.97**	3.26	3.86**	13.75	-1.42*	1.70*	0.00
PYM 7 X KRANTI	-5.22*	-3.81*	-3.55	-2.28*	-22.68	-0.65	-4.76**	-0.47
PYM 7 X SKM 9825	-5.44	-2.19	-4.30	3.47**	39.45**	1.07	3.30**	-0.33
PCR 7 X PSR 48	4.80*	3.36*	-9.83*	0.84	-54.66	0.73	-3.84**	0.07
PCR 7 X KRANTI	0.77	0.19	7.19	3.90**	27.38*	-1.51*	2.47**	0.24
PCR 7 X SKM 9825	3.14	3.14*	0.11	8.32**	15.77	1.01	5.68**	0.05
PSR 48 X KRANTI	0.22	-1.22	3.62	-2.76*	22.51	-0.93	-3.90**	0.38
PSR 48 X SKM 9825	-1.34	0.72	6.61	-9.01**	17.97	0.15	9.68**	0.12
KRANTI X SKM 9825	0.46	1.89	7.73	7.75**	-34.23	-1.35*	2.05*	-0.18
S. E. (S_{ij})	5.67	4.13	13.51	3.07	35.11	1.68	2.314	0.92
Range	**-9.14 to 13.41**	**-7.41 to 12.16**	**-10.78 to 18.04**	**-9.01 to 11.73**	**-54.66 to 59.95**	**-3.64 to 3.35**	**-14.39 to 21.57**	**-1.43 to 1.07**

*,** Indicates level of significance at 5% and 1%, respectively.

The parents Pusa bold and GM1 were good general combiner for seed yield plant^{-1}, number of branches plant^{-1}, number of siliquae plant^{-1} and 1000 seed weight. Above parents can be considered as a good source of favourable genes for increasing seed yield along with other yield attributes. It is evident from these results that high gca effects for seed yield plant^{-1} was mainly due to high gca effects for yield contributing characters. Therefore, it would be worthwhile to use above parental lines in the hybridization programmes. However, PCR 7, PSR 48 and Kranti were good combiners for earliness but poor general combiners for seed yield. From these results it may be concluded that high SCA alone could not be a sole criterion for getting a heterotic hybrid. Similar results have earlier been reported by Swarnkar *et al.* (2002) in Indian mustard. Any sort of combination among the parents could give hybrid vigour which might be due to favourable dominant genes or epistatic action. Above findings were supported by Sood *et al.* (2000) in Indian mustard. Top three crosses *viz.,* GM1 x BIO 902, GM3 x GDM4 and Pusa bold x Kranti exhibited high sca effects for yield plant^{-1} involved at least one good general combiner, indicated additive x dominance type of gene interaction, which could produce desirable transgressive segregants in subsequent generations. Akbar *et al.* (2008), and Singh and Lallu (2004) have reported the involvement of additive x additive, additive x dominance and epistatic type of gene action in expression of yield and other traits in Brassica family. The crosses, where poor x poor and poor x good general combiners produced high sca effects may be attributed due to presence of genetic diversity in the form of heterozygous loci for specific traits.

Based upon the results obtained in the present study, it is summed up that the parents Pusa bold and GM1 were identified as good general combiners for most of the characters and the specific crosses combinations namely GM1 x BIO 902, GM3 x GDM4 and Pusa bold x Kranti should be exploited through heterosis breeding or should be used in recombination programme for tapping desirable transgressive segregants in segregating generations. The intermating between selected segregants in advance generations of segregation would help to accumulate favourable, desirable alleles for further improvement in seed yield and its component characters in Indian mustard.

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EFFECT OF INDUSTRIAL WASTE WATER AND IRRIGATION METHODS ON RESIDUAL CONCENTRATION OF AGRICULTURAL PRODUCE IN KONKAN REGION OF MAHARASHTRA

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ABSTRACT

An investigation entitled 'Effect of industrial waste water and irrigation methods on residual concentration of agriculture produce in Konkan region of Maharashtra' was carried out during the year 2009-10. Most of the waste water of Rasayani industrial area is being discharged in the Patalganga River through different drains. The 10 observation points in the drain contributing to Patalganga river were selected. The nearby field was selected for conducting the experiment on which Spinach crop was grown. The soil samples were analyzed before and after crop period. In the experiment two irrigation sources viz., waste water and well water were used as main treatments. Three irrigation methods viz., check basin, raised bed and ridges and furrow were used as sub-treatments. The biometric observations of the plants irrigated with waste water showed that the growth and yield of spinach crop (181.76 g) was better than that of the well water irrigated plants (143.89 g). The average plant weight was significantly higher in irrigation with industrial waste water (155.85 g) as compared to irrigation with fresh water (132.85 g). The highest average plant weight 162.82 g plant^{-1} was observed in check basin, while the minimum average plant weight of 135.06 g plant^{-1} was observed in ridges and furrows. The effect of irrigation methods was significant. In case of interaction maximum plant weight of 181.76 g was reported in the treatment combination of irrigation with industrial waste water and checks basin method and was significantly superior over all other treatment combinations. The analysis of crop samples in atomic adsorption spectrometer showed that the concentration of micro-nutrients like Cu, Zn, Fe and Mn was in trace amount. Though the effect of waste water on yield was significant, the long term effect of this waste water on soil needs to be studied.

(Key words: Industrial waste water, spinach, residue analysis)

INTRODUCTION

Rapid industrialization, intensive agriculture and other anthropogenic activities have led to land degradation, environmental pollution and decline in crop productivity and sustainability causing great concern to human and animal health. One of the prominent sources contributing to increased soil contamination is disposal of municipal waste water. The city sewage water is being largely used for irrigation in the adjoining areas of the cities for growing vegetable crops. In order to maintain the soils in better fertility as well as productivity for supply of essential plant nutrients for crop production on sustainable basis without deteriorating the soil health, it becomes imperative to make thorough studies on impact of sewage water applied to agriculture lands. The city sewage water contains significant organic matter and macro-micro-nutrients essential for plant growth. However, it may also contain potential contaminants such as heavy metals like Ni, Cd, As, Cr etc. and pathogens and therefore, it must be used cautiously. This is a matter of great concern, because of persistence of metal pollutants in soil, uptake by crops and cumulative effects on health of animals and human beings.

The total wastewater generated by 299 class-I cities is 16,652.5 MLD. Out of this, about 59 per cent generated by 23 metro cities (Patankar, 2001). The state of Maharashtra alone contributes about 23 per cent, while the Ganga river basin contributes about 31 per cent of the total wastewater generated in class-I cities.

Banerjee and Sawant (1996) monitored the heavy metals in industrial and traffic area. The investigation of heavy metals in industrial environment was carried out at two sites viz., Thane and Sion circle and King circle, Mumbai. Roadside deposits, surface soil, grass, leaves and water samples were collected and were analysed for Pb, Zn, Cu, Cr, Ni and As. The samples were collected on seasonal basis. The data showed higher concentration of these metals in water samples. Pb was found to be much above the permissible limit. Summer and winter collections showed maximum concentration of the heavy metals, whereas monsoon collections showed lower concentrations. The data indicated increasing trend in the metal content with the time during the study period in Thane and Sion circle. The results showed that metal content in the Thane and Sion circle area was comparatively higher than that at Kings circle.

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Kulkarni and Tekale (1998) demonstrated the use of waste water for irrigation purpose at field of Water and Land Management Institute (WALMI), Aurangabad (India). The study revealed that the waste water having maximum pH (8.20) and EC (0.45 mmhos cm^{-1}) were found to be safe to use as irrigation water. The yield of sugarcane, groundnut, wheat obtained were 66.37 $t.ha^{-1}$, 17.04 $q.ha^{-1}$ and 24.25 $q.ha^{-1}$, respectively. This water can be categorised as good water (0.45 $mmhos.cm^{-1}$) as suggested by Wilcox (1948). From the study, it was revealed that there was not any adverse effect after the use of waste water on light and medium soil field at WALMI. Also there was increase in the yield especially in case of wheat, maize, pearl millet and groundnut. Raw sewage water was used for the experiment.

Lone *et al.* (2003) observed the increase in heavy metal contents of vegetables irrigated by sewage/ tube well water at Hassanabad area of district Attock in Pakistan. Three adjacent fields were selected for each crop and separately irrigated by sewage water, tube well water and mixture of sewage and tube well water. Okra (*Abelmoschus esculentus*) and spinach (*Spinacea oleracea* L.) were planted in spring and winter, respectively. The heavy metal and micronutrient contents in both vegetables were present in significantly higher amount in order of sewage >sewage and tube well water >tube well water except Cu and Fe which showed variation for both the crops. Spinach leaves showed higher accumulation of heavy metals and micronutrients as compared to okra fruits.

The review indicated that the waste water can be used for irrigating the agricultural crops. This water will not only meet the crop water need but also increase the yield of crop. In the area where water is in scarcity, this water would be a good option to be used as irrigation water source. Hence, the present study was planned with the following objectives,

1. To study the quality parameters of waste water.
2. To assess the effect of waste water as an irrigation source on residual content of agricultural produce.

MATERIALS AND METHODS

Experimental site

The experiment was conducted in the field located in the M.I.D.C. Rasayani, Tal.-Panvel, District, Raigad. The co-ordinates of the locations are 18.89^0 N, 73.15^0 E. At present in the industrial area various industries such as chemical industries and fertilizer industries are present. Most of the waste water from various chemical industries in Rasayani industrial area is received by the perennial drain which is contributed to the Patalganga River.

To study the effect of industrial waste water on crop, the field trial was conducted on the field owned by local farmer Mr. Mali Dharma Kanu, at village Rasayani, Tal.-Panvel, District, Raigad. For the trial 250 sq m field area was used. The strip plot design was used for the study.

To study effect of industrial waste water irrigation on plant, short duration leafy vegetable Spinach (*Spinacia oleracea* L.) was cultivated. In the experiment two irrigation sources viz., waste water (S_1) and fresh water (S_2) were used. Also three irrigation methods viz., check basin method (I_1), raised bed (I_2) and ridges and furrows method (I_3) were used. Before planting in plot, beds were prepared. Dimension of the bed was 2 m x 3 m. There were 7 replications of six combinations of the treatments of irrigation water and irrigation methods.

The seeds of spinach were sown on 05^{th} January, 2010. After sowing the crop was irrigated at the interval of 7 days with both waste water and fresh water. The study of effect of waste water irrigation and fresh water irrigation on soil and crop was done. The well, present in the field was used as a source of fresh water irrigation. The irrigation schedule was done after every 7 days. The recommended fertilizer dose for spinach was 100:50:50 kg N:P:K ha^{-1}. For giving fertilizer, water soluble fertilizer 19:19:19 was used and was applied in two splits, the first at 7 and second at 14 days after sowing. For meeting additional requirement of nitrogen, i.e. 50 kg N ha^{-1}, urea was used. It was applied by broadcasting in equal doses on 21 and 28 days after sowing of crop. The last two broadcasts were of urea. Before harvesting the crop, biometric observations such as height of plant, length of plant leaves, width of leaves and weight of sample plants were taken. Twenty plants $plot^{-1}$ were selected as a sample for the study.

The crop was harvested 45 days after sowing.

Samples of harvested crop were then taken immediately to the laboratory of M/s. Aditya Environmental Services Pvt. Ltd., Rasayani for plant residue analysis, as this facility was not available at the University laboratory. The samples were collected from all 7 replications for each treatment combination. The collected samples were analysed for heavy metals like copper (Cu), manganese (Mn), iron (Fe) and zinc (Zn). The analysis of the samples was done with the help of DTPA method proposed by Tandon (2004).

The chemical analysis of soil samples was done in the laboratory of Department of Agricultural Chemistry and Soil Science, College of Agriculture, Dapoli. The micronutrients were determined with the help of atomic absorption spectrophotometer (AAS). The method of sample preparation was same for all the micronutrients. 1 g oven dried plant samples were digested using diacid mixture and made upto 100 ml using deionized water on cooling. For determining Cu, 1000 ppm solution was prepared by dissolving 1 g of copper metal in minimum volume of 1 ml HNO_3. Then, it was diluted to 1 litre with 1 per cent (v/v) HNO_3. Then 3.929 g $CuSO_4$. $5H_2O$ was dissolved in distilled water and volume was made upto 1000 ml. This gives a solution of 1000 ppm Cu. 10 ml of this solution was diluted to 100 ml to get 100 ppm solution of Cu. For determining the Mn, the similar procedure was used. Then 1 g of Mn metal was dissolved in a minimum volume of 1 ml NHO_3 and diluted to 1 litre with 1 per cent (v/v) HCl. Then dissolve 3.076 g of $MnSO_4$ H_2O in deionized water and make volume upto 1000 ml. This gave a solution of 1000 ppm Mn. Then10 ml of this solution was diluted to 100 ml for getting a solution of 100 ppm Mn. This solution was used for preparation of final standards. For determining the Fe, the procedure for sample preparation was same. For determining the stock standard solution, 1 g of pure iron wire was dissolved in 50 ml of (1+1) analytical grade HNO_3. This was diluted to 1 litre with deionized water. Then 7.022 g of analytical grade $(NH_4)_2$ Fe $(SO_4)_2$ $6H_2O$ was dissolved in 400 ml deionized water. Then 5 ml of con. H_2SO_4 was added to it. This gave a stock solution of 1000 ppm Fe. From this, solution of 100 ppm was prepared which was used for preparation of final standard solutions. For determining Zn, the procedure of sample preparation was same. For stock standard solution, 0.5 g of zinc metal was dissolved in a minimum volume of (1+1) HCl and diluted to 1 litre with 1 per cent (v/v) HCl. Then 4.398 g of $ZnSO_4$ $7H_2O$ was dissolved in distilled water and volume was made upto 1000 ml. This gave a solution of 1000 ppm zinc. 10 ml of this solution was diluted to 100 ml for getting 100 ppm Zn solution. The final standard solution was prepared from this 100 ppm solution.

The determination of Fe, Mn, Zn and Cu was done by using atomic absorption spectrophotometer with the following specifications (Tandon, 2004) for mono element hollow cathode lamp.

Specifications	Fe	Mn	Zn	Cu
Lamp current (mA)	30	20	6	15
wave length (A^0)	2483	2795	2139	3248
Linear range (ppm)	0 to 5	0 to 2	0 to 1	0 to 5
Slit width (A^0)	2	2	7	7
Integration time (sec)	2	2	2	2

For determination of Zn, instead of hollow cathode lamps, electrode less discharge lamp (EDL) was used. EDL provided improved sensitivity and lower detection limits than hollow cathode lamp.

RESULTS AND DISCUSSION

Effect of waste water and irrigation methods on residual concentration of the plant parts'

The effect of irrigation water and irrigation methods on residual concentration of Cu, Zn, Fe and Mn in spinach crop was studied and the results are given hereafter.

Concentration of Cu (ppm)

The analysis of Cu concentration in the residue of plant was done and reported in table 1. It was in the range of 0.028 to 0.061 ppm for interaction between irrigation source and irrigation method. Maximum average concentration of Cu (0.060 ppm) was found in plants irrigated with waste water, while minimum average concentration (0.031 ppm) was reported in fresh water irrigation source. In the irrigation methods viz., check basin, raised bed and ridges and furrows, the average concentration of Cu was in the range of 0.0444 to 0.0468 ppm and its effect was non-significant. The effect of water source showed significant effect on crop residue, while the effect of irrigation methods and their interaction was non-significant.

Concentration of Zn (ppm)

The analysis of Zn concentration in the residue of plant was done and reported in table 2. It was in the range of 0.0016 to 0.0053 ppm for interactions. Maximum average concentration of Zn (0.0045 ppm) was found in plants irrigated with waste water, while minimum average concentration (0.0019 ppm) was reported in fresh water irrigation source. In the irrigation methods viz., check basin, raised bed and ridges and furrows, the average concentration of Zn was in the range of 0.0029 to 0.0034 ppm and its effect was non-significant. The effect of water source showed significant effect on crop residue, while the effect of irrigation methods and their interaction was non-significant.

Concentration of Fe (ppm)

The analysis of Fe concentration in the residue of plant was done and reported in table 3. It was in the range of 0.032 to 0.114 ppm for interactions. Maximum concentration of Fe (0.114 ppm) was found in plant irrigated with waste water, while minimum average concentration (0.042 ppm) was reported in fresh water irrigation source. In the irrigation methods viz., check basin, raised bed and ridges and furrows, the average concentration of Fe was in the range of 0.053 to 0.084 ppm and its effect was non-significant. The effect of water source showed significant effect on crop residue, while the effect of irrigation methods and their interaction was non-significant.

Concentration of Mn (ppm)

The analysis of Mn concentration in the residue of plant was done and reported in table 4. It was in the range of 0.045 to 0.410 ppm for interactions. Maximum concentration of Mn (0.410 ppm) was found in plants irrigated with waste water, while minimum average concentration (0.060 ppm) was reported in fresh water irrigation source. In the irrigation methods viz., check basin, raised bed and ridges and furrows, the average concentration of Mn was in the range of 0.174 to 0.218 ppm and its effect was non-significant. The effect of water source showed significant effect on crop residue, while the effect of irrigation methods and their interaction was non-significant.

Lone *et al.* (2003) observed the increase in heavy metal contents of vegetables irrigated by sewage/ tube well water at Hassanabad area of district Attock in Pakistan. Three adjacent fields were selected for each crop and separately irrigated by sewage water, tube well water and mixture of sewage and tube well water. Okra (*Abelmoschus esculentus*) and spinach (*Spinacea oleracea*) were planted in spring and winter, respectively. The heavy metal and micronutrient contents in both vegetables were present in significantly higher amount in order of sewage >sewage and tube well water >tube well water except Cu and Fe which showed variation for both the crops. Spinach leaves showed higher accumulation of heavy metals and micronutrients as compared to okra fruits. Present findings are more or less similar to their findings as far as micro-nutrients are concerned for spinach crop. Alarcon and Pedrero (2006) observed the higher accumulation of heavy metals in leaf status of lemon trees in Spain due to irrigation with the industrial waste water.

Wang *et al.* (2007) classified the contaminants and treatability evaluation of domestic waste water in China. They conducted long-term sampling and analysis in a domestic waste water treatment plant for the investigation on the characteristics of the representative contaminants in raw sewage such as SS, COD, BOD, TP and TN. All these constituents were classified into dissolved and suspended groups by using a 0.45 micro metre membrane filter and the concentration of each constituent in each group was analyzed. As a result, almost 100 per cent of the SS was found to be suspended matter, as well as about 65 per cent of COD, 60 per cent of BOD, 50 per cent of P and 20 per cent of N were found in suspended matter. All these could be easily removed by sedimentation or coagulation/sedimentation. They proposed a treatability evaluation diagram for a rational selection of waste water treatment process in accordance with raw water quality.

Yeole *et al.* (2012) evaluated pollution potential of irrigation by domestic waste water on fertile soil quality of Manurabad watershed area near Jalgaon urban centre, Maharashtra. Total six samples of soil and four samples of waste water of Lendi nala were analyzed from the study area. The results showed that EC, COD, BOD, SO_4, Cl, NO_3 and Fe and

Cu were observed above the critical limit. The calculated values of sodium adsorption ratio and residual sodium carbonate suggest the long-term use of untreated sewage will lead to some serious pollutional aspects and ultimately to the health of the peoples in the study area. Anthropogenic activities affect the variation of sewage quality. In the present case the industrial waste water was used and hence the impact was different than as reported by them.

Effect of waste water and irrigation methods on yield contributing parameters of the plant parts : The data regarding the effect of irrigation water source and irrigation methods on yield contributing parameters of the spinach crop are presented in table 5 and 6 and results are reported in the following sections :-

Plant height

The observations related to plant height are reported in table 5. It was in the range of 27.43 cm to 39.36 cm for interactions. Maximum average plant height (34.02 cm) was found in plant irrigated with waste water, while minimum average plant height (28.95 cm) was reported in fresh water irrigation source. The effect of water source was significant. In case of irrigation methods viz., check basin, raised bed and ridges and furrows, the average plant height was in the range of 29.36 cm to 35.68 cm. The highest average plant height was observed in check basin (35.68 cm), while the minimum average plant height of 29.36 cm was observed in ridges and furrows. The effect of irrigation methods was significant. This showed the superiority of check basin irrigation method over raised bed and ridges and furrows. However, the interaction effect of irrigation methods and water source was non-significant.

Plant weight

The observations related to plant weight are reported in table 6. It was in the range of 127.26 g $plant^{-1}$ to 181.76 g $plant^{-1}$ for interactions. Maximum average plant weight (155.85 g $plant^{-1}$) was found in plants irrigated with waste water, while minimum average plant weight (132.85 g) was reported in fresh water irrigation source. The effect of water source was significant. In case of irrigation methods viz., check basin, raised bed and ridges and furrows, the average plant weight was in the range of 135.06 g $plant^{-1}$ to 162.82 g $plant^{-1}$. The highest average plant weight of 162.82 g $plant^{-1}$ was observed in check basin, while the minimum average plant weight of 135.06 g $plant^{-1}$ was observed in ridges and furrows. The effect of irrigation methods was significant. This showed the superiority of check basin irrigation method over raised bed and ridges and furrows.

The increased yield in waste water source might be due to increased availability of micro-nutrients. The analysis of soil samples in the waste water source showed the increased availability of N, P, K and micro-nutrients as given in table 7. The N, P, K were increased from 39.2 to 56 kg ha^{-1} (42.86 %), 17.4 to 22.8 kg ha^{-1} (31.03 %) and 15.6 to 21.8 kg ha^{-1} (39.74 %), respectively in the soils irrigated with waste water; while the micro-nutrients like Fe, Mn, Cu and Zn were increased from 0.25 to 0.28 ppm (12 %), 0.035 to 0.04 ppm (14.29 %), 0.05 to 0.08 ppm (60 %) and 0.03 to 0.06 ppm (100 %), respectively in the soils irrigated with waste water over the soils irrigated with fresh water. The other elements like calcium and sodium were also increased from 3.80 to 5.30 meL^{-1} and 0.45 to 0.63 meL^{-1}, indicating that the source might be contaminated by these elements. This effect is in conformity with the findings of Ahmad *et al.* (2006). They studied the effect of sewage water on spinach yield in Pakistan. A total of 70 spinach growers were interviewed. The study showed that the spinach growers using sewage water obtained higher yield, since sewage water contains a large amount of organic nutrients.

In case of irrigation methods, the check basin method gave the maximum plant weight of 181.76 g $plant^{-1}$. This might be due to uniform distribution of irrigation water in this irrigation method. The lower plant weight of 127.26 g $plant^{-1}$ was reported in the irrigation method ridges and furrows.

Table 1. Effect of water source and irrigation method on Cu concentration in Spinach

	S_1	S_2	Mean
I_1	0.061	0.032	0.0468
I_2	0.058	0.033	0.0453
I_3	0.061	0.028	0.0444
Mean	0.060	0.031	
	Water source	Methods	Interaction
SE (±)	0.002	0.003	0.004
CD (5 %)	0.007	-	-

Where, S_1: waste water irrigation source, S_2: fresh water irrigation source,
I_1: check basin method, I_2: raised bed method, I_3: ridges and furrow method

Table 2. Effect of water source and irrigation method on Zn concentration in Spinach (ppm)

	S_1	S_2	Mean
I_1	0.0053	0.0016	0.0034
I_2	0.0039	0.0020	0.0029
I_3	0.0043	0.0021	0.0032
Mean	0.0045	0.0019	
	Water source	Methods	Interaction
SE (±)	3×10^{-4}	3×10^{-4}	5×10^{-4}
CD (5 %)	8×10^{-4}	-	-

Table 3. Effect of water source and irrigation method on Fe concentration in Spinach (ppm)

	S_1	S_2	Mean
I_1	0.109	0.032	0.071
I_2	0.067	0.040	0.053
I_3	0.114	0.053	0.084
Mean	0.097	0.042	
	Water source	Methods	Interaction
SE (±)	0.014	0.017	0.024
CD (5 %)	0.040	-	-

Table 4. Effect of water source and irrigation method on Mn concentration in Spinach (ppm)

	S_1	S_2	Mean
I_1	0.306	0.410	0.174
I_2	0.361	0.045	0.203
I_3	0.341	0.095	0.218
Mean	0.336	0.060	
	Water source	Methods	Interaction
SE (±)	0.019	0.023	0.033
CD (5 %)	0.055	-	-

Table 5. Effect of water source and irrigation method on plant height (cm)

	S_1	S_2	Mean
I_1	39.36	32.00	35.68
I_2	31.43	27.43	29.43
I_3	31.29	27.43	29.36
Mean	34.02	28.95	
	Water source	Methods	Interaction
SE (±)	0.625	0.765	1.082
CD (5 %)	1.805	2.210	-

Table 6. Effect of water source and irrigation method on plant weight (gm)

	S_1	S_2	Mean
I_1	181.76	143.89	162.82
I_2	142.94	127.40	135.17
I_3	142.87	127.26	135.06
Mean	155.85	132.85	
	Water source	**Methods**	**Interaction**
SE (±)	2.603	3.189	4.509
CD (5 %)	7.519	9.209	13.020

Table 7. Chemical properties of soil irrigated with industrial waste water

Sr.No.	Parameters	Soil before irrigation	Soil after irrigation with waste water	Soil after irrigation with fresh water	Unit
1	Total dissolved salts (TDS)	714.88	841.12	721.30	mgL^{-1}
2	Electrical conductivity (EC)	0.30	0.59	0.36	dSm^{-1}
3	Acidity/basicity, pH	7.00	7.25	7.18	--
4	Calcium	3.80	5.30	4.06	meL^{-1}
5	Sodium	0.45	0.63	0.48	meL^{-1}
6	Carbonate	--	--	-	meL^{-1}
7	Bicarbonate	6.50	8.70	6.90	meL^{-1}
8	Fe	0.25	0.28	0.26	ppm
9	Mn	0.035	0.040	0.039	ppm
10	Cu	0.050	0.080	0.060	ppm
11	Zn	0.030	0.060	0.040	ppm
			Major Nutrients		
12	N	39.20	56.00	41.30	$Kg\ ha^{-1}$
13	P	17.40	22.80	17.80	$Kg\ ha^{-1}$
14	K	15.60	21.80	15.90	$Kg\ ha^{-1}$

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STABILITY ANALYSIS OF YIELD AND YIELD COMPONENTS IN SESAME (*Sesamum indicum* L.)

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ABSTRACT

Twenty sesame genotypes including two checks *viz*, JLT-7 and GT-1 were subjected for stability analysis in three environments during *kharif* 2011-2012 at three locations *viz*, Research Farm, Department of Agriculture Botany, College of Agriculture Latur (E_1), Research farm, Safflower Research Station, M.K.V. Parbhani (E_2), and Agriculture Research Station, Badnapur (E_3). Data were generated on various growth and yield attributes. Stability and character association were carried out as per model of Eberhart and Russell (1966). Mean squares for genotypes and linear component of environments were significant for all characters. Genotype x environment (G X E) interactions were highly significant for all the growth and yield characters except capsule length. On the basis of stability analysis genotypes IC-413189, IC-413201, IC-413205 were found stable for early 50% flowering whereas IC-413214, IC-413216 showed stable performance for days to maturity but identified as late genotype. However, the genotype IC-413214 exhibited wider adaptability for number of branches plant^{-1}. Regarding the most important character seed yield plant^{-1} the genotype IC-413223 showed wide adaptability to all environments.

(Key words: Sesame, genotype x environment interaction, adaptability, stability)

INTRODUCTION

Sesame *(Sesamum indicum* L.) known as gingelly, til or beniseed is a most important and ancient oilseed crop. It is rich in oil (53.53%) and protein (26.25%). Sesame oil is noted for its stability and quality. As it is a short day plant and sensitive to photoperiod, temperature and prolonged moisture stress, the yield of sesame is not stable and varies widely (Velu and Shunmugavalli, 2005). A specific difference in environment may have a greater effect on some genotypes than others (Falconer, 1981). When genotypes respond differently to a change in the environment, the phenomenon of Genotype x Environment Interaction (GEI) is said to occur. Information on the adaptation and stability of the genotypes over seasons and over sites is useful for recommending the varieties that should be grown under particular production environments and predicting the yield expectations of the test varieties (genotypes). A variety or genotype is considered to be the most adaptive or stable one if it has a high mean yield but a low degree of fluctuation in yielding ability when grown over diverse environments (Arshad *et al.* 2003). A significant portion of the resources of crop breeding is devoted determining GEI through replicated multilocation trial. Hence, present investigation was taken up utilizing 20 genotypes to study the nature and magnitude of genotype x environment interaction of seed yield of sesame genotypes grown at different locations and to identify stable genotypes that can give high seed yield under a wide range of growing conditions.

MATERIALS AND METHODS

The experimental material consisted 18 genotypes along with two checks *viz.,* JLT-7 and GT-1 which were evaluated at three locations *viz.,* Department of Agriculture Botany, College of Agriculture Latur (E1), Research farm Safflower Research Station, Marathwada Krishi Vidyapeeth. Parbhani (E2) and Agriculture Research Station, Badnapur (E3) during *kharif* 2011-2012 under rainfed condition. These locations were situated within the altitudinal ranges of 409 to 633.8 m and have soil characteristics of Heavy black, Medium to heavy black and Medium black (Table 1).

The experiment was laid out in a randomized block design with three replications in each environment. The unit plot size in a replication measured 4 m in length and 1.5 m in width accommodating 5 rows of 200 plants genotype^{-1} after thinning keeping row distance to 0.3 m and plant to plant distance 0.1 m. Normal cultural practices were followed. The observations were recorded on five randomly selected plants for days to 50 per cent flowering, number of branches plant^{-1}, plant height at maturity (cm), number of capsules plant^{-1}, number of seeds capsule^{-1}, length of capsule (cm), days to maturity, 1000- seed weight (gm), oil content (%) and

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seed yield plant^{-1} (gm) and were analyzed for stability parameters by using Eberhart and Russell model (1966). Oil content was estimated by using NMR (Nuclear Magnetic Resonance) spectrometer.

RESULTS AND DISCUSSION

Analysis of variance for ten characters over three environments

The analysis of variances for ten traits in each environment revealed that the mean square due to genotypes were highly significant for all characters in all environment indicating the existence of sufficient variability among the genotypes. Pooled analysis of variances for ten characters over three environments revealed that the mean square due to genotype was significant for all characters and in case of environment were highly significant for all characters except capsule length (Table 1). Muhammad *et al.* (2013) reported that pooled analysis of variance revealed highly significant difference among the genotype for branches plant^{-1}, capsules plant^{-1} and seed yield. This suggest that the effect of the environment on the expression of the genotype was much pronounced on this character, on the other hand influence of environment was the least on capsule length, this suggest that the least influence characters could be improved to the extent expected on the basis of individual environment. Variance due to G X E interaction were highly significant for all the characters except capsule length indicating the differential response of genotype in expression of the character to varying environments, the existence of G X E interaction for days to 50% flowering, days to maturity, plant height, number of branches plant^{-1}, number of capsules plant^{-1}, number of seeds capsule^{-1} and oil content. Velu and Shunmugavalli (2005) and Kumar *et al.* (2006) estimated that the variance under different environments brought out the differential response of characters to varied environmental effects. The phenotypic and genotypic variances were comparatively high for number of capsules, plant height and number of seeds capsule^{-1}, indicating wide range of variability in these characters. Significant genotype x environment interaction effects were observed for all characters except for capsule length.

The data regarding analysis of variance for stability parameters are presented in table 2, which revealed that the variances due to environment + (Genotype x Environment) interaction were highly significant for days to maturity, number of branches plant^{-1}, 1000 seed weight, plant height, number of capsules plant^{-1} and oil content indicating that the genotype interacted significantly with environments. Further the environment (linear) was highly significant for all characters indicating the presence of linear variation among genotypes. Krishnaswami and Appadurai (1985) also reported significant environment (linear) for plant height, number of capsules plant^{-1}, number of branches plant^{-1}. Considering the stability performance of genotypes for different characters across the environments, it was observed that the variance due to non linear component of environment (pooled deviation) was significant for all the characters under study except days to 50% flowering, capsule length, number of seeds capsule^{-1} and seed yield plant^{-1} indicating the role of unpredictable portion of environment influencing this trait. Kumaresan and Nadarajan (2005) also reported similar results of unpredictable portion of environment for characters days to maturity, plant height, number of capsules plant^{-1}, oil content, number of branches plant^{-1} and 1000 seed weight. The high magnitude of environment (linear) effect in comparison to genotype x environments (linear) for all characters were observed which may be responsible for adaptation in relation to yield and yield contributing components of sesame.

Stability parameters

Estimates of regression coefficients and the deviation from regression (Table 3) showed a wide range of values for each character. The phenotypic stability of the genotype was measured by three parameters namely, mean performance over the environments, linear regression and deviations from regression function. A stable genotype should have high mean performance, unit linear regression (bi) and deviation from regression (S^2di) as small as possible (Eberhart and Russell, 1966).

In the present investigation genotypes IC-413189, IC-413201 and IC-413205 identified as early genotypes for 50% flowering, while IC-413216 as late stable genotype as they possessed (bi) near to unity and non significant (S^2di). In respect to days to maturity IC-413216 and IC-413214 were stable genotypes, while the genotype IC-413238 was stable genotype for days to maturity but identified as late genotype. Cherinet and Tadesse (2014) indicated that genotype by environment interaction was statistically significant for days to maturity and showed stable genotype in linseed. The genotypes IC-413240, IC-413253 had high mean and regression coefficient higher than unity (bi>1) means above average indicated its suitability for better environment. The genotypes IC-413187, IC-413189, IC-413201, IC-413205, IC-413221 and IC-413238 had regression coefficient more than unity (bi>1) with significant deviation from regression coefficient (S^2di) indicates unstable over environment. For number of branches plant^{-1} the genotype IC-413214 showed wider adaptability as they possessed high mean and regression coefficient near to unity. Diana *et al.* (2013) had also reported two stable genotypes in mustard for number of primary branches. The genotypes IC-413189 and IC-413221 indicated adaptabilities to better environments and genotypes IC-413193, IC-413204, IC-413231, IC-413248 adapted to poor environment.

In respect to number of capsules plant^{-1} the genotypes indicating IC-413223 and IC-413238 had regression coefficient near to unity indicates wider adaptability over all environments. Kumaresan and Nadarajan (2010) evaluated high mean and low interaction effects that are generally adaptable to all environments for number of capsules. While genotypes IC-413216, IC-413231, IC-413240, IC-413253 and JLT-7(C) had low mean with regression coefficient less than unity (bi<1) revealed that it's adaptability specially to poor environments. Muhammad *et al.* (2013) reported that the two varieties (V-90005 and PARS-1) had regression coefficients with negative sign and below average response, hence suitable for poor environment conditions and were stable in sesame. The genotype IC-413223 had high mean with regression coefficient (bi) near to unity indicates wider adaptability for number of seeds capsule^{-1}. Cherinet and Tadesse (2014) reported that genotype x environment interaction was significant for number of seeds capsule^{-1} in linseed. While genotypes IC-413187, IC 413189, IC 413190, IC413193, IC-413216, IC-413221, IC-413231, IC-413238 and IC-413240 had significant regression coefficient from deviation indicating unstable performance and eight genotypes for this characters specially adapted to poor environment. For 1000 seed weight, the genotypes IC-413231 and IC-413223 had unit regression coefficient (bi) with non significant deviation from regression coefficient (S^2di) and higher mean performance indicates suitable over all environmental conditions and hence considered as stable genotypes, while the genotypes IC-413190, IC-413114, IC-413216, IC-413221, IC-413229, IC-413253 and GT-1 had high mean and below average stability indicates and were recommended for poor environment.

The genotypes IC-413205 and IC-413221 had high mean with below average stability (bi<1) with non significant deviation from regression coefficient (S^2di) showed their adaptabilities to poor environment, while the genotypes IC-413190, IC-413197, IC-413201, IC-413114, IC-413216, IC-413231, IC-413238, IC-413248, JLT-7 and GT-1 were observed with significant S^2di. Zenebe and Hussien (2009) showed the high-yielding genotypes Tatte, Mehado-80 and E were unstable and specifically adapted in sesame. Regarding seed yield plant^{-1} the genotype IC-413223 showed wide adaptability to all environments. Suvarna *et al.* (2011) reported significant differences for seed yield and identified different promising genotypes in sesame. The nine genotypes IC-413189, IC-413190, IC-413193, IC-413214, IC-413216, IC-413223, IC-413229 and IC-413231 had low mean with non significant S^2di showed considerable degree of stability to poor environment. Such type of low mean with non significant regression coefficient results were also observed by Anuradha and Reddy (2005), Kumar *et al.* (2006), Kumaresan and Nadarajan (2005), Raghuwanshi *et al.* (2003) and Muhammad *et al.* (2013).

On the basis of mean performance and stability analysis the genotype IC 413223 found for high seed yield and showed wider adaptability and the genotypes IC-413189, IC-413190, IC-413193, IC-413214, IC-413216, IC-413221, IC-413229 and IC-413231 were found specially to adapted to poor environments.

Table 1. Description of the experimental locations and their overall agro-climatic conditions

Sr. No.	Particulars	Environments		
1.	Location	Department of Agricultural Botany, MAU, Parbhani	Oilseed Research Station, Latur	Agriculture Research Station, Badnapur
2.	Latitude	19^o 16'^{N}	18^o 24'^{N}	19^o 50'^{N}
3.	Longitude	67^o 47'E	76^o 36' E	47^o 53' E
4.	Altitude	409.0 m	633.8 m	519.6 m
5.	Soil type	Heavy black	Medium to heavy black	Medium black
6.	Climatic zone	Assured rainfall zone (865.3 mm)	Moderate to assured rainfall zone (652.4 mm)	Assured rainfall zone (585.3mm)
7.	Temperature (^{o}C) Min. Max.	 08.5 35.0	 11.0 38.3	 07.5 39.5
8.	Humidity (%) Min. Max.	 50 100	 15 91	 12 100

Table 2. Pooled analysis of variance for ten characters over environments

Source of variation	Df	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of branches $Plant^{-1}$	No. of capsules $plant^{-1}$	Capsule length (cm)	No. of seeds $capsule^{-1}$	1000 seeds weight (g)	Oil content	Seed yield $plant^{-1}$(g)
Genotype	19	13.272**	14.969**	553.20**	1.1011**	251.53**	0.2812**	226.63**	0.5594**	27.283**	19.698**
Environment	02	0.7565*	2.9522**	24.897**	0.3703*	7.936**	0.0129	2.5267**	0.0824**	4.0655**	0.2698**
Geno. x Env.	38	1.7722**	0.2026**	2.3657**	0.2540*	0.5630**	0.0045	0.7688**	0.2991*	1.694**	0.1613**
Pooled error	114	0.1777	0.1611	0.5037	0.0400	0.1611	0.0403	0.1594	0.0400	0.1648	0.0400

*, ** = Significant at 5% and 1% level respectively

Table 3. Analysis of variance for stability parameters of sesame over three environments

Source of variation	Df	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of branches $plant^{-1}$	No. of capsule $plant^{-1}$	Capsule length (cm)	No. of seeds $capsule^{-1}$	1000 seeds weight (g)	Oil Content	Seed yield $plant^{-1}$(g)
Genotype	19	13.272**	14.969**	553.20**	1.1011**	251.53**	0.2812**	226.63**	0.5594**	27.283**	19.698**
Env.+ (Geno. x Env.)	40	0.3000	0.6709**	5.6682**	0.0784**	2.0467**	0.0055	0.9776	0.2870**	3.7966**	0.0694
Env. (linear)	1	1.5130**	5.9045**	49.795**	0.7406**	15.872**	0.0258**	5.0535**	0.1649**	8.1310**	0.5397**
Geno. x Env. (linear)	19	0.2361	0.3955*	3.3457**	0.0436	1.3190*	0.0044	0.7631	0.2016**	3.5685**	0.0447
Pooled deviation	20	0.2945	0.5884**	4.3257*	0.6170**	2.0750**	0.0043	0.7573	0.341**	5.4456**	0.0280
Pooled error	114	0.1777	0.1611	0.5037	0.0400	0.1611	0.0403	0.1594	0.0400	0.1648	0.0400

*, ** = Significant at 5% and 1% level respectively

Table 4. Estimates of stability parameters of sesame over three environments

Sr. No.	Genotypes	Days to 50% flowering			Days to maturity			Plant height (cm)			Number of branches plant^{-1}			Number of capsules plant^{-1}		
		Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di
1	**IC-413187**	38.66	-0.89	0.48**	84.88	-0.87	0.75**	111.73	2.57*	10.45**	3.66	1.97*	0.03*	53.26	0.17	0.54**
2	**IC-413189**	38.33	0.86	-0.03	84.61	0.09	-0.12	116.35	1.95	14.63**	4.26	1.49	0.00	54.10	-0.34	0.50**
3	**IC-413190**	39.33	0.86	-0.03	84.67	0.07	-0.06	111.03	-0.41	-0.41	3.96	0.60	0.01	55.77	-0.46	0.32**
4	**IC-413193**	37.66	-1.00	-0.17	83.53	-1.15	0.05	106.93	-0.97	-0.50	3.90	-1.42	-0.03	59.40	-0.42	-0.06
5	**IC-413197**	38.33	-1.00	-0.17	84.30	-0.16	-0.01	113.20	-0.76	-0.16	4.43	-0.22	-0.03	65.93	1.27	0.65**
6	**IC-413201**	37.33	0.86	-0.03	82.51	-0.20	-0.14	109.93	0.16	1.80**	4.30	-0.52	-0.03	54.06	4.32**	1.27**
7	**IC-413204**	38.00	-1.00	-0.17	83.20	-0.59	-0.12	99.40	-0.00	-0.03	3.36	-0.34	-0.03	48.86	-0.60	0.27**
8	**IC-413205**	38.66	0.75	0.02	85.01	0.24	-0.13	114.40	0.77	3.18**	4.50	-0.52	-0.02	54.26	0.03	0.58**
9	**IC-413214**	40.66	2.62*	-0.17	85.53	0.41	-0.03	107.93	-0.46	0.33	4.20	0.73	-0.03	40.60	0.23	-0.15
10	**IC-413216**	42.00	0.75	0.02	86.17	0.33	-0.01	108.06	-0.38	4.39**	4.46	-0.34	-0.00	41.60	-0.07	-0.02
11	**IC-413221**	38.00	-1.00	-0.17	83.54	-1.06	1.01**	112.00	0.73	0.79**	3.46	1.80*	-0.02	50.10	-0.00	0.26**
12	**IC-413223**	39.00	-1.00	-0.17	84.44	-0.12	-0.14	111.26	-0.33	-0.47	4.14	-1.08	-0.01	51.53	0.44	-0.15
13	**IC-413229**	39.00	-1.00	-0.17	84.68	-0.33	-0.07	109.59	-0.45	-0.45	4.93	0.14	-0.03	52.40	-0.90	-0.15
14	**IC-413231**	38.66	-1.00	-0.17**	84.04	-0.87	-0.16	109.23	-0.06	-0.49	3.40	-0.21	-0.01**	38.20	-0.99	-0.14
15	**IC-413238**	46.33	2.62*	-0.16	91.50	0.87	-0.07	127.66	0.53	2.30**	5.52	0.43	0.05	54.23	0.40	1.27
16	**IC-413240**	40.66	2.73*	0.37**	86.53	1.59	-0.14	112.63	-0.03	-0.48	4.20	-0.52	-0.00	42.26	-0.48	-0.13
17	**IC-413248**	39.33	-1.11	0.48**	89.73	3.01**	-0.04	98.51	-0.75	-0.44	3.30	-0.57	-0.03	37.56	0.14	1.97**
18	**IC-413253**	40.33	-1.11	0.48**	85.54	1.10	0.14**	90.33	-0.34	-0.21	4.56	-0.40	-0.33	39.13	-0.08	0.31
19	**JLT-7(C)**	42.66	-1.00	-0.17	87.83	-0.61	-0.16	100.53	-0.89	-0.07	3.56	-0.45	-0.01	33.70	-0.84	-0.11
20	**GT-1(C)**	39.33	-1.00	-0.17	83.30	-0.18	0.11	59.20	-0.86	0.28	2.80	-0.52	-0.03	32.26	-0.61	0.41**
	Mean	39.61			85.27			106.24			4.03			47.96		

*, ** = Significant at 5% and 1% level respectively

Table 4. Contd..

Sr. No.	Genotype	Number of seeds capsule^{-1}			1000 Seed weight (g)			Oil content (%)			Seed yield plant^{-1} (g)		
		Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di
1	IC-413187	57.82	2.39	5.53**	2.61	2.02	0.02*	49.50	-0.60	-0.15	8.44	1.10	0.06**
2	IC-413189	54.16	-0.24	0.16*	2.89	-0.16	-0.03	49.66	-0.63	0.02	8.41	0.32	0.00
3	IC-413190	53.00	-0.56	0.48**	3.16	-0.73	-0.03	49.52	-1.39	0.21**	8.19	-0.20	-0.01
4	IC-413193	52.90	-1.48	2.68**	2.50	-0.09	-0.03	52.08	-0.17	1.19**	7.80	-1.19	-0.02
5	IC-413197	52.33	-0.69	-0.15	2.63	-0.36	-0.04	48.96	-0.39	0.28**	9.60	0.59	-0.03
6	IC-413201	53.63	3.50*	-0.01	2.60	-0.09	-0.03	51.46	-0.78	0.32**	9.13	0.52	-0.03
7	IC-413204	46.76	-0.15	-0.11	2.46	-0.63	-0.03	49.60	-1.60	0.07	6.40	1.01	-0.04
8	IC-413205	62.90	-0.14	0.02	3.83	3.52**	-0.03	52.88	-0.46	0.10	13.53	0.13	0.01
9	IC-413214	42.88	-0.71	-0.04	3.30	-0.00	-0.03	47.97	-0.01	0.66**	6.14	-0.53	-0.03
10	IC-413216	48.23	-0.28	0.12*	3.62	-0.71	-0.04	49.57	0.36	0.54**	7.40	-0.19	0.00
11	IC-413221	50.63	-0.88	0.12*	3.10	-0.00	-0.03	50.42	-0.31	-0.15	7.71	-0.84	-0.02
12	IC-413223	66.20	1.05	-0.07	3.33	3.52**	-0.03	48.95	-2.22	-0.15	10.36	1.06	-0.03
13	IC-413229	51.37	-1.69	0.40**	3.70	-0.09	-0.03	45.68	-1.54	-0.16	8.50	0.19	-0.03
14	IC-413231	59.20	0.19	0.62**	2.83	0.63	-0.03	54.17	-0.47	1.31**	6.06	-0.14	-0.03
15	IC-413238	71.43	0.81	1.14**	2.46	-0.73	-0.03	43.62	-1.80	1.07**	15.03	-0.07	-0.04
16	IC-413240	70.26	0.51	0.68**	3.33	-1.27	-0.03	49.80	-0.69	-0.10	13.36	-0.14	-0.03
17	IC-413248	68.85	-0.05	0.06	2.76	-0.73	-0.03	49.50	-1.17	0.07	9.16	-0.33	-0.03
18	IC-413253	71.43	-0.69	-0.15	3.53	-1.27	-0.03	50.30	-0.63	1.29**	11.73	-0.26	-0.02
19	JLT-7(C)	63.56	-0.14	0.02	2.96	-1.54	-0.01	52.38	-1.13	0.18**	12.26	-0.15	0.16**
20	GT-1(C)	60.52	-0.70	-0.11	3.13	-1.27	-0.03	54.12	0.00	0.25**	10.56	-1.36	0.55**
	Mean	57.92			3.04			50.29			9.49		

*, ** = Significant at 5% and 1% level respectively

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PATHOGENIC, MORPHOLOGICAL, BIOCHEMICAL VARIATIONS IN THE ISOLATES OF *Colletitrichum truncatum*

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ABSTRACT

Colletotrichum **causes many important diseases like leaf blight, anthracnose, pod blight, dieback and fruit rot etc. The disease samples having typical characteristics of symptoms were collected from soybean [(*Glycine max* L.(Merill)] from different locations in the Maharashtra state. After the isolation the isolates were categorized and grouped according to their pathogenic ability. Morphological study was undertaken. Among six isolates of *C. truncatum* Ct_1, Ct_7 and Ct_8 formed the sclerotia. Micrometrical observations also revealed large variations in dimension of conidia, acervuli and setae. Isolate Ct_4 recorded 19.11 mm radial mycelia growth on 3rd day while on 9th day it was 63.80 mm whereas the maximum growth 76.46 mm was achieved by Ct_1. Six highly pathogenic isolates were selected for the study viz., Ct_1, Ct_2, Ct_4, Ct_5, Ct_6 and Ct_7. The above highly pathogenic isolates were used for the estimation of proteins and isozyme banding pattern on electrophoresis. Electrophoretic analysis of protein and isozymes i.e. peroxide and esterase were carried out for assessing the biochemical variation. Electrophoretic pattern of peroxidase, esterase and protein have been used to estimate the polymorphism in different fungal populations or species. Cluster analysis of protein banding pattern showed four major cluster. The first includes Ct_1 which is distinct from other isolates. Second cluster includes Ct_2, third cluster comprised with Ct_4 and fourth includes Ct_7 and Ct_6. Isolate Ct_6 and Ct_7 showed close similarity. Therefore, studies were undertaken at Department of Plant Pathology Dr. PDKV., Akola inthe year 2008 to know the biochemical variation among the selected isolates of *Colletotrichum truncatum* in the form of appearance of isozyme and protein banding pattern on polyacrylamide gel. Isolate Ct_6 and Ct_7 showed similarity coefficient range as tested by un weighted pair group arithmetic mean average method (UPMGA). Thus, it is inferred from the present investigation that the presence or absence of a specific band could not correlate with the pathogenic ability of the either pathogen. Therefore, all the biochemical markers studied were marginally polymorphic and monomorphic in nature.**

(Key words : *C. truncatum*, protein, isozymes, PAGE)

INTRODUCTION

Colletotrichum is an economically important genus of the fungi belongs to family Melanconiaceae, order Melanconiales, class Coelomycetes and sub division Deuteromycotina. *Colletotrichum gloeosporioides*, *C. truncatum*, *C. capsici*, *C. graminicola*, *C. lindemuthianum*, *C. dematium* and *C. falcatum*, are the common species responsible for causing economically important diseases in cereals, cucurbits, legumes, forage crops, fruits and vegetables.

Several crops are susceptible to this genus causing the diseases in Vidarbha region of Maharashtra. In India more than hundred species have been reported (Ramkrishnan and Subramanian, 1952). Isozyme electrophoresis has been used to discriminate between similar species such as *C. fragariae* and *C. gloeosporioides.* Bonde *et al.*, (1993) suggested that the isozymes with amino acid composition of different net charge or those have large variations in shape of enzyme, can be differentiated by electrophoresis. Electrophoretic analysis of proteins and isoenzymes can be used as an identifying tool for morphological and pathogenic variability of different isolates of *Colletotrichum* spp.

MATERIALS AND METHODS

The disease samples of leaves, pods, fruits, seed, bolls, stem having typical characteristics symptoms of *Colletotrichum* were collected from soybean (*Glycine max*) fields in the districts of Akola, Nasik, Amravati, Washim, Mangrulpir, Bhaurad, Achalpur and Buldhana. *Colletotrichum truncatum* and *Colletotrichum gloeosporioides* isolates (Table 1) were obtained on PDA from infected sample of *Glycine max* in the year 2008 . The isolated fungi were identified on the basis of colony character, conidial size, shape, perithecia, appresoria and acervuli formation (Mordue, 1971, Potdukhe,1991, Thind and Jhooty, 1990). These isolates were further purified by single spore isolation method and maintained on PDA. Pathogenicity was proved as per Koch's Postulate (Agrios, 2005).Observations were recorded (Table 2) on initiation of symptoms (hr), per cent disease intensity, spot size (mm) and categorized into various groups (Table 6) such as highly pathogenic (HP), strongly pathogenic (SP), moderately pathogenic (MP), weakly pathogenic (WP) and non pathogenic (NP). Morphological

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characters (Table 3) of 10 isolates pertaining to colony growth, conidia characters, setae and acervuli of different *Colletotrichum* spp. were studied on PDA (Table 3). Ten isolates of *Colletotrichum* belongs to soybean crop of which nine isolates of *Colletotrichum truncatum* and one isolate of *C. gloeosporioides*. Radial mycelial growth of the fungus was recorded on third, fifth, seventh and ninth day respectively. The colony diameter was measured in (mm) in two marked directions at right angles to each other, passing through the centre of colony.

Dimension of conidia, setae and acervuli were measured by using ocular micrometer. The observations were based on hundred conidia/setae/acervuli and the mean size were worked out under Olympus 91885 research microscope. Six isolates from *C. truncatum* species were selected on the basis of aggressiveness for further studies. The pathogenic isolates were grouped and categorized on aggressiveness of the pathogen. Proteins and isozyme markers are the constituents for determination of biochemical variation and pathogenic ability of fungal isolate. These molecular markers are comparatively more stable and reliable than that of conventional methods. Therefore, SDS-PAGE method has been used to estimate the protein and isozyme pattern of different selected isolates of *Colletotrichum truncatum* in the form of appearance of isozyme and protein banding pattern on polyacrylamide gel. Electrophoresis of protein and isozyme in polyacrylamide gel was carried out in buffer gel (native PAGE) in vertical gel electrophoresis using the procedure given by Sadasivam and Manickam (1996).

RESULTS AND DISCUSSION

The characteristic symptoms under field condition most often observed on soybean leaves, stems, pods and petioles in the form of irregular shaped brown areas (Table 2). In advance stages infected tissues were covered with black fruiting bodies (acervuli). Several spots coalesce and blighting of leaves appeared, on pods and pedicel, dark brown lesions consisting of acervuli and setae were also observed. Under artificial conditions, circular brown spots with dark brown margin all over the leaf area was observed. *C. truncatum* was isolated from soybean seed (Lambat *et al*., 1969), Girard (1979) observed that *C. dematium* var. *truncatum* was responsible for pod blight of soybean and studied its pathogenicity. Koch *et al*. (1989), Gaikwad *et al*. (1993) and Bhale *et al*. (1999) observed the symptoms of anthracnose in soybean. Similar work was conducted by Rathaiah and Sharma (2004) on leaf spot disease on mungbean caused by *Colletotrichum truncatum* forming blood red spots of 8-11 mm diameter on the upper surface of leaves. Sharma and Kaushal (2001) categorised eleven infected leaf sample of urdbean on the basis of colony characters found by the isolates. Among 10 Colletotrichum spp. nine isolates belongs to *C. truncatum* and one *C. gloeosporioides*. Similar studies were carried by Lambat *et al*. (1969) who isolated *C. truncatum* from soybean seed.

It is revealed from the observations (Table 2) that there were differences on initiation of symptom (DAI) ranging from 4 – 8 days depending on *Colletotrichum* species and hosts. Ten *Colletotrichum* isolates were inoculated on leaves of soybean to study the pathogenicity. It was observed from the data that Ct_5, Ct_6 and Ct_7 isolates developed the symptoms within 4-5 days recording 72.00 to 74.00 per cent disease intensity having spot size in the range of 3-4 to 4-5 mm. These isolates produced typical symptoms on leaves with brown margin at centre of spots and categorized as highly pathogenic isolates. Similarly Ct_1 and Ct_2 isolates initiated the symptoms from 4 to 5 days after inoculation with disease intensity ranged between 70.10 to 72.00 per cent with a characteristics margins on developed spots and also grouped under highly pathogenic (HP) group. Rest of the isolates were less efficient as compared to other isolates. The categorization of different isolates was made on the basis of literature of Beynon *et al*. (1995) in coffee berry disease caused by *C. kahawae*. Based on the above category further investigation were undertaken. Palarpawar and Ghurde (1994) categorized the isolates of *C. truncatum* into two categories as a aggressive and less aggressive.

C. truncatum isolates exhibited variations (Table 3) among the same species collected from different geographical areas in the form of colony colour with circular growth, sickle shaped conidia and acervuli formation. Isolates Ct_1, Ct_2, Ct_4, Ct_6 and

Ct_7 exhibited thick black colony colour with grey mycelium, circular growth forming concentric rings, with sickle shaped conidia. Acervuli were prominent and bigger in size, whereas isolate Ct_5 exhibited dark brown to black with a felt of grey mycelium. Acervuli were minute in size (Ct_6) as compared to other Ct isolates. Conidia falcate, apices obtuse and globulate at the centre, conidial mass was honey coloured and the sclerotia formed in abundance. Acervuli were sparse at the margin and aggregated in the centre forming concentric rings were observed in isolate Ct_1 and Ct_4. These cultural characteristics on morphology and the differences in micrometry i.e. dimension of conidia, setae and acervuli revealed the variability. These variations coincides with the reports of Sharma and Kausal (2001) in *Vigna mungo* and McGhee (1992) in soybean. The isolates of *C. gloeosporioides* (Cg_1) showed grayish white to dark grey coloured colonies with abundant grayish mycelium. Conidia were hyaline oblong, one celled with the presence of conspicuous oil globule at the centre. Sirsat (1970) observed similar colony character and conidial morphology of *C. gloeosporioides* of papaya isolate.

Colletotrichum truncatum (Ct_4) recorded 19.11 mm radial mycelial growth (Table 4) on 3^{rd} day while on 9^{th} day it was 63.80 mm whereas, the maximum growth i.e. 76.46 mm was achieved by Ct_1. The radial mycelial growth of colonies in all the isolate indicated the variation as they showed the ability to utilize the nutrient at different proportion through their metabolic activities. Maximum growth was attained by Cg_2 (84.86 mm) while minimum was recorded by Ct_7 isolate (54.90 mm). Thus, the rate and magnitude of growth on PDA clearly establish the facts that all the isolate differed from each other. This may be because of differences in their abilities to utilize nutrient present in medium. Akhtar Jameel and Singh (2007) reported the differences in radial mycelial growth on PDA of *C. capsici*.

Micrometrical observations (Table 5) revealed the differences among the isolates of *Colletotrichum* spp. causing diseases to different hosts. However, *C. truncatum* conidial length and breadth ranges between 23.39–27.31 x 3.74 - 5.03 µm while Ct_1 had 27.31 x 4.57 µm. The measurement of acervuli was ranged from 75.27 – 292.96 x 74.61 – 239.11µm length and breadth. The dimension of setae was measured in the range of 59.77 – 170 x 3.80 – 7.15 µm and 94.6 x 5.43 µm in Ct_6. It clearly indicates the variation in size among these isolates collected from different geographical areas. Potdukhe (1991) studied the size of acervuli, setae and conidia. Maximum conidial size was measured in isolate Ct_3 i.e. 28.60 x 4.97 µm whereas minimum in Cg_5 8.29 x 3.86 µm. However, variable size in acervuli was also noticed with maximum in Cg (292.96 x 239.11 µm) while minimum in Cg_4 (60.80 x 61.99 µm). The micrometrical data of present study coincides with the reports published by Sirsat (1970) in *C. gloeosporioides* recording variation in size, shape and mean size of conidia ranging between 14.83 x 5.42µ, Mordue (1971) in *C. dematium* with16 to 30 x 2.5 to 4.0 µ in size of conidia, Sharma and Kausal (2001) in *C. truncatum* and Dhambhare (1981) in *C. gloeosporioides* with 8-10 to 10-12 µ conidial size and Potdukhe (1991) reported the variation in size of conidia in *C. gloeosporioides* and *C. capsici.* The results of the present investigation showed the existence of the variability among all the isolates in relation to dimension to conidia, setae and acervuli and significant variation in conidial dimension of different *C. casici* isolates was reported by Akhtar Jameel and Singh (2007).

The pathogenicity of *Colletotrichum* spp. was tested on various respective host from which they were originally isolated. Only *C. truncatum* and *C. capsici* were categorized on the basis of aggressiveness as highly pathogenic, weakly pathogenic, moderately pathogenic and non pathogenic (Table 6). The categorization of different isolates was made on the basis of literature of Beynon *et al*. (1995) in coffee berry disease caused by *C. kahawae*. Based on the above category further investigation were undertaken. Palarpawar and Ghurde (1994) categorized the isolates of *C. truncatum* into two categories as a aggressive and less aggressive. Zuiefield *et al*. (1977) classified 18 isolates of *Fusarium oxysporium* f.sp. *narcissi* based on their pathogenic behaviour as virulent, avirulent and low virulent. Giri (2002) classified four groups of *Fusarium udum* as highly pathogenic, weakly pathogenic, moderately pathogenic and strongly pathogenic. Choi *et al*. (2011) also studied the pathogenicity of *C. panacicola* causing anthracnose of korcan ginseng. Girard (1979) observed that *C. dematium* var. *truncatum* was responsible for pod blight of soybean and studied its pathogenicity.

Gaikwad *et al*. (1993) and Bhale *et al*. (1999) observed the symptoms of anthracnose in soybean. Similar work was also conducted by Rathaiah and Sharma (2004) on leaf spot disease on mungbean caused by *Colletotrichum truncatum* forming blood red spots of 8-11 mm diameter on the upper surface of leaves. Sharma and Kaushal (2001) categorised eleven infected leaf samples of urdbean on the basis of colony characters found in the isolates. Rojas *et al.* (2010) studied pathogenecity of *C. gloeosporioides* in bromacacao.

Electrophoretic banding pattern of proteins from different *Colletotrichum truncatum* of soybean contained 17 protein bands of different molecular weight with Rm value ranging from 0.08 to 0.77. Isolate Ct_7 exhibited only Pt_4 band, whereas Ct_5 exhibited only Pt_6 band (Rm value 0.21). The presence and absence of protein band in all the isolates showed the variation among the six isolates of *C. truncatum*.

Data presented in table7, plate 1 and fig. 1 on electrophoretic banding pattern of proteins from different *Colletotrichum truncatum* of soybean contained 17 protein bands of different molecular weight with Rm value ranging from 0.08 to 0.77. Isolate Ct_7 exhibited only Pt_4 band, whereas Ct_5 exhibited only Pt_6 band (Rm value 0.21). The presence and absence of protein band in all the isolates showed the variation among the six isolates of *C. truncatum*.

With regard to peroxidase and esterase showed (Table 8, plate 2 and fig. 2) above similarity and all the isolates of *Colletotrichum truncatum* were grouped closely and exhibited the very short similarity coefficient range on the basis of peroxidase and esterase. Banding pattern of peroxidase in isolate Ct_1 and Ct_4 exhibited five isozyme bands, whereas Ct_2 exhibited 4 bands, while Ct_5 and Ct_6 showed only two bands in *Colletotrichum truncatum*.

The isozyme pattern of esterase are shown in table 9 plate 3 and fig. 3. Six esterase isozyme bands were observed in isolate Ct_1, Ct_2, Ct_4 and Ct_5 ranging the Rm value from 0.09 to 0.44 whereas isolate Ct_6 exhibited five bands of esterase isozyme and absence of E_6 of 0.44 Rm value. Isolate Ct_7 liberated only three esterase bands with an absence E_3, E_5 and E_6 bands. This indicates the variation though isolate belongs to same species, but exhibiting the biochemical variations. There is no existence correlation with the bands and pathogenic ability of isolates. Significant variation was observed among the six isolates with respect to protein and esterase pattern. Variations in banding pattern of isozymes were observed in *Colletotrichum truncatum*. Similar observations were recorded by Zuber and Manibhushanrao (1982) who reported marked variation in five isolates of *R. solani* and observed no correlation in enzyme pattern and virulence of the isolates. No correlation was obtained with the enzyme pattern and virulence of the isolates. The data in respect of virulence or aggressiveness does not correlates with the presence or absence of any isozyme bands. These results support the present investigation on this studies could not ascertain any correlation with banding pattern and pathogenic ability of isolates.

Cluster analysis of protein banding pattern exhibited four major clusters among six isolates. Isolate Ct_6 and Ct_7 showed close similarity. While peroxidase and esterase showed short similarity coefficient range as tested by UPMGA. Uma Devi *et al.* (2001) reported the variability on the basis of isozyme and protein profile in twelve isolates of *Ascochyta rabiae.* Biochemical markers were found to be supplementary to prove the heterogenity among the tested six isolates from each group. Isozyme pattern of polyphenol oxidases, peroxidases, acetyl esterases, acid and alkali phosphate in mycelia and extra cellular extracts were used to differentiate the avirulent and virulent isolates of *Rhizoctonia solani* by PAGE.

A phylogenetic tree (dendrogram) was constructed based on protein pattern profile by cluster method using unweighted pair group arithmetic mean average method (UPMGA). Cluster analysis of protein banding pattern showed four major clusters. The first includes Ct_1 which is distinct from other isolates. The second cluster consists of Ct_2 which is also distinct with other. The third comprised Ct_4 while the fourth comprised sub cluster of two isolates i.e. Ct_7, Ct_6 and Ct_5 at separate place. Isolates Ct_6 and Ct_7 showed close similarity while in *C. capsici* short similarity coefficient range was observed. Phylogenetic relationship of *Colletotrichum acutatum* have been reported by Garrido *et al.* (2009),

Table 1. Collection and isolation of *Colletotrichum* spp. from various sources and locations

Isolates	Abbre-vations	Tissue isolated	Locations
C. truncatum	Ct_1	Leaves	Akola
C. truncatum	Ct_2	Leaves	Amravati
C. truncatum	Ct_4	Leaves	Nasik
C. truncatum	Ct_5	Pods	Mangrulpir
C. truncatum	Ct_6	Culture procured	Anand
C. truncatum	Ct_7	Leaves	Bhaurad
C. truncatum	Ct_3	Leaves	Washim
C. truncatum	Ct_8	Pods	Achalpur
C. truncatum	Ct_9	Fruit	Buldana
C. gloeosporioides	Cg_1	Leaves	Nasik

Table 2. Studies on pathogenicity of *Colletotrichum* spp. on various hosts

Isolates	Initiation of symptoms (DAI)	% disease intensity (21 DAI)	Spot size (mm)	Category	Symptoms
Ct_1	4	72.00	0.5-1.0	HP	Circular brown spots all over the leaf with dark brown margin
Ct_2	5	70.10	2-3	HP	Circular to irregular spots with dark brown margin
Ct_4	5	70.80	5-6	HP	Dark brown margin with lighter brown in the centre
Ct_5	5	72.00	4-5	HP	Irregular spots with brown margin
Ct_6	4	72.66	4-5	HP	Longitudinal (blight) spot on the leaves with light brown colour in the centre
Ct_7	4	74.00	3-4	HP	Brown spots with dark margin (margin is broader than other symptoms)
Ct_3	6	19.44	1-1.5	WP	Irregular spots withbrown margin
Ct_8	6	21.29	1-2	MP	Light brown spots with dark brown margin
Ct_9	6	19.44	1-2	WP	Brown spots with dark brown margin
Cg_1	6	21.29	1-2	MP	Circular to irregular spots with dark brown margin

Table 3. Morphological characters of *Colletotrichum truncatum* on PDA

Isolates	Geographical tracks	Colony characters	Conidial characters	Acervuli	Identification of isolate
Ct_1	Akola	Colony medium, thick, black in colour, circular, white mycelium in concentric rings formation, white patches form in between colony, medium acervuli production, slow growth, reverse back grey black in colour.	Conidia sickle shape, hyaline pointed at both ends, conidia pinkish when in mass, oil globules at the centre.	Acervuli prominent with long setae	*C.truncatum*
Ct_2	Amravati	Colony medium to thick, aerial, grey mycelial growth forms concentric rings, circular, reverse back black in colour.	Conidia sickle shape, hyaline pointed at both ends, conidia light pinkish when in mass, oil globules at the centre.	Acervuli bigger in size and sparse growth at the margin and aggregated in the centre forming concentric rings.	*C.truncatum*
Ct_4	Nasik	Colony colour black, circular growth, concentric rings, formation of acervuli minute, overall appearance gives shining, reverse back dark black in colour.	Conidia sickle shaped, hyaline, pointed at both ends, conidial mass light pinkish in colour, oil globules at the centre.	Acervuli smaller in size and sparse growth at the margin and aggregated in the centre forming concentric rings.	*C.truncatum*
Ct_5	Mangrulpir	Colony colour dark brown to black with a felt of grayish mycelium through which the tufted to irregular often confluent black sclerotial protrude occasionally with scattered tufts to pale grey to white.	Conidia falcate, apices, obtuse, gluttulate, oil globule at the centre. Conidial mass honey coloured.	Sclerotia formed in abundance	*C.truncatum*
Ct_6	Anand	Colony growth circular, grey, concentric rings, minute acervuli, reverse back grayish black in colour.	Conidia sickle shaped, hyaline, acute ends, conidial mass light pinkish in colour, oil globules at the centre.	Acervuli minute	*C.truncatum*
Ct_7	Bhaurad	Colony growth circular, grey, concentric rings, white patches are formed in between colony. Reverse back grayish black in colour.	Conidia sickle shaped, hyaline, pointed acute ends, flask shaped sclerotial formation, oil globules at the centre.	Big acervuli sparse at the margin	*C.truncatum*
Ct_3	Washim	Colony medium to thick, aerial, white mycelial growth form concentric rings with sclerotial formation, colony grayish type, reverse back grayish black in colour.	Conidia sickle shape, hyaline, pointed at both ends, conidia light pinkish when in mass, oil globules at the centre.	Acervuli bigger in size and aggregated in the centre and sparse at the margin. Acervuli forms concentric rings.	*C.truncatum*
Ct_8	Achalpur	Aerial mycelial growth, dark grayish in colour, irregular growth, reverse back dark black.	Conidial mass light pink in colour, sickle shaped conidia with flask shaped sclerotia, oil globules at the centre.	Acervuli dark black in colour, erupting upward.	*C.truncatum*
Ct_9	Buldana	Colony growth aerial, dark black in colour, circular, reverse back dark black.	Light pink colour conidial mass having obtuse ends with sickle shaped conidia with slerotial formation, flask shaped, oil globules at the centre.	Acervuli medium size.	*C.capsici*
Cg_1	Nasik	Colony circular, aerial mycelium, colony colour white to dull white.	Conidia hyaline, oblong, one celled, Conidial mass, pinkish in colour	Acervuli dark and showed slightly raised conidial mass. Setae not clearly observed.	*C.gloeosporioides*

Table 4. Radial growth (mm) of different *Colletotrichum* isolates

Isolates	Colony diameter (mm) at various DAI			
	3rd	5th	7th	9th
Ct_1	15.15	25.65	60.55	76.46
Ct_2	20.16	23.23	53.95	74.43
Ct_4	19.11	29.55	58.25	63.80
Ct_5	16.71	23.26	54.41	69.98
Ct_6	14.78	25.71	57.66	72.61
Ct_7	17.51	23.20	48.73	54.93
Ct_3	18.18	26.56	57.86	69.13
Ct_8	16.75	20.73	47.01	58.11
Ct_9	19.81	24.13	56.56	69.05
Cd_3	17.60	25.06	62.25	80.05
Cg_1	16.93	25.18	56.43	69.23

Table 5. Dimension of conidia, acervuli and setae of *Colletotrichum* spp.

Isolate	Conidia (40x)		Acervuli (10x)		Setae (40x)	
	Length (µm)	Breadth (µm)	Length (µm)	Breadth (µm)	Length (µm)	Breadth (µm)
Ct_1	27.31±1.258	4.57±0.744	159.40±36.64	139.48±44.169	114.9±50.14	7.15±2.030
Ct_2	24.45±2.402	3.74±0.286	292.96±42.2	239.11±87.121	59.77±16.96	4.60±2.230
Ct_4	26.31±4.061	4.94±0.715	257.9±131.7	216.97±79.593	88.37±24.42	3.80±0.686
Ct_5	23.39±1.83	4.54±1.487	75.27±19.37	74.61±19.373	115.5±12.87	5.69±0.085
Ct_6	24.59±2.202	5.03±0.601	179.33±17.05	158.3±27.122	94.6±32.66	5.43±0.400
Ct_7	24.59±2.488	4.60±0.601	181.5±52.47	163.8±28.893	170.4±25.83	4.84±0.457
Ct_3	28.60±1.258	4.97±0.629	169.3±65.87	158.3±66.199	87.23±57.66	5.29±1.515
Ct_8	25.70±2.402	5.63±0.601	190.4±52.58	146.12±47.822	103.2±33.63	5.60±0.886
Ct_9	22.59±1.602	5.31±1.115	190.40±51.03	146.12±44.501	115.83±38.98	6.72±1.172
Cg_1	11.52±1.544	5.74±3.575	285.60±166.9	221.40±110.92	-	-

Table 6. Grouping of *Colletotrichum* spp. based on their pathogenic ability

	Isolates groups	No. of isolates	Reaction on susceptible varieties (%)	Isolates
I	Non pathogenic isolate (NP)	1	0.0	
II	Weakly pathogenic isolate (WP)	12	1-20	Ct_3, Ct_9,
III	Moderately pathogenic (MP)	4	21-50	Cg_1, Ct_8,
IV	Strongly pathogenic isolate (SP)	2	50-70	
V	Highly pathogenic (HP)	12	>70	Ct_1, Ct_2, Ct_4, Ct_5, Ct_6, Ct

Table 7. Electrophoretic banding pattern of proteins in different *Colletotrichum truncatum* isolates

Protein band	Rm	Ct_1	Ct_2	Ct_4	Ct_5	Ct_6	Ct_7
Pt_1	0.08	+	+	+	+	+	+
Pt_2	0.11	+	+	+	-	+	+
Pt_3	0.15	+	+	-	-	+	-
Pt_4	0.17	-	-	-	-	-	+
Pt_5	0.19	-	-	-	-	+	+
Pt_6	0.21	-	-	-	+	-	-
Pt_7	0.24	+	+	+	+	+	+
Pt_8	0.28	+	+	+	+	+	+
Pt_9	0.30	+	+	+	+	+	+
Pt_{10}	0.35	+	-	-	-	-	-
Pt_{11}	0.38	-	+	-	-	-	-
Pt_{12}	0.40	-	-	+	+	+	+
Pt_{13}	0.44	+	+	+	+	+	+
Pt_{14}	0.50	+	+	+	+	+	+
Pt_{15}	0.61	+	+	+	+	+	+
Pt_{16}	0.68	+	+	+	+	+	+
Pt_{17}	0.77	+	+	+	+	+	+

Table 8. Electrophoretic banding pattern of peroxidase isolated from different *Colletotrichum truncatum* isolates

Enzyme	Rm	Ct_1	Ct_2	Ct_4	Ct_5	Ct_6	Ct_7
P_1	0.08	+	+	+	+	+	+
P_2	0.11	+	+	+	+	+	+
P_3	0.17	+	+	+	-	-	+
P_4	0.21	+	+	+	-	-	-
P_5	0.30	+	-	+	-	-	-

Table 9. Electrophoretic banding pattern of esterase in different *Colletotrichum truncatum* isolates

Enzyme	Rm	Ct_1	Ct_2	Ct_4	Ct_5	Ct_6	Ct_7
E_1	0.09	+	+	+	+	+	+
E_2	0.13	+	+	+	+	+	+
E_3	0.23	+	+	+	+	+	-
E_4	0.31	+	+	+	+	+	+
E_5	0.39	+	+	+	+	+	-
E_6	0.44	+	+	+	+	-	-

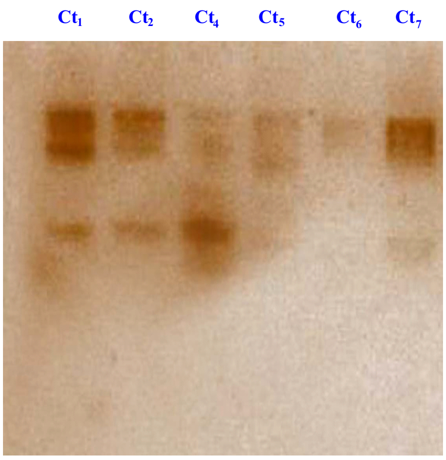

Plate 2. Peroxidase banding pattern in the isolates of *Colletotrichum truncatum*

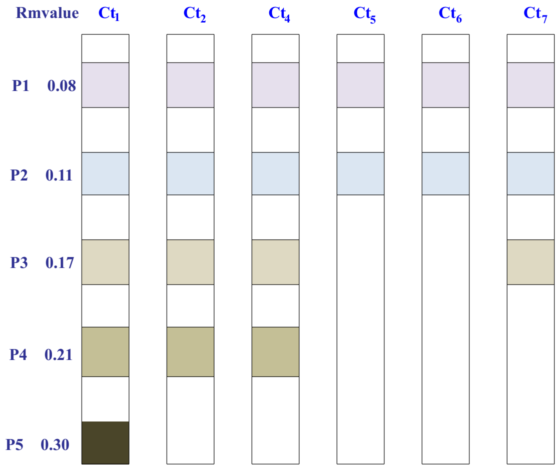

Fig 2. Peroxidase isozyme zymogram in the isolates of *Colletotrichum truncatum*

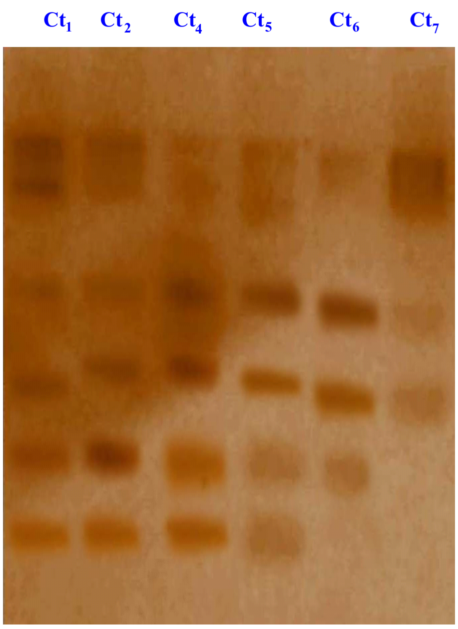

Plate 3. Electrophoretic banding pattern of esterase isolates from *Colletotrichum truncatum*

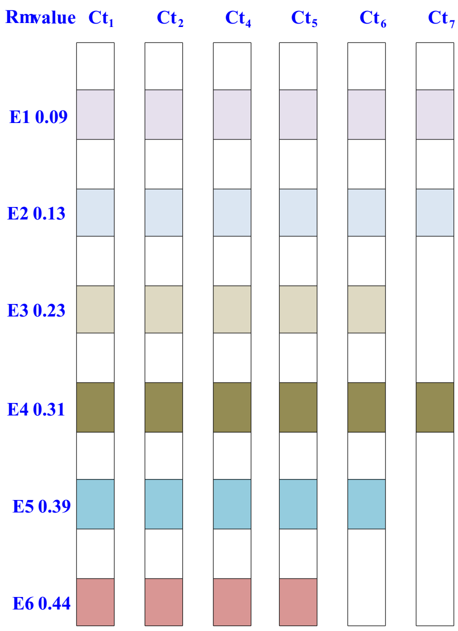

Fig 3. Esteraseisozyme zymogrm in the isolates of *Colletotrichum truncatum*

Isolates of *Colletotrichum truncatum*

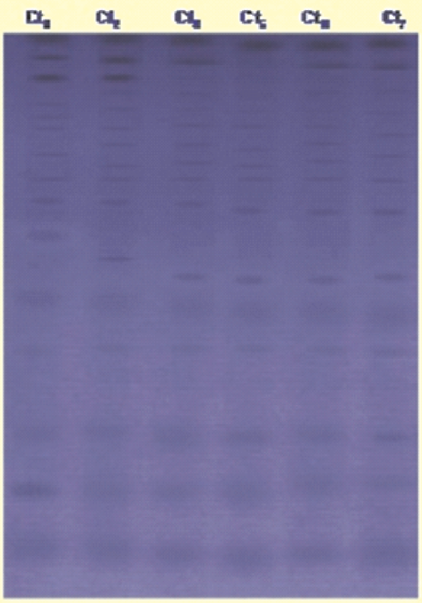

Plate 1. Electrophoretic banding pattern of proteins isolated from *Colletotrichum truncatum*

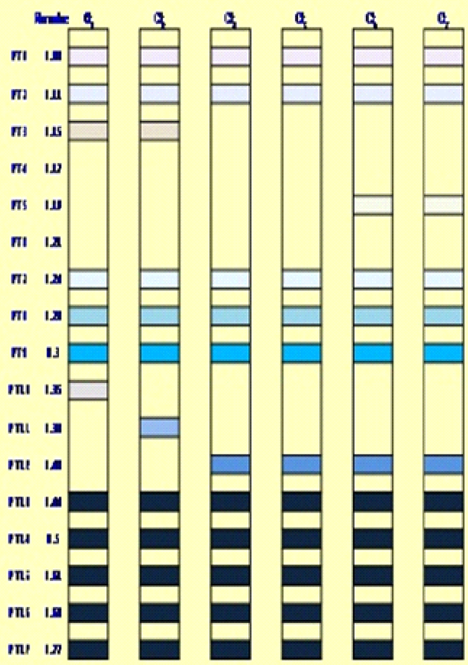

Fig. 1. Protein dendrogram of *Colletotrichum truncatum* by native PAGE

Glomerella sp. in apple by Giaretto *et al.* (2010), *Colletotrichum* isolates in strawberry by Hemelrijk (2010) and *C. boninense* in avocado by Silva *et al.* (2011). Thus, it is inferred from the present investigation that the presence or absence of a specific band could not correlate with the pathogenic ability of the either pathogen. Therefore, all the biochemical markers studied were marginally polymorphic and monomorphic in nature.

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COMBINIG ABILITY STUDIES IN MAIZE (*Zea mays* L.)

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ABSTRACT

Thirty two F_1 crosses obtained by crossing four females and eight males in a line x tester fashion were used to study the general and specific combining ability effects of parents and crosses respectively. Thirty two crosses and twelve parents along with check Rajarshi were raised in *kharif* 2013-14 and observations on days to 50 % tasseling, days to 50 % silking, days to maturity, plant height, length of internode, cob length, cob girth, number of grains cob^{-1}, 100 grain weight, grain yield plant^{-1}, grain yield plot^{-1} and fodder yield plot^{-1} were recorded high significant sca effect in the desirable direction. The gca and sca effects showed wide variation in the level of significance for different characters. The parents NM-32-1-1, NM-62-4- 1 and NM-60-4 were identified as good general combiner for yield and yield contributing characters. Among the crosses NM-32-1-1 x NM-62-4-1 and NM-32-1-1 x NM-60-4 were identified as best crosses on the basis of high *per se* performance and high significant sca effect in the desirable direction. Hence, it is suggested that these parents could be utilised for the development of either the synthetic varieties or elite breeding population and these two crosses identified could be directly used for heterosis breeding in maize.

(Key words: Maize, gca effects, sca effects and combining ability)

INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal grain in the world after wheat and rice. Maize is of American origin, particularly Mexico. Maize belongs to family Poaceae also called as Graminae and subfamily Panicoideae. Wild species of maize are *Zea mexicana* (2n = 20), *Zea perennis* (2n = 40), *Zea luxurians* (2n = 20), *Zea diploperennis* (2n = 20). Maize is monoecious plant, highly cross pollinated species. It is also one of the first plant species identified to photosynthesize by C_4 path way with high yield potential. (Dass *et al.,* 2010).

Maize being a cross-pollinated crop there is wide scope for the development of single cross hybrids and varieties. The *per se* performance of parents themselves does not always gives a correct indication of their breeding potential, therefore, important to single cross hybrids and varieties. The *per se* performance of parents themselves does not always gives a correct indication of their breeding potential, therefore, important to study the general combining ability of parents and specific combining ability of crosses which gives high level of heterosis. This information concerning to breeding behaviour of parents is of prime importance in planning the breeding programme.

Information on combining ability provides guidelines to the plant breeders in selecting the elite parents and desirable cross combinations and at the same time reveals the nature of gene action involved in the inheritance of various traits and thereby helps in formulation of breeding methodology to be used. The information derived from this research work will help in identifying superior inbreds for further breeding programme.

MATERIALS AND METHODS

Four females were crossed with eight males by following line x tester mating design to produce thirty two crosses in *rabi* 2012. These thirty two crosses along with twelve parents and one check (Rajarshi) were grown in Randomized Complete Block design in two replications with the spacing of 60 cm x 20 cm accommodating 15 plants in each row for the estimation of combining ability analysis in *kharif* 2013. Recommended package of practices were followed to raise a good crop. The data were recorded on five randomly selected plants from each genotype on following six characters *viz*., length of internode, cob length, cob girth, number of grains cob^{-1}, 100 grain weight and grain yield. The data on days to 50 % tasseling, days to 50% silking and days to maturity were recorded on plot basis. The analysis of variance for experimental design was analysed by the method given by Panse and Sukhatme (1954) and the combining ability analysis was carried out by following the methodology of Kempthorne (1957) with fixed effect model (model I) of Eisenhart (1947).

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RESULTS AND DISCUSSION

The present study was undertaken to assess the general and specific combining ability of parents and crosses respectively and to identify superior parents and crosses. The results on *per se* performance and sca effects revealed that the cross NM-32-1-1 x NM-62-4-1 was found to be significantly superior over check Rajarshi for grain yield plant^{-1}, grain yield plot^{-1}, number of grains cob^{-1}, days to maturity. Similarly the cross NM-32-1-1 x NM-60-4 performed significantly superior over check Rajarshi for grain yield plant^{-1}, grain yield plot^{-1} and 100 grain weight. Another cross NM-32-1-1 x NM-78-1 showed significant superiority over check Rajarshi for number of grains cob^{-1}, grain yield plot^{-1} and days to maturity. The mean performance of thirty two crosses when compared with the check hybrid Rajarshi, the crosses NM-32-1-1 x NM-62-4-1, NM-32-1-1 x NM-60-4 and NM-32-1-1 x NM-78-1 were identified as superior crosses. Therefore, these three crosses were identified as potential crosses for exploiting heterosis on the basis of *per se* performance.

Estimates of gca and sca effects among the parents and crosses showed wide variation in the level of significance for different characters. Some of the parents and crosses had significant gca and sca effects in the desirable direction for most of the characters studied. The significant gca and sca effects were also reported by Hossain *et al.* (2007), Wani *et al.* (2007), Legesse *et al.* (2009), Singh and Gupta (2009), Udasi *et al*. (2012) and Tajwar and Chakraborty (2013) in maize. The estimates of gca effects showed that among the lines NM-32-1-1 was found to be the best general combiner as it recorded significant positive gca effect for grain yield plant^{-1}, grain yield plot^{-1}, number of grains cob^{-1}, cob girth and length of internode. Among the testers, NM-62-4-1 was identified as good general combiner as it recorded significant positive gca effect for grain yield plot^{-1}, grain yield plant^{-1}, number of grains cob^{-1}, cob girth, cob length, days to 50% tasseling. Similarly tester NM-60-4 was also identified as a good general combiner as it exhibited significant positive gca effect for grain yield plot^{-1}, grain yield plant^{-1} and 100 grains weight. From this study three parents NM-32-1-1, NM-62-4-1 and NM-60-4 were identified as best general combiner for yield and other yield contributing characters.

The significant sca effect observed in different crosses for different characters had the combination of either high x high, high x low, low x high or low x low combining parents. It is important to note that among the crosses showing significant sca in desirable direction in respect to all the traits either involved or did not involved one or both the parents as good general combiner for the concerned trait. This indicated that non-additive type gene action, which are non-fixable were predominant in these crosses. It was also inferred that all the crosses which exhibited high mean were not necessarily having significant sca effect indicating the non-correspondence between *per se* performance and sca effects, but in few cases correspondence between *per se* performance and sca effect were observed.

Out of thirty two crosses studied two crosses *viz.,* NM-32-1-1 x NM-62-4-1 and NM-32-1-1 x NM-60-4 were identified as superior crosses on the basis of *per se* performance and sca effects. These crosses were also found to exhibit positive significant sca effects for yield and yield contributing characters like number of grains cob^{-1} or 100 grain weight. The superiority of these crosses having high sca effect involved high x high, combiner as parents. This could be explained on the basis of interaction between the positive alleles from two good combiner parents. The high performance of such crosses is due to non-fixable dominant gene action and thus could be exploited for heterosis breeding (Iqbal *et al.,* 2007). Therefore, these two crosses NM-32-1-1 x NM-62-4-1 and NM-32-1-1 x NM-60-4 were identified to be suitable for direct use in hybrid production in order to utilize the hybrid vigour expressed in F_1, instead of going for selecting segregants in advance generation.

Table 1. Analysis of variance for various characters in maize

Sources of variation	Mean squares												
	Degrees of freedom	Days to 50 % tasseling	Days to 50 % silking	Days to maturity	Plant height (cm)	Length of internode (cm)	Cob length (cm)	Cob girth (cm)	Number of grains cob^{-1}	100 grain weight (g)	Grain yield $plant^{-1}$ (g)	Grain yield $plot^{-1}$ (kg)	Fodder yield $plot^{-1}$ (kg)
Replication	1	0.54	0.18	0.18	16.10	1.6	1.38	1.45	548.59	0.80	45.53	0.090	0.029
Genotypes	44	12.88**	13.56**	10.07**	261.99	1.18**	2.20**	0.74	2132.59**	3.90**	147.50**	0.032**	0.017
Error	44	0.52	0.86	1.13	176.52	0.37	0.80	0.46	618.04	0.25	19.90	0.005	0.026

*, ** = significant at 5% and 1% level respectively

Table 2. Analysis of variance for combining ability

Sources of variation	Mean squares												
	d f	Days to 50 % tasseling	Days to 50 % silking	Days to maturity	Plant height	Length of internode	Cob length	Cob girth	Number of grains cob^{-1}	100 grain weight	Grain yield $plant^{-1}$	Grain yield $plot^{-1}$	Fodder yield $plant^{-1}$
Lines (l)	3	8.44**	13.77	5.08*	756.04**	3.05**	2.72	1.43**	8277.61**	3.83**	459.27**	0.085**	0.001
Testers (t)	7	13.31**	15.41	9.96**	301.70	1.30*	4.29**	0.93*	2314.78**	4.83**	205.52**	0.048**	0.015
Lines X Testers	21	8.66**	8.33**	8.51**	209.81	1.19**	1.59	0.64*	1631.59*	3.62**	110.55**	0.025**	0.022
Error	31	0.43	0.75	1.21	209.79	0.43	0.94	0.31	703.23	0.25	20.26	0.005	0.019
GCA vs. SCA		0.71	0.83	0.63	0.83	0.78	0.81	0.78	0.86	0.70	0.85	0.84	0.42

*, ** = significant at 5% and 1% level respectively

Table 3. Mean performance of parents and their crosses for different characters

Sr. No.	Genotypes	Days to 50% tasseling	Days to 50% silking	Days to maturity	Plant height (cm)	Length of internode (cm)	Cob length (cm)
1	NM-32-1-1	54.50	63.50	93.00	139.51	14.64	13.40
2	NM-44-3-1	55.00	63.00	98.00	129.28	14.32	14.90
3	NM-72-2	54.50	64.50	98.00	128.67	14.04	14.49
4	NM-2-1	58.00	67.00	95.00	140.86	14.47	13.96
5	NM-62-4-1	60.50	69.50	96.50	127.28	13.58	12.15
6	NM-60-4	60.50	69.00	97.50	127.95	14.48	12.25
7	NM-46-3-1	57.00	66.00	94.00	129.12	13.90	13.73
8	NM-26-1	58.00	66.50	98.00	132.75	13.97	11.87
9	NM-44-1	59.50	68.50	101.50	145.99	14.60	14.69
10	NM-36-5	59.50	68.50	99.00	145.31	14.50	12.91
11	NM-4-2	59.00	68.00	98.00	150.50	15.09	14.44
12	NM-78-1	58.50	67.00	98.00	137.03	15.35	13.99
13	NM-32-1-1xNM-62-4-1	55.50	63.50	92.50	143.76	13.53	14.17
14	NM-32-1-1xNM-60-4	55.00	63.00	96.00	141.19	15.21	13.49
15	NM-32-1-1xNM-46-3-1	56.50	64.00	98.00	127.51	13.89	12.26
16	NM-32-1-1xNM-26-1	52.00	61.50	94.50	151.51	15.12	14.06
17	NM-32-1-1xNM-44-1	51.50	60.00	98.50	148.02	15.87	14.40
18	NM-32-1-1xNM-36-5	53.00	61.50	98.00	177.16	16.90	15.00
19	NM-32-1-1xNM-4-2	54.00	62.50	92.50	167.03	16.11	13.23
20	NM-32-1-1xNM-78-1	56.00	64.00	95.00	166.53	15.59	14.07
21	NM-44-3-1xNM-62-4-1	57.00	66.50	94.00	146.33	14.56	14.45
22	NM-44-3-1xNM-60-4	52.50	61.50	95.50	152.45	15.80	14.24
23	NM-44-3-1xNM-46-3-1	56.00	65.00	98.50	149.81	14.68	10.68
24	NM-44-3-1xNM-26-1	58.50	67.50	97.00	139.40	14.55	11.65
25	NM-44-3-1xNM-44-1	53.50	62.50	93.50	131.47	14.63	12.30
26	NM-44-3-1xNM-36-5	56.00	65.00	92.50	145.74	15.24	14.40
27	NM-44-3-1xNM-4-2	55.50	63.50	97.00	131.85	14.05	13.16
28	NM-44-3-1xNM-78-1	58.00	66.50	95.00	130.52	15.09	13.75
29	NM-72-2xNM-62-4-1	54.50	63.50	96.00	127.32	14.69	14.81
30	NM-72-2xNM-60-4	56.00	65.00	93.00	123.32	15.15	15.13
31	NM-72-2xNM-46-3-1	52.00	60.50	95.00	132.22	13.75	12.20
32	NM-72-2xNM-26-1	57.00	65.00	93.50	146.29	14.26	13.27
33	NM-72-2xNM-44-1	53.00	60.50	97.00	141.04	14.04	14.03
34	NM-72-2xNM-36-5	52.50	62.00	92.50	145.80	15.54	12.76
35	NM-72-2xNM-4-2	56.00	65.50	96.00	132.72	13.61	13.59
36	NM-72-2xNM-78-1	57.00	66.00	93.00	143.93	12.91	15.21
37	NM-2-1xNM62-4-1	57.50	67.50	92.00	138.07	14.89	14.83
38	NM-2-1xNM60-4	54.00	63.00	99.00	145.64	14.33	12.54
39	NM-2-1xNM46-3-1	57.50	66.50	97.50	138.63	14.31	13.55
40	NM-2-1xNM-26-1	58.00	67.50	97.00	138.46	14.73	14.20
41	NM-2-1xNM-44-1	54.00	63.00	94.50	140.53	15.26	14.21
42	NM-2-1XNM-36-5	51.00	60.00	94.00	156.90	13.91	14.86
43	NM-2-1xNM-4-2	53.00	62.00	96.00	143.80	14.48	14.26
44	NM-2-1xNM-78-1	51.50	61.00	96.00	148.80	14.57	13.37
45	Rajarshi (Check)	55.00	65.50	95.50	128.51	15.46	14.28
	SE(m) ±	**0.51**	**0.66**	**0.75**	**9.39**	**0.44**	**0.64**

Table 3a. Mean performance of parents and their crosses for different characters

Sr. No.	Genotypes	Cob Girth (cm)	Number of grains cob^{-1}	100 grain wt. (g)	Grain yield $plant^{-1}$ (g)	Grain yield $plot^{-1}$ (kg)	Fodder yield plot (kg)
1	NM-32-1-1	11.45	200.20	23.40	47.40	0.71	1.35
2	NM-44-3-1	11.91	205.10	23.68	48.60	0.73	1.50
3	NM-72-2	12.04	228.90	24.47	54.10	0.77	1.25
4	NM-2-1	11.52	220.50	24.12	53.88	0.81	1.25
5	NM-62-4-1	11.40	161.30	22.72	32.82	0.49	1.28
6	NM-60-4	11.44	235.70	20.37	49.35	0.74	1.40
7	NM-46-3-1	11.67	231.90	23.15	50.15	0.75	1.30
8	NM-26-1	12.02	198.10	23.46	40.52	0.61	1.40
9	NM-44-1	11.20	236.50	22.65	44.51	0.67	1.25
10	NM-36-5	11.10	225.90	21.04	42.90	0.64	1.20
11	NM-4-2	11.29	279.50	23.87	59.14	0.89	1.38
12	NM-78-1	10.48	200.60	20.10	41.11	0.62	1.30
13	NM-32-1-1xNM-62-4-1	12.20	300.60	23.50	72.95	1.09	1.43
14	NM-32-1-1xNM-60-4	12.70	251.30	24.50	66.30	0.99	1.31
15	NM-32-1-1xNM-46-3-1	12.18	233.00	23.98	53.54	0.80	1.35
16	NM-32-1-1xNM-26-1	12.47	206.50	22.90	44.01	0.66	1.34
17	NM-32-1-1xNM-44-1	11.80	208.40	21.08	43.25	0.60	1.43
18	NM-32-1-1xNM-36-5	12.91	271.20	24.39	61.80	0.93	1.40
19	NM-32-1-1xNM-4-2	11.94	247.40	23.40	49.34	0.74	1.45
20	NM-32-1-1xNM-78-1	12.38	289.50	21.23	61.21	0.92	1.27
21	NM-44-3-1xNM-62-4-1	13.08	258.30	22.24	56.74	0.85	1.40
22	NM-44-3-1xNM-60-4	12.31	225.70	23.94	53.53	0.80	1.55
23	NM-44-3-1xNM-46-3-1	11.37	195.60	25.30	51.14	0.74	1.25
24	NM-44-3-1xNM-26-1	10.87	192.10	20.28	37.72	0.57	1.34
25	NM-44-3-1xNM-44-1	12.19	232.90	24.49	51.44	0.79	1.35
26	NM-44-3-1xNM-36-5	12.44	206.30	24.61	42.95	0.64	1.43
27	NM-44-3-1xNM-4-2	11.61	163.50	22.81	35.93	0.54	1.35
28	NM-44-3-1xNM-78-1	11.01	210.30	24.79	50.36	0.75	1.40
29	NM-72-2xNM-62-4-1	12.60	187.20	24.26	50.61	0.76	1.35
30	NM-72-2xNM-60-4	11.81	172.70	25.36	41.29	0.69	1.33
31	NM-72-2xNM-46-3-1	11.29	156.70	22.60	32.64	0.50	1.38
32	NM-72-2xNM-26-1	11.35	193.50	21.55	42.63	0.69	1.33
33	NM-72-2xNM-44-1	11.20	200.30	20.11	42.24	0.63	1.45
34	NM-72-2xNM-36-5	11.50	250.70	21.85	53.96	0.81	1.35
35	NM-72-2xNM-4-2	11.47	178.60	22.35	37.43	0.56	1.36
36	NM-72-2xNM-78-1	11.58	242.10	21.75	52.82	0.79	1.43
37	NM-2-1xNM62-4-1	12.82	215.00	22.49	48.11	0.72	1.32
38	NM-2-1xNM60-4	11.72	253.40	23.93	57.55	0.86	1.50
39	NM-2-1xNM46-3-1	11.69	236.60	24.14	59.12	0.89	1.58
40	NM-2-1xNM-26-1	12.78	224.20	23.45	52.68	0.79	1.40
41	NM-2-1xNM-44-1	11.73	243.80	24.66	58.69	0.88	1.40
42	NM-2-1XNM-36-5	10.85	191.60	22.69	43.81	0.69	1.33
43	NM-2-1xNM-4-2	11.51	195.30	23.57	45.86	0.69	1.35
44	NM-2-1xNM-78-1	12.64	223.10	22.85	48.57	0.73	1.03
45	Rajarshi (Check)	11.88	225.30	23.01	55.20	0.83	1.35
	SE (m) ±	**0.48**	**17.58**	**0.35**	**3.15**	**0.05**	**0.9**

Table 4. General combining ability effects of parents

Sr. No.	Genotypes	Days to 50 % tasseling	Days to maturity	Plant height (cm)	Length of internode (cm)	Cob length (cm)	Cob girth (cm)	Number of grains cob^{-1}	100 grain wt. (g)	Grain yield $plant^{-1}$	Grain yield $plot^{-1}$ (kg)
Lines											
1	NM-32-1-1	-0.66**	0.31	9.28*	0.55**	0.14	0.39**	30.44**	-0.04	6.54**	0.09**
2	NM-44-3-1	1.03**	0.06	-2.61	0.10	-0.61*	-0.08	-9.96	0.40**	-2.53*	-0.04
3	NM-72-2	-0.09	-0.81**	-6.98	-0.48**	0.18	-0.34*	-22.82**	-0.08**	-5.80**	-0.07**
4	NM-2-1	-0.28	0.44	0.30	-0.17	0.29	0.03	2.33	0.32	1.79	0.03
	S.E.(gi)	**0.16**	**0.27**	**3.62**	**0.16**	**0.24**	**0.14**	**6.63**	**0.12**	**1.12**	**0.02**
Testers											
1	NM-62-4-1	1.28**	-1.69**	-4.69	-0.31	0.87**	0.74**	19.73*	-0.04	7.10**	0.10**
2	NM-60-4	-0.47*	0.56	-2.91	0.40	0.16	0.20	5.23	1.28**	4.66**	0.09**
3	NM-46-3-1	0.66**	1.94**	-6.51	-0.57*	1.52**	-0.31	-15.07	0.85**	-0.90	-0.02
4	NM-26-1	1.53**	0.19	0.36	-0.06	-0.40	-0.07	-16.47	-1.11**	-5.75**	-0.08**
5	NM-44-1	-1.84**	0.56	-3.29	0.22	0.04	-0.21	0.81	-0.57**	-1.10	-0.03
6	NM-36-5	-1.72**	-1.06**	12.85*	0.67**	0.56	-0.01	9.41	0.23	0.62	0.01
7	NM-4-2	-0.22	0.06	0.30	-0.16	-0.13	-0.31	-24.34*	-0.13	-7.87**	-0.12**
8	NM-78-1	0.78**	-0.56	3.89	-0.19	0.41	-0.04	19.73*	-0.50**	3.23	0.05*
	S.E.(gj)	**0.23**	**0.39**	**5.12**	**0.23**	**0.34**	**0.20**	**9.37**	**0.18**	**1.59**	**0.02**

*, ** = significant at 5% and 1% level respectively

Note :GCA effect of parent for days to 50% silking and fodder yield $plot^{-1}$ were not calculated as its mean square was non-significant

Table 5. Specific combining ability effects of crosses

Sr. No.	Genotypes	Days to 50 % tasseling	Days to 50 % silking	Days to maturity	Length of internode	Cob length	Cob girth	Number of grains cob^{-1}	100 grain wt.	Grain yield plant^{-1}	Grain yield plot^{-1}	Fodder yield plot^{-1}
	Crosses											
1	NM-32-1-1xNM-62-	0.03	-0.61	-1.44*	-1.44**	-0.54	-0.86*	29.88	0.42	9.30**	0.150	0.052
2	NM-32-1-1xNM-60-	1.28**	1.02*	-0.19	-0.46	-0.50	0.18	-4.92	0.10	5.09	0.067	-0.111
3	NM-32-1-1xNM-46-	1.66**	1.14*	0.44	-0.82	-0.06	0.16	-2.92	0.01	-2.11	-0.017	-0.037
4	NM-32-1-1xNM-26-	-3.72**	-2.73**	-1.31*	-0.10	0.62	0.22	-28.02	0.89	-6.79*	-0.105	-0.013
5	NM-32-1-1xNM-44-	-0.84	-0.36	2.31*	0.37	0.52	-0.32	-43.39*	-1.47**	-12.20*	-0.216**	0.019
6	NM-32-1-1xNM-36-	0.53	0.52	3.44*	0.95	0.60	0.60	10.81	1.04**	4.63	0.071	0.025
7	NM-32-1-1xNM-4-2	0.03	0.27	-3.19*	1.00*	-0.47	-0.08	20.76	0.41	0.66	0.019	0.074
8	NM-32-1-1xNM-78-	1.03*	0.77	-0.06	0.50	-0.17	0.09	17.81	-1.39**	1.43	0.031	-0.010
9	NM-44-3-1xNM-62-	-0.16	0.14	0.31	0.04	0.50	0.48	27.98	-1.28**	2.17	0.035	0.015
10	NM-44-3-1xNM-60-	-2.91**	-2.73**	-0.44	0.58	1.00	0.25	9.88	-0.89*	1.39	0.007	0.117
11	NM-44-3-1xNM-46-	-0.53	-0.11	1.19*	0.43	-0.88	-0.19	0.08	0.90*	4.56	0.050	-0.149
12	NM-44-3-1xNM-26-	1.09*	1.02*	1.44*	-0.21	-1.03	-0.92	-2.02	-2.17**	-4.01	-0.069	-0.025
13	NM-44-3-1xNM-44-	-0.53	-0.11	-2.44*	-0.42	-0.82	0.54	21.51	1.51**	5.07	0.110*	-0.068
14	NM-44-3-1xNM-36-	1.84**	1.77**	-1.81*	-0.26	0.76	0.59	-13.69	0.83*	-5.15	-0.081	0.039
15	NM-44-3-1xNM-4-2	-0.16	-0.98	1.56*	-0.61	0.21	0.06	-22.74	-0.62	-3.68	-0.051	-0.038
16	NM-44-3-1xNM-78-	1.34**	1.02	0.19	0.45	0.26	-0.82*	-20.99	1.73**	-0.35	-0.001	0.109
17	NM-72-2xNM-62-4-	-1.53**	-1.61**	3.19*	0.76	0.06	0.26	-30.26	1.82**	-0.69	-0.023	-0.022
18	NM-72-2xNM-60-4	1.72**	2.02**	-2.06*	0.51	1.10	0.01	-30.26	1.61**	-7.57*	-0.071	-0.095
19	NM-72-2xNM-46-3-	-3.41**	-3.36**	-1.44*	0.08	-0.16	-0.01	-25.96	-0.73*	-10.07*	-0.161*	-0.011
20	NM-72-2xNM-26-1	0.72	-0.23	-1.19	0.08	-0.21	-0.18	12.24	0.19	4.17	0.087	-0.022
21	NM-72-2xNM-44-1	0.09	-0.86	1.94*	-0.43	0.11	-0.19	1.77	-1.79**	-0.86	-0.019	0.045
22	NM-72-2xNM-36-5	-0.53	0.02	-0.94	0.63	-1.68	-0.09	43.57*	-0.86*	9.13**	0.116*	-0.023
23	NM-72-2xNM-4-2	1.47**	2.27**	1.44*	-0.47	-0.15	0.18	5.22	0.00	1.10	0.003	-0.020
24	NM-72-2xNM-78-1	1.47**	1.77**	-0.94	-1.15*	0.93	0.02	23.67	-0.23	5.38	0.068	0.147
25	NM-2-1xNM62-4-1	1.66**	2.08**	-2.06*	0.64	-0.02	0.12	-27.61	-0.95*	-10.78**	-0.162*	-0.045
26	NM-2-1xNM60-4	-0.09	-0.30	2.69*	-0.63	-1.60*	-0.45	25.29	-0.82*	1.09	-0.003	0.088
27	NM-2-1xNM46-3-1	2.28**	2.33**	-0.19	0.32	1.09	0.03	28.79	-0.18	8.22*	0.128*	0.197
28	NM-2-1xNM-26-1	1.91**	1.95**	1.06	0.23	0.62	0.88*	17.79	1.09**	6.63*	0.086	0.060
29	NM-2-1xNM-44-1	1.28**	1.33*	-1.81*	0.48	0.19	-0.03	20.12	1.76**	7.99*	0.126*	0.003
30	NM-2-1XNM-36-5	-1.84**	-2.30**	-0.69	-1.32**	0.32	-1.11**	-40.68*	-1.01**	-8.61*	-0.106*	-0.041
31	NM-2-1xNM-4-2	-1.34**	-1.55**	0.19	0.08	0.41	-0.15	-3.23	0.22	1.92	0.028	-0.017
32	NM-2-1xNM-78-1	-3.84**	-3.55**	0.81	0.20	-1.02	0.71	-20.48	-0.12	-6.46	-0.098	-0.246*
	SE (ij)	**0.46**	**3.49**	**0.78**	**0.46**	**0.68**	**0.39**	**18.75**	**0.35**	**3.18**	**0.05**	**0.10**

*, ** = significant at 5% and 1% level respectively

Note: SCA effect of crosses for days plant height was not calculated as its mean square was non-significant

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FOOD CONSUMPTION PATTERN IN MAHARASHTRA

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ABSTRACT

In present study an attempt has been made to examine food consumption pattern in Maharashtra. The study was based on Secondary data collected from National Sample Survey Organisation (NSSO) respondents located in urban area and rural area of Maharashtra state. The household consumer expenditure data of the 61st round of the NSSO conducted in 2004-05 and 66th round 2009-10 were used as the main source of secondary data for the study. Percentages were calculated to analyze the changes in the pattern of food consumption over the years. The monthly capita^{-1} cereal consumption was declined from10.51 kgs to 10.34 kgs in rural areas, while the corresponding decrease in the urban area sector was from 8.40 kgs to 8.20 kgs. The percentage of urban area (-2.3) was decrease more than rural area (-1.6). Thus the consumption of cereals has declined in Maharashtra over the periods. The monthly capital^{-1} consumption of pulses varied from 0.82 kgs and 0.86 kgs a marginal decline of -2.33 per cent was noticed in urban areas while no change was observed in rural areas. The monthly capita^{-1} expenditure (MPCE) on food was Rs.291.03 during the year 2004-05 in rural areas and it increased to Rs.617 during 2009-10, the percentage increase was 112 per cent over the base period in rural area. The percentage in urban area, the MPCE increased from Rs.445.24 to Rs.995.60 witnessed about 123 per cent change over the base period. The expenditure elasticities for different food items varied between 0.371 to 0.474 in the case of in rural areas and the elasticity of urban area was 0.622 to 0.831. The highest expenditure elasticities was observed for clothing (2.458) followed by and milk and milk product in urban areas. An increase in income would shift the consumption expenditure for clothing and milk and milk product in urban areas

(Key words : Monthly capita^{-1} expenditure, expenditure elasticity, food consumption)

INTRODUCTION

The consumption pattern is very important because it reveals a clear picture of standard of living of people, poverty level, human development and the nature of its economic growth. The average monthly capita^{-1} consumer expenditure (MPCE) in 2009-10 stood at Rs. 1053 in rural India and Rs. 1984 in urban India. The capita^{-1} consumption expenditure in urban areas stood 88 per cent more than that of rural areas. (Anonymous, 2013). It facts necessary to study the consumption pattern under the changing situations of liberalization, privatization and globalization.

The analysis of temporal and spatial change in food consumption pattern would help in designing appropriate policies related to food production, processing and distribution. Hence, the study was under taken with the objectives viz., to analyze the changes in food consumption pattern and to estimate expenditure elasticities of demand for food in rural and urban area.

MATERIALS AND METHODS

The study was conducted in the year2012-13.The present study utilized the secondary data for evaluating and analyzing the specific objectives of the study. Time series data on monthly capita^{-1} expenditure for Maharashtra were collected from various issues of National Sample Survey Organization (NSSO) published by Government Of India (GOI). The published data of NSSO of 27th round (1972-73), 61st round (2004-05) and 66th round (2009-10) were collected for the present study and was used to analyze the changes in food consumption pattern for the recent years. Further, the data on physical quantities on selected food items (cereals and pulses) were collected from 50th round (1993-94) onwards. The percentages and per cent changes were calculated to analyze the pattern of food consumption. The functional analysis was done to estimate expenditure elasticities. The proportional response of consumption to a given proportional increase in expenditure typically declines as expenditure rises. Therefore, it is desirable to use functional form which exhibits this characteristic. The function was selected on the basis of the nature of the data. The log-inverse function and log-log inverse function were used. The log-log inverse function has the property that it can model an increase in consumption followed by a consumption decline as expenditure rises through time .These two functional relationships were estimated (Musebe and Kumar, 2006) to compute the expenditure elasticities of demand for different food items.

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Log -inverse function

$\ln Y = a_0 + a_1 (1/X) + u$

Log-log-inverse function

$\ln Y = b_0 + b_1 \ln X + b_2 (1/X) + u$

Where,

Y = Monthly capita^{-1} expenditure on a specific food item (Rs.).

X = Monthly capita^{-1} total consumption expenditure (Rs.).

a_0, b_0, a_1, b_1 and b_2 are the regression coefficients

u = Random error term

The monthly capita^{-1} total consumption expenditure was used as proxy for income since, the data on consumer income was not available in NSSO publications.

The expenditure elasticities (ex) for each commodity were derived from the derivatives of each equation with respect to expenditure as follows.

$ex = dY/dX * X/Y = b_1 - b_2/x$

The elasticities (ex) were evaluated at the sample mean values for X are:- a_1/X and $b_1 - b_2/X$ for log-inverse and log-log inverse and log-log-inverse function proved to be superior on the basis of the high value of the coefficient of determination (R^2) and low standard errors of the coefficients. The food items were considered as essential, if the elasticity was between zero and one, inferior good, if the elasticity was less than zero and luxury, if the elasticity was greater than one. The elasticity of demand are useful for predicting consumer behavior and evaluating the likely effect of the contemplated policy. The high and significant R^2 values for all commodity groups implied that the model provided a better explanation.

RESULTS AND DISCUSSION

The data presented in table1 represent that, capita^{-1} consumption (MPC) of cereals and pulses in Maharashtra state. It revealed a decline in the quantity consumed for all food items except wheat, rice and maize in rural and wheat in urban areas. The monthly capita^{-1} consumption of cereals in physical terms was 10.51 kgs during 2004-05 which declined to 10.34 kgs in the year 2009-10 for rural areas and corresponding figures for urban areas were 8.40 to 8.20 kgs. Similar findings were reported by Giri (2006),Nasurudeen *et al.* (2006) and Chandha (2007). The study of Nasurudeen *et al.* (2006) revealed that the cereal consumption of 11.2 kg during 43[rd] round (1987-88) declined to 9.8 kg during 58[th] round (2002) for Tamil Nadu. The person^{-1} monthly consumption of wheat was increased from 3.41 kgs during 2004-05 to 4.30 kgs in the year 2009-10 in rural areas, whereas, the corresponding increase was 4.30 kgs to 4.42 kgs for urban areas because of high protein content and less fat content, thus the consumers choice was shifted in favour of wheat. Further wheat was supplied through Public Distribution System (PDS) both in rural and urban areas. There was substitution of fine grains for the coarse ones and subsequent replacement of cereal by protective foods like milk, fruits and vegetables. The overall shift in terms of increased wheat consumption and reduced coarse grain consumption during 2004-05 to 2009-10 was visible both in rural and urban areas. Jowar, being a coarse cereal, exhibited a decline in its consumption both in rural and urban areas of Maharashtra state.

The changes in the monthly capita^{-1} expenditure on various food items over two periods across two locations were worked out and the same has been presented in table 2. Data revealed that the monthly capita^{-1} expenditure on food was Rs.291.03 during 2004-05 in rural areas which was increased to Rs.617.50 in the year 2009-10, showing an increase of about 112.17 per cent over the base period. The monthly capita^{-1} expenditure in urban areas increased from Rs. 445.24 to Rs. 995 witnessing about 124 per cent change over the two periods. The share of expenditure on cereals in the total food expenditure was between 20 to 28 per cent. This showed that expenditure on cereals was the major item of food expenditure and the monthly capita^{-1} expenditure on cereals increased by 57.58 per cent in rural areas and 82.02 per cent in urban areas. The share of expenditure on pulses in total food expenditure varied between 5.01 to 8.20 per cent both rural and urban areas witnessed a rise in the expenditure to the extent of 148 per cent in pulses and 82 per cent in milk and milk products. The expenditure on edible oil whose share was around 9 per cent in rural and urban areas which, witnessed a rise of 52.65 per cent in rural areas and 51.09 per cent in urban areas. The proportion of expenditure on vegetables was around 11 per cent and it has increased by 162.43 per cent in urban and 185.18 per cent in rural areas. This was also true for food items like fruits and nuts, sugar, spices and beverages. The expenditure on meat, fish, and egg increased by more than 185.47 per cent in rural and urban areas.

The changes in capita^{-1} expenditure on individual commodities affect the relative importance of these commodities as measured by their proportion in expenditure. As far as individual food commodity groups were concerned, it was observed that there was a decline in the proportion of expenditure on cereals. In rural areas it was declined from 28.30 per cent during 2004-05 to 21.01 per cent in the year 2009-10 and in urban areas it was declined from 19.90 per cent during 2004-05 to 16.25 per cent in the year 2009-10 to 16.20 per cent. The increasing trend over the years was seen in the case of pulses both in rural and urban Maharashtra. The rise in the proportion of expenditure on Vegetables, Meat, fish, egg, spices and beverages were higher in rural Maharashtra than that in urban Maharashtra. The similar results were shown by Biswanger *et al.* (1984); and Nasurudeen *et al.* (2006). They observed higher consumption of these products in rural area than urban. The improvement in economic access to food due to increased income, did not result in a higher consumption of cereals, but has increased the consumption of vegetables, fruits and nuts and livestock products, especially milk and eggs.

The total monthly capita^{-1} food expenditure was higher (Rs. 995.60) due to higher income, urbanization and varied preferences. While it was Rs.617.50 person^{-1} month^{-1} in rural areas during 2009-10.

Capita^{-1} expenditure on non food items

Table 3 shows that the monthly capita^{-1} expenditure of rural consumer on non-food items was Rs.274.46 in 2004-05 which increased to Rs.495.81 in 2009-10 and similarly rural consumers was Rs.684.00, which was increased to Rs.1405.23 in the year 2009-10.

The expenditure made on miscellaneous goods and services, rent and taxes accounted for major share in the monthly capita^{-1} expenditure on non-food items and this expenditure was increased by 82.52 per cent in rural area and by 97.95 per cent in urban areas. The expenditure on intoxicants, fuel and light and clothing also shared a considerable portion of total non-food expenditure in both the periods in rural and urban areas. The expenditure on fuel and light was increased by 55.50 per cent in urban areas and 64.40 per cent in rural areas.

The monthly capita^{-1} expenditure in clothing increased from Rs.42.97 to Rs.94.20 in urban areas and from Rs.19.43 to Rs.39.16 in rural areas The expenditure on durables was increased by 325.45 per cent in urban area and by 92.94 per cent in rural areas. Among non-food items, the expenditure on miscellaneous goods and services, rent, tax had the highest percentage share in capita^{-1} monthly non-food expenditure both in rural and urban areas.

Expenditure elasticity of demand for food items

The table 4 revealed that the estimated expenditure elasticity of demand for all food items was positive except durable goods in rural as well as in urban areas. The elasticities were less than one for almost all the food items in urban areas, whereas the expenditure elasticities were more than one for milk and milk product, clothing, and fruit in rural areas. The expenditure elasticity was the highest for clothing 2.458 in of urban area and was the lowest 1.865 for durable goods in urban areas. For both rural and urban sample households, cereals form the basic necessary item of consumption. It was found that the elasticity of expenditure on cereals was higher for urban household (0.627) compared to rural households (0.474). This substantiates the result put forward by Geeta (2011) i.e. for cereals it was higher for urban household (0.72) as compared to rural households (0.70).

The expenditure elasticities for different food items varied between 0.371 and 0.474 in the case of pulses in rural areas and 0.627 to 0.831 in urban areas. The highest expenditure elasticity was observed for clothing (2.458) followed by and milk and milk product in urban areas. An increase in income would shift the consumption expenditure for clothing and milk and milk product in urban areas. Thus, rural areas expenditure elasticities for Cereals, Pulses, Edible-oil, Sugar and Eggs were 0.474, 0.371, 0.361, 0.554 and 0.461 respectively. It considered as essential commodity, while milk and milk product 1.245 and fruits 1.288 were found to be luxuries because its elasticities were greater than one.

Table1. Monthly capita^{-1} consumption (kg) of cereals and pulses in Maharashtra

Food items	Rural			Urban		
	2004-05	2009-10	% change	2004-05	2009-10	% change
Rice	2.97 (28.26)	3.36 (32.50)	13.13	3.00 (35.71)	2.94 (35.85)	- 2.00
Wheat	3.41 (32.45)	4.30 (41.59)	26.09	4.30 (51.19)	4.42 (53.90)	2.79
Jowar	2.84 (27.02)	2.07 (20.01)	-27.11	0.85 (10.12)	0.71 (8.66)	-16.47
Bajara	1.15 (10.94)	0.56 (5.42)	-51.30	0.24 (2.86)	0.13 (1.59)	- 45.83
Maize	0.03 (0.29)	0.04 (0.39)	33.33	0.002 (0.02)	0.002 (0.2)	0.00
Other cereals	0.11 (1.04)	0.01 (0.09)	-90.90	0.009 (0.11)	0.001 (0.01)	- 88.88
Total cereals	10.51 (100.00)	10.34 (100.00)	-1.61	8.40 (100.00)	8.20 (100.00)	- 2.38
Bengal gram	0.16 (19.51)	0.17 (20.73)	6.25	0.15 (17.44)	0.14 (16.67)	-6.67
Red gram	0.39 (47.56)	0.31 (37.80)	- 20.51	0.41 (47.67)	0.37 (44.04)	-9.76
Green gram	0.13 (15.85)	0.13 (15.86)	0.00	0.14 (16.28)	0.14 (16.67)	0.00
Black gram	0.05 (6.09)	0.05 (6.10)	0.00	0.03 (3.49)	0.05 (5.95)	66.66
Soybean	0.001 (0.12)	0.00 (0.00)	0.00	0.03 (3.49)	0.00 (0.00)	0.00
Other pulses	0.09 (10.98)	0.16 (19.51)	77.77	0.10 (11.63)	0.14 (16.67)	40.00
Total pulses	0.82 (100.00)	0.82 (100.00)	0.00	0.86 (100.00)	0.84 (100.00)	-2.32

(Figures in parentheses indicates percentages to total)

Table 2. Monthly capita^{-1} expenditure on food item in (Rs.) Maharashtra

Food items	Rural			Urban		
	2004-05	2009-10	% change	2004-05	2009-10	% change
Cereals	82.36 (28.30)	129.79 (21.01)	57.58	88.61 (19.90)	161.29 (16.20)	82.02
Pulses	22.44 (7.71)	50.64 (8.20)	125.66	22.34 (5.01)	60.80 (6.11)	172.15
Milk & MP	34.65 (11.91)	61.36 (9.94)	77.08	72.45 (16.27)	136.73 (13.73)	88.72
Edible oil	33.90 (11.65)	51.75 (8.38)	52.65	44.15 (9.92)	66.71 (6.70)	51.09
Meat, fish, egg	14.24 (4.89)	44.04 (7.13)	209.27	26.57 (5.97)	75.85 (7.62)	185.47
Vegetables	28.95 (9.95)	82.56 (13.37)	185.18	45.52 (10.23)	119.46 (12.0)	162.43
Fruits & nuts	17.97 (6.17)	47.58 (7.72)	164.77	34.56 (7.76)	94.12 (9.45)	172.33
Sugar	18.10 (6.22)	32.64 (5.29)	80.33	17.56 (3.94)	32.43 (3.26)	84.68
Salt	1.15 (0.40)	1.94 (0.31)	68.69	1.47 (0.33)	2.30 (0.23)	56.46
Spices	13.49 (4.64)	37.39 (6.05)	177.16	16.07 (3.61)	44.39 (4.46)	176.22
Beverages	23.78 (8.17)	77.81 (12.60)	227.20	75.94 (17.06)	201.52 (20.24)	165.36
Total Food	291.03 (100.00)	617.5 (100.00)	112.17	445.24 (100.00)	995.6 (100.00)	123.60

(Figures in the parentheses indicates percentages to total)

Table 3. Monthly capita^{-1} expenditure on non-food items (Rs.) in Maharashtra

Non Food Items	Rural			Urban		
	2004-05	2009-10	% change	2004-05	2009-10	% change
Pan, tobacco, intoxicants	11.62 (4.23)	18.2 (3.67)	56.62	15.30 (2.24)	18.86 (1.34)	23.26
Fuel & light	61.39 (22.37)	100.93 (20.36)	64.40	113.50 (16.60)	176.50 (12.56)	55.50
Clothing	19.43 (7.08)	39.16 (7.90)	101.54	42.97 (6.28)	94.20 (6.70)	119.22
Footwear	2.87 (1.05)	7.84 (1.58)	173.17	7.41 (1.08)	19.82 (1.41)	167.47
Miscellaneous goods & services, rent, tax	153.35 (55.87)	279.9 (56.45)	82.52	462.33 (67.59)	915.19 (65.13)	97.95
Durable good	25.80 (9.40)	49.78 (10.04)	92.94	42.47 (6.21)	180.69 (12.86)	325.45
Total non-food	274.46 (100.00)	495.81 (100.00)	80.64	684.00 (100.00)	1405.23 (100.00)	105.45

(Figures in the parentheses indicates percentages to total)

Table 4. Estimated expenditure elasticities of demand for different food items

Food items	Rural	Urban
Cereals	0.474	0.627
Pulses	0.371	0.831
Milk and MilK Products	1.245	1.313
Edible oil	0.361	0.788
Egg, Fish, Meat	0.461	0.858
Vegetables	0.710	1.011
Fruits	1.288	0.846
Sugar	0.554	0.363
Salt and spices	0.485	0.450
Beverage	0.472	0.590
Fuel	0.863	0.032
Clothing	2.236	2.458
Footwear	0.536	1.340
Durable goods	-1.162	-1.865

One important point to be noted was that since all expenditure elasticities were less than unity, all the food items were treated as necessities for the food items. Expenditure elasticity was lower for pulses (0.37 & 0.371) in rural and (0.831) in urban area. While the expenditure elasticity was lower for cereals (0.627) in urban area. This was because food is basic necessity for subsistence of life. The expenditure elasticity for milk and milk products and fruits was 1.245 and 1.288 which are higher than the elasticities of food items. This indicate that an increase in income would shift the consumption expenditure from cereals to milk and milk products. Thus, there was a greater appreciation in the importance of milk and milk products in Maharashtra as the income level increase. The similar results were reported by Sharma (2011) i.e. lowest expenditure was observed for cereals (0.51) in rural and 0.53 in urban India. However, the highest expenditure elasticity was observed for pulses and beverages (0.85) in urban and beverages in rural India (1.54). An increase in income would shift the consumption expenditure for cereals to beverages and pulses in urban India and beverages in rural India.

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YIELD, CHEMICAL COMPOSITION AND *IN VITRO* DRY MATTER DIGESTIBILITY OF AZOLLA AT DIFFERENT STAGES OF HARVEST

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ABSTRACT

Azolla (*Azolla pinnata*), one of the high yielding fodder, it is a genus of aquatic fern with world wide distribution in temperate and tropical regions. The present study was conducted during *rabi* season of the year 2013-2014 at Animal Husbandry and Dairy Science Section, College of Agriculture, Nagpur, to study the yield, chemical composition and *in vitro* dry matter digestibility of azolla at different stages of harvest with four treatments in Completely Randomized Block Design. The treatments comprised in different days of harvest (18th, 20th, 22nd and 24th). The results showed that, on the 22nd day of harvest significantly maximum yield of Azolla on wet basis (7.33 tons ha^{-1}) and dry basis (0.47 tons ha^{-1}) was recorded. Crude protein (25.60%), ether extract (4.32%) and total ash (16.36%) were maximum on 22nd day of harvest, dry matter (6.68%) and crude fibre were maximum on 24th day of harvest, whereas nitrogen free extract (45.55%) was significantly maximum on the 18th day of harvest. *In- vitro* dry matter digestibility of Azolla was significantly maximum (72.40 %) on the 22nd day of harvest.

(Key words: Azolla, yield, chemical composition and in vitro dry matter digestibility, days of harvest)

INTRODUCTION

The name *Azoll*a is derived from the two Greek words, *Azo* (to dry) and *Ollyo* (to kill) thus reflecting that the fern is killed by drought. *Azolla* is a genus of six species of aquatic ferns, the only genus in the family Azollaceae. It grows naturally in stagnant water in drains, canals, ponds, rivers and water bodies including marshy lands with temperature range of 15-35°C(Chatterjee *et al.,* 2013).

The rural population of India is more than 833 million, accounting for 69 per cent of total population. Over 70 million rural households own cattle and income from cattle constitute 20 per cent of their total earnings (Giridhar and Rajendran, 2013). In recent times, the share of agricultural residues that form the bulk of cattle feed is declining due to reasons like low straw to grain ratio of high-yielding varieties, use of the combined harvester that cause wastage of straw in the field and also, burning of residues. The nutritional quality of straw is also low (Giridhar and Rajendran, 2013). With shrinking grazing lands and expanding cities, marginal dairy farmers have to depend more and more on commercial cattle feed. Azolla, an aquatic free floating fern, holds promise as a nutritive supplemental feed. It is widely used as a bio-fertilizer in many rice-growing regions of the world (Giridhar and Rajendran, 2013).

Despite India being largest producer of milk, there is acute shortage of feed and fodder for dairy animals. Shortage of dry fodder, green fodder and concentrate has been estimated to be 12 to 14 per cent, 25 to 30 per cent and 30 to 35 per cent, respectively (Mathur *et al*., 2013). The shortage of fodder is, therefore, compensated with the use of readymade commercial feed resulting in increased cost of milk production. The search for alternatives to green fodder and concentrates led to a wonderful plant. *Azolla*, which holds the promise of providing a sustainable feed for livestock (Mathur *et al*., 2013).

Azolla has long been used as a green manure and as a feed for poultry (Basak *et al*., 2002), pig and fish (Nwanna and Falaye, 1997). Feeding azolla to poultry improves the weight of broiler chickens and increases the egg production of layers (Pillai *et al*., 2005). Azolla can also be fed to sheep, goats, pigs and rabbits. In China, cultivation of azolla along with paddy and fish is said to have increased the rice production by 20 per cent and fish production by 30 per cent (Pillai *et al*., 2005).

Azolla cultivation can be easily practiced in minimum area by the dairy farmers. It is very economical to produce. Azolla improves the monthly milk yield by 10 litres animal^{-1} in the low yielders (Giridhar and Rajendran, 2013).It is a nutritive feed supplement for the livestock. The cost of milk production can be reduced by replacing a part of concentrate requirement with Azolla (Giridhar and Rajendran, 2013).

Azolla is rich in protein (25 - 35%), minerals (10 - 15%), amino acids (7 - 10%), vitamins and

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growth promoting intermediates. Its nutritional composition makes it an efficient and ideal feed supplement for livestock, poultry, pigs and fish (Prabina and Kumar, 2010).

Azolla produces more than 4 to 5 times of protein of excellent quality in comparison to lucerne and hybrid napier. Besides this, the bio- mass production is almost 4 to 10 times when compared with hybrid napier and lucerne, respectively. These two parameters are very important to enhance economic livestock production to establish that *Azolla* is reckoned as "The Super Plant" (Mathur *et al.*, 2013).

Azolla also can be used as fodder for livestock and as fish feed because of its high nutrient content. It has protein, vitamins, calcium, phosphorus, iron, copper, magnesium, beta carotene and amino acids. It can be fed to cattle without chaffing because of its small size. Azolla supplies fodder throughout the year if planned and cultivated properly. Azolla grows on water and floats on it with small, closely overlapping scale like leaves with roots in the water (Anonymous, 2012).Keeping the above views in mind a study was undertaken to assess the yield, chemical composition and *in vitro* dry matter digestibility of Azolla.

MATERIALS AND METHODS

A field experiment on Azolla was conducted at an experimental farm of Section of Animal Husbandry and Dairy Science, College of Agriculture, Nagpur. The present investigation was undertaken during the *rabi* season of 2013-2014. The yield, chemical composition and *in-vitro* dry matter digestibility of Azolla under four treatments of harvest at different stages of Azolla in Completely Randomized Design (CRD) with five replications were studied. The treatments comprised of different days of Azolla harvest viz., 18^{th}, 20^{th} , 22^{nd} and 24^{th} day after inoculation.

The culture of Azolla for multiplication was received from Maharashtra Animal and Fishery Science University, Nagpur and about 20 g m^{-2} of fresh Azolla seeds were inoculated into each tank of size 0.91× 0.60×0.30 cm (LBD). Each tank was dosed with 50 g of superphosphate at 15 days interval. Complete harvesting of Azolla was done as per treatments on 18^{th},20^{th}, 22^{nd} and 24^{th} days after inoculation in all the replications. Fresh yield on wet basis was recorded treatment wise at harvest. Immediately after harvesting azolla was washed thoroughly with fresh water and dried in oven till constant weight was stabilised and was stored in plastic containers for yield on dry basis, chemical composition and *in- vitro* dry matter digestibility.

Based on achieving constant dry matter weight of Azolla, treatment wise dry matter yield of Azolla was recorded treatment $plot^{-1}$ $replication^{-1}$ and thus, mean yield $plot^{-1}$ was determined and was then converted into dry matter yield $hectare^{-1}$. From this treatment wise dry matter yield, the required (4) samples of dry matter were ground in feed mill to pass through 1 mm sieve and then stored in airtight containers, labelled and used for further analysis to determine chemical composition i.e. crude protein, crude fibre, ether extract, total ash, nitrogen free extract and *In vitro* dry matter digestibility.

The dry matter, crude protein, crude fibre, total ash and ether extract percentage were determined as per the procedure recommended by BIS (IS: 7874, part I 1975) (Anonymous, 1975). Nitrogen free extract was calculated by subtracting total sum of crude protein, crude fibre, ether extract and total ash from 100 and *in vitro* dry matter digestibility was determined as per the procedure recommended by Barnes *et al.* (1971) using crossbred male animal rumen liquor.

RESULTS AND DISCUSSION

Yield of Azolla

Yield of Azolla obtained from four different days of harvest i.e.18^{th} , 20^{th}, 22^{nd} and 24^{th} day for different parameters i.e. wet basis and dry basis varied significantly($P< 0.05$) (Table 1). The maximum yield of Azolla on wet basis (7.33 tons ha^{-1}) and dry basis (0.47 tons ha^{-1}) was recorded on 22^{nd} day of harvest whereas minimum yield of Azolla was recorded on the 18^{th} day of harvest (5.12 and 0.25 tons ha^{-1} respectively). The next best treatment was the harvest on 24^{th} day after inoculation(6.74 ton ha^{-1} and 0.45 ton ha^{-1} on wet and dry basis respectively) and was followed by the harvest on 20^{th} day after inoculation in which 6.20 ton ha^{-1} wet and 0.34 ton ha^{-1} dry yield was obtained.

Table 1. Yield, chemical composition and *in vitro* dry matter digestibility of Azolla at different stages of harvest

Particulars	Stages						
	18^{th} days of harvest	20^{th} days of harvest	22^{nd} days of harvest	24^{th} days of harvest	Mean	SE±	CD at 5 %
Yield of Azolla (tones ha^{-1})							
Wet basis**	5.12^{d}	6.20^{c}	7.33^{a}	6.74^{b}	6.35	0.16	0.50
Dry basis**	0.25^{d}	0.34^{c}	0.47^{a}	0.45^{b}	0.38	0.01	0.04
Dry matter (% wet basis)	4.94^{d}	5.54^{c}	6.38^{b}	6.68^{a}	5.89	0.09	0.29
Chemical composition (% DM basis)							
Crude Fibre**	13.48^{d}	14.30^{c}	14.98^{b}	15.66^{a}	14.61	0.17	0.51
Crude Protein**	23.09^{d}	24.76^{b}	25.60^{a}	24.30^{c}	24.44	0.15	0.45
Ether Extract**	3.38^{d}	3.98^{b}	4.32^{a}	3.68^{c}	3.84	0.09	0.29
Total Ash**	14.50^{d}	15.70^{b}	16.36^{a}	15.00^{c}	15.39	0.15	0.46
Nitrogen Free Extract**	45.55^{a}	41.26^{c}	38.74^{d}	41.36^{b}	41.73	0.29	0.89
In-vitro Dry Matter Digestibility **	71.36^{c}	71.84^{b}	72.40^{a}	70.62^{d}	71.56	0.14	0.42

**** (P< 0.05)**

Rivaie *et al*. (2013) recorded the yield of Azolla on wet basis as 4, 6 and 8 tons ha^{-1} and Gevrek (2004) recorded the dry basis yield of 1 ton ha^{-1}.

The significantly maximum average dry matter (6.68 per cent) was obtained on 24^{th} day of harvest followed by 22^{nd} day of harvest (6.38 per cent), 20^{th} day of harvest (5.54 per cent) and least on 18^{th} day of harvest (4.94 per cent). The results obtained by Sujatha *et al*.(2013) showed that the dry matter content of Azolla was 6.6 per cent. The present results are in general agreement with them for the harvesting on 24^{th} and 22^{nd} day after inoculation.

Chemical composition of Azolla

Chemical compositions of Azolla obtained from pure dried samples were ground in feed mill to pass through 1 mm sieve.

The significantly maximum average crude fibre (15.66 per cent) was obtained on 24^{th} day of harvest followed by 22^{nd} day of harvest (14.98 %), 20^{th} day of harvest (14.30 %) and least on 18^{th} day of harvest (13.48%). The crude fibre content of Azolla increases as the plant matures due to the lignifications. Results obtained by Sujatha *et al*. (2013) showed that the crude fibre content of Azolla was 14.6±0.54 per cent respectively. Thus, the present results are in general agreement with them.

The maximum average crude protein, ether extract and total ash in Azolla were obtained on 22^{nd} day of harvest (25.60, 4.32 and 16.36 per cent respectively) followed by 20^{th} day of harvest (24.76, 3.98 and 15.70 per cent respectively), 24^{th} day of harvest (24.30, 3.68 and 15.00 per cent respectively) and 18^{th} day of harvest (23.09, 3.38 and 14.50 per cent respectively).The findings of the present experiment corroborate well with the findings of Chatterjee *et al*.(2013), who revealed that crude protein content of Azolla ranged from 22 to 26 per cent, while Indira *et al*.(2009), reported that the ether extract and total ash were in the range from 2.73-4.6 per cent and 14.80-15.30 per cent respectively.

The average reported values of nitrogen free extract were maximum on the 18^{th} day of harvest (45.55 per cent) followed by 24^{th} days of harvest (41.36 per cent), 20^{th} day of harvest (41.26 per cent) and 22^{nd} day of harvest (38.74 per cent). Parashuramulu *et al.*(2013) reported 47.30 per cent nitrogen free extract content. Their value is slightly more than the values found in present investigation.

***In vitro* dry matter digestibility**

In- vitro dry matter digestibility of Azolla at different stages of harvest differed significantly. The highest value of 72.40 per cent was recorded on 22^{nd} day of harvest followed by 20^{th} day of harvest (71.84 per cent), 18^{th} day of harvest (71.36 per cent) and 24^{th} day of harvest (70.62 per cent). Parashuramulu and Nagalakshmi (2012) reported 72.30 per cent in vitro dry matter digestibility of Azolla. Thus, the present results are in general agreement with them.

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EXPLOITATION OF GENETIC VARIABILITY IN EARLY SEGREGATING GENERATION OF MUSTARD (*Brassica juncea* L.)

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ABSTRACT

The genetic study of F_2 crosses in mustard was undertaken with a view to identify the potential F_2 crosses for their use in individual plant selection. Three F_2 crosses were C-I (Varuna X RH-819), C-II (Ashirwad X RH-819) and C-III (ACN-9 X Geeta) raised during *rabi* 2012-2013 and data were recorded on six characters i.e. days to first flower, days to maturity, plant height, number of primary branches plant^{-1}, number of siliqua plant^{-1} and seed yield plant^{-1}. GCV and PCV were higher for number of primary branches plant^{-1} and GCV was moderate for number of siliqua plant^{-1} in C-II and C-III and for seed yield plant^{-1} in all the three crosses. High heritability were observed for all the six characters in all the crosses. The traits like number of siliqua plant^{-1} in all the crosses and plant height in C-II expressed high genetic advance with high heritability. This suggested that selection would be effective in improving these traits. Rest of the traits had high heritability with low genetic advance indicating the influence of environments on these traits. The correlation studies at genotypic level revealed positive significant association of seed yield plant^{-1} with number of siliqua plant^{-1} and with number of primary branches plant^{-1} in all the crosses studied and with plant height in some cases. The study on path analysis indicated the significance of number of siliqua plant^{-1} and number of primary branches plant^{-1} as the promising characters to increase seed yield plant^{-1} either directly or indirectly.

(Key worlds: F_2 population, GCV, PCV, heritability, genetic advance, genotypic correlation co-efficient, path coefficient analysis)

INTRODUCTION

Mustard (*Brassica juncea*) is a second important oil seed crop in India after groundnut in area and production. Oil content of Indian mustard seed varies from 30 to 48%. In Maharashtra the sole crop of mustard is seldom grown but with its low cost of production and high yielding potential it can be grown in Vidarbha. Generation of variability is a pre-requisite either for development of varieties or inbred lines followed by hybrid isolation. Generally amount of variability generated is more in the early segregating generations as compared to later generations. It is established fact that the probability of isolating an outstanding inbred line depends primarily on two factors (1) the proportion of superior genotypes in the base population from which inbreds are isolated and (2) the effectiveness of selection during inbreeding process in increasing frequency of desirable genes or gene combinations. Selection based on multiple traits is always better than selection based on yield alone. As we know that yield is a quantitative character controlled by many genes, therefore an adequate knowledge about the magnitude and degree of association of yield with its attributing characters is of great significance to the breeders, through which they can clearly understand the strength of correlated traits, when they have to exercise selection for simultaneous improvement of more than one character. Hence, this study was undertaken to exploit the variability of the segregating generation.

MATERIALS AND METHODS

The experimental material comprised of three F_2 crosses C-I (Varuna X RH-819), C-II (Ashirwad X RH-819) and C-III (ACN-9 X Geeta) which were grown during *rabi* 2012 in randomized complete block design with two replications with a spacing of 45 x 15 cm^2 at the experimental farm of Agricultural Botany Section, College of Agriculture, Nagpur. Each replication consisted of 15 rows for F_2 generation in each cross. The observations were recorded on 250 plants from each individual F_2 cross for the following six characters. i.e. days to first flower, days to maturity, plant height (cm), number of primary branches plant^{-1}, number of siliqua plant^{-1} and seed yield plant^{-1}.The data recorded were subjected to the statistical and biometrical analysis. The estimation of genetic parameters in each F_2 population were done by the method given by Burton and Devane (1953), Hanson *et al.*,1956, Robinson *et al.,* 1949, Johnson *et al.* (1955), Sharma (1998), Wright (1921) and Dewey and Lu (1959).

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RESULTS AND DISCUSSION

The measure of effectiveness with which selection can be expected to exploit the genetic variability is the measure of expected progress under selection and it depends on the magnitude of genetic variation in the population, heritability and genetic advance. Therefore, it is imperative to estimate these parameters in the segregating population to determine the progress under selection and hence, were estimated. The results obtained from the present study are discussed under the following heads.

Mean and range for different characters

Minimum days taken for first flowering were observed in C-III (39.97 days), C-II (44.13 days) and C-I (49.71 days) respectively reported in table 1. A large proportion of plants in F_2 flowered between 46-50 days, 41-45 days and 36-40 days in C-I, C-II and C-III respectively. Minimum days taken for maturity was observed in 97.18, 98.68 and 112.71 days generations in C-III, C-II and C-I respectively. A majority of plants in F_2 matured between 111-115 days, 101-105 days and 96-100 days in C-I , C-II and C-III respectively. The highest mean plant height was observed in C-II (162.50 cm), C-III (153.79 cm) and C-I (132.67 cm) crosses. The majority of plants in F_2 ranged from 130.10 to 150 cm in C-I, 150.10 to 170 cm in C-II and 130.10 to 150 cm and 150.10 to 170 cm in C-III. The mean number of branches plant^{-1} was higher in C-II (4.66), C-III (3.47)and C-I (2.95). A large proportion of plants in F_2 ranged from 3-4 in C-I, 3-4 and 5-6 in C-II and 3-4 in C-III. The highest mean number of siliqua plant^{-1} was observed in C-II (201.24), C-III (168.24) and C-I (131.20). A large proportion of the plants in F_2 ranged from 101-150 and 151-200 in C-I, 151-200 and 201-250 in C-II and 110-150 and 151-200 in C-III. The highest mean seed yield plant^{-1} was observed in C-II (7.04 g), C-III (5.89 g) and C-I (4.59 g) crosses. A large proportion of the plants in F_2 ranged between 3.01 - 6.00 g in C-I, 6.01 - 9.00 g in C-II and 3.01 - 6.00 g, 6.01 - 9.00 g in C-III.

Genetic variability parameters

The estimates of PCV and GCV were low and heritability estimates were high (>55%) with low genetic advance for all the crosses in case of days to first flower as observed from table 2. The estimates of GCV and PCV were low and heritability estimates were high (>57%) along with low genetic advance for days to maturity. For plant height the estimates of GCV and PCV were low and higher estimates of heritability (>33%) in all the three crosses along with higher genetic advance was observed in C-II (18.15%).The GCV and PCV estimates were comparatively higher for number of primary branches plant^{-1} in C-I (14.1%, 28.1%), C-II (28.68%, 35.9%) and in C-III (25.01%, 29.78%) and heritability estimates are higher (>25%) and genetic advance was low in all the generations of all crosses. In case of number of siliqua plant^{-1} the estimates of GCV and PCV were higher in C-I whereas in C-II and C-III, GCV was moderate and higher estimates of heritability (>66%) and genetic advance (>37%) was recorded in all the crosses. The estimates of GCV for seed yield plant^{-1} was moderate in C-I, C-II and C-III and low PCV was observed in all the crosses and higher estimates of heritability (>47%) coupled with lower genetic advance was observed for seed yield plant^{-1} in all the crosses.

Better scope for improvement through selection existed for different characters and was confirmed through phenotypic and genotypic coefficient of variation (PCV and GCV) in this experimental material. The results of the present study revealed that GCV and PCV were higher for number of primary branches plant^{-1} and GCV was moderate for number of siliqua plant^{-1} in C-II and C-III and for seed yield plant^{-1} in all the three crosses. The results were in conformity with Patel *et al.* (2006) for number of siliqua plant^{-1} and seed yield plant^{-1}. High heritability were observed for all the six characters in all the crosses. Similar results of high heritability were also observed by Patel *et al*. (2006) for days to maturity, plant height, number of primary branches plant^{-1}, number of siliqua plant^{-1} and seed yield plant^{-1} in mustard. Estimated genetic advance revealed relative difference among the characters studied. The traits like number of siliqua plant^{-1} in all the crosses and plant height in C-II expressed high genetic advance with high heritability. This suggested that selection would be effective in improving these traits. Rest of the traits had high heritability with low genetic advance indicating the influence of environments on these traits. In addition to this, it is also expected to help in maintaining a greater variability for selection to be effective for longer

Table 1. Mean and range for different characters in three F_2 crosses of mustard

Characters	C I		C II		C III	
	Mean	Range	Mean	Range	Mean	Range
Days to first flower	49.71 ± 1.75	44 - 52	44.13 ± 1.41	41 - 46	39.97 ± 1.56	32 - 42
Days to maturity	112.71 ± 2.99	107 - 118	98.68 ± 1.87	96 - 102	97.18 ± 1.59	93 - 100
Plant height	132.67 ± 4.86	125.00 - 148.60	162.50 ± 11.97	140.00 - 183.00	153.79 ± 11.73	135 - 178
Number of primary branches plant^{-1}	2.95 ± 0.82	2 - 4	4.66 ± 1.67	2 - 7	3.47 ± 1.03	2 - 5
Number of siliqua plant^{-1}	131.20 ± 31.94	84 - 186	201.24 ± 42.62	120 - 275	168.24 ± 33.65	106 - 234
Seed yield plant^{-1}	4.59 ± 1.11	2.86 - 06.51	7.04 ± 1.49	4.20 - 09.63	5.89 ± 1.18	3.71 - 08.19

Table 2. Estimates of genetic variability parameters for different characters in F_2, F_3 and BIP populations of mustard

Characters	C-I				C-II				C-III			
	GCV (%)	PCV (%)	h^2(bs) (%)	GA (10%)	GCV (%)	PCV (%)	h^2(bs) (%)	GA (10%)	GCV (%)	PCV (%)	h^2(bs) (%)	GA (10%)
Days to first flower	2.78	3.53	62.21	1.92	2.39	3.19	55.96	1.38	3.05	3.91	60.80	1.67
Days to maturity	2.34	2.65	78.17	4.12	1.44	1.89	58.23	1.91	1.24	1.64	57.22	1.60
Plant height	2.13	3.66	33.92	2.90	6.83	7.36	86.11	18.15	4.85	7.63	40.45	8.35
Number of primary branches plant^{-1}	14.10	28.10	25.18	0.36	28.68	35.9	63.82	1.88	25.01	29.78	70.54	1.28
Number of siliqua plant^{-1}	19.82	24.34	66.63	37.29	20.00	21.18	89.22	66.93	16.39	20.00	67.13	39.76
Seed yield plant^{-1}	16.79	24.33	47.67	0.93	14.84	21.23	48.88	1.28	15.66	20.06	60.95	1.26

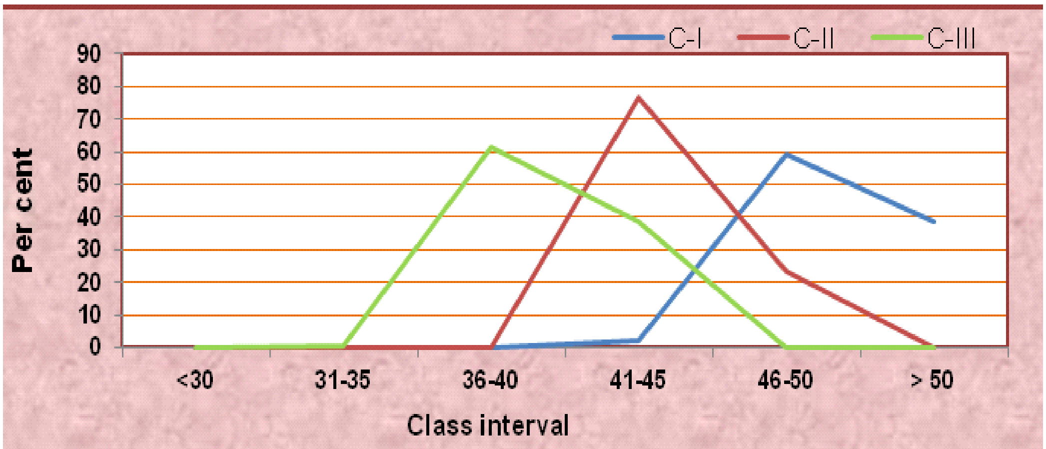
Table 3. Genotypic correlation coefficient for different characters with seed yield plant^{-1}

Characters	C-I	C-II	C-III
Days to first flower	- 0.1321	0.1861*	- 0.0193
Days to maturity	- 0.7654**	0.0753	0.1629**
Plant height	- 0.9855**	0.9136**	0.9798**
Number of primary branches plant^{-1}	0.9138**	0.9938**	0.9456**
Number of siliqua plant^{-1}	0.9998**	0.9811**	0.9999**

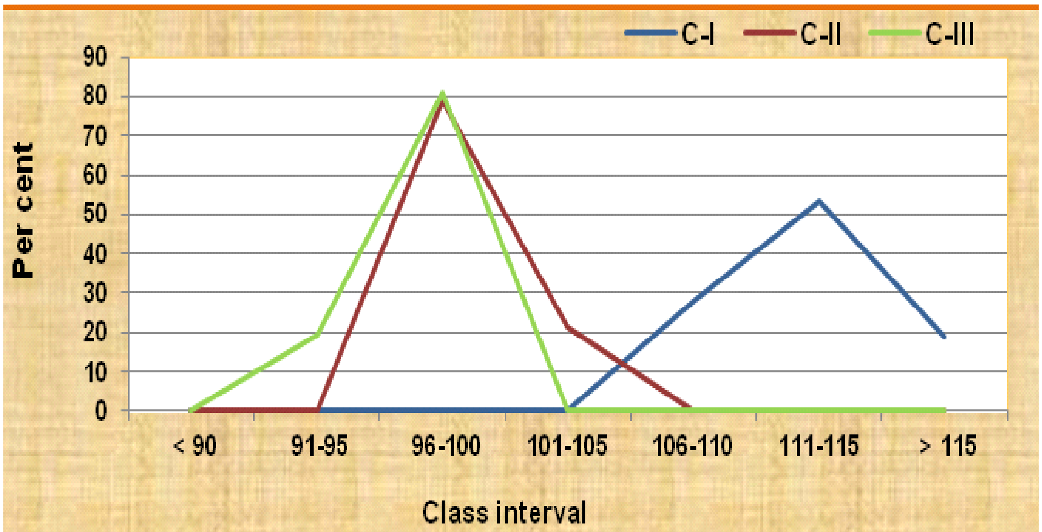
*, ** = significant at 5% and 1% level respectively.

Table 4. Estimates of direct and indirect effects of different traits on seed yield plant^{-1} in mustard

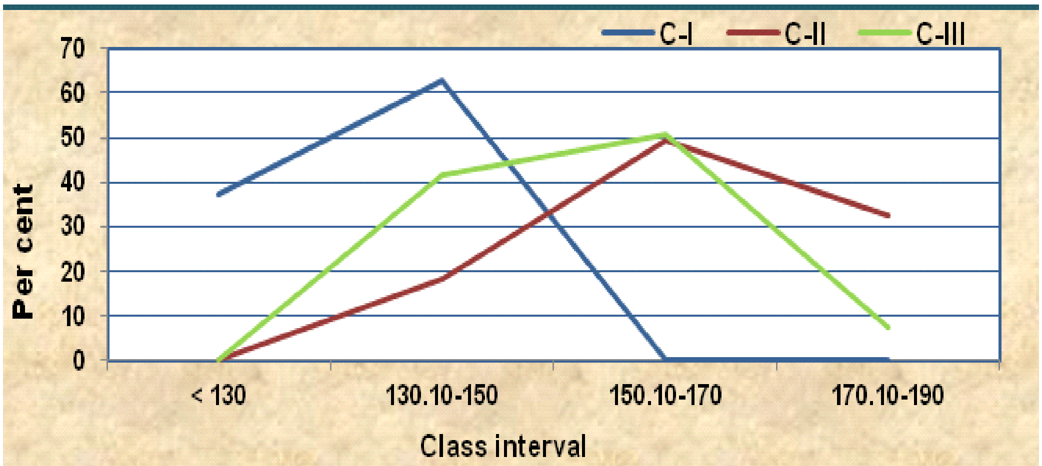
Cross	Characters	Genotypic correlation	Direct effect	% Direct effect	Total indirect effect	% indirect effect	Major contributing characters with their percentage
CI	Days to first flower	- 0.1321	-0.2463	186.45	0.1142	-86.45	-
	Days to maturity	- 0.7654**	-0.5361	70.04	-0.2292	29.95	Number of primary branches plant^{-1} (43.96) Number of siliqua plant^{-1} (36.51)
	Plant height	- 0.9855**	-0.7379	74.87	-0.2475	25.12	Number of siliqua plant^{-1} (27.98) Number of primary branches plant^{-1} (21.94)
	Number of primary branches plant^{-1}	0.9138**	0.3699	40.48	0.5439	59.51	Days to maturity (53.36) Plant height (47.21)
	Number of siliqua plant^{-1}	0.9998**	0.3692	36.92	0.6306	63.07	Plant height (55.12) Days to maturity (40.59)
CII	Days to first flower	0.1861*	-0.0141	-7.57	0.2002	107.57	Number of primary branches plant^{-1} (58.58) Number of siliqua plant^{-1} (46.57) Days to maturity (13.09)
	Days to maturity	0.0753	-0.0365	-48.48	0.1119	148.48	Number of primary branches plant^{-1} (102.72) Number of siliqua plant^{-1} (48.53) Days to first flower (12.47)
	Plant height	0.9136**	- 0.1256	-13.75	1.0393	113.75	Number of primary branches plant^{-1} (65.01) Number of siliqua plant^{-1} (49.34)
	Number of primary branches plant^{-1}	0.9938**	0.6633	66.73	0.3305	33.26	Number of siliqua plant^{-1} (48.53)
	Number of siliqua plant^{-1}	0.9811**	0.4508	45.95	0.5302	54.04	Number of primary branches plant^{-1} (102.72)
CIII	Days to first flower	- 0.0193	0.0373	-192.68	-0.0567	292.68	Number of primary branches plant^{-1} (202.83) Plant height (79.19)
	Days to maturity	0.1629**	-0.0138	-8.49	0.1767	108.49	Plant height (61.83), Number of primary branches plant^{-1} (28.89) Number of siliqua plant^{-1} (17.62)
	Plant height	0.9798**	0.5780	58.99	0.4017	41.00	Number of primary branches plant^{-1} (24.04) Number of siliqua plant^{-1} (18.28)
	Number of primary branches plant^{-1}	0.9456**	0.2630	27.81	0.6826	72.18	Number of primary branches plant^{-1} (27.81) Number of siliqua plant^{-1} (17.30)
	Number of siliqua plant^{-1}	0.9999**	0.1730	17.30	0.8269	82.69	Plant height (56.67) Number of primary branches plant^{-1} (26.29)



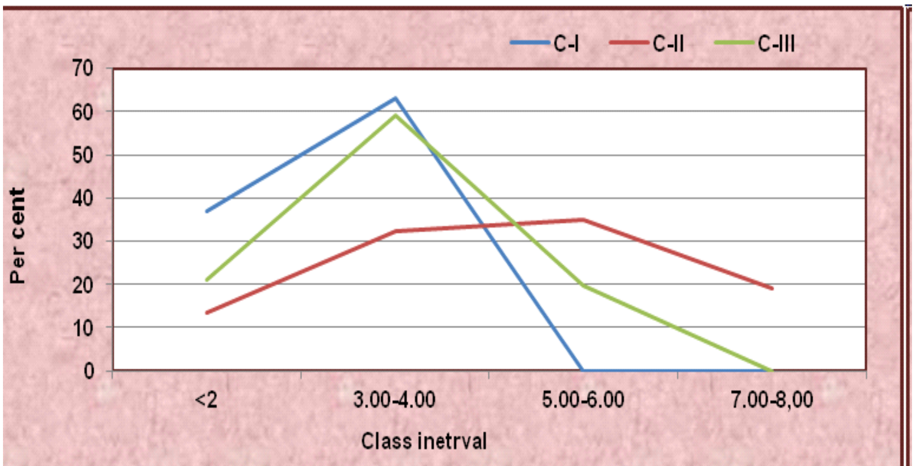
Frequency distribution of days to first flower in three crosses of mustard



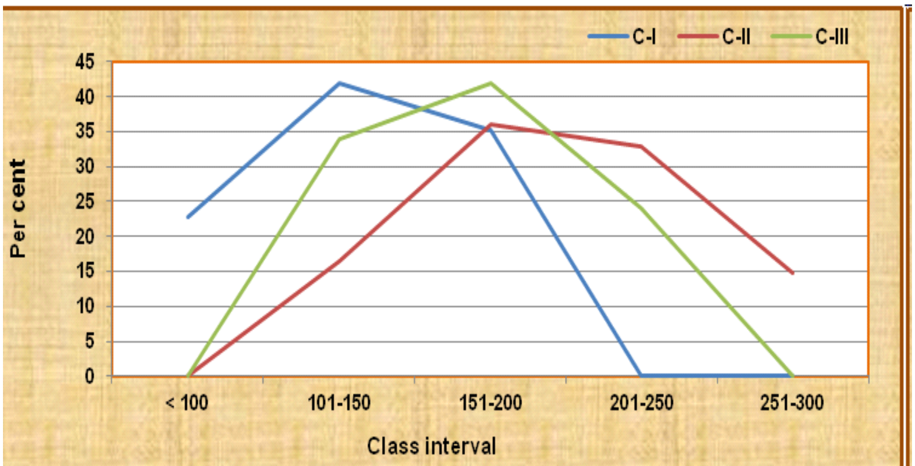
Frequency distribution of days to maturity in three crosses of mustard



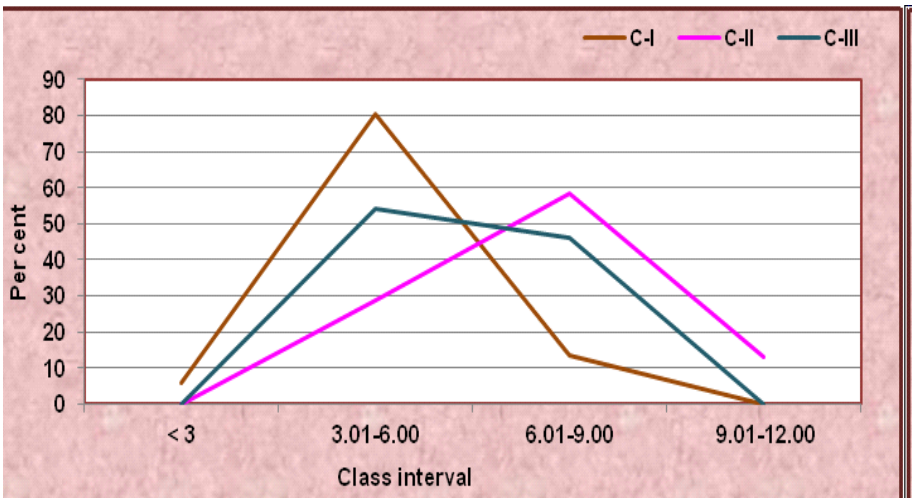
Frequency distribution of plant height in three crosses of mustard



Frequency distribution of number of primary branches plant^{-1} in three crosses of mustard



Frequency distribution of number of siliqua plant^{-1} in three crosses of mustard



Frequency distribution of seed yield plant^{-1} in three crosses of mustard period in crops like mustard where lack of variability has been implicated as one of the important causes for limited progress.

Interrelationship of seed yield plant^{-1} with component traits

The knowledge of interrelationship of plant characters with seed yield plant^{-1} also help the breeders in improvement of a complex character like seed yield for which direct selection is not much effective. Recombination in segregating generation leads to formation of new pattern of association of linked characters, hence the genotypic correlation co-efficient of different characters with seed yield plant^{-1} were estimated and presented in table 3.

It was observed from the correlation study that strength and direction of correlation in different character combinations depends on the nature of the experimental material and environmental condition in which they have been studied. The correlation studies at genotypic level carried out in three F_2 crosses in the existing agroclimatic situation of Nagpur revealed positive significant association of seed yield plant^{-1} with number of siliqua plant^{-1} and with number of primary branches plant^{-1} in all the crosses studied. Plant height was also associated with seed yield plant^{-1} in some cases. This indicates that an increase in any one of these three characters especially number of siliqua plant^{-1} and number of primary branches plant^{-1} can result in increase in the seed yield of mustard. Hence, it is stressed that more emphasis should be given for number of siliqua plant^{-1} and number of primary branches plant^{-1} as they showed very high degree of positive association with seed yield plant^{-1}. Similar results of positive significant correlation of number of siliqua plant^{-1}, number of primary branches plant^{-1} with seed yield plant^{-1} were also reported by Patel *et al*. (2000), Badsra and Choudhary (2001), Mahla *et al*. (2003) and Kardam and Singh (2005) in mustard.

Path co-efficient analysis

Path analysis studies carried out in three crosses revealed that seed yield plant^{-1} was highly influenced directly by number of siliqua plant^{-1} followed by number of primary branches plant^{-1} in all the crosses as observed from table 4. Similar to this results direct effect of number of siliqua plant^{-1} on seed yield was also reported by Patel *et al*. (2000), Badsra and Choudhary (2001), Singh (2004), Kardam and Singh *et al.* (2005) in mustard. Number of primary branches plant^{-1} was found to be the next significant character. This study on path analysis indicated the significance of number of siliqua plant^{-1} and number of primary branches plant^{-1} as the promising characters to increase seed yield plant^{-1} either directly or indirectly.

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EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON YIELD AND CHANGES IN SOIL FERTILITY STATUS UNDER SORGHUM BASED INTERCROPPING SYSTEM

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ABSTRACT

The field experiment was conducted to study the effect of integrated nutrient management on yield and changes in soil fertility status under sorghum based intercropping system during *kharif* season of 2010-11 at the farm of Agronomy section, College of Agriculture, Nagpur. The experiment was laid out in split plot design with three nutrient supply combinations replicated four times. Basically, four main cropping systems viz., C_1-(sole sorghum), C_2-(sorghum + green gram), C_3-(sorghum + black gram), C_4-(sorghum + soybean) and three sub treatments viz., N1-RDF (80:40:40 kg NPK ha^{-1}), N_2- 75% RDF (60:30:30 kg NPK ha^{-1}) + 25%N through vermicompost + *Azospirillum* + PSB , N_3-50% RDF (40:20:20 kg NPK ha^{-1}) + 25% N through vermicompost + *Azospirillu*m + PSB were selected. Soil pH, electrical conductivity and organic carbon were improved with the application of 75%RDF + 25% N through vermicompost + *Azospirillum* + PSB. The highest available N status of soil (284.22 kg ha^{-1}) was recorded under sorghum + soybean intercropping system in the treatment of 75% RDF + 25% N through vermicompost + *Azospirillum* + PSB which remained statistically at par in sorghum + green gram (273.98 kg ha^{-1}) intercropping system under same nutrient supply system. The lowest value of available N status of soil (239.83 kg ha^{-1}) was registered under sole sorghum with the application of 100% RDF. Observations showed that the highest sorghum equivalent grain yield (35.94 q ha^{-1}) was obtained under 100% RDF followed by 75% RDF + 25% N (34.65 q ha^{-1}) was obtained under 100% RDF followed by 75% RDF + 25% N (34.65 q ha^{-1}) through vermicompost + *Azospirillu*m + PSB whereas the highest sorghum equivalent straw yield (413.75 q ha^{-1}) was recorded under 50% RDF + 25% N through vermicompost + *Azospirillum* + PSB. Inclusion of leguminous crop in cropping system helps to improve the soil quality through maintenance of physico-chemical properties of the soil. The findings showed that sorghum + soybean intercropping system with 75% RDF in conjunction with vermicompost and biofertilizers proved superior over sole cropping of sorghum for maintaining fertility status of soil.

(Key words: Sorghum based intercropping, INM Vertisol, grain and straw yield, soil fertility status)

INTRODUCTION

Sorghum (*Sorghum bicolor*) ranks the third in the major food crops in India whereas it is the fourth food grain crop of the world. Maharashtra is the highest contributor in respect of acreage and production. In India it is grown over an area of 7.53 million hectares with the production of 7.25 million tones with an average productivity of 962 kg ha^{-1} (Anonymous, 2010). The low productivity of sorghum has been attributed to the fact that large area is under rainfed situation. Under such situation, inclusion of grain legumes as intercrops can increases the productivity of the system (Elmore and Jackobs, 1986). Introducing or improving an intercropping system with these crops can significantly benefit the small holders by increasing yield on a limited amount of land, reducing risk of total crop failure, and maximizing the efficiency of labour utilization.

Integrated nutrient management is actually the technical managerial component of achieving the objective of integrated Plant Nutrient Supply System under farm situation (Mader *et al.*, 2002). Integrated nutrient management helps in the maintenance of soil fertility and it supplies plant nutrient to an optimum level for sustaining desired crop productivity through optimization of benefits from all possible sources of plant nutrients in an integrated manner (Blaise and Prasad, 2005). The appropriate combination of chemical fertilizer, organic manures, crop residues and bio-fertilizers varies according to the system of land use considering ecological, social and economic condition. The use of organic material is much more useful in maintaining soil fertility and especially useful in improving the physical, chemical and biological properties of soils which contribute in adequate plant nutrient supply (Rathore and Rathore, 2006).

Intercropping is an important agronomic practice to insure against the failure of crops owing to unexpected abiotic and biotic stresses. It results in ensuring some yield under such situations in one or other component crops. Cereal-legume intercropping plays an impotant role in subsistence food production in both developed and developing countries, epecially in situations of limited water resources (Tsubo *et al.,*

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2005). The reasons are mainly that resources such as water, light and nutrients can be utilized more effectively than in the respective sole cropping systems (Li *et al.*, 2006). In recent years, the significance of intercropping of cereals in leguminous crops has been recognized by many researchers due to complementary effect of each other in growth habit, nutrient management and quality of the produce. While legumes are able to meet their nitrogen requirement through biological nitrogen fixation, a part of it is also made available to companion cereal intercrops. Further, the slow growth and wider space between the cereals in the initial stages of crop growth is fully exploited by the short statured legume like mungbean, urdbean, soybean etc. The deep and tap root system of legumes further complement the shallow and fibrous root system of cereals leading to greater below ground and above ground adjustment in exploiting the rhizosphere as well as micro environment above the soil surface. The cereals too get benefited in the intercropping system with legumes by way of lesser competition for resoruces owing to their diversified growth requirements (Layek *et al.,* 2012). Integrated nutrient management is studied in sole cropping but under intercropping system its study is limited. Hence, the study on the effect of integrated nutrient management on yield and changes in soil fertility status under sorghum based intercropping system was undertaken.

MATERIALS AND METHODS

The field experiement was conducted to study the effect of intergrated nutrient management on yield and fertility status of soil in sorghum based intercropping system during *kharif* season of 2010-11 at the farm of Agronomy section, College of Agriculture, Nagpur. The soil of the experimental field was clayey in texture and clay per cent was 56.1%. The chemical analysis indicated that the soil was moderately alkaline in nature (pH 8.09), organic carbon content (4.75 g kg^{-1}), electrical conductivity (0.30 d sm^{-1}), low in available nitrogen (230.12 kg ha^{-1}), medium in available phosphorus (14.30 kg ha^{-1}) and very high in available potassium (326 kg ha^{-1}).

The experiment was laid out in split plot design with three nutrient supply combinations and four replications. The treatment comprised of four main cropping systems viz., C_1-sole sorghum, C_2-Sorghum + green gram, C_3- sorghum + black gram, C4-sorghum + soybean and three sub-treatment viz., N_1-RDF (80:40:40 kg NPK ha^{-1}), N_2- 75% RDF (60:30:30 kg NPK ha^{-1}) + 25N through vermicompost +*Azospirillum* + PSB, N_3-50% RDF (40:20:20kg NPK ha^{-1}) + 25% N through vermicompost + *Azospirillum* + PSB. The nitrogen was applied in the form of urea in 2 splits. Half dose of N, full dose of phosphorus and potash were applied as single super phosphate and muriate of potash at the time of sowing as per treatments. Remaining half dose of N was applied on 45 DAS. Vermicompost was added @ 1.66 t ha^{-1} at the time of sowing to meet 25% N requirement. In inoculation treatment seeds were treated with *Azospirillum* and phosphate solubilising bacteria both @ 25 g kg^{-1} seed. The intercrop seed was treated with *Rhizobium* @ 25 g ka^{-1} of seed. No fertilizer dose was applied in intercrops. Sorghum CSH-14 was sown @ 12 kg ha^{-1} with a spacing of 45 cm x 10 cm. Green gram TAU-1, black gram AKM-8802 and soybean JS-335 were sown with a spacing of 45 cm x 10 cm as per intercropping system. Sowing of all crops was taken up during the monsoon season on 2nd July 2010.

The grain and straw yield of all crops were recorded at harvest. Sorghum equivalent yield (SEY) was worked out by taking into account price of produce of individual intercrops and sorghum to compare the crops grown in intercropping situation.

$$\text{Sorghum equivalent yield} = \frac{\text{Yield of intercrop x market price of intercrop}}{\text{Market price of sorghum}}$$

Soil samples were collected from 0-15 cm depth after harvesting of crops. Soil samples were analyzed for pH (1:2.5 soil: water suspension, Piper, 1966), electrical conductivity by using condiuctivity bridge (Piper, 1966), organic carbon by wet oxidation method (Walkley and Black, 1934). available nitrogen by alkaline permanganate method (Subbiah and Asija, 1956), available phosphorus was extracted from soil by 0.5 N sodium bicarbonate (pH 8.5) determined by spectrophotometer (Olsen *et al.,* 1954). available potassium was extracted from soil with 1N NH_4OAC solution (pH 7) by flame photometer (Jackson, 1967) and available sulphur by using turbidimeteric method (Williams and Steinbergs,1959).

RESULTS AND DISCUSSION

Sorghum equivalent yield of grain and straw

The data pertaining grain and straw equivalent yield of sorghum as affected by cropping system and nutrient supply system are depicted in table 1. The results indicated that the sorghum equivalent yield of grain was found significant due to cropping system. Whereas, the sorghum equivalent yield of straw was found non-significant. However, the higher (37.31 q ha^{-1}) sorghum equivalent grain yield was recorded in sorhum + soybean intercropping system than that of the sole cropping. Kshitaria *et al.* (1996) observed that sorghum grain and fodder yield was the highest in sole sorghum treatment as compared to sorghum equivalent grain yield was recorded in sorghum + pigeonpea intercropping than sole cropping. Among the nutrient supply system, the results with respect to sorghum equivalent grain yield were found significant, whereas sorghum equivalent straw yield was found non-significant.

The highest sorghum equivalent grain yield (35.94 q ha^{-1}) was observed in 100% RDF followed by 75% RDF + 25% N through vermicompost + *Azospirillum* + PSB (34.65 q ha^{-1}). Gable *et al.* (2008) studied on all the growth parameters and yield of maize crop which were significantly influenced by the various integrated nutrient management treatments and were significantly the highest with 100% RDF followed by 75% RDF + 25% N through leucaena lopping + biofertilizers. The balance use of fertilizer either alone or in combination with organic manure and seed inoculants is necessary for sustaining soil fertility and productivity of crops (Tiwari *et al.,* 2002 and Thakur *et al*., 2011). Interaction effect between main plot cropping system and sub plot nutrient supply system on sorghum equivalent yield of grain and straw was found non-significant.

Effect of cropping system on N,P,K and S status of soil

The data on available N,P, K and S status of soil after harvest of sorghum are presented in table 2. Results indicated that the status of available N,P, K and S were found significantly improved due to various cropping systems. The highest available N (267.32 kg ha-1), available P (25.70 kg ha^{-1}), available K (356.89 kg ha^{-1}) and available S (17.65 kg ha^{-1}) were found in sorghum + soybean intercropping system followed by sorghum + green gram.

Effect of nutrient supply on N,P,K and S status of soil

The available N,P,K and S status of soil were increased significantly due to different nutrient supply system. The highest available N (270.42 kg ha^{-1}), available P (28.35 kg ha^{-1}), available K (360.02 kg ha^{-1}) and available S (17.58 kg ha^{-1}) were recorded in the soil in the treatment of 75% RDF + 25% N through vermicompost + *Azospirillum* + PSB. The results clearly indicated the benefits of available N, P, K and S from the above nutrient supply system which comprised the use of inorganic, organic and biofertilizers. Rather and Sharma (2009) reported that the treatment comprising of 100% RDF + vermicompost + zinc + PSB increased the available N from 197.0 to 219.0 kg ha^{-1}, available P from 13.0 to 19.0 kg ha^{-1} and available K from 113.0 to130.4 kg ha^{-1}. Thakur and Sawarkar (2009) reported that maximum build up of S was recorded in plots that had received 100% RDF + FYM Khambalkar *et al.* (2012) reported that biofertilizer and FYM are not only a substitute, but a supplement to chemical fertilizers which result in build up of organic carbon, available N,P,K and sustain soil pH and EC as compared to chemical fertilizer alone, sub optimal dose treatment and unfertilized plot.

Interaction effect of cropping system and nutrient supply on N,P,K and S status of soil

The interaction effect between cropping system and nutrient supply system had significant effect with respect of available N, P and K status of soil, whereas in available S it was found statistically non-significant. The highest available N status of soil (284.22 kg ha^{-1}) was recorded under sorghum + soybean intercropping system in the treatment of 75% RDF + 25% N through vermicompost + *Azospirillum* + PSB which remained statistically at par in sorghum + green gram (273.98 kg ha^{-1}) intercropping system under same nutrient supply system. The lowest value of available N status of soil (239.83 kg ha^{-1}) was registered under sole sorghum with the application of 100% RDF.

The highest available P (29.33 kg ha^{-1}) status of soil were recorded under sorghum + soybean % intercropping system in the treatment containing 75% RDF + 25% N through vermicompost + *Azospirillum* + PSB which remained statistically at par with available P (28.48 kg ha^{-1}) and available K (364.14 kg ha^{-1}) in sorghum + black gram intercropping system under the same nutrient supply whereas the lowest value of available P (24.11 kg ha^{-1}) and available K (325.85 kg ha^{-1}) were recorded under sole sorghum in the treatment of 100% RDF. This clearly shows that the continuous inclusion of leguminous crops along with inorganic, organic and biofertilizers registered more available N status in soil than inorganic treatment in cereals. Sharma and Bajpai (1986) reported that the available N in soil increased after *rabi* legumes (pea, chickpea) and *kharif* legumes (Green gram and black gram) as compared to those under their respective cereal crops in *rabi* wheat, in *kharif* sorghum and fallow.

Effect of cropping system on chemical properties

The data presented in table 4 revealed that the pH and electrical conductivity of soil was found non-significant with cropping system whereas the organic carbon content of soil was found significant with cropping system. The highest organic carbon content (6.02 g kg^{-1}) was observed in sorghum + soybean intercropping followed by sorghum + black gram (5.54 g kg^{-1}).

Effect of nutrient supply system on chemical properties

The pH and electrical conductivity of soil were found non-significant, while organic carbon content was found significant when correalated with nutrient supply. The highest organic carbon status (5.93 g kg^{-1}) was noticed under the treatment of 75% RDF + 25% N through vermicompost + *Azospirillum* + PSB. Babhulkar *et al.* (2000) reported that organic carbon content of soil (6.2 g kg^{-1}) increased slightly with the application of FYM @ 7.5 t ha^{-1} along with half dose of N and P to soybean over the RDF (5.3 g kg^{-1}) after the completion of 5 year in soybean based cropping system. The increased organic carbon content might be due to use of chemical fertilizer plus direct incorporation of organic matter through FYM which attributed the higher contribution of biomass to the soil in the form of better root growth, crop stubbles biomass and residues (Katyal *et al.,* 2003 and Gathala *et al.,* 2007).

Interaction effect of cropping system and nutrient supply system on chemical properties of soil

The interaction effect between cropping system and nutrient supply system on chemical properties of soil was found non-significant with respect to pH and electrical conductivity, while organic carbon content in soil was found significant. The highest organic carbon content (6.5 g kg^{-1}) was found under sorghum + soybean intercropping system in the treatment containing 75% RDF + 25% N through vermicompost + *Azospirillum* + PSB. Sharma and Bajpai (1986) also reported that the organic carbon content of soil increased due to cultivation of leguminous crop (0.41%) as compared to soil under cereal (0.38%) and fallow (0.36%) Ravankar *et al.* (2000) reported that the addition of 50% N through manure increased the organic carbon content from 0.71% to 0.73%. Khambalkar *et al.* (2012) reported that biofertilizer and FYM are not only a substitute, but a supplement to chemical fertilizers in build up of organic carbon and in sustaining soil pH and EC as compared to chemical fertilizer alone.

It is inferred from the above revelation that continuous use of inorganic fertilizers along with organic and biofertilizers favourable influenced grain yield, uptake of nutrients, organic carbon and available nutrients, over inorganic fertilizer alone. Inclusion of leguminous crops in cropping system can check the resource degradation and sustain the productivity of cropping systems by imporving the soil quality through maintenance of physico-chemical properties of the soil. These findings showed that sorghum + soybean intercropping system with 75% RDF in conjunction with vermicompost and biofertilizers proved over sole cropping for maintaining fertility status of soil.

Table 1. Sorghum equivalent yield of grain and straw obtained in various cropping system and nutrient supply

Treatments	Sorghum equivalent grain yield (q ha^{-1})	Sorghum equivalent straw yield (q ha^{-1})
Cropping system		
C_1 (Sole sorghum)	33.16	422
C_2 (Sorghum + green gram)	35.78	400
C_3 (Sorghum + black gram)	32.64	411
C^4 (Sorghum + soybean)	37.31	417
SE (m) ±	0.48	5.0
CD at 5%	1.67	-
Nutrient supply		
N_1 RDF (80:40:40)	35.94	413.66
N_2 75% RDF + 25% N through vermicompost + *Azospirillum* + PSB	34.65	411.0
N_3 50% RDF + 25% N through vermicompost + *Azospirillum* + PSB	33.58	413.75
SE (m) ±	0.39	2.9
CD at 5%	1.18	-
Interaction (Cropping system x nutrient supply) grain yield		
SE (m) ±	0.65	
CD at 5%	-	
Interaction (Cropping system x nutrient supply) straw yield		
SE (m) ±	6.94	
CD at 5%		

Table 2. Available N,P,K and S status of soil at harvest as influenced by cropping system in combination with nutrient supply

Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available S (kg ha^{-1})
Cropping system				
C_1 (Sole sorghum)	245.79	24.79	336.68	15.95
C_2 (Sorghum + green gram)	264.71	25.14	338.69	17.00
C_3 (Sorghum + black gram)	261.36	25.32	347.85	17.43
C^4 (Sorghum + soybean)	267.32	25.70	356.89	17.64
SE (m) ±	0.270	0.11	0.61	0.11
CD at 5%	0.93	0.38	2.12	0.40
Nutrient supply				
N_1 RDF (80:40:40)	248.92	24.17	330.02	16.33
N_2 75% RDF + 25% N through vermicompost + *Azospirillum* + PSB	270.42	28.35	360.02	17.58
N_3 50% RDF + 25% N through vermicompost + *Azospirillum* + PSB	260.04	23.19	344.90	17.09
SE (m) ±	0.469	0.14	0.46	0.07
CD at 5%	1.40	0.44	1.39	0.21

Table 3. Interaction of Cropping system x nutrient supply for available nutrients in soil

	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (kg ha^{-1})
SE (m) ±	5.33	0.61	7.42	0.25
CD at 5%	15.98	1.48	22.25	--

Interaction (Cropping system x nutrient supply) for available N (kg ha^{-1})

	N_1	N_2	N_3
C_1 (Sole sorghum)	239.83	252.15	245.39
C_2 (Sorghum + green gram)	252.68	273.98	267.46
C_3 (Sorghum + black gram)	250.76	271.32	262.0
C^4 (Sorghum + soybean)	252.40	284.22	265.32

Interaction (Cropping system x nutrient supply) for available P (kg ha^{-1})

	N_1	N_2	N_3
C_1 (Sole sorghum)	24.11	27.24	23.02
C_2 (Sorghum + green gram)	24.32	28.37	22.72
C_3 (Sorghum + black gram)	24.24	28.48	23.25
C^4 (Sorghum + soybean)	24.03	29.33	23.75

Interaction (Cropping system x nutrient supply) for available K (kg ha^{-1})

	N_1	N_2	N_3
C_1 (Sole sorghum)	325.84	350.10	334.11
C_2 (Sorghum + green gram)	331.12	351.40	333.56
C_3 (Sorghum + black gram)	326.03	364.14	352.79
C^4 (Sorghum + soybean)	337.07	374.46	359.14

Table 4. Chemical properties of soil at harvest of sorghum and intercrops

Treatments	pH	EC (dSm^{-1})	Organic carbon (g kg^{-1})
Cropping system			
C_1 (Sole sorghum)	7.81	0.22	4.90
C_2 (Sorghum + green gram)	7.81	0.21	5.11
C_3 (Sorghum + black gram)	7.81	0.21	5.54
C^4 (Sorghum + soybean)	7.80	0.21	6.02
SE (m) ±	0.004	0.003	0.059
CD at 5%	-	-	0.20
Nutrient supply			
N_1 RDF (80:40:40)	7.81	0.20	4.57
N_2 75% RDF + 25% N through vermicompost + *Azospirillum* + PSB	7.81	0.21	5.93
N_3 50% RDF + 25% N through vermicompost + *Azospirillum* + PSB	7.80	0.21	5.67
SE (m) ±	0.003	0.003	0.060
CD at 5%	-	-	0.18

Interaction (Cropping system x nutrient supply) and chemical properties of soil

	pH	EC (dSm^{-1})	OC (kg ha^{-1})
SE (m) ±	0.003	0.006	0.27
CD at 5%	NS	NS	0.82

Interaction (Cropping system x nutrient supply) for available N (kg ha^{-1})

	N_1	N_2	N_3
C_1 (Sole sorghum)	4.23	5.26	5.20
C_2 (Sorghum + green gram)	4.33	5.63	5.36
C_3 (Sorghum + black gram)	4.36	6.33	5.93
C^4 (Sorghum + soybean)	5.36	6.50	6.20

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EFFECT OF FOLIAR SPRAYS OF NITRATE SALTS ON CHEMICAL, BIOCHEMICAL PARAMETERS AND YIELD OF GREEN GRAM

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ABSTRACT

A field experiment was conducted during *kharif* 2013-14 at farm of Botany section, College of Agriculture, Nagpur to study the effect of two foliar sprays of nitrate salts [($Ca(NO_3)_2$ and KNO_3] with different concentrations (0.25, 0.50, 0.75 and 1%) at 25 and 35 DAS on chemical, biochemical, parameters and yield of green gram. Data revealed that foliar application of 0.50% KNO_3 followed by 0.50% $Ca(NO_3)_2$ significantly increased leaf chlorophyll, leaf nitrogen, leaf phosphorus, leaf potassium, seed protein, pod length and yield of green gram.

(Key words:Chemical and biochemical parameters, nitrate salts [($Ca(NO_3)_2$ and KNO_3)] and yield)

INTRODUCTION

Green gram is one of the pulse crop cultivated in India. Green gram have excellent source of high quality protein.

Green gram is a small herbaceous annual erect or 45 to120 cm tall plant having chromosome number 2n =24 belongs to family "Leguminoceae" and sub family "Papilinaceae". Green gram grains provide about 18 to 22 % protein, 1.3 % fat, 56.7 to70 % carbohydrate, 3.5% mineral and traditionally consumed after processing into various products.

Green gram is grown through out in Southern Asia including India, Pakistan, Bangladesh, Srilanka, Thailand, Vietnam, Indonesia, Malysia and China etc. It is also grown in parts of Africa and U.S.A. In India it grown in Maharashtra, Rajasthan, Bihar, Andhra Pradesh, Gujarat, Orissa, Madhya Pradesh, Punjab, and Uttar Pradesh.

Nitrate availability, growth regulators, light, and other physiological and environmental parameters are the factors which effect the regulation of nitrate. Potassium affects respiration, photosynthesis, chlorophyll development, water content of leaves, carbon dioxide (Co_2) assimilation, and carbon movement (Sangakkara *et al*., 2000). Potassium has also an important role in the translocation of photosynthates from sources to sinks (Cakmak *et al*., 1994).

Calcium is an important constituent of plant tissues and has a vital role in maintaining and modulating various cell functions (Conway and Sams, 1987).Calcium is involved in cell membrane stability and permeability in addition to its involment in cell division and elongation (Marschner,1995).

MATERIALS AND METHODS

A field experiment on soybean was conducted at an experimental farm of Botany section, College of Agriculture, Nagpur with the object to know the influence of foliar sprays of nitrate salts (calcium nitrate and potassium nitrate) on chemical, biochemical parameters and yield of green gram. The present investigation was undertaken during the *kharif* season of 2013-2014. The field experiment was laid out in Randomized block Design (RBD) with three replications consisting of nine treatments comprising of different concentrations of $Ca(NO_3)_2$ (0.25, 0.50, 0.75 and 1%) and KNO_3 (0.25, 0.50, 0.75 and 1%) at 25 and 35 DAS. Plot size of individual treatment was gross 3.00 m x 2.20 m and net 2.40 m x 2.00 m. Seeds were sown at the rate of 15 kg ha^{-1} by dibbling method at a spacing of 30 cm x 10 cm. Observations were recorded at different stages i.e. at 40 and 55 DAS on chlorophyll content, leaf nitrogen, leaf phosphorus, leaf potassium content. Nitrogen content in leaves was estimated as per methods suggested by Somichi *et al.* (1972), phosphorus and potassium content from leaves were estimated as per method suggested by Jackson (1967). Chlorophyll from leaves was estimated by colorimetric method as suggested by Bruinsma (1982). Nitrogen content in seed was analysed (Somichi *et al.,* 1972) and the same was converted to crude protein by multiplying N_2 percentage in seed. Seed yield ha^{-1} and pod length were recorded after harvesting. Data were analysed by statistical method as suggested by Panse and Sukhatme (1954). Keeping above facts under

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consideration, an experiment was carried out to study the response of nitrate salts on chemical, biochemical parameters and yield of green gram.

RESULTS AND DISCUSSION

Biochemical and chemical observations

Observations on chlorophyll, nitrogen, phosphorus and potassium content in leaves were recorded at 40 and 55 DAS. Protein content in seeds was also recorded.

Leaf chlorophyll content

At 40 DAS all the treatments showed their significance in leaf chlorophyll content and significantly maximum leaf chlorophyll content was noticed with the foliar application of 0.50% KNO_3 (T_7) followed by foliar application of 0.50% $Ca(NO_3)_2$ (T_3) and 0.75% KNO_3 (T_8) when compared with control (T_1) and rest of the treatments under study. Similarly foliar application of 0.75% $Ca(NO_3)_2$ (T_4), 1% KNO_3 (T_9) and 1% $Ca(NO_3)_2$ (T_5) in a descending manner also significantly increased leaf chlorophyll content when compared with control (T_1) and rest of the treatments. But treatments T_6 (0.25% KNO_3) and T_2 (0.25% $Ca(NO_3)_2$) were found at par with treatment T_1 (control).

At 55 DAS significantly maximum leaf chlorophyll content was noticed with the foliar application of 0.50% KNO_3 (T_7) followed by foliar application of 0.50% $Ca(NO_3)_2$ (T_3) when compared with control (T_1) and rest of the treatments under study. Similarly foliar application of 0.75% KNO_3 (T_8) 0.75% $Ca(NO_3)_2$ (T_4), 1% KNO_3 (T_9) and 1% $Ca(NO_3)_2$ (T_5) were also increased leaf chlorophyll content when compared with control (T_1) and rest of treatments under observation. Treatments T_6 (0.25% KNO_3) and T_2 (0.25% $Ca(NO_3)_2$) were found at par with treatment T_1 (control).

Basole *et al*. (2003) conducted an experiment to study the effect of foliar sprays of hormone i.e. 50 ppm NAA and nutrients ($FeSO_4$, KNO_3, $ZnSO_4$ and $MgSO_4$ 0.55%) on soybean and found increase in chlorophyll content in leaves significantly.

Leaf nitrogen content

Nitrogen is the important constituent of protein and protoplasm and essential for plant growth. Nitrogen deficiency causes chlorosis and malfunctioning of the photosynthesis process. Plant cells require adequate supply of N for normal cell division and growth of the plant. Tender shoots, tips of shoots buds, leaves contains higher nitrogen.

Data on leaf nitrogen content were recorded at two stages viz., 40 and 55 DAS.

At 40 DAS significantly maximum leaf nitrogen content was recorded with the foliar application of 0.50% KNO_3 (T_7) over control. Next to this treatment foliar application of 0.50% $Ca(NO_3)_2$ (T_3) and 0.75% KNO_3 (T_8) significantly increased nitrogen content over control (T_1) and rest of the treatments under observation.Treatments T_4 (0.75% Ca $(NO_3)_2$), T_9 (1% KNO_3), T_5 (1% $Ca(NO_3)_2$), T_6 (0.25% KNO_3) and T_2 (0.25% $Ca(NO_3)_2$) were found at par with treatment T_1 (control).

At 55 DAS significantly maximum leaf nitrogen content was recorded with the foliar application of 0.50% KNO_3 (T_7) followed by foliar application of 0.50% $Ca(NO_3)_2$ (T_3) and 0.75% KNO_3 (T_8) when compared with control (T_1) and rest of the treatments under observation. Similarly foliar application of 0.75% $Ca(NO_3)_2$ (T_4) and 1% KNO_3 (T_9) also increased nitrogen content significantly when compared with control T_1 and rest of the treatments. But treatments T_5 (1% $Ca(NO_3)_2$), T_6 (0.25% KNO_3) and T_2 (0.25% $Ca(NO_3)_2$) were found at par with treatment T_1 (control).

Basole *et al*. (2003) conducted an experiment to study the effect of foliar sprays of hormone i.e. 50 ppm NAA and nutrients ($FeSO_4$, KNO_3, $ZnSO_4$ and $MgSO_4$ 0.55%) on soybean and found increase in N content in leaves significantly.

Brar and Brar (2004) observed that foliar application of potassium nitrate increased the N and K contents by 4.2 and 31.6%, while urea enhanced the N and K content by 11.3 and 21.1% in cotton leaves, respectively.

Leaf phosphorus content

Data on Leaf phosphorus content were recorded at two stages viz., 40 and 55 DAS.

At 40 DAS significantly maximum leaf phosphorus content was noticed with the foliar application of 0.50% KNO_3 (T_7) followed by foliar application of 0.50% $Ca(NO_3)_2$ (T_3) when compared with control (T_1) and rest of the treatments under study. Similarly foliar application of 0.75% KNO_3 (T_8) 0.75% $Ca(NO_3)_2$ (T_4), 1% KNO_3 (T_9) and 1% $Ca(NO_3)_2$ (T_5) were also increased leaf phosphorus content when compared with control (T_1) and rest of treatments under observation. Treatments T_6 (0.25% KNO_3) and T_2 (0.25% $Ca(NO_3)_2$) were found at par with treatment T_1 (control).

At 55 DAS significantly maximum leaf phosphorus content was recorded with the foliar application of 0.50% KNO_3 (T_7) followed by treatments 0.50% $Ca(NO_3)_2$ (T_3) and 0.75% KNO_3 (T_8) when compared with control (T_1) and rest of the treatments under observation. Similarly foliar application of 0.75% $Ca(NO_3)_2$ (T_4) and 1% KNO_3 (T_9) also increased phosphorus content significantly when compared with control (T_1) and rest of the treatments. But treatments T_5 (1% $Ca(NO_3)_2$), T_6 (0.25% KNO_3) and T_2 (0.25% $Ca(NO_3)_2$) were found at par with treatment T_1 (control).

Basole *et al.* (2003) conducted an experiment to study the effect of foliar sprays of hormone i.e. 50 ppm NAA and nutrients ($FeSO_4$, KNO_3, $ZnSO_4$ and $MgSO_4$ 0.55%) on soybean and found increase in P content in leaves significantly.

Leaf potassium conent

Data on leaf potassium content were recorded at the two growth stages i.e. 40 and 55 DAS gave significant variation.

At 40 DAS significantly maximum leaf potassium content was noticed with the foliar application of 0.50% KNO_3 (T_7) followed by foliar application of 0.50% $Ca(NO_3)_2$ (T_3) significantly increased leaf potassium content when compared with control (T_1) and rest of the treatments under study. Similarly foliar application of 0.75% KNO_3 (T_8) 0.75% $Ca(NO_3)_2$ (T_4), 1% KNO_3 (T_9) and 1% $Ca(NO_3)_2$ (T_5) were also increased leaf potassium content when compared with control (T_1) and rest of the treatments under observation. Treatments T_6 (0.25% KNO_3) and T_2 (0.25% $Ca(NO_3)_2$) were found at par with treatment T_1 (control).

At 55 DAS significantly maximum leaf potassium content was recorded with the foliar application of 0.50% KNO_3 (T_7) followed by foliar application of 0.50% $Ca(NO_3)_2$ (T_3) and 0.75% KNO_3 (T_8) significantly increased leaf potassium content when compared with control (T_1) and rest of the treatments under observation. Similarly foliar application of 0.75% $Ca(NO_3)_2$ (T_4) and 1% KNO_3 (T_9) also increased potassium content significantly when compared with control (T_1) and rest of the treatments. But treatments T_5 (1% $Ca(NO_3)_2$), T_6 (0.25% KNO_3) and T_2 (0.25% $Ca(NO_3)_2$) were found at par with treatment T_1 (control).

Brar and Brar (2004) observed that foliar application of potassium nitrate increased the N and K contents by 4.2 and 31.6%, while urea enhanced the N and K content by 11.3 and 21.1% in cotton leaves, respectively.

Protein content in seed

The maximum seed protein were recorded with the foliar application of 0.50% KNO_3 (T_7) followed by foliar application of 0.50% $Ca(NO_3)_2$ (T_3), 0.75% KNO_3 (T_8) and 0.75% $Ca(NO_3)_2$ (T_4) when compared with control (T_1) and rest of the treatments. Similarly treatments T_9 (1% KNO_3), T_5 (1% $Ca(NO_3)_2$), T_6 (0.25% KNO_3), T_2 (0.25% $Ca(NO_3)_2$) in a descending manner were found at par with treatment T_1 (control).

Nitrogen is the constituent of protein. Hence, increase in nitrogen content ultimately resulted in the increase in protein content in seeds of green gram in the present investigation.

Borowski and Sławomir Michałek (2009) found that foliar application potassium salts (1% solutions of KCl, KNO_3, K_2SO_4 and $C_6H_5K_3O_7{\cdot}H_2O$) resulted increase in protein content in spinach.

Zheng and Zhang (2010) tried foliar spray of KNO_3 on wheat in the heading stage at 100 mM NaCl+10 mM KNO_3 and recorded higher protein content over the control.

Table 1. Effect of foliar sprays of nitrate salts (calcium nitrate and potassium nitrate)on chemical, biochemical parameters and yield of green gram

Treatments	Leaf chlorophyll (mg g^{-1}		Leaf nitrogen (%)		Leaf phosphorus (%)		Leaf potassium (%)		Seed protein content (%)	Pod length (cm)	Seed yield ha^{-1}
	40 DAS	55 DAS	40 DAS	55 DAS	40 DAS	55 DAS	40 DAS	55 DAS			
T_1 (Control)	1.24	1.07	2.51	1.97	0.53	0.48	0.57	0.53	20.87	7.69	8.66
T_2(0.25%$Ca(NO_3)_2$)	1.31	1.13	2.55	2.01	0.55	0.49	0.60	0.56	21.52	8.04	8.99
T_3 (0.50% $Ca(NO_3)_2$	1.75	1.55	3.41	2.55	0.78	0.70	0.91	0.79	23.17	8.71	10.29
T_4 (0.75% $Ca(NO_3)_2$	1.64	1.46	2.76	2.34	0.70	0.61	0.76	0.71	22.74	8.48	9.73
T_5 (1% $Ca(NO_3)_2$)	1.48	1.30	2.64	2.20	0.63	0.54	0.69	0.63	22.19	8.19	9.49
T_6 (0.25% KNO_3)	1.39	1.21	2.59	2.09	0.58	0.53	0.65	0.61	21.93	8.12	9.29
T_7 (0.50% KNO_3)	1.83	1.69	3.68	2.71	0.85	0.74	0.98	0.87	24.51	9.26	10.66
T_8 (0.75% KNO_3)	1.69	1.50	3.25	2.46	0.74	0.67	0.83	0.76	22.89	8.58	9.89
T_9 (1% KNO_3)	1.58	1.41	2.72	2.24	0.66	0.58	0.72	0.67	22.43	8.26	9.56
SE(m) ±	0.056	0.050	0.097	0.088	0.027	0.026	0.037	0.034	0.614	0.276	0.350
CD at 5%	0.168	0.152	0.290	0.264	0.082	0.080	0.112	0.102	0.873	0.874	0.051

Pod length

Significantly more pod length was recorded with the foliar application of 0.50% KNO_3 (T_7) followed by treatments 0.50% $Ca(NO_3)_2$ (T_3) and 0.75% KNO_3 (T_8) when compared with control (T_1) and rest of the treatments under observation. But treatments T_4 (0.75% $Ca(NO_3)_2$), T_9 (1% KNO_3), T_5 (1% Ca $(NO_3)_2$), T_6 (0.25% KNO_3) and T_2 (0.25% $Ca(NO_3)_2$) were found at par with T_1 (control) in respect of pod length in green gram.

The treatment combination of 0.25% KNO_3 + 0.20% $Ca(NO_3)_2$ showed highest pod length in groundnut (Sarkar *et al.*, 1999).

Pal and Keorah (2012) conducted a field experiment to find out the effect of nitrate salts on green gram. Foliar spray of nitrate salts (i.e. 0.5% potassium nitrate with 0.4% calcium nitrate) increased the pod length as compared to control.

Seed yield ha^{-1}(q)

Significantly maximum seed yield ha^{-1} were recorded with the foliar application of 0.50% KNO_3 (T_7) followed by foliar application of 0.50% $Ca(NO_3)_2$ (T_3), 0.75% KNO_3 (T_8) and 0.75% $Ca(NO_3)_2$ (T_4) when compared with control (T_1) and rest of the treatments. While, treatments T_9 (1% KNO_3), T_5 (1% $Ca(NO_3)_2$), T_6 (0.25% KNO_3) and T_2 (0.25% Ca $(NO_3)_2$) were found at par with treatment T_1 (control).

Sarkar and Pal (2006) studied the effect of pre-sowing seed treatment with *Rhizobium* (*Bradyrhizobium japonicum*) and foliar spray of nitrate salts on the growth and yield of green gram (*Vigna radiata*). Foliar spray of nitrate salts during 50% flowering stage showed beneficial effect on growth parameters and yield attributes, thereby increasing grain yield by 7 to 23%. Among the foliar spray treatments, spray of 0.406% Ca $(NO_3)_2$ and 0.5% KNO_3 exhibited maximum increase in grain yield over the control (23 and 19%, respectively).

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GENETIC STUDIES IN F_2 POPULATION OF MUSTARD (*Brassica juncea*)

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ABSTRACT

Genetic analysis of F_2 crosses in mustard was undertaken with a view to identify the potential F_2 crosses for their use in individual plant selection. Ten F_2 crosses along with eight parents (Rohini, BIOYSR, JD-6, BIO-902, Laxmi, GM-2, PCR-7 and Pusa bahar) and two checks (Shatabdi and Pusa bold) were raised during *rabi* 2013-14 and data were recorded on six characters i.e. days to maturity, plant height at maturity (cm), number of primary branches plant^{-1} number of siliqua plant^{-1}, yield plant^{-1}, and oil content (%) with fatty acid composition. The high genotypic coefficient of variation was recorded for yield plant^{-1} and number of siliqua plant^{-1}. High heritability estimates were recorded for all the characters under study. The expected genetic advance among all the F_2 crosses indicated significant progress under selection for number of siliqua plant^{-1} and plant height at maturity which was ranging from 39.24 to 65.46 and 8.03 to 41.10 respectively. The ten F_2 population i.e. Rohini x JD-6, Rohini x Laxmi, Rohini x BIO-902, Rohini x PCR-7, Rohini x GM-2, Rohini x Pusa bahar, BIOYSR x JD-6, BIOYSR x BIO-902, BIOYSR x Laxmi and BIOYSR x GM-2 were identified on the basis of high mean performance, genotypic coefficient of variation, heritability in broad sense and genetic advance for economic characters like number of siliqua plant^{-1} and yield plant^{-1} which were subjected to individual plant selection. The percentage of individual plant selected in these ten crosses were 13.33%, 11.11%, 16.00%, 17.33%, 12.28%, 11.31%, 12.44%, 9.77%, 10.22% and 12.88% respectively for number of siliqua plant^{-1} and 12.44%, 13.33%, 15.55%, 17.33%, 14.61%, 10.40%, 12.88%, 11.11%, 12.00% and 14.44% respectively for yield plant^{-1}.

(Key words: F_2 population, GCV, PCV, heritability, genetic advance)

INTRODUCTION

Indian mustard (*Brassica juncea*) called as 'rai', 'raya' or 'laha' is an important oil seed crop next to groundnut in India for both area and production which belonging to *Brassicae* group. The Oil content in Indian mustard seed varies from 30 to 48%. At present, mustard is a minor oilseed crop in Vidarbha region. In Mharashtra the sole crop of mustard is seldom grown but with its low cost of production and high yielding potential it can be grown in Vidarbha. The important breeding programme in mustard is oriented to develop new varieties with high potential, wider adaptability, disease resistance and oil content. Designing efficient and desirable plant type requires the existence of genetic variability in the material. In order to incorporate desirable characters to maximize economic yields, the information on the nature and extent of genetic variability present in a population for desirable characters, their association and relative contribution to yield constitutes the basic requirement. F_2 generation provides an active breeding material from which desirable plants may be selected. Considering the above facts genetic studies in F_2 population of mustard (*Brassica juncea*) was undertaken.

MATERIALS AND METHODS

The experimental material comprised of ten F_2 crosses selected on the basis of yield performance of F_1 and their eight parents viz., Rohini, JD-6, BIOYSR, BIO-902, Laxmi, GM-2, PCR-7 and Pusa bahar. Ten F_2 crosses, eight parents involved in the crosses and two checks (Shatabdi and Pusa bold) were grown during *rabi,* 2013-2014 to detect the presence of F_2 variance, genotypic variance, phenotypic variance, heritability and genotypic advance for different traits and identify potential F_2 crosses and parents for mustard breeding programme. The experimental material was sown in randomized complete block design with three replications. The seed material of each F_2 cross was hand dibbled in an individual plot which consist of ten rows, three meter long, spaced 45 cm apart with an intra-row spacing of 15 cm. The parental seeds and that of checks were dibbled in an individual plot which consisted of two rows, three meter long, spaced 45 cm apart with an intra-row spacing of 15 cm. Experiment was sown on 29th October 2013. The recommended cultural practices and plant protection measures were undertaken as per the schedule to raise a healthy crop. The observations were recorded on 225 plants from each individual F_2 cross and five randomly selected plants in each parent for six characters i.e. days to maturity, plant height (cm), number of primary branches plant^{-1}, number of siliqua plant^{-1}, yield plant^{-1} and oil content with fatty acid composition. Oil content was estimated by Soxhlet apparatus (Sankaram,1965) and palmitic acid, oleic acid,

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linoleic acid, linolenic acid, Arachid acid and erucic acid composition by liquid gas chromatography method (Chauhan *et al*., 2001).

The data recorded were subjected to the statistical and biometrical analysis. Analysis of variance was done by the method given by Panse and Sukhatme (1967) and estimation of genetic parameters in each F_2 population were done through method given by Burton (1953), Allard (1960) and Johnson *et al.* (1955).

RESULTS AND DISCUSSION

Data regarding analysis of variance for five different characters are presented in table 1. The mean squares due to genotypes (crosses + parents + checks) were significant for all the characters namely days to maturity, number of primary branches plant^{-1}, plant height (cm), number of siliqua plant^{-1}, and yield plant^{-1} indicating a substantial genetic variability among the genotypes. This revealed that the genetic parameters can be estimated for all these characters under study. These results were in confirmity with that of Bansod *et al*. (2006) and Lole *et al.* (2012) who also reported significant variability among the genotype for all the characters under study in mustard.

Estimation of magnitude of genetic variation in the population heritability and genetic advance is to determine the progress under selection. The data regarding mean performance of parents and crosses, range, variance, genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance of each F_2 cross are presented in the table 2 to table 7.

Days to maturity

Among the ten parents JD-6 (101.80 days) matured early followed by PCR-7 (103.53 days) and BIOYSR (104.67 days) as observed from table 2. The F_2 cross of BIOYSR x BIO-902 matured earlier in 93.03 days followed by BIOYSR x JD-6 (95.42 days) and Rohini x Pusa bahar (96.30 days). The F_2 cross of BIOYSR x Laxmi took maximum number of days to mature (112.16 days) followed by Rohini x Laxmi (111.98 days). The maximum range (Table 4) for days to maturity was recorded in F_2 cross of BIOYSR x GM-2 (100 to 117 days) followed by BIOYSR x Laxmi (107 to 122 days) whereas minimum range was recorded in Rohini x Pusa bahar (94 to 99 days).

The maximum F_2 variance and genotypic coefficient of variation was recorded in the F_2 cross BIOYSR x GM-2 (9.61 and 2.77 % respectively) followed by Rohini x GM-2 (7.29 and 2.44% respectively) and Rohini x JD-6 (7.24 and 2.53% respectively). Phenotypic coefficient of variation was maximum in BIOYSR x GM-2 (2.81%) followed by Rohini x JD-6 (2.58%) and Rohini x JM-2 (2.47%). Estimates of heritability was maximum in Rohini x GM-2 (97.47%) followed by BIOYSR x GM-2 (97.11%) and Rohini x Laxmi (97.07%). Maximum genetic advance was observed in F_2 cross BIOYSR x GM-2 (6.20) followed by Rohini x GM-2 (5.42) and Rohini x JD-6 (5.35).

The data regarding genetic parameters were calculated for days to maturity revealed that for most of the crosses having high heritability and high genotypic coefficient of variation, genetic advance were found to be low indicating significant role of non-additive gene action. Higher heritability values observed in the crosses indicated the significant role of environment and hence, it is not effective for making selection for early maturing plant in segregating generation. These results were not in confirmation with Singh *et al.* (2012) who observed low heritability with low genetic advance for days to maturity and Titare (2000) observed high heritability with high genetic advance for days to maturity.

Plant height (cm)

Maximum plant height at maturity was recorded for the parent GM-2 (121 cm) followed by Rohini (110.13 cm). The minimum plant height was recorded in the parent PCR-7 (91.73 cm) followed by Shatabdi (94.07 cm) and BIO-902 (94.13 cm) as observed in table 3. Cross combination of Rohini x PCR-7 (128.08 cm) recorded the maximum plant height whereas minimum plant height was observed in BIOYSR x BIO-902 (102.11 cm) followed by BI0YSR x Laxmi (103.04 cm) and Rohini x GM-2 (105.92 cm). Maximum range for plant height was observed in F_2 cross of BIOYSR x BIO-902 (49 to158 cm). The minimum range of plant height was observed in cross Rohini x PCR-7 (100 to156 cm).

The maximum F_2 variance was recorded in the cross BIOYSR x Laxmi (484.67) followed by Rohini x Laxmi (317.73) and Rohini x GM-2 (316.85). The cross combination of BIOYSR x Laxmi was found to have maximum genotypic coefficient of variation i.e. 19.04% followed by Rohini x GM-2 (16.07%) and BIOYSRx GM-2 (14.25%). F_2 cross of BIOYSR x Laxmi recorded maximum phenotypic coefficient of variation (21.36%) followed by Rohini x GM-2 (16.80%) and Rohini x Laxmi (15.66%).

Maximum heritability estimates were recorded in the cross Rohini x GM-2 (91.73%) followed by BIOYSR x GM-2 (91.02%) and BIOYSR x Laxmi (90.63%). Maximum genetic advance was recorded in F_2 cross of BIOYSR x Laxmi (41.10) followed by Rohini x GM-2 (33.64) and BIOYSR x GM-2 (33.35).

The crosses BIOYSR X Laxmi and Rohini x GM-2 had high F_2 variance, genotypic coefficient of variation, heritability and high genetic advance which indicated the predominance of additive gene action for these trait, there by suggesting amenability of these characters through selection. High heritability coupled with high genetic advance for plant height was observed by Singh *et al.* (2004) and Singh *et al.* (2012).

Number of primary branches plant^{-1}

Maximum number of primary branches (Table 4) was observed in parent JD-6 and GM-2 (3.20) followed by Laxmi (3.13) and BIOYSR (3.00) whereas the minimum number of primary branches plant^{-1} was observed in the parent BIO-902 (2.33).The crosses exhibiting maximum number of primary branches plant^{-1} were Rohini x BIO-902 (3.75), Rohini x PCR-7 (3.29) and BIOYSR x GM-2 (3.10) while the cross exhibiting minimum number of primary branches plant^{-1} was BIOYSR x Laxmi (2.64). The maximum range for the character, number of primary branches plant^{-1} was observed in the cross BIOYSR x BIO-902 (1 to 6) and almost all other crosses exhibited a range of 1 to 5 for number of primary branches plant^{-1}.

The F_2 variance was maximum in the cross BIOYSR x BIO-902 (0.86) followed by Rohini x GM-2 (0.65). Maximum genotypic coefficient of variation was recorded in the cross BIOYSR x BIO-902 (32.53%) followed by BIOYSR x Laxmi (25.77%) and Rohini x GM-2 (25.20). The cross BIOYSR x BIO-902 (34.63%) recorded maximum phenotypic coefficient of variation followed by BIOYSR x Laxmi (27.62%) and Rohini x GM-2 (26.98%). The highest heritability estimates were observed in cross BIOYSR x BIO-902 (88.25%) followed by Rohini x GM-2 (87.23%) and BIOYSR x GM-2 (87.06%). The expected genetic advance was highest in the cross BIOYSR x BIO-902 (1.68) followed by Rohini x GM-2 (1.45) and Rohini x PCR-7 (1.39).

The genetic parameters calculated for number of primary branches plant^{-1} revealed that the crosses BIOYSR x BIO-902 and Rohini x GM-2 possessed maximum F_2 variance, high genotypic coefficient of variation, high heritability but low genetic advance hence, selection of these crosses in F_2 generation would not be rewarding as there is significant role of environment in the expression of character. Mahmood *et al.* (2003) observed low estimates of heritability for number of primary branches plant^{-1} which was in contrast to the result obtained in the presence study. Singh *et al.* (2011) also recorded high heritability along with moderate genetic advance for number of primary branches plant^{-1}. High heritability was observed in present study but genetic advance was low.

Number of siliqua plant^{-1}

Laxmi (86.60) was a parent which produced maximum number of siliqua plant^{-1} which was followed by GM-2 (84.67) and Rohini (78.13) as observed in table 5 and BIO-902 (57.40) a parent which produced minimum number of siliqua plant^{-1}. The maximum number of siliqua plant^{-1} was produced by the cross Rohini x BIO-902 (86.73) which was followed by Rohini x PCR-7 (85.85) and Rohini x JD-6 (82.53). The minimum number of siliqua plant^{-1} was produced by the F_2 cross observed BIOYSR x Laxmi (60.52). The maximum range was recorded in F_2 cross of BIOYSR x Laxmi (26 to 252) followed by Rohini x JD-6 (38 to 249) whereas the minimum range was recorded in BIOYSR x JD-6 (32 to 156) as noticed from table 7.

Among the F_2 variance maximum variance was recorded in the cross Rohini x PCR-7 (1100.86) followed by Rohini x Laxmi (890.42) and Rohini x GM-2 (871.71). The highest genotypic coefficient of variation was observed in the cross Rohini x GM-2 (45.28%) followed by BIOYSR x Laxmi (43.17%) and BIOYSR x BIO-902 (42.06%). The crosses Rohini x Laxmi (41.59%) and Rohini x PCR-7 (37.71%) also exhibited higher genotypic coefficient of variation. Estimated heritability was maximum in F_2 cross of Rohini x JD-6 (97.74%) followed by Rohini x JD-6 (96.73%) and BIOYSR x BIO-902 (96.41%). The crosses Rohini x PCR-7 (96.33%) and Rohini x Laxmi (93.68) also exhibited higher heritability. The F_2 cross of Rohini x PCR-7 (65.46) exhibited maximum genetic advance followed by Rohini x Laxmi (57.58) and Rohini x GM-2 (57.51).

Higher values of F_2 variance, genotypic coefficient of variation, heritability and expected genetic advance were exhibited by the crosses Rohini x Laxmi and Rohini x PCR-7. This indicated that predominant role of additive gene action for the character number of siliqua plant^{-1} and hence selection in the F_2 generation will be effective. Several other workers have reported similar findings of high heritability and corresponding genetic advance (Mahmood *et al*., 2003, Bansod *et al.* 2007 and Lole *et al*., 2012).

Yield plant^{-1} (g)

Among the parents GM-2 yielded highest (2.57g) followed by Laxmi (2.51g), JD-6 (2.31g) and lowest yielders were the parent BIO-902 (1.07g) and PCR-7 (1.51g) as observed from table 6. The maximum seed yield was recorded by F_2 cross of Rohini x PDR-7 (2.97g) followed by Rohini x BIO-902 (2.80g). The F_2 cross of BIOYSR x BIO-902 yielded the lowest (1.62g).

The data from table 6 showed that the maximum range for seed yield plant^{-1} was observed in the F_2 cross of Rohini x Laxmi (0.6 to 11.5g) and BIOYSR x JD-6 (0.8 to 5.1g) scored the lowest range for seed yield plant^{-1}. The highest F_2 variance was recorded in Rohini x PCR-7 (2.56) followed by Rohini x Laxmi (1.86). The highest genotypic coefficient of variation and phenotypic coefficient of variation were observed in the F_2 cross of Rohini x Pusa bahar (65.72% and 68.07% respectively) followed by Rohini x Laxmi (59.87% and 62.94% respectively) and BIOYSR x BIO-902 (57.15% and 58.18% respectively). The crosses Rohini x PCR-7 and Rohini x BIO-902 also exhibited higher values for genotypic coefficient for variation (52.97% and 41.18% respectively) and phenotypic coefficient of variation (53.93% and 41.84% respectively).

The highest heritability estimate was observed in the F_2 cross Rohini x BIO-902 (96.90%) followed by BIOYSR x BIO-902 (96.50%) and Rohini x PCR-7 (96.47%). The highest genetic advance was recorded by the F_2 cross of Rohini x PCR-7 (3.18) followed by Rohini x Laxmi (2.54) and Rohini x BIO-902 (2.34).

The crosses, Rohini x BIO-902 and Rohini x PCR-7 exhibited relatively higher values of F_2 variance, genotypic coefficient of variation, phenotypic coefficient of variance and lower values for expected genetic advance. High heritability coupled with low genetic advance indicates the presence of non-additive gene action, and that the selection of superior plants in F_2 generation for seed yield would not be rewarding. The results of the present study for high heritability were in confirmity with Khulbe *et al.* (2000), Chauhan *et al.* (2001), Mahla *et al.* (2003), Mahmood *et al*. (2003), Bansod *et al.* (2007), Lole *et al*. (2012) and Singh *et al*. (2012) but in all these studies estimates of genetic advance were also higher whereas in the present study genetic advance was found to be lower for seed yield plant^{-1} as observed by Singh *et al.* (2011), Singh *et al.* (2002) who also observed high heritability coupled with low genetic advance for seed yield plant^{-1}.

Oil content (%) and fatty acid composition

The mean oil content (%) and fatty acid composition of parents, checks and crosses were estimated from bulk samples and data are presented in table 7.

Among the eight parents and two checks studied, mean oil content of Rohini, JD-6, Shatabdi and Pusa Bold were highest with 40% followed by Laxmi and Pusa bahar (36% for both). The highest oil content was recorded in F_2 cross of Rohini x Laxmi and Rohini x Pusa bahar (40% for both) followed by Rohini x JD-6, Rohini x GM-2 and BIOYSR x BIO-902 (36% for all).

Among parents PCR-7 (3.58%) content high Palmitic acid whereas parent BIO-902 (2.71%) having low level of palmitic acid. Within F_2 crosses Rohini x BIO-902 (3.19%) exhibits high level of palmitic acid followed by BIOYSR x BIO-902 (3.09%) and cross BIOYSR x GM-2 (2.48%) content low level of palmitic acid. High level of oleic acid was found in parent Shatabdi (12.41%) whereas low in JD-6 (8.62%). F_2 crosses BIOYSR x JD-6 (13.17%) content high oleic acid followed by Rohini x JD-6 and F_2 cross Rohini x BIO-902 (9.93%) content in low level. High level of linoleic acid was found in parent Shatabdi (21.58%) and low level found in JD-6 (18.92%) as well as high level of linoleic acid found in F_2 cross BIOYSR x BIO-902 (20.31%) and low level found in Rohini x JD-6 (16.65%). High level of Linolenic acid was observed in parent BIOYSR (12.14%) and low in Pusa bold (10.55%). F_2 crosses Rohini x BIO-902 (12.82%) exhibited high level of linolenic acid whereas BIOYSR x BIO-902 (9.96%) exhibited in low level. The high level of arachidic acid content was recorded in parent Shatabdi (9.50%) and low level in parent JD-6 (5.58%). F_2 cross BIOYSR x JD-6 (8.88%) exhibited high level of arachidic acid and low in Rohini x GM-2 (6.69%). High erucic acid level was found in parent JD-6 (51.95%) whereas low in parent Shatabdi (41.14%). F_2 cross Rohini x JM-2 (49.70%) exhibited high level of erucic acid and F_2 cross BIOYSR x JD-6 exhibited low in level (43.76%).

Fatty acid profiles determine the quality mustard oil, which is an important component of Indian diet prevalent mustard varieties, including those involved in the present study, yields oil having low (about 7%) standard fatty acid (palmitic + steric acid), high erucic acid (50%), low oleic (9-18%) and linolic and linolenic acid (13-25%) as reported by Chauhan *et al*. (2006). The preferred oil should have low saturated fatty acid (around 4%), low erucic acid (less than 2%) and appreciable amount of unsaturated fatty acid (olic and linolic acid) i.e. 40 to 45% olic, 30 to 35% linolic and 15 to 20% linolenic acid.

As oil content and fatty acid composition was estimated from bulk samples of parents, checks and crosses the data were not subjected to analysis of genetic parameters.

Crop improvement programme in mustard is mainly oriented to develop suitable variety, which have high yield, high oil and desirable level of fatty acid composition. Knowledge of relative magnitude of heritability and additive and non-additive genetic variation for these quantitative traits would help to decide most probably breeding method to be followed in mustard. The information about mean performance magnitude of genetic variance heritability and genetic advance in the F_2 population will determine the success of selecting potential F_2 and the possibility of extracting superior or segregating generation. Since only the genetic portion of the total variability contributes to gain under selection, the important of information about the parameter of genotype enrichment complex should be clear to the breeder as the better estimate of these parameters, the breeder will be able to anticipate that he can expect from different intensity of selection. (Allard, 1960).

Therefore, the presence investigation were conducted to estimate the additive and dominant component of different characters, to estimate heritability and genetic advance for different F_2 crosses and to identify potential F_2 crosses for further selection. Moderately high coefficient of variation was observed for number of siliqua plant^{-1} (11.84%) and seed yield plant^{-1} (15.43%) whereas days to first flower (1.10%), days to maturity (0.41%) plant height at maturity (7.76%), and number of primary branches plant^{-1} (6.65%) showed lower coefficient of variation.

Hence, only number of siliqua plant^{-1} and seed yield plant^{-1} were considered as objectives of selection in this study. The crosses Rohini x JD-6, Rohini x Laxmi, Rohini x Bio-902, Rohini x PCR-7, Rohini x GM-2, Rohini x Pusa bahar, BIOYSR x JD-6, BIOYSR x BIO-902, BIOYSR x Laxmi, and BIOYSR x GM-2 were observed to record high mean, variance, heritability for both number of siliqua plant^{-1} and yield plant^{-1}, but genetic advance was high for number of siliqua plant^{-1} and low for seed yield plant^{-1}, hence these ten crosses were identified and subjected to individual plant selection. Chauhan *et al.* (2001) and Lole *et al.* (2012) also reported the scope of single plant selection in F_2 in mustard which was inline with the present findings. Selection criteria for individual plant selection was based on mean of best check ± S. E. Plants exhibiting greater value than mean of best check ± S. E. for number of siliqua plant^{-1} and seed yield plant^{-1} were selected. The percentage of

Table 1 . Analysis of variance for five characters in mustard

Source of variation	d.f.	Mean Squares				
		Days to maturity	Number of primary branches $plant^{-1}$	Plant height (cm)	Number of siliqua $plant^{-1}$	Yield $plant^{-1}$ (g)
Replications	2	0.057	0.243	632.989	264.078	0.352
Genotypes	19	118.70**	0.304**	333.934**	264.549**	0.582**
Error	38	0.192	0.037	67.498	74.602	0.105

**Significant at 1%

Table 2. Estimation of genetic parameters in each F_2 cross for days to maturity

F_2 Crosses/ Parents/ Checks	Mean ± S $E_{(m)}$	Range	VF_2	GCV (%)	PCV (%)	h^2 (%)	Genetic Advance
Rohini x JD-6	104.32 ± 2.69	14.00 (99-113)	7.24	2.53	2.58	96.63	5.35
Rohini x Laxmi	111.98 ± 2.25	12.00 (105-117)	5.08	1.98	2.01	97.07	4.50
Rohini x BIO-902	98.38 ± 1.27	8.00 (95-103)	1.62	1.18	1.29	83.55	2.19
Rohini x PCR-7	100.99 ± 2.21	13.00 (95-108)	4.88	2.14	2.18	95.86	4.36
Rohini x GM-2	109.17 ± 2.70	14.00 (101-115)	7.29	2.44	2.47	97.47	5.42
Rohini x Pusa bahar	96.30 ± 1.11	5.00 (94-99)	1.24	1.08	1.15	87.14	2.00
BIOYSR x JD-6	95.24 ± 1.17	7.00 (92-99)	1.38	1.07	1.23	75.66	1.83
BIOYSR x BIO-902	93.03 ± 1.34	6.00 (90-96)	1.79	1.28	1.44	80.00	2.21
BIOYSR x Laxmi	112.16 ± 2.05	15.00 (107-122)	4.20	1.77	1.82	94.25	3.98
BIOYSR x GM-2	110.08 ± 3.10	17.00 (100-117)	9.61	2.77	2.81	97.11	6.20
Rohini	112.07	-	-	-	-	-	-
BIOYSR	104.67	-	-	-	-	-	-
JD-6	101.80	-	-	-	-	-	-
BIO-902	107.27	-	-	-	-	-	-
Laxmi	106.87	-	-	-	-	-	-
GM-2	108.13	-	-	-	-	-	-
PCR-7	103.53	-	-	-	-	-	-
Pusa bahar	112.07	-	-	-	-	-	
Shatabdi	113.73	-	-	-	-	-	-
Pusa bold	111.00	-	-	-	-	-	-
Grand mean	105.63						
S E (m)±	0.06						
C V (%)	0.41						

Table 3. Estimation of genetic parameters in each F_2 cross for plant height (cm)

F_2 Crosses/ Parents/ Checks	Mean ± S E(m)	Range	VF_2	GCV (%)	PCV (%)	h^2 (%)	Genetic Advance
Rohini x JD-6	111.19 ± 15.83	82.00 (68-150)	250.86	13.48	14.24	83.92	27.38
Rohini x Laxmi	113.81 ± 17.82	90.00 (72-162)	317.73	12.85	15.66	86.41	31.73
Rohini x BIO-902	123.96 ± 15.06	92.00 (76-168)	226.80	11.36	12.14	80.40	24.94
Rohini x PCR-7	128.08 ± 12.20	56.00 (100-156)	149.03	5.26	9.53	31.95	8.03
Rohini x GM-2	105.92 ± 17.80	89.00 (63-152)	316.85	16.07	16.80	91.73	33.64
Rohini x Pusa bahar	117.30 ± 16.43	105.00 (73-178)	270.05	11.04	14.00	84.05	28.45
BIOYSR x JD-6	106.84 ± 13.63	73.00 (69-142)	185.86	8.60	12.75	77.11	21.65
BIOYSR x BIO-902	102.11 ± 15.57	109.00 (49-158)	242.51	13.70	15.251	80.76	25.90
BIOYSR x Laxmi	103.04 ± 22.01	101.00 (60-161)	484.67	19.04	21.36	90.63	41.10
BIOYSR x GM-2	119.01 ± 17.78	77.00 (78-155)	316.37	14.25	14.94	91.02	33.35
Rohini	110.13	-	-	-	-	-	-
BIOYSR	98.53	-	-	-	-	-	-
JD-6	103.07	-	-	-	-	-	-
BIO-902	94.13	-	-	-	-	-	-
Laxmi	103.53	-	-	-	-	-	-
GM-2	121.00	-	-	-	-	-	-
PCR-7	91.73	-	-	-	-	-	-
Pusa bahar	97.20	-	-	-	-	-	-
Shatabdi	94.07	-	-	-	-	-	-
Pusa bold	100.53	-	-	-	-	-	-
Grand mean	107.11						
$S E_{(m)}\pm$	4.74						
C V (%)	7.67						

Table 4. Estimation of genetic parameters in each F_2 cross for number of primary branches plant^{-1}

F_2 Crosses/ Parents/ Checks	Mean ± S E(m)	Range	VF_2	GCV (%)	PCV (%)	h^2 (%)	Genetic Advance
Rohini x JD-6	3.05 ± 0.72	4.00 (1-5)	0.52	21.36	23.76	80.83	1.21
Rohini x Laxmi	2.74 ± 0.71	4.00 (1-5)	0.50	23.83	25.90	84.66	1.23
Rohini x BIO-902	3.75 ± 0.80	4.00 (1-5)	0.64	19.47	21.37	82.97	1.37
Rohini x PCR-7	3.29 ± 0.80	4.00 (1-5)	0.64	22.40	24.40	84.32	1.39
Rohini x GM-2	2.99 ± 0.80	4.00 (1-5)	0.65	25.20	26.98	87.23	1.45
Rohini x Pusa bahar	2.98 ± 0.67	4.00 (1-5)	0.45	19.68	22.60	75.88	1.05
BIOYSR x JD-6	3.00 ± 0.75	4.00 (1-5)	0.56	22.84	25.00	83.49	1.29
BIOYSR x BIO-902	2.68 ± 0.92	5.00 (1-6)	0.86	32.53	34.63	88.25	1.68
BIOYSR x Laxmi	2.64 ± 0.73	3.00 (1-4)	0.53	25.77	27.62	87.06	1.31
BIOYSR x GM-2	3.10 ± 0.75	4.00 (1-5)	0.56	22.62	24.27	86.81	1.34
Rohini	2.73	-	-	-	-	-	-
BIOYSR	3.00	-	-	-	-	-	-
JD-6	3.20	-	-	-	-	-	-
BIO-902	2.33	-	-	-	-	-	-
Laxmi	3.13	-	-	-	-	-	-
GM-2	3.20	-	-	-	-	-	-
PCR-7	2.80	-	-	-	-	-	-
Pusa bahar	2.67	-	-	-	-	-	-
Shatabdi	2.60	-	-	-	-	-	-
Pusa bold	2.60	-	-	-	-	-	-
Grand mean	2.92						
S E $_{(m)}$±	0.11						
C V (%)	6.65						

Table 5. Estimation of genetic parameters in each F_2 cross for number of siliqua $plant^{-1}$

F_2 Crosses/ Parents/ Checks	Mean ± S E(m)	Range	VF_2	GCV (%)	PCV (%)	h^2 (%)	Genetic Advance
Rohini x JD-6	82.53 ± 24.42	211.00 (38-249)	596.36	29.09	29.58	96.73	48.66
Rohini x Laxmi	69.44 ± 29.84	178.00 (28-206)	890.42	41.59	42.97	93.68	57.58
Rohini x BIO-902	86.73 ± 24.62	143.00 (39-182)	606.50	28.07	28.39	97.74	49.58
Rohini x PCR-7	85.85 ± 32.99	169.00 (33-202)	1100.86	37.71	38.42	96.33	65.46
Rohini x GM-2	63.40 ± 29.52	140.00 (25-165)	871.71	45.28	46.56	94.56	57.51
Rohini x Pusa bahar	71.47 ± 23.74	165.00 (31-196)	563.73	31.76	33.22	91.42	44.71
BIOYSR x JD-6	75.04 ± 20.51	124.00 (32-156)	420.69	26.34	27.33	92.88	39.24
BIOYSR x BIO-902	60.52 ± 25.92	179.00 (27-206)	672.15	42.06	42.83	96.41	51.49
BIOYSR x Laxmi	60.63 ± 27.42	226.00 (26-252)	751.89	43.17	45.22	91.13	51.47
BIOYSR x GM-2	75.24 ± 29.52	181.00 (21-202)	871.45	37.90	39.23	93.36	56.77
Rohini	78.13	-	-	-	-	-	-
BIOYSR	69.53	-	-	-	-	-	-
JD-6	72.80	-	-	-	-	-	-
BIO-902	57.40	-	-	-	-	-	-
Laxmi	86.60	-	-	-	-	-	-
GM-2	84.67	-	-	-	-	-	-
PCR-7	62.00	-	-	-	-	-	-
Pusa bahar	68.67	-	-	-	-	-	-
Shatabdi	76.47	-	-	-	-	-	-
Pusa bold	75.40	-	-	-	-	-	-
Grand mean	73.01						
S E $_{(m)}$±	4.99						
C V (%)	11.84						

Table 6. Estimation of genetic parameters in each F_2 cross for yield plant^{-1}

F_2 Crosses/ Parents/ Checks	Mean ± S E(m)	Range	VF_2	GCV (%)	PCV (%)	h^2 (%)	Genetic Advance
Rohini x JD-6	2.25 ± 0.95	8.00 (0.8-8.8)	0.90	40.51	42.26	91.91	1.80
Rohini x Laxmi	2.16 ± 1.36	10.90 (0.6-11.5)	1.86	59.87	62.94	90.46	2.54
Rohini x BIO-902	2.80 ± 1.17	8.60 (1-9.6)	1.37	41.18	41.84	96.90	2.34
Rohini x PCR-7	2.97±1.60	8.70 (0.8-9.5)	2.56	52.97	53.93	96.47	3.18
Rohini x GM-2	2.18 ± 1.14	5.90 (0.7-6.6)	1.32	50.66	52.52	93.04	2.20
Rohini x Pusa bahar	1.69 ± 1.15	7.40 (0.6-8)	1.32	65.72	68.07	93.23	2.21
BIOYSR x JD-6	2.35 ± 0.80	4.30 (0.8-5.1)	0.64	32.38	34.06	90.39	1.49
BIOYSR x BIO-902	1.62 ± 0.94	5.00 (0.5-5.5)	0.89	57.15	58.18	96.50	1.88
BIOYSR x Laxmi	1.76 ± 1.01	9.90 (0.5-10.5)	1.02	52.39	57.24	83.77	1.74
BIOYSR x GM-2	2.18 ± 1.08	7.50 (0.6-8.1)	1.17	47.98	49.71	93.17	2.08
Rohini	2.24	-	-	-	-	-	-
BIOYSR	1.76	-	-	-	-	-	-
JD-6	2.31	-	-	-	-	-	-
BIO-902	1.17	-	-	-	-	-	-
Laxmi	2.51	-	-	-	-	-	-
GM-2	2.57	-	-	-	-	-	-
PCR-7	1.51	-	-	-	-	-	-
Pusa bahar	2.05	-	-	-	-	-	-
Shatabdi	1.91	-	-	-	-	-	-
Pusa bold	2.22	-	-	-	-	-	-
Grand mean	2.10						
S E $_{(m)}$±	0.18						
C V (%)	15.43						

Table 7. Oil content (%) and fatty acid composition of crosses, parents and checks

F_2 Crosses/ Parents/ Checks	Oil content (%)	Palmitic acid (%)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)	Arachidic acid (%)	Erucic acid (%)
Rohini x JD -6	36.00	2.59	12.62	16.65	12.18	6.99	48.94
Rohini x Laxmi	40.00	2.70	12.39	17.79	11.66	7.88	47.55
Rohini x BIO -902	32.00	3.19	9.93	18.40	12.82	7.56	48.07
Rohini x PCR -7	32.00	2.85	11.11	18.94	10.88	7.67	48.51
Rohini x GM -2	36.00	2.68	11.28	18.03	11.59	6.69	49.70
Rohini x Pusa bahar	40.00	3.00	10.06	19.60	11.80	6.72	48.78
BIOYSR x JD -6	32.00	2.81	13.17	20.24	11.10	8.88	43.76
BIOYSR x BIO -902	36.00	3.09	12.21	20.31	9.96	8.31	46.11
BIOYSR x Laxmi	32.00	2.73	11.70	18.77	11.35	7.59	47.83
BIOYSR x GM -2	32.00	2.48	12.33	18.63	11.40	8.02	47.12
Rohini	40.00	3.23	10.28	20.50	11.69	6.49	47.78
BIOYSR	32.00	2.75	9.99	18.94	12.44	6.19	49.96
JD-6	40.00	2.99	8.62	18.92	11.91	5.58	51.95
BIO-902	32.00	2.71	10.55	19.38	11.76	6.71	48.86
Laxmi	36.00	3.20	9.63	20.39	11.12	6.20	49.42
GM-2	32.00	2.81	10.54	19.72	11.03	6.36	49.51
PCR-7	32.00	3.58	9.22	21.44	11.96	6.21	47.57
Pusa bahar	36.00	3.10	9.65	20.07	11.99	6.24	48.92
Shatabdi	40.00	3.51	12.41	21.58	11.83	9.50	41.14
Pusa bold	40.00	3.21	9.74	20.56	10.55	6.49	49.42

selected plants ranges from 9.77 % to 17.33 % for number of siliqua plant^{-1} and from 10.40 % to 17.33 % for seed plant^{-1}. These selected plants are recommended for forwarding to next generation for evaluating the performance of progeny. Mean performance of number of siliqua plant^{-1} and yield plant^{-1} of selected plants indicate the chances of getting good progenies with high yield in further generations.

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RESPONSE OF *Helicoverpa armigera* (Hubner) TO ORGANOPHOSPHATE ALONG WITH SYNERGIST IN VIDARBHA REGION OF MAHARASHTRA

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ABSTRACT

Studies on "Response of *Helicoverpa armigera* (Hubner) to organophosphate along with synergist in Vidarbha region of Maharashtra" was carried out during *kharif* season of 2012-2013 in insectary of Entomology Section, College of Agriculture, Nagpur with seven treatments replicated thrice in Completely Randomised Design using direct spraying method and the observations were recorded 72 hrs after treatment application. Among the various combinations of organophosphate with sesamum oil and karanj oil against *H. armigera* of Akola, Nagpur and Yavatmal strain, the treatment quinalphos 25 EC 0.05 per cent + sesamum oil 2 ml l^{-1} proved the most effective by recording least resistance (34.44 per cent) followed by quinalphos 25 EC 0.05 per cent + karanj oil 2 ml l^{-1} (40.00 per cent), monocrotophos 36 WSC 0.06 per cent + sesamum oil 2 ml l^{-1}(41.11per cent), and monocrotphos 36 WSC 0.06 per cent + karanj oil 2 ml l^{-1} (44.44%). Whereas quinalphos 25 EC 0.05 per cent reported to be the best one among sole treatments which recorded 60.00 per cent resistance followed by monocrotophos 36 WSC 0.06 per cent with 63.33 per cent resistance.

The resistance levels recorded under all the treatments revealed that all the treatments were found more effective against Nagpur strain followed by Yavatmal and Akola strain, indicating the strain existing at Nagpur was less resistant to the insecticides. From the results of present investigation, it can be opined that sesamum oil could be used as a synergist with quinalphos or monocroophos for the effective management of *Helicoverpa armigera* and to delay the development of insecticide resistance.

(Key words : Organophosphate, resistance, *Helicoverpa armigera*)

INTRODUCTION

Helicoverpa armigera (Hubner) is a cosmopolitan and polyphagous lepidopteran insect pest, infesting important crops like cotton, sunflower, pigeonpea, chickpea, okra and corn occurring throughout Europe, Africa, Asia and Australia. It is generally considered to be the most important species due to its feeding habit on different plant parts in various regions in the world commonly known as American cotton bollworm, gram pod borer, corn earworm, tobacco budworm or tomato fruit borer. No plant seems to be strong enough to avoid attack of *Helicoverpa armigera* (Thirasack, 2001).

This pest has been recorded feeding on 182 plant species across 47 families in Indian subcontinent, of which 56 are heavily damaged and 126 are rarely affected (Chaturvedi, 2007). In Vidarbha region of Maharashtra during 2000-01, the damage caused by *Helicoverpa armigera* on pegionpea was 35.00 per cent (Aherkar *et al.,* 2002). It caused considerable yield loss of 2,50,000 tonnes of pegionpea annum^{-1} worth more than 3750 million rupees year^{-1} (Banu *et al.,* 2005). It caused annual losses on red gram and bengal gram around to Rs 300 million in India(Pawar, 1998). In USA alone,*Helicoverpa* spp. caused a loss of more than a billion dollars to various crops, despite the cost of insecticide applications, worth $ 250 million year^{-1} (Johnson *et al.,*1986). About 70 per cent of all pesticides are used for the management of bollworm (Bharathan, 2000).

Indiscriminate use of insecticides against *H. armigera* has resulted in developing resistance to it. Overdependence of a particular group of chemicals is one of the important reasons for rapid development of resistance. Effectivity of organophosphate can be increased by using various synergists like sesamum oil and karanj oil. Among the oils, sesame performed better as synergist,increasing the efficacy of organophosphates i.e. quinalphos and monocrotophos (Lande *et al*., 2005). All synergists appear to work by preventing the detoxification of the insecticides with which they are applied (Rao *et al*., 2005). The varoius commercial synergists known are sesamum oil, niger oil, sunflower oil, piperonyl butoxide, neem oil in resistance management programme and can provide better scope for controlling early stage resistance in *H. armigera* (Tripathy and Singh, 2004).

Present studies were undertaken for understanding the efficacy of quinalphos and monocrotophos against *Helicoverpa armigera*

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by adding sesamum oil and karanj oil which are considered as synergists. Also the resistance pattern within above insecticides alone and in combination with sesamum oil and karanj oil was studied, so that best alternative could be used as synergist with organophosphate against *Helicoverpa armigera.*It is also considered as essential in the formulation of diagnostics for use in resistance management.

MATERIALS AND METHODS

The studies were conducted in the insectary of Agricultural Entomology Section, College of Agriculture, Nagpur during *kharif* season 2012-2013 with seven treatments each replicated thrice in Completely Randomised Design. During the present investigation, organophosphates individually and in combination with synergists were tested against third instar larvae of *H. armigera* of three various strains i.e. Akola, Yavatmal and Nagpur in order to assess the per cent mortality and per cent resistance. The insecticides viz., quinalphos 25 EC 0.05 per cent and monocrotophos 36 WSC 0.06 per cent and synergists viz., sesamum oil and karanj oil 2 ml l^{-1} each were tested. The testing of insecticides was done by direct spraying method under laboratory condition.

Details of treatments

T1	Quinalphos 25 EC 0.05%
T2	Monocrotophos 36 WSC 0.06%
T3	Monocrotophos 36 WSC 0.06%+ Sesamum oil 2 ml l^{-1}
T4	Monocrotophos 36 EC 0.06% + karanj oil 2 ml l^{-1}
T5	Quinalphos 25 ECO 0.05% + Sesamum oil 2 ml l^{-1}
T6	Quinalphos 25 ECO 0.05% + Karanj oil 2 ml l^{-1}
T7	Un-treated control (distilled water)

Rearing of field collected *H. armigera*

Larval population of *Helicoverpa armigera* ranged from third to fifth instar were collected from the unsprayed fields of cotton from Akola, Yavatmal and Nagpur and they were reared separately on chickpea based semi-synthetic diet as per Armes *et al*. (1992) using following ingredients to get F_2 generation, as per the standard method of laboratory rearing for *H. armigera* which has following ingredients.

Chickpea based semi-synthetic diet as per Armes *et al.* (1992)

Ingredients	Quantity
a) Part I	
1) Chick pea flour	160 g
2) Wheat germ	60.0 g
4) Methyl -4-Hydroxybenzoate	3.3 g
5) Sorbic acid	1.7 g
6) Aureomycin	2.5 g
7) Formaldehyde(10%)	15.0 ml
8) Distilled water	550.0 ml
b) Part II	
1) Yeast	53.0 g
2) Agar -agar	16.0 g
3) Distilled water	600.0 ml

Insecticide bioassay

Preperation of insecticide solution for treatment

The required concentration of each insecticide was prepared by using following formula:

$$V = \frac{C \times A}{\% a.i}$$

Where,

V = Volume of insecticide
C = Concentration required
A = Quantity of water required
% a.i. = Percentage of active ingredient in commercial insecticide formulation.

The required quantity of water and insecticides were taken into a beaker by using micro pipette and was stirred with glass rod.

For each strain of *H. armigera*, 10 larvae of laboratory reared F_2 generation were taken treatment^{-1} with three replications. Thus, for each strain, 210 larvae were required. Ten third instar larvae weighing 30 to 40 mg each were kept in petri dish and 1 ml of each concentration of insecticide and / or synergist was directly sprayed on the larvae as per treatment. Sprayed petridishes were dried for 5 minutes under fan. The treated larvae were then, transferred to separate plastic vials one larvae each in a vial containing the artificial diet. Control was maintained by spraying 1ml of distilled water. After treatment, plastic vials containing one treated larva per vial were kept at constant temperature at 27 ± 2°C and 70 ± 2% relative humidity in BOD incubator.

Recording observation of resistance on mortality basis

Larval death was recorded 72 hrs after treatment. The moribund larvae were also considered as dead. Per cent resistance of each strain (Akola, Yavatmal, Nagpur) for each treatment was worked out as the mean of resistance of three replications. Per cent resistance was calculated by using following formula (Lande *et al*., 2005).

$$\textbf{Per cent resistance} = 1 - \frac{r}{n} \times 100$$

Where,
r = number of larvae dead
n = number of total larvae treated with chemical and / or synergist

RESULTS AND DISCUSSION

The observations on mortality were recorded 72 hours after treatment and per cent mortality and resistance was calculated and presented in table 1 and 2. After each treatment it was observed that the mortality in the control treatment was invariably nil in all the cases during experimentation.

Efficacy of individual organophosphate and its combination with synergist

The data on larval mortality of *H.armigera* are presented in table 1 and the results were found statistically significant.

According to the mortality in Akola strain, quinalphos 0.05 per cent + sesamum oil 2 ml l^{-1} caused maximum mortality i.e. 66.67 per cent. Monocrotophos 0.06 per cent + sesamum oil 2 ml l^{-1}, quinalphos 0.05 per cent + karanj oil 2 ml l^{-1} and monocrotophos 0.06 per cent + karanj oil 2 ml l^{-1} proved next in effectiveness by recording 56.67 per cent, 56.67 per cent and 53.33 per cent mortality respectively and were found statistically at par with each other. Whereas quinalphos 0.05 per cent and monocrotophos 0.06 per cent were found less effective treatments which are statistically at par with each other by observing 36.67 per cent and 33.33 per cent mortality respectively. All the treatments were superior over the control.

Regarding Nagpur strain, the highest mortality was recorded in the treatment of quinalphos 0.05 per cent + sesamum oil 2 ml l^{-1} i.e. 66.67 per cent followed by quinalphos 0.05 per cent + karanj oil 2 ml l^{-1} and monocrotophos 0.06 per cent + sesamum oil 2 ml l^{-1} recording 63.33 per cent and 60 per cent mortality respectively and were found statistically at par with each other. Monocrotophos 0.06 per cent + karanj oil 2 ml l^{-1} was the next effective treatment with 56.67 per cent mortality. Whereas sole treatments quinalphos 0.05 per cent and monocrotophos 0.06 per cent were found less effective but statistically at par with each other by achieving 43.33 per cent and 40 per cent mortality respectively. All the treatments were superior over the control.

As per the mortality data of Yavatmal strain, the highest mortality was recorded in the treatment of quinalphos 0.05 per cent + sesamum oil 2 ml l^{-1} i.e. 63.33 per cent followed by monocrotophos 0.06 per cent + sesamum oil 2 ml l^{-1}, quinalphos 0.05 per cent + karanj oil 2ml l^{-1} and monocrotophos 0.06 per cent + karanj oil 2ml l^{-1} recording 60 per cent, 60 per cent, 56.67 per cent mortality respectively and were found statistically at par with each other. The remaining sole treatments i.e. quinalphos 0.05 per cent and monocrotophos 0.06 per cent were found less effective and were at par with each other and recorded 40 per cent and 36.67 per cent mortality respectively. All the treatments were superior over the control.

In the present studies. the highest mortality was recorded in the treatment of quinalphos 0.05 per cent + sesamum oil 2 ml l^{-1} i.e. 65.55 per cent. More mortality of *H.armigera* in Nagpur strain indicated that quinalphos performed well in combination with sesamum oil due to less resistant strain. Present findings support the observation of Lande *et al.*(2005)who reported that addition of sesamum oil to quinalphos caused 63.33 per cent mortality. Next effective treatment in both Yavatmal and Akola strain was monocrotophos 0.06 per cent + sesamum oil 2 ml l^{-1} causing 60 and 56.67 per cent mortality respectively. Lande *et al.* (2005) reported that addition of sesame oil to monocrotophos increased the efficacy of monocrotophos from 36.66 to 63.33 per cent larval mortality. Among the sole insecticides, quinalphos 0.05 per cent proved superior treatment against *Helicoverpa armigera* of Akola, Nagpur and Yavatmal strain by observing 36.67, 43.33 and 40 per cent mortality respectively. Results of present studies are consistant with the result of Lodam *et al.* (2001) who reported 43.33 per cent larval mortality due to sole spraying of quinalphos at Akola. Similarly Bharathi (2010) recorded 58.5 per cent larval mortality due to quinalphos at Thondamuthur. Monocrotophos proved less effective than quinalphos which recorded less mortality in all the three strains. The combination of organophosphate with synergists gave maximum mortality of *H.armigera* in Akola, Nagpur and Yavatmal strain.

The mortality levels recorded under all the treatments revealed that all the treatments were found more effective against Nagpur strain followed by Yavatmal and Akola strain, indicating the strain existing at Nagpur was more susceptible to the insecticides than other strains from Akola and Yavatmal.

Resistance in *H. armigera* to organophosphates alone and in combination with synergist

The data in respect of per cent insecticidal resistance to *H.armigera* are presented in table 2 and were found significant.

The maximum per cent resistance was observed in Akola strain of *H. armigera* in the treatment monocrotophos 0.06 per cent i.e. 66.67 per cent followed by quinalphos 0.05 per cent i.e. 63.33 per cent and were found at par with each other. Reduced level of resistance was noticed in monocrotophos 0.06 per cent + karanj oil 2 ml l^{-1} and quinalphos 0.05 per cent + karanj oil 2 ml l^{-1}, monocrotophos 0.06 per cent + sesamum oil 2 ml l^{-1} which recorded 46.67 per cent, 43.33 per cent, and 43.33 per cent resistance respectively. These three treatments were found statistically at par with each other. The minimum per cent resistance was noticed in the treatment, quinalphos 0.05 per cent+ sesamum oil 2 ml l^{-1} i.e. 33.33 per cent.

Regarding the data of Nagpur strain, the maximum per cent resistance was observed in the treatment monocrotophos 0.06 per cent i.e. 60 per cent followed by quinalphos 0.05 per cent i.e. 56.67 per cent and were found at par with each other. Resistance level fell down in monocrotophos 0.06 per cent + karanj oil 2 ml l^{-1} i.e. 43.33 per cent followed by monocrotophos 0.06 per cent + sesamum oil 2 ml l^{-1} and quinalphos 0.05 per cent + karanj oil 2 ml l^{-1} which recorded 40 per cent and 36.67 per cent resistance respectively and were found at par with each other. The minimum per cent resistance was noticed in the treatment, quinalphos 0.05 per cent + sesamum oil 2 ml l^{-1} i.e. 33.33 per cent.

According to per cent resistance in Yavatmal strain, the maximum per cent resistance was observed in the treatment monocrotophos 0.06 per cent i.e. 63.33 per cent followed by quinalphos 0.05 per cent i.e. 60 per cent and were found at par with each other. Reduced level of resistance was noticed in monocrotophos 0.06 per cent + karanj oil 2 ml l^{-1} i.e. 43.33 per cent followed by monocrotophos 0.06 per cent + sesamum oil 2 ml l^{-1} and quinalphos 0.05 per cent + karanj oil 2 ml l^{-1}, which recorded 40 per cent resistance each. The minimum per cent resistance was noticed in the treatment, quinalphos 0.05 per cent + sesamum oil 2 ml l^{-1} i.e. 36.67 per cent. These four treatments were statistically at par with each other.

In the present investigation, resistance got decreased with addition of synergist i.e. sesamum oil and karanj oil, into quinalphos and monocrotophos. As the maximum resistance was observed in the treatment monocrotophos and quinalphos when applied as a sole treatment, both the treatments were less effective. Yadav *et al.*(2010) estimated the status of quinolphos in Khandwa population of *H. armigera* using the standard topical application method and found that the mean resistance frequencies of quinolphos 0.75 ml $l^{-1}$was 50.35 per cent. Shrivastava *et al.* (2008) also reported that the resistance of 46 per cent to quinalphos in the field strains of Khandwa. Thus the population of *H. armigera* from Akola, Nagpur and Yavatmal appear to be more resistant than Khandwa population.

Rao *et al.* (2005) carried out insecticide resistance studies on *Helicoverpa armigera* (Hub.) in Andhra Pradesh (India) during 2003-04 and 2004-05 crop seasons to quinalphos. Quinalphos showed moderate to above moderate level frequencies ranged from 26.35 ± 4.4 to 78.24 ± 8.24 and the mean was 52.41±2.78. Kumar and Regupathy (2009) determined the resistance levels to quinalphos in populations around experimental sites varied from 25.0 per cent to 56.5 per cent. Yadav *et al.* (2010) reported that application of quinalphos 0.75 μg and

Table 1. Mean per cent mortality in *H.armigera* (Hubner) of Akola, Nagpur and Yavatmal strain

Sr. No.	Treatments	Per cent Mortality			Mean
		Akola	Nagpur	Yavatmal	
T_1	Quinalphos 25 EC 0.05 %	36.67 (37.22)	43.33 (41.15)	40.00 (39.15)	40 (39.17)
T_2	Monocrotophos 36 WSC 0.06 %	33.33 (35.22)	40.00 (39.23)	36.67 (37.14)	36.66 (37.19)
T_3	Monocrotophos 36 WSC 0.06 % + Sesamum oil $2mll^{-1}$	56.67 (48.85)	60.00 (50.77)	60.00 (50.77)	58.89 (50.13)
T_4	Monocrotophos 36 WSC 0.06 % + Karanj oil 2ml l^{-1}	53.33 (46.92)	56.67 (48.85)	56.67 (48.85)	55.55 (48.20)
T_5	Quinalphos 25 EC 0.05 % + Sesamum oil 2ml l^{-1}	66.67 (54.78)	66.67 (54.78)	63.33 (52.78)	65.55 (54.11)
T_6	Quinalphos 25 EC 0.05 % + Karanj oil 2ml l^{-1}	56.67 (48.85)	63.33 (52.78)	60.00 (50.77)	60 (50.8)
T_7	Control (Distilled water)	0	0.00	0.00	0
	SE (m)	1.82	1.49	2.23	1.84
	CD at 5%	5.52	4.51	6.76	5.59

(Figures in parenthesis are arc sin transformation)

Table 2. Mean per cent resistance in *H.armigera* (Hubner) of Akola, Nagpur and Yavatmal strain

Sr. No.	Treatments	Per cent resistance			Mean
		Akola	Nagpur	Yavatmal	
T_1	Quinalphos 25 EC 0.05 %	63.33 (52.78)	56.67 (48.85)	60.00 (50.85)	60 (50.82)
T_2	Monocrotophos 36 WSC 0.06 %	66.67 (54.78)	60.00 (50.77)	63.33 (52.86)	63.33 (52.80)
T_3	Monocrotophos 36 WSC 0.06 % + Sesamum oil 2ml l^{-1}	43.33 (41.15)	40.00 (39.23)	40.00 (39.23)	41.11 (39.87)
T_4	Monocrotophos 36 WSC 0.06 % + Karanj oil 2ml l^{-1}	46.67 (43.08)	43.33 (41.15)	43.33 (41.15)	44.44 (41.79)
T_5	Quinalphos 25 EC 0.05 % + Sesamum oil 2ml l^{-1}	33.33 (35.22)	33.33 (35.22)	36.67 (37.22)	34.44 (35.88)
T_6	Quinalphos 25 EC 0.05 % + Karanj oil 2ml l^{-1}	43.33 (41.15)	36.67 (37.22)	40.00 (39.23)	40 (39.2)
T_7	Control (Distilled water)	100.00 (90)	100.00 (90)	100.00 (90)	100 (90)
	SE (m)	1.82	1.49	2.23	1.84
	CD at 5%	5.52	4.51	6.76	5.59

(Figures in parenthesis are arc sin transformation)

Chlorpyriphos 1.0 μg larvae^{-1} showed low to moderate resistance and monocrotophos 1.0 μg larvae^{-1} showed constant moderate to high resistance throughout the season. Wargantiwar *et al.* (2013) reported that the cultivators have resorted to indiscriminate and excessive use of chemical insecticides to control *H. armigera*. This has led to emergence of serious problem of resistance development to different groups of insecticides such as pyrethroids (Cypermethrin 0.75 ug) and organophosphate (Monocrotophos 1.0 μg). Mironidis *et al.* (2013) found relatively moderate resistance level against third instar larvae of *H. armigera* with resistance ratios below 10- fold for organophosphate and carbamate and up to 16- fold for the pyrethroid alpha-cypermethrin. Results of the present investigation are consistant with the findings of above mentioned authors.

In the present studies, least resistance was recorded in the treatment of quinalphos 0.05 per cent + sesamum oil 2 ml l^{-1} i.e. 34.44 per cent. More mortality of *H.armigera* in Nagpur strain indicated that quinalphos performed well in combination with sesamum oil due to less resistant strain.The resistance levels recorded under all the treatments revealed that all the treatments were found more effective against Nagpur strain followed by Yavatmal and Akola strain, indicating the strain existing at Nagpur was less resistant to the insecticides.

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EFFECT OF FOLIAR APPLICATION OF ZINC AND IRON ON GROWTH AND YIELD OF MARIGOLD

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ABSTRACT

An investigation was conducted to study the effect of foliar application of zinc and iron on growth, flowering and yield of marigold at the field of Horticulture Section, College of Agriculture, Nagpur during the year 2013-2014. Experiment was laid out in Randomized Block Design with three replications and nine treatments of foliar application of zinc and iron with different concentrations alone and in combinations viz., 0.5% $FeSO_4$, 1% $FeSO_4$, 0.5% $ZnSO_4$, 1% $ZnSO_4$, 0.5% $FeSO_4$ + 0.5% $ZnSO_4$, 0.5% $FeSO_4$ + 1% $ZnSO_4$, 1% $FeSO_4$ + 0.5% $ZnSO_4$, 1% $FeSO_4$ + 1% $ZnSO_4$ and control. It is evident from the experimental findings that, in terms of growth parameters viz., height of plant (42.97 cm), stem diameter (1.38 cm), number of branches plant^{-1} (18.53) and spread of plant at 50% flowering (32.92 cm), flowering parameters viz., early flower bud initiation (31.43 days), minimum days to fully opened flower (13.05 days), minimum days to 50% flowering (44.00 days), minimum days to first harvesting after transplanting (49.67 days), maximum flowering span (68.00 days) and yield parameter viz., flower yield hectare^{-1} (21.97 t) were found maximum with the foliar application of 0.5% $FeSO_4$ + 0.5% $ZnSO_4$ followed by 0.5% $ZnSO_4$ when compared with control and rest of the treatments under study.

(Key words: Marigold, zinc, iron, foliar spray)

INTRODUCTION

Marigold is one of the most popular annual flowers in India for garden display as well as for commercial cultivation. In India marigold rank first among the loose flowers. Marigold is a native of Central and South America especially Mexico and belongs to family 'Asteraceae' and genus *Tagetes*. The name *Tagetes* was given after 'Tages' a demigod known for its beauty. The African marigold (*Tagetes erecta* L.) is hardy annual about 90 cm tall, erect and produces branches. Leaves are pinnately divided and leaflets are lanceolate and serrated. The flowers are single to fully double and of large size with globular heads. The florets are either two lipped or quilled. The flower colour varies from lemon yellow or yellow, golden yellow or orange. Because of its size, shape and colour the African marigold are popular among the people. It is an important raw material for perfume industries. The essential oil from plant and flower can be readily extracted by steam distillation. The oil has a pronounced odour and it acts as repellent to flies. It has been found that the marigold plants are highly useful for suppressing the population of nematodes in the field. Roots of nursery plants of apple and rose are almost free from *Pratylenchus* species of nematodes when they were grown in a two years rotation with marigold. Infestation of fruit borer can be reduced by planting of marigold as an intercrop in the crops. Both leaves and flowers are equally important from the medicinal point of view. Leaf paste is externally used against boils and carbuncles. Leaf extract is a good remedy for earache. Flower extract is consider a blood purifier, a cure for bleeding piles and is also a good remedy for eye diseases and ulcers.

Micronutrients like zinc and iron have major role in growth and flowering of ornamental plants and therefore, these nutrients are becoming extremely important and valuable in the commercial floriculture for increasing the growth and yield of flower crops. These micronutrients generally activate several enzymes and involve themselves in chlorophyll synthesis and various physiological activities by which plant growth and development are encouraged. The nutrition of marigold is concentrated on major nutrients only. The application of micronutrients are neglected due to lack of its knowledge. Further the marigold crop is general cultivated on shallow soils which are many times deficient in micronutrients. The results of micronutrient on flower crops showed promises. Hence, considering the important role of optimum level of foliar application of zinc and iron in enhancing the growth, flowering and yield of flowers, the present study was undertaken to study the effect of foliar application of zinc and iron on growth and yield of marigold.

MATERIALS AND METHODS

An investigation entitled, “Effect of foliar application of zinc and iron on growth, flowering and yield of marigold” was carried out at the experimental

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farm of Horticulture Section, College of Agriculture, Nagpur during the year 2013-2014. The experiment was laid out in Randomized Block Design with three replications and nine treatments of foliar application of zinc and iron with different concentrations alone and in combinations. The treatments comprised of T_1 (control), T_2 (0.5% $FeSO_4$), T_3 (1% $FeSO_4$), T_4 (0.5% $ZnSO_4$), T_5 (1% $ZnSO_4$), T_6 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$), T_7 (0.5% $FeSO_4$ + 1% $ZnSO_4$), T_8 (1% $FeSO_4$ + 0.5% $ZnSO_4$) and T_9 (1% $FeSO_4$ + 1% $ZnSO_4$). The sources of zinc and iron were zinc sulphate and iron sulphate respectively. The zinc sulphate and iron sulphate were sprayed as per treatments at an interval of 30 days and 45 days after transplanting. The field was prepared by ploughing and harrowing. Flat beds of size 1.8 m x 1.8 m were prepared and transplanting of marigold seedling was done at spacing of 45 cm x 30 cm. A half dose of nitrogen (50 kg ha^{-1}), full dose of potassium (25 kg ha^{-1}) and phosphorus (50 kg ha^{-1}) were applied as a basal dose at the time of transplanting. Remaining half dose of nitrogen (50 kg ha^{-1}) was applied 30 days after transplanting. Various observations viz., height of plant, stem diameter, number of branches $plant^{-1}$, spread of plant at 50% flowering, days to first flower bud initiation, days to fully opened flower, days to 50% flowering, days to first harvesting after transplanting, flowering span and flower yield $hectare^{-1}$ were recorded. The data were statistically analyzed as per the method suggested by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

The data in table 1 revealed that, significant differences were recorded among the treatments in respect of height of plant, stem diameter of plant, branches $plant^{-1}$ and spread of plant at 50% flowering. Significantly maximum plant height (42.97 cm) was observed in treatment T_6 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatment T_4 (39.43 cm, 0.5% $ZnSO_4$). However, minimum plant height was recorded in the control treatment T_1 (33.42 cm). Treatments T_2 (0.5% $FeSO_4$), T_3 (1% $FeSO_4$), T_5 (1% $ZnSO_4$), T_7 (0.5% $FeSO_4$ + 1% $ZnSO_4$), T_8 (1% $FeSO_4$ + 0.5% $ZnSO_4$) and T_9 (1% $FeSO_4$ + 1% $ZnSO_4$) were found significantly superior over control. Similarly, stem diameter of plant was recorded maximum in treatment T_6 (1.38 cm, 0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatment T_4 (1.31 cm, 0.5% $ZnSO_4$). However, minimum stem diameter of plant was recorded in the control treatment T_1 (1.04 cm). Treatments T_2 (0.5% $FeSO_4$), T_3 (1% $FeSO_4$), T_5 (1% $ZnSO_4$), T_7 (0.5% $FeSO_4$ + 1% $ZnSO_4$) and T_9 (1% $FeSO_4$ + 1% $ZnSO_4$) were found significantly superior over control. Similarly, maximum number of branches $plant^{-1}$ (18.53) was observed in treatment T_6 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatment T_4 (17.20, 0.5% $ZnSO_4$). However, minimum number of branches was recorded in treatment T_1 (control, 11.60). Treatments T_2 (0.5% $FeSO_4$), T_3 (1% $FeSO_4$), T_5 (1% $ZnSO_4$), T_7 (0.5% $FeSO_4$ + 1% $ZnSO_4$), T_8 (1% $FeSO_4$ + 0.5% $ZnSO_4$) and T_9 (1% $FeSO_4$ + 1% $ZnSO_4$) were found significantly superior over control. Also, significantly maximum spread of plant at 50% flowering (32.92 cm) was recorded in treatment T_6 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatments T_4 (30.93 cm, 0.5% $ZnSO_4$) and T_2 (28.70 cm, 0.5% $FeSO_4$). However, minimum spread of plant at 50% flowering was recorded in the control treatment T_1 (26.10 cm). The favourable effect of zinc and iron in promoting the plant height, stem diameter, branches and spread was might be due to the role of zinc in active synthesis of tryptophan, an amino acid which is a precursor of IAA which stimulates the growth of plant. There exist a positive correlation between zinc and phosphorus. Zinc has synergetic effect on absorption of phosphorus which may serve as a source of energy for the synthesis of auxin and it could attributed as one for the elongation of stem. The iron which is a component of ferrodoxin, an electron transferring protein and associated with chloroplast. It enhances the rate of photosynthesis leading to better vegetative growth. The results are in close agreement with the results of Kakade *et al.* (2009). They observed that foliar application of $ZnSO_4$ 0.5% at an interval of 30, 45 and 60 days after transplanting produced maximum plant height, plant spread and number of branches $plant^{-1}$ in China aster. Also, Kumar *et al.* (2010) reported that foliar spray of $FeSO_4$ 1.0% recorded the highest number of primary branches $plant^{-1}$ and $FeSO_4$ 1.5% resulted in the maximum production of secondary branches $plant^{-1}$ and plant spread in African marigold. Katiyar *et al.* (2012) also noticed that, foliar spray of zinc 0.5% influenced the leaf length and number of leaves $plant^{-1}$ in gladiolus.

Similarly, significant differences were recorded among the treatments in respect of days to first flower bud initiation, days to fully opened flower, days to 50% flowering, days to first harvesting and flowering span. Significantly minimum days to first flower bud initiation (31.43 days) was recorded in treatment T_6 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatment T_4 (33.63 days, 0.5% $ZnSO_4$). However, maximum days to first flower bud initiation was recorded in the control treatment T_1 (37.33 days). Treatment T_2 (0.5% $FeSO_4$) was found significantly superior over control. Similarly, minimum days to fully opened flower (13.05 days) was recorded in the treatment T_6 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatment T_4 (13.94 days, 0.5% $ZnSO_4$). However, maximum days to fully opened flower was recorded in the control treatment T_1 (16.22 days). Treatments T_2 (0.5% $FeSO_4$), T_3 (1% $FeSO_4$), T_5 (1% $ZnSO_4$), T_7 (0.5% $FeSO_4$ + 1% $ZnSO_4$), T_8 (1% $FeSO_4$ + 0.5% $ZnSO_4$) and T_9 (1% $FeSO_4$ + 1% $ZnSO_4$) were found significantly superior over control. Zinc plays vital role in growth and development of plant because of its stimulatory and catalyst effect on various physiological and metabolic processes of plant. Zinc favours the storage of more carbohydrates through photosynthesis, which may be the attributing factor for the positive effectiveness of zinc on early flowering. Also, iron is involved in the synthesis of plant hormones and also plays an important role in chlorophyll synthesis, photosynthesis and respiration. This might have been the reason for early flowering. Kumar *et al.* (2010 a) recorded 150 ppm Fe spray at 15 and 30 days after transplanting required minimum days taken to first flower bud appearance and earlier opening of flower in African marigold. Similarly, minimum days to 50% flowering (44.00 days) was recorded in treatment T_6 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatment T_4 (47.33 days, 0.5% $ZnSO_4$). However, maximum days to 50% flowering was recorded in the control treatment T_1 (54.00 days). Treatments T_2 (0.5% $FeSO_4$) and T_3 (1% $FeSO_4$) were found significantly superior over control. Similarly minimum days to first harvesting after transplanting (49.67 days) was recorded in treatment T_6 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatment T_4 (53.00 days, 0.5% $ZnSO_4$). However, maximum days to first harvesting was recorded in the control treatment T_1 (61.00 days). Treatments T_2 (0.5% $FeSO_4$), T_3 (1% $FeSO_4$), T_5 (1% $ZnSO_4$), T_7 (0.5% $FeSO_4$ + 1% $ZnSO_4$) and T_8 (1% $FeSO_4$ + 0.5% $ZnSO_4$) were found significantly superior over control. Application of zinc and iron resulted in the earliest initiation of first flower bud and fully opened flower which might have reduced the days required for 50% flowering and first harvesting after transplanting. Balkrishnan *et al.* (2007) reported that, spraying of African marigold with 0.5% zinc sulphate + 0.5% ferrous sulphate recorded the early flowering.

Similarly, flowering span (68.00 days) was found significantly maximum in treatment T_6 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatment T_4 (65.33 days, 0.5% $ZnSo_4$). Whereas, minimum flowering span was observed in the control treatment T_1 (55.67 days). Treatments T_2 (0.5% $FeSO_4$), T_3 (1% $FeSO_4$), T_5 (1% $ZnSO_4$), T_7 (0.5% $FeSO_4$ + 1% $ZnSO_4$) and T_9 (1% $FeSO_4$ + 1% $ZnSO_4$) were found significantly superior over control. The positive impact of zinc might be due to the ability of this nutrient in activating several enzymes catalase, peroxidase, tryptophan synthate and its involvement in chlorophyll synthesis and various physiological activities, ultimately leading the longer blooming period over all the treatments. Kumar *et al.* (2009) reported in chrysanthemum that the duration of flowering was recorded maximum with foliar spray of $FeSO_4$ 0.2% (62.3 days).

The data from the table 1 revealed that, significant differences were recorded among the treatments in respect of flower yield hectare^{-1}. Maximum flower yield hectare^{-1} (21.97 t) was found in treatment T_6 (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) followed by treatment T_4 (19.34 t, 0.5% $ZnSO_4$). However, minimum flower yield hectare^{-1} was recorded in the control treatment T_1 (14.28 t). Treatments T_2 (0.5% $FeSO_4$), T_3 (1% $FeSO_4$), T_5 (1% $ZnSO_4$), T_7 (0.5% $FeSO_4$ + 1% $ZnSO_4$), T_8 (1% $FeSO_4$ + 0.5% $ZnSO_4$) and T_9 (1% $FeSO_4$ + 1% $ZnSO_4$) were found significantly superior over control. Zinc and iron play vital role in the production of vegetative growth ultimately encourage the number of branches by involving in oxidation-reduction process, photosynthesis and breakdown of IAA, auxin and protein synthesis. Also, more zinc and iron received by plant produced larger canopy development, associated with leaf area, resulting in accumulation of higher amount of photosynthate which showed the

Table 1. Influence of foliar application of zinc and iron on growth, flowering and yield of marigold

Treatments	Height of plant (cm)	Stem diameter of plant (cm)	Branches $plant^{-1}$	Spread of plant at 50% flowering (cm)	Days to first flower bud initiation	Days to fully opened flower	Days to 50% flowering	Days to first harvesting	Flowering span (Days)	Flower yield ha^{-1} (t)
T_1- Control	33.42	1.04	11.60	26.10	37.33	16.22	54.00	61.00	55.67	14.28
T_2 - 0.5% $FeSO_4$	39.05	1.18	15.62	28.70	33.73	14.45	48.33	54.67	64.33	18.66
T_3 - 1% $FeSO_4$	38.09	1.13	15.10	27.20	35.77	14.84	51.00	56.67	62.00	16.62
T_4 - 0.5% $ZnSO_4$	39.43	1.31	17.20	30.93	33.63	13.94	47.33	53.00	65.33	19.34
T_5 - 1% $ZnSO_4$	38.43	1.15	15.13	27.29	36.20	14.99	51.67	57.00	62.67	18.48
T_6 - 0.5% $FeSO_4$ + 0.5% $ZnSO_4$	42.97	1.38	18.53	32.92	31.43	13.05	44.00	49.67	68.00	21.97
T_7 - 0.5% $FeSO_4$ + 1% $ZnSO_4$	38.03	1.12	15.00	27.14	36.53	15.46	52.33	58.00	61.00	16.56
T_8 - 1% $FeSO_4$ + 0.5% $ZnSO_4$	37.45	1.09	14.82	26.94	36.27	15.16	52.00	57.33	58.00	16.40
T_9 - 1% $FeSO_4$ + 1% $ZnSO_4$	37.65	1.11	14.90	27.00	36.67	15.84	52.67	58.67	59.00	16.42
SE (m) ±	0.61	0.018	0.32	0.41	0.62	0.35	0.84	0.91	0.78	0.54
CD at 5%	1.83	0.054	0.97	1.23	1.88	1.06	2.53	2.75	2.36	1.62

positive effect on yield contributing characters. These results are in conformity with the result obtained by Ganga *et al*. (2008). They reported in chrysanthemum that foliar spray of zinc sulphate at 0.4 per cent increased the flower yield plant^{-1} and total yield hectare^{-1}. Kumar *et al*. (2010 b) also reported in African marigold that foliar spray of $FeSO_4$ 1.5% increased maximum flower yield plant^{-1} and flower yield hectare^{-1}. Jagtap *et al*. (2012) also reported in rose that foliar spray of 0.3 % $ZnSO_4$ + 0.3 % $MnSO_4$+ 0.3% $FeSO_4$ increased flower yield. Sharma *et at.* (2013) observed that the foliar spray of zinc 0.75% increased yield of spike and corms in gladiolus.

Keeping in view the results summarized above it may be concluded that the foliar spraying of 0.5% $FeSO_4$ + 0.5% $ZnSO_4$ to marigold plant was effective in influencing the growth, flowering and yield parameters followed by 0.5% $ZnSO_4$ application.

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UTILIZATION OF GULKAND IN THE PREPARATION OF SHRIKHAND

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ABSTRACT

The shrikhand was prepared with constant level of sugar (40 per cent by weight of chakka) and different levels of gulkand viz., 1.5, 2.0, 2.5 and 3.0 per cent by replacing the chakka in formulation. The product was analyzed for chemical composition like fat, total solids, protein, titratable acidity and ash as well as for sensory attributes like flavour, body and texture, colour and appearance in completely randomized design. The cost of production was also calculated by considering the retail market prices of different ingredients used. The results showed that fat, protein and titratable acidity were significantly decreased, while the total solids and ash percentage were significantly increased with the increase in the levels of gulkand. The significantly highest score for flavour, body and texture, colour and appearance and overall acceptability were obtained in shrikhand prepared with 2.5 per cent gulkand.

Good quality shrikhand can prepared by using 2.5 per cent gulkand had mild pleasant flavour, smooth body and texture and light reddish colour. The cost cost of shrikhand increased with increase in the levels of gulkand. However, it is opined that superior quality shrikhand can be produced by addition of 2.5 per cent of gulkand with cost of production of Rs. 117.26 Kg^{-1}.

(Key words: Shrikhand, gulkand, physicochemical parameters, sensory attributes, cost structure)

INTRODUCTION

Cultured dairy products are the vital component of the human diet in India. Apart from imparting nutrition and novelty, these products help to preserve the precious nutrients in milk which tend to quick deterioration. The indigenous fermented milk based dessert, most popular in many parts of the country. The importance of milk and milk products in India is realized since vedic period. Due to high nutritive characteristics flavour, taste, palatable nature and possible therapeutic value of shrikhand is one amongst the most preferred dairy products in western India. Shrikhand is a traditional indigenous fermented semi soft, sweetened whole milk product prepared using Chakka (strained dahi). Further, taste and the appearance of the product can be improved by adding sugar and other ingredients like nuts, colours etc. Because of the change in the economic status and food habit of consumers the other varieties of shrikhand such as fruit shrikhand are also in great demand (Laxmi *et al*., 2013).

Gulkand is an Arabic word Gul means Rose and Kand means Sugar. Gulkand is undoubtedly the most delicious ayurvedic preparation known to mankind. Gulkand is commonly used as an ingredient of Paan, a popular dessert and digestive of India, Pakistan and Bangladesh. The flowers of *Rosa damascena*, more commonly known as the Damascus rose, are used for making Gulkand. Though there are suggestions of some other varieties of roses also, Damascus rose is the most common variety used. traditionally gulkand has been used as a cooling tonic to combat fatigue, lathery, muscular aches, biliousness itching, and heat-related conditions. It is good for memory and eyesight as well as a good blood purifier. Gulkand also helps reducing hyperacidity. It is also rich in calcium and has antioxidant properties. It can be used year-round by persons of all constitutions, especially Vata and Pitta. Indian Ayurvedic doctors, use it combined with other specific herbs for several types of cancer patients undergoing radiation or chemotherapies to counter the ill effects of these therapies (Sundaram, 2010).

Addition of gulkand may enhance the flavour, colour, body and texture and overall acceptability of shrikhand. As the gulkand is having nutritional and medicinal importance, it is expected that the product may fulfil consumers appeal regarding nutritional quality to the newly formulated product. Gulkand and rose petals can be used as flavouring and colouring agent in Shrikhand without adversely affecting the quality of the product (Nadaf *et al.,* 2012).

Therefore, it was planned to study on utilization of gulkand in the preparation of shrikhand.

MATERIALS AND METHODS

During the entire study fresh, clean, whole cow milk was obtained from Section of Animal Husbandry and Dairy Science, College of

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Agriculture, Nagpur. The milk was strained through clean muslin cloth and transferred into well cleaned and sterilized flat bottom stainless steel vessel and standardized at 4 per cent fat. Gulkand available in the market was used for preparation of shrikhand. Clean crystalline sugar purchased from local market. The freeze dried curd culture of *Lactobacillus bulgaricus* and *Lactobacillus bulgaricus* and from National Culture Collection Unit, N.D.R.I., Karnal was used in 1:1 proportion @ 1 per cent. The cultures were maintained during the investigation in 10 ml sterilized skim milk media in test tubes. The cultures were transferred by inoculation in tubes and incubated at 37°C temperature in incubator for 12 hours. After coagulation, the cultures were stored in the refrigerator at 8 to 10°C. Laboratory cultures were activated three times separately in sterilized skim milk before use for preparation of curd. Curd was prepared from boiled milk cooled and fermented with mixed starter culture *(Lactobacillus bulgaricus* and *Lactobacillus bulgaricus* used in 1:1 proportion) @1 per cent and incubated at 12 hours (30 ^{0}C). Curd was transferred to muslin cloth and whey was allowed to drain out by hanging it for 8-10 hours to obtain chakka which was then used for preparation of shrikhand by the addition of sugar and other ingradients. The shrikhand was prepared with constant level of sugar (40 per cent by weight of chakka) and different levels of gulkand viz., 1.5 T_1, 2.0 T_2, 2.5 T_3 and 3.0 T_4 per cent by replacing the sugar blended chakka in formulation.

After the addition of gulkand and sugar as per treatment, the mixture was well kneaded to obtain firm body and texture of shrikhand. Analytical grade chemicals were used for chemical analysis.

Fat content in shrikhand was determined by Mojonnier fat extraction apparatus method as prescribed in B.I.S. Handbook of food analysis. IS: 11721 (Anonymous, 2005). The total solids percentage in shrikhand was determined by using gravimetric method as per the procedure of IS: 1479 Part II (Anonymous, 1961). The protein content in shrikhand was determined as per the procedure recommended in IS: 1479 Part II, (Anonymous, 1961). Titratable acidity was determined by the method described in BIS-1960; IS-1479, part I (Anonymous, 1960). The ash content was determined as per the method recommended in B.I.S. Handbook of food analysis. IS: 1167(Anonymous, 1967).

The quality of shrikhand were judged by sensory evaluation in respect of flavour, body and texture, colour and appearance, by offering sample to panel of 5 judges in each trial separately with help of 100 point numeric score prescribed by Pal and Gupta (1985).

Sr. No.	Characters	Score
1	Flavour	45
2	Body and Texture	35
3	Colour and Appearance	20
	Total	100

The experiment was laid out in CRD with 4 treatments and five replications. The data were analyzed statistically according to method described by Snedecor and Corchan (1967).

RESULTS AND DISCUSSION

Chemical quality of gulkand shrikhand was evaluated with respect to fat, total solids, protein, titratable acidity and ash content and data are presented in table 1.

Fat content

The highest fat content i.e. 10.75 per cent was observed in shrikhand prepared with 1.5 per cent gulkand. While the fat percentage was decreased to 9.95, 9.57 and 9.22 per cent in shrikhand prepared with 2.0, 2.5 and 3.0 per cent levels of gulkand respectively. The fat percentage of shrikhand was decreased continuously with increase in the levels of gulkand.

The results of present investigation are in line with the findings of Nadaf *et al.* (2012). They reported that increase in the level of gulkand and rose petal powder there was proportionately decrease in the fat content of shrikhand. Likewise, Nigam *et al.* (2009) also noticed that with the addition of papaya pulp in chakka during the manufacture of shrikhand there was decrease in the fat content in shrikhand and vice-versa.

Total solids content

It was seen that the treatment 3.0 per cent gulkand had highest total solids content i.e. 52.67, followed by 2.5 per cent gulkand (52.32 per cent), 2.0 per cent gulkand (51.97 per cent) and 1.5 per cent gulkand (51.46 per cent). Thus, the addition of gulkand also increased the total solids content of shrikhand. The results indicated that with the increase in levels of gulkand there was significant increase in the total solids percentage of shrikhand.

Increase in the level of banana pulp, there was significant increase in the total solids content in shrikhand (Narayanan and Lingam, 2013). These results are comparable with the findings of present study.

Protein content

Protein content of shrikhand was significantly affected due to the addition of different levels gulkand. Protein content of shrikhand under the treatment 1.5 per cent gulkand, 2.0 per cent gulkand, 2.5 per cent gulkand and 3.0 per cent gulkand were 7.14, 7.00, 6.83 and 6.67 per cent respectively. The protein content of shrikhand was decreased with the increase in the levels of gulkand.

Mali *et al.* (2010) reported that with increase in the level of papaya pulp there was significant decrease in the protein content of shrikhand. The result of Nadaf *et al.* (2012) indicated that with increased level of gulkand and rose petal powder there was decrease in the protein content of shrikhand. Similarly, Kolape *et al.* (2010) also reported that with the increase in the level of papaya pulp there was significant decrease in the protein content of shrikhand.

Titratable acidity content

Titratable acidity content of shrikhand was significantly affected due to the addition of gulkand in different levels. Titratable acidity content of shrikhand under treatment 1.5 per cent gulkand, 2.0 per cent gulkand, 2.5 per cent gulkand and 3.0 per cent gulkand were 1.71, 1.67, 1.63 and 1.59 per cent respectively. Titratable acidity content of shrikhand decreased continuously with the increased levels of gulkand from 1.71 in 1.5 per cent gulkand to 1.59 per cent in 3.0 per cent gulkand.

The results of present investigation are in conformity with the results of Dadarwal *et al.* (2005) who also reported that with the increase in the levels of Banana, Guava and Sapota pulp there was decrease in the titratable acidity content of shrikhand. The results are also in line with the results of Kolape *et al.* (2010) who reported that with the increase in levels of papaya pulp decreased the titratable acidity content of shrikhand.

Ash content

The highest ash percentage was observed in shrikhand prepared with 3.0 per cent gulkand i.e. 1.31 per cent, followed by 2.5, 2.0 and 1.5 per cent levels of gulkand which contains 1.26, 1.19 and 1.13 per cent ash respectively. The ash content of shrikhand increased with the increase in the levels of gulkand.

The results of this investigation are in agreement with the results obtained by Mali *et al.* (2010) who used papaya pulp in shrikhand preparation and concluded that with the increase in the levels of papaya pulp there was significant increase in the ash content of shrikhand. Also Nadaf *et al.* (2012) reported increasing trend of ash content of shrikhand with increased levels of gulkand and rose petal powder.

Sensory evaluation of shrikhand

The results with respect to sensory evaluation of gulkand shrikhand are presented in table 2.

Flavour score

It was found that, as the levels of gulkand increased, there was a simultaneous increase in the flavour score of shrikhand upto certain limit and thereafter, it decreased. Shrikhand prepared by using 2.5% gulkand scored the highest marks (42.2 out of 45) while the lowest score (37 out of 45) was secured by the shrikhand prepared by 3.0% gulkand. Statistically, the treatment 2.5 per cent gulkand was superior among all the treatments, which had mild pleasant flavour (Table 2).

Kumar *et al.* (2011) reported that with the increase in the levels of apple pulp and *Celosia argentea* flower powder increased the flavour score of shrikhand. Landge *et al.* (2011) who reported that increase in the levels of ashwagandha powder increased the flavour score of shrikhand.

Table 1. Chemical composition of gulkand shrikhand

Treatments	Fat	Total solids	Protein	Titratable acidity	Ash
T_1 1.5 per cent gulkand	10.75[a]	51.46[d]	7.14[a]	1.71[a]	1.13[d]
T_2 2.0 per cent gulkand	9.95[b]	51.97[c]	7.00[b]	1.67[b]	1.19[c]
T_3 2.5 per cent gulkand	9.57[c]	52.32[b]	6.83[c]	1.63[c]	1.26[b]
T_4 3.0 per cent gulkand	9.22[d]	52.67[a]	6.67[d]	1.59[d]	1.31[a]
SE(m)±	0.044	0.24	0.031	0.007	0.0058
CD at 5%	0.13	0.73	0.095	0.022	0.017

Values with different superscripts differ significantly (P<0.05)

Table 2. Table for sensory evaluation of shrkhand as affected by different levels of gulkand

Treatments	Flavour	Body & Texture	Colour & Appearance
T_1 1.5 per cent gulkand	37.80[c]	30.00[d]	14.60[d]
T_2 2.0 per cent gulkand	39.00[b]	30.60[c]	15.20[c]
T_3 2.5 per cent gulkand	42.20[a]	33.40[a]	17.60[a]
T_4 3.0 per cent gulkand	37.00[d]	31.40[b]	15.60[b]
SE(m)±	0.18	0.14	0.074
CD	0.54	0.44	0.22

Values with different superscripts differ significantly (P<0.05)

Body and texture score

The body and texture score of shrikhand seems to be mainly depending on levels of gulkand added. It was observed that as the levels of gulkand increased, there was a simultaneous increase in the body and texture score of shrikhand upto 2.5% gulkand containing shrikhand, after that, it decreased. Shrikhand prepared with 2.5% gulkand scored the highest marks (33.4 out of 35), while the lowest score (30 out of 35) secured by the shrikhand prepared with 1.5% gulkand. Statistically, the treatment 2.5 per cent gulkand was superior among all the treatments (Table 2).

The above results are in agreement with the results obtained by Narayanan and Lingam (2013) who prepared shrikhand by using banana pulp and reported increasing trend of body and texture score of shrikhand with increased levels of banana pulp. Laxmi *et al.* (2013) reported that with increase in levels of jamun fruit pulp, there was increased body and texture score of shrikhand.

Colour and appearance score

The colour and appearance score of shrikhand seems to be mainly depends on levels of gulkand. As the level of gulkand increased, colour intensity and appearance was also improved. The highest score for colour and appearance was obtained (17.60 out of 20) by the shrikhand prepared with 2.5 % gulkand, while the lowest score was secured (14.60 out of 20) by the shrikhand prepared with 1.5 % gulkand. Statistically, treatment with 2.5 per cent gulkand was superior among all the treatments (Table 2).

Tale (2013) reported that with increase in the level of turmeric powder, colour and appearance score of shrikhand was also increased. Also Nadaf *et al.* (2012) used gulkand and rose petal powder to enhance the flavour and colour of shrikhand and they noticed that increase in the levels of gulkand and rose petal powder, there was increased in colour and appearance score of shrikhand. Similarly, Mali *et al.* (2010) reported the increased colour and appearance score with increased levels of papaya pulp.

Cost of production

The cost of production of 1 kg gulkand shrikhand under various treatments 1.5 per cent gulkand, 2.0 per cent gulkand, 2.5 per cent gulkand and 3.0 per cent gulkand were Rs. 115.57, 116.42, 117.26 and 118.11 respectively. The cost of production increases with increased levels of gulkand. The lowest cost of production Rs. 115.57 was recorded in case of shrikhand prepared with 1.5 per cent gulkand, while the highest cost of production recorded in shrikhand prepared with 3.0 per cent gulkand. However, the cost of production of shrikhand prepared with 2.5% gulkand was found to be Rs. 117.26 kg^{-1} which is the best treatment selected by judges for sensory evaluation.

Tale (2013) also conducted similar type of work by using turmeric powder and concluded that with increase in the level of turmeric powder, cost of shrikhand was also increased. Meshram (2010) noticed that cost of shrikhand increased with the increase in the levels of orange concentrate.

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STUDIES ON PRODUCTIVE PERFORMANCE AND QUALITY OF MILK OF CROSSBRED COWS

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ABSTRACT

The investigation on productive performance and quality of milk of total 126 crossbred cows (Jersey x Sahiwal) was carried out at College Dairy Farm, Animal Husbandry and Dairy Science section, College of Agriculture, Nagpur during the year 2013-2014. The ten year data (2004-2013) on milk yield upto 4th lactation and chemical quality in terms of fat, SNF and TS percentage in milk of crossbred cows were collected and analysed statistically to see the productive performance and to know the chemical quality of milk.

Average maximum lactation milk yield was recorded during the 3rd lactation and minimum in the 1st lactation. Average maximum weekly milk yield did not show any distinct trend during 1st to 8th week of lactations. Whereas, in all lactations performance remained constant with respect to weekly milk yield for a period of four weeks from. 9th to 12th week after attaining peak yield. In 17th to 24th week of lactations maximum milk yield was recorded 20th week of lactation, thereafter declining trend was observed upto 24th week of lactation. In relation to chemical quality the overall fat, SNF and TS were recorded as 4.40 %, 8.67% and 13.08% respectively. These three components in milk of crossbred cows were unaffected by lactation numbers.

The results indicated that the milk production increased with the advancement of lactation upto the 3rd lactation. The chemical quality of milk of crossbred cows in terms of fat, SNF and TS percentage remained more or less constant under different lactations.

(Key words: Productive performance, quality of milk, crossbred cows))

INTRODUCTION

Milk is an important product that contains almost all the nutrients required for human life by virtue of its composition, high nutritive value and digestibility. It advocates itself as a very important article of diet from the Vedic period. Milk has got prime importance in diet of human being. The total milk production of India was estimated at 127 million tonnes during the year 2012 (Anonymous, 2012).

Now a days the demand for crossbred cows are very high because of higher production of milk (ranging between 10 -15 kg day $^{-1}$). It is interesting to note that a reasonable number of landless and marginal farmers have found crossbred cows as a profitable enterprises under improved nutrition, better disease control and management. No specialized breed has yet developed in the country to gear up the milk production (Mondal *et al*., 2005).

The demand for milk and its products increased sharply now a days with the increase in population worldwide. The selective breeding and crossbreeding are the main tools to enhance the milk production potentiality of tropical indigenous cattle. Marked improvement in cattle has been reported, through crossbreeding (Eleman *et al.,* 2012).

The proportion of chemical constituents of raw milk not only reflect the dairy quality and health status of dairy cows, but also indicate the nutritional value of milk and dairy products. Therefore, it is necessary to study the chemical quality of milk through scientific management of feeding nutritional supplementation (Yang *et al.,* 2013).

Keeping this in mind the above revelations an attempt was made to study the productive performance and quality of milk of crossbred cows (Jersey x Sahiwal).

MATERIALS AND METHODS

The crossbred animal (Jersey x Sahiwal) having 50% exotic inheritances irrespective of their parental breeds were selected on the basis of lactation number viz., I, II, III and IV for the study. The milking cows upto 4th lactation were searched out from the record maintained at College Dairy Farm , Animal Husbandry and Dairy Science Section, College of Agriculture, Nagpur during the period of 2004 to 2013 . During this period, crossbred cows which completed four lactations were traced out and data on various aspects were gathered during first to fourth tactations of these crossbred cows. The information regarding weekly milk yield upto 24 weeks in each lactation for each of the 126 cows were complied and finally weekly milk yield of these cows was determined.

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With a view to determining the chemical quality of milk during 1st to 4th lactation, milk samples were collected from morning milking of crossbred cows. The first milk sample from each lactation cow $^{-1}$ was collected after the period of colostrums milk period after calving was over. Thereafter, four samples of morning milk were collected at an interval of 5 days. Thus, in all 5 samples cow $^{-1}$ were collected during each lactation and used for analysing various composition of milk. The fat content in the milk during each lactation was determined by Gerber's method as described in IS: 1224 (part-I), (Anonymous, 1977). SNF content was calculated by using ISI lactometer and total solids content was calculated by addition of fat and SNF content in milk.

The data collected in respect of all above parameters were tabulated and subjected to statistical evaluation by adopting the standard technique prescribed by Panse and Sukhatme (1985). To find out mean, standard deviation and coefficient of variation so as to estimate the central value and the extent at variability in the data. The standard deviation and coefficient of variation was calculated by adopting the following formula.

$$= \frac{\sqrt{\left(X_i - \overline{X}\right)^2}}{n}$$

Where,

= Standard deviation
= Values of the variables
= Mean
= Number of observation of the series

Coefficient of variation was used to compare the magnitude of relative dispersion among the data of different variations.

$$\text{C.V.} = \frac{\text{S.D.}}{X} \times 100$$

Where,
C.V. = Coefficient of variation
S.D. = Standard Deviation
X = Mean

RESULTS AND DISCUSSION

It is evident from the table 1 that the overall average weekly milk yield based on 126 calvings over a period of experimental period i.e. upto 24th week of lactation was 36.94±1.48 l. Maximum milk yield was recorded in 3rd lactation (40.36±1.75 l.) followed by 2nd (37.64±1.48 l.), 4th lactation (35.66±1.68l.) and 1st lactation (34.18±1.53 l), respectively with coefficient of variation 21.29, 19.31, 23.19, 21.96 respectively.

It was observed that average weekly milk yield showed inclined performance upto 8th week of lactation in all lactations except 1st lactation. Maximum weekly milk yield was recorded (50.95 l) during 4th week of lactations, while minimum milk yield was recorded (24.03 l) during 24th week of lactations. After attaining the peak yield , the productive performance examined was more or less constant for a period of four weeks i.e.9th to 12th week with respect of average weekly milk yield during 1st to 4th lactations. On the otherhand, during 2nd and 3rd lactation peak yield did not show any distinct trends. After 16th week of all lactations declined trend was observed upto the 24th week of lactation in average weekly milk yield.

The results of present investigation are in general agreement with the results obtained by Haider *et al.* (1984) who recorded highest lactational milk yield in J x S and F x ND crossbred cows during 3rd lactation. Ahmad *et al.* (2011) reported that the milk yield increased gradually from the 1st to 3rd lactations. The highest milk yield was recorded in 3rd lactation and the lowest in 1 st lactation. These findings are more or less supported the results of present study.

The milk yield tended to increase with lactation number in crossbred cows but maximum milk yield was recorded in third lactation (Bhaskar *et al.* 2007). Likewise, Lateef *et al.* (2008) recoded the maximum lactation milk yield in the 3rd lactation in IHF, IJ, FBHF cows.

Chemical quality of milk Fat (%)

It is seen from table 2 that the fat percentages in 1st to 4th lactations with their standard error were recorded as 4.27±0.36, 4.39 ± 0.17,4.25 ± 0.02, 4.72 ± 0.17 % respectively. The overall average fat % in milk of crossbred cows was recorded as 4.40 ± 0.10 %.

Bhaskar *et al*. (2007) recorded 4.43% fat in milk of crossbred cows (1st to 4th lactations). They further noticed that the lactation number had little effect on fat percentage. Krovvidi *et al*. (2013) also reported that the fat percentage showed non-significant effect due to lactation order.

Table 1. Mean weekly milk yield(lit) during the period from 2004 to 2013 in different lactations of 126 crossbred cows (Jersey x Sahiwal)

Weeks	Lactations				Average
	I	II	III	IV	
1st	33.40	33.67	38.93	34.45	35.11
2nd	42.87	41.95	46.80	43.60	43.80
3rd	45.05	40.70	45.00	43.20	43.48
4th	49.20	47.40	55.45	51.85	50.95
5th	43.55	47.60	46.20	43.10	45.11
6th	33.70	46.63	48.51	41.80	42.66
7th	42.95	43.20	49.05	42.95	44.53
8th	40.55	54.95	52.10	48.25	48.96
9th	36.70	42.30	46.00	41.90	41.72
10th	35.50	35.65	46.00	40.11	39.31
11th	35.60	38.45	42.25	41.40	39.42
12th	37.30	41.25	24.15	43.40	36.52
13th	35.45	37.75	43.75	34.35	37.82
14th	33.35	32.10	40.70	26.15	33.07
15th	31.20	33.35	37.70	26.70	32.23
16th	35.65	40.55	46.10	30.20	38.12
17th	28.15	33.60	32.70	31.85	31.57
18th	28.75	31.80	33.90	28.90	30.85
19th	28.45	30.55	37.50	28.25	31.18
20th	32.40	36.95	40.65	28.90	34.72
21st	23.95	31.10	36.05	26.65	29.43
22nd	21.80	29.15	27.15	28.10	26.55
23rd	22.25	27.50	26.75	25.95	25.61
24th	22.55	25.35	25.40	23.90	24.03
Avg.	34.18	37.64	40.36	35.66	36.94
S E (m) ±	1.53	1.48	1.75	1.68	1.48
CV%	21.96	19.31	21.29	23.19	19.56

Table 2. Chemical quality of milk in terms of fat % in milk of crossbred cows under different lactations

Sr. No.	Lactation No.	Fat %	SE (±)	CV	SD
1	First	4.27	0.36	19.18	0.81
2	Second	4.39	0.17	8.76	0.36
3	Third	4.25	0.02	0.79	0.03
4	Fourth	4.72	0.17	5.23	0.24
	Overall average	**4.40**	**0.10**	**4.93**	**0.19**

(Mean based on 5 milk samples)

Table 3. Chemical quality of milk in terms of SNF (solids not fat) % in milk of crossbred cows under different lactations

Sr. No.	Lactation No.	SNF %	SE (±)	CV	SD
1	First	8.58	0.18	2.18	0.22
2	Second	8.85	0.06	2.56	0.19
3	Third	8.63	0.08	1.39	0.12
4	Fourth	8.63	0.12	2.04	0.17
	Overall average	**8.67**	**0.03**	**1.39**	**0.12**

(Mean based on 5 milk samples)

Table 4. Chemical quality of milk in terms of TS (Total solid) % in milk of crossbred cows under different lactations

Sr. No.	Lactation No.	TS %	SE (±)	CV	SD
1	First	12.85	0.39	6.68	0.87
2	Second	13.24	0.14	2.54	0.32
3	Third	12.88	0.13	1.46	0.19
4	Fourth	13.35	0.21	2.25	0.29
	Overall average	**13.08**	**0.05**	**0.88**	**0.11**

(Mean based on 5 milk samples)

SNF (solids not fat- %)

It is evident from table 3 that the SNF per cent from 1st to 4th lactations were recorded as 8.58±0.18, 8.85±0.06, 8.63±0.08, 8.63±0.12 % respectively. The overall SNF percentage in milk of crossbred cows was recorded as 8.67±0.06 with standard deviation 0.12 and coefficient of variation 1.39. Average maximum SNF % (8.85±0.18%) was recorded during 2nd lactation and minimum (8.58%) was recorded during 1st lactation.The results indicated that the SNF percentage in milk of crossbred cows was lower in 1st lactation (8.85±0.18%) which increased in 2nd lactation (8.85±0.06 %) and remained constant thereafter in the subsequent lactations i.e.,3rd and 4th lactations (8.63 %).However, the variations were not alarming.

Bhasker *et al.* (2007) reported the lower percentage of SNF in milk during 1st lactation. It increased in 2nd lactation and remaind static thereafter in subsequent lactations. Likewise, Krovvidi *et al.* (2013) also reported that the order of lactation showed significant effect on SNF percentage.

TS (Total solids) %

From table 4 it is seen that the total solid percentage in milk of crossbred cows under different lactations i.e. 1st to 4th were as 12.85±0.39, 13.24±0.14, 12.88±0.13, 13.35±0.21% respectively. Average maximum TS % (13.35±0.21%) was recorded in the 4th lactation and minimum (12.85±0.39%) recorded in the 1st lactation.

The results indicated that the total solid percentage in different lactations remained unaffected in 1st to 4th lactations.

Talukder *et al.* (2013) recorded overall total solid percentage in the range of 13.01 to 13.81 % in milk of Sahiwal and Friesian crossbred cows, the findings of the present study are almost similar to their findings. Likewise, Bhaskar *et al.* (2007) reported that the total solid percentage in milk of crossbred cows remained unaffected by the lactation number.

The present investigation further revealed that the chemical composition in terms of fat percentage was marginally affected, SNF and TS percentage in milk of crossbred cows remained unaffected by the lactation numbers. Therefore, the results from present study suggested that the crossbred should be provided quality nutrition and protection from the environmental condition for maintaining calving pattern, rate of milk production in every lactation and chemical quality of milk.

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INFLUENCE OF FOLIAR SPRAYS OF GROWTH RETARDANT TIBA ON BIOCHEMICAL, YIELD AND YIELD CONTRIBUTING PARAMETERS OF CHICKPEA

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ABSTRACT

The present study was carried out during year *rabi* 2013-14. The experiment was laid out in RBD with four replications comprising of different concentrations of TIBA. Spraying of TIBA was done at 25 and 40 DAS. The different treatments tested were control, 25 ppm TIBA, 50 ppm TIBA, 75 ppm TIBA, 100 ppm TIBA, 125 ppm TIBA and 150 ppm TIBA. Foliar sprays of growth retardant TIBA showed their significance over control. Foliar sprays of 50 ppm TIBA followed by 25 ppm TIBA significantly increased leaf chlorophyll, nitrogen, phosphorus and potassium, protein content in seed, number of pods plant^{-1}, number of unfilled pods plant^{-1}, grain yield plant^{-1}, grain yield plot^{-1} and harvest Index of chickpea.

(Key words: Chickpea, TIBA, N, P, K and protein)

INTRODUCTION

Chickpea is one of the most important pulses crop in the world. India ranks first in the world in respect of production. Chickpea plays an important role in cereal based diet because of its high protein content which is used for making dal. Chickpea grains provide about 18 to 22 % protein, 4 to 10 % fat and 52 to 70 % carbohydrate. The vegetative parts of chickpea are covered with glandular hairs which exclude and acidic liquid which contains about 94.2% malic acid, 5.6% oxalic acid and 0.2% acetic acid.

In India area under chickpea crop during 2012-13 was 85.67 million hectares with the production of 82.21 million tonnes having productivity of yield was 932 kg ha^{-1} (Anonymous, 2013 a). In Maharashtra total area under chickpea cultivation during 2012-13 was 10.55 million hectares with the production of 9.20 million tonnes having average productivity of 790 kg ha^{-1} (Anonymous, 2013 b). In Maharashtra, Vidharbha region contributes major share in area as well as production of chickpea.

In Vidharbha total area under chickpea was 4.98 million hectares with a total production of about 4.54 million tonnes having productivity of 780 kg ha^{-1} during the year 2012-13 (Anonymous , 2013 c).

Cathey (1964) defines a growth retardant as a chemical that decreases the cell division and cell elongation in the shoot apex and regulates plant height physiologically without formative effects. The effects of growth retardant vary with species, genotype, concentration used and method of application, stage of plant and various other factors which influence the uptake and translocation of the chemicals.

The inhibitory effects of TIBA were proportional to its concentration. Thus, TIBA which might be expected to be a direct auxin competitor, has been shown to lower the auxin levels of treated root to vanishingly low values and may exert part of its antagonistic action (Audus and Thresh, 1956). Another way in which the normal functioning of auxin may be impeded is by blocking its movement in the plant. This kind of action may underlie the antagonisms of TIBA (Niedergang and Skoog, 1956; Kese and Vardar, 1953).

Sabins and Audus (1957) found that TIBA may block IAA uptake for example in segment of *Avena* coleoptile, yet another effects seems to be that TIBA immobile in pea tissues, presumably by promoting its binding to protein (Winter, 1968) and this has been suggested as the main cause of its blockage of IAA transport. Considering the above facts present investigation was undertaken to see the effect of foliar sprays of growth retardant TIBA on chemical and biochemical, yield and yield contributing parameters of chickpea.

MATERIALS AND METHODS

The present studies on the influence of foliar sprays of growth retardant TIBA on biochemical, yield and yield contributing parameters of chickpea was conducted in field of Agril. Botany Section,

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College of Agriculture, Nagpur during *rabi* 2013-14. Growth retardant TIBA like T_1 control, T_2 (25 ppm TIBA), T_3 (50 ppm TIBA), T_4 (75 ppm TIBA), T_5 (100 ppm TIBA), T_6 (125 ppm TIBA) and T_7 (150 ppm TIBA) were tested. Chickpea seed variety Jaki-9218 was used for experimentation. Observations on biochemical parameters like leaf chlorophyll (colorimetric method, Bruinsma, 1982), nitrogen (Kjeldhal's method, Piper, 1966), phosphorus (vanadomolybdate yellow colour method, Jackson,1967) and potassium (flame photometer by di-acid extract method, Jackson1967) were analyzed at 45, 65 and 85 DAS stage. Whereas, protein content (Kjeldhal's method, Piper, 1966) in seed was also estimated. Observations on yield and yield contributing parameters like, number of pods plant^{-1}, number of unfilled pods plant^{-1}, grain yield plant^{-1}, grain yield plot^{-1} and harvest Index was also worked out. The data collected were subjected to statistical analysis suggested by Panse and Sukatme (1954).

RESULTS AND DISCUSSION

Biochemical parameters

Leaf chlorophyll content

The greenness of the leaf is generally considered to be a parameter contributing to yielding ability of the cultivar. Leaves constitute most important aerial organ of the plants, playing a major role in the anabolic activities by means of the so called "green pigments or chlorophyll" is the sole medium of the photosynthetic progress which in turn is the major synthesis pathway operatives in plants.

Data pertaining to leaf chlorophyll content in leaves of chickpea are presented in table 1. At 45, 65 and 85 DAS significantly highest chlorophyll content was found in treatment T_3 (50 ppm TIBA) followed by treatment T_2 (25 ppm TIBA). Similarly foliar application of 75 ppm TIBA (T_4), 100 ppm TIBA (T_5) and 125 ppm TIBA (T_6) observed significantly more chlorophyll content when compared with control (T_1) and rest of the treatments. Treatment T_7 (150 ppm TIBA) was found at par with control (T_1).

At 65 DAS chlorophyll content in leaves ranged from 1.58 – 2.10 mg g^{-1}. Significantly highest chlorophyll content was found in treatment T_3 (50 ppm TIBA) followed by treatment T_2 (25 ppm TIBA). While, treatments T_4 (75 ppm TIBA), T_5 (100 ppm TIBA), T_6 (125 ppm TIBA) and T_7 (150 ppm TIBA) also gave significantly more chlorophyll content when compared with control (T_1). Similar trend was found at 85 DAS. At 85 DAS chlorophyll content in leaves ranged from 0.99 – 2.02 mg g^{-1}. The variation in chlorophyll content due to different concentrations of TIBA may be attributed to decrease chlorophyll degradation and increase chlorophyll synthesis. From the data, it is clear that chlorophyll content was maximum at 65 DAS and decreased at later stages which may be attributed due to senescence of leaves (Arteca and Dong, 1981).

Ganiger *et al.* (2002) studied the effect of foliar application of plant growth regulators NAA (250 or 500 ppm), TIBA (25 or 50 ppm), gibberellic acid (25 or 50 ppm), cycocel [chlormequat] (250 or 500 ppm), cytozyme (500 or 1000 ppm) and 2% urea on the growth of cowpea cv. C 152. TIBA (25 and 50 ppm) and GA (50 ppm) recorded significantly more chlorophyll 'a' content than control. TIBA 25 and 50 ppm recorded significantly more chlorophyll 'b' content than control. TIBA 25 ppm recorded maximum chlorophyll content (3.09 mg g^{-1} fresh weight). More chlorophyll content in these treatments has helped in increasing the photosynthetic rate and there by seed yield.

The experiment was conducted by Tripathi *et al.* (2003) on chickpea cv. Avarodhi by the application of different growth regulators i.e. 20 ppm TIBA, 1000 ppm ALAR [daminozide], 5 ppm Miraculam, 50 ppm IAA, 50 ppm gibberellic acid, 50 ppm NAO [2-naphthoxyacetic acid], and 50 ppm Planofix [NAA], 5 ppm cytokinin, 10 ppm Mixtalol [triacontanol] and 4000 ppm CCC [chlormequat] . Chlorophyll content was highest with 20 ppm TIBA treatment at pre and post-anthesis (2.60 and 2.82, respectively).

Leaf nitrogen content

The data obtained about the nitrogen content in leaves are given in table1. At 45 DAS, significantly maximum leaf nitrogen content was recorded in treatment T_3 (50 ppm TIBA) followed by foliar application of 25 ppm TIBA (T_2) when compared with control and rest of the treatments under study. Whereas foliar application of 75 ppm TIBA (T_4), 100 ppm TIBA (T_5) and 125 ppm TIBA (T_6) were also recorded higher nitrogen content in a descending manner when compared with control (T_1). Application of 150 ppm TIBA (T_7) was found at par with control (T_1).

At 65 DAS significantly maximum leaf nitrogen content was recorded in treatment T_3 (50 ppm TIBA) followed by foliar application of 25 ppm TIBA (T_2) when compared with control and rest of the treatments. Next to this treatments foliar application of 75 ppm TIBA (T_4), 100 ppm TIBA (T_5), 125 ppm TIBA (T_6) and 150 ppm TIBA (T_7) were also recorded higher nitrogen content in a descending manner when compared with treatment control (T_1).

At 85 DAS significantly maximum leaf nitrogen content was recorded in treatment T_3 (50 ppm TIBA) followed by treatments T_2 (25 ppm TIBA), T_4 (75 ppm TIBA) and T_5 (100 ppm TIBA) in a descending manner when compared with control and rest of the treatments. While, treatments T_6 (125 ppm TIBA) and T_7 (150 ppm TIBA) were also recorded more nitrogen content as compared to control (T_1).

Poonkodi (2003) stated that decrease in nitrogen content at later stage might be due to translocation and utilization of nutrient for flower and pod formation.

Deotale *et al.* (1994) conducted field experiment on physiological studies in safflower (*Carthamus tinctorius* L.) cv. Bhima. Plants were sprayed with 100-1100 ppm TIBA at 40 days after sowing. TIBA application @ 600 ppm significantly increased leaf nitrogen contents over control and rest of the treatments.

Leaf phosphorus content

The data with respect to phosphorus content in leaves are tabulated in table1. At 45 DAS significantly maximum leaf phosphorus content was recorded in treatment T_3 (50 ppm TIBA) followed by treatments T_2 (25 ppm TIBA) and T_4 (75 ppm TIBA) when compared with control and rest of the treatments under study. Next to this treatments foliar application of 100 ppm TIBA (T_5) and 125 ppm TIBA (T_6) were also increased phosphorus content significantly when compared with control and rest of the treatments. Treatment T_7 (150 ppm TIBA) was found at par with treatment T_1 (control).

At 65 DAS significantly maximum leaf phosphorus content was recorded in treatment T_3 (50 ppm TIBA) followed by treatment T_2 (25 ppm TIBA), T_4 (75 ppm TIBA) and T_5 (100 ppm TIBA) in a descending manner when compared with control and rest of the treatments under study. Treatments T_6 (125 ppm TIBA) and T_7 (150 ppm TIBA) were found at par with treatment T_1 (control).

At 85 DAS significantly maximum leaf phosphorus content was recorded in treatment T_3 (50 ppm TIBA) followed by treatment T_2 (25 ppm TIBA), T_4 (75 ppm TIBA), T_5 (100 ppm TIBA) and T_6 (125 ppm TIBA) in a descending manner when compared with control and rest of the treatments. But application of 150 ppm TIBA (T_7) was found at par with control (T_1).

It is evident from the data that phosphorus content in leaves was increased gradually upto 45-65 DAS and decreased at 85 DAS. It might be due to translocation of leaf phosphorus and it's utilization for development of food storage organ. It was also known that growth hormone increases the uptake of nutrients from soil and also increases metabolic activities in the plant cell (Sagare and Naphade, 1987).

Leaf potassium content

Data regarding the leaf potassium content at 45, 65 and 86 DAS are presented in table 1. At 45 and 85 DAS significantly more leaf potassium content was noticed in treatment T_3 (50 ppm TIBA) followed by treatments T_2 (25 ppm TIBA) and T_4 (75 ppm TIBA) when compared with control (T_1) and rest of the treatments under observations. Similarly treatments T_5 (100 ppm TIBA), T_6 (125 ppm TIBA) and T_7 (150 ppm TIBA) also gave more potassium content in a descending manner when compared with control (T_1).

At 65 DAS significantly maximum leaf potassium content was noticed in treatment T_3 (50 ppm TIBA). Next to this treatment foliar application of 25 ppm TIBA (T_2) also increased leaf potassium content significantly when compared with control and rest of the treatments under observations. Whereas foliar application of 75 ppm TIBA (T_4), 100 ppm TIBA (T_5), 125 ppm TIBA (T_6) and 150 ppm TIBA (T_7) were also recorded maximum potassium content in a descending manner as compared to treatment T_1 (control).

Shanmugam and Muthuswamy (1974) conducted an experiment on *Crysanthemum indicum* plants, receiving supplementary light and spread with GA, MH and TIBA or CCC at various rates. All long day treatments increased foliar N, K, Ca and Carbohydrate. K was greater in plants treated with CCC or TIBA and GA. Carbohydrate was increased by CCC and TIBA while reduced by MH and GA.

Protein content in seed

Data regarding protein content in seeds are given in table 1. The maximum seed protein was recorded in treatment T_3 (50 ppm TIBA) followed by treatments T_2 (25 ppm TIBA), T_4 (75 ppm TIBA), T_5 (100 ppm TIBA) and T_6 (125 ppm TIBA) when compared with control (T_1) and rest of the treatments in a descending manner. But application of 150 ppm TIBA (T_7) was found at par with control (T_1).

Nitrogen is the constituent of protein. Hence, increase in nitrogen content ultimately resulted in the increase in protein content in seeds of chickpea in the present investigation.

The experiment was conducted by Tripathi *et al.* (2003) on chickpea cv. Avarodhi by the application of different growth regulators i.e. 20 ppm TIBA, 1000 ppm ALAR [daminozide], 5 ppm Miraculam, 50 ppm IAA, 50 ppm gibberellic acid, 50 ppm NAO [2-naphthoxyacetic acid], and 50 ppm Planofix [NAA], 5 ppm cytokinin, 10 ppm Mixtalol [triacontanol] and 4000 ppm CCC [chlormequat]. Protein and starch content were highest with the 20 ppm TIBA, 5 ppm cytokinin and 50 ppm IAA treatments, respectively.

Tripathi and Kumar (2006) noticed that application of different plant growth regulator treatments, i.e. TIBA (500 ppm), GA (50 ppm), AA [ascorbic acid] (50 ppm), IAA (50 ppm), NAA (50 ppm), cytokinin (5 ppm), miraculan [triacontanol] (10 ppm) and CCC [chlormequat] (4000 ppm) on pea cv. Rachana. The growth regulators were sprayed twice at 35 and 75 days after sowing. Cytokinin and TIBA significantly increased protein content when compared with the other treatments.

Yield and yield contributing parameters

Number of pods plant^{-1}

Significantly more number of pods plant^{-1} were recorded in treatment receiving T_3 (50 ppm TIBA) followed by treatments T_2 (25 ppm TIBA), T_4 (75 ppm TIBA) and T_5 (100 ppm TIBA) in a descending manner when compared with treatment T_1 (control) and rest of the treatments under study. While, treatments T_6 (125 ppm TIBA) and T_7 (150 ppm TIBA) were also found significantly superior over control (T_1).

Kumar *et al*. (2006) reported that foliar application of TIBA (50 ppm), cycocel (250 ppm) and mepiquat chloride (1000 ppm) on soybean recorded highest number of pods plant^{-1} and shelling percentage as compared to control.

Tripathi *et al.* (2009) studied the effect of foliar application of TIBA (2, 3, 5-triiodobenzoic acid, 25 mg and 50 mg l^{-1}) on flower drop, growth and yield of pigeonpea variety 'UPAS-120'. Spraying of TIBA (50 mg l^{-1}) significantly increased number of pods plant^{-1} over control.

Number of unfilled pods plant^{-1}

Significantly lowest number of unfilled pods plant^{-1} was recorded in treatment T_3 (50 ppm TIBA) followed by treatment T_2 (25 ppm TIBA) when compared with treatment T_1 (control) and rest of the treatments under observations. Similarly, significantly lowest number of unfilled pods plant^{-1} was also observed in treatments T_4 (75 ppm TIBA), T_5 (100 ppm TIBA), T_6 (125 ppm TIBA) and T_7 (150 ppm TIBA) in a descending manner over control (T_1).

Gavisiddappa *et al*. (2013) studied the effects of foliar application of growth regulator and micro-nutrients on sunflower hybrid KBSH-53. Spraying of TIBA at 50 ppm was recorded lowest number of unfilled seeds capitalum^{-1} (163.80) when compared with control (291.60).

100 seed weight (g)

Variation in data of 100 seed weight owing to different concentrations of TIBA was significant. Spraying of 50 ppm TIBA (T_3) gave significantly maximum 100 seed weight (i.e. 25.1 g). Treatments T_2 (25 ppm TIBA) and T_4 (75 ppm TIBA) were also found significantly superior over treatment T_1 (control) and rest of the treatments under study. While, Treatments T_5 (100 ppm TIBA), T_6 (125 ppm TIBA) and T_7 (150 ppm TIBA) were found at par with treatment T_1 (control).

Tripathi *et al.* (2009) studied the effect of foliar application of TIBA (2, 3, 5-triiodobenzoic acid, 25 mg and 50 mg l^{-1}) on flower drop, growth and yield of pigeonpea variety 'UPAS-120'. Spraying of TIBA (50 mg l^{-1}) significantly increased 1000-seed weight over control.

Seed yield plant^{-1} (g) and plot^{-1} (kg)

Seed yield is the economic yield which is final result of physiological activities of plant. Economic yield is the part of biomass that is converted into economic product. (Nichiporovic, 1960).

The significantly maximum seed yield plant^{-1} and plot^{-1} were recorded in treatment T_3 (50 ppm TIBA) when compared with control and rest of the treatments under observations. Treatments T_2 (25 ppm TIBA), T_4 (75 ppm TIBA), T_5 (100 ppm TIBA) and T_6 (125 ppm TIBA) were also found significantly superior in a descending manner when compared with treatment T_1 (control) and rest of the treatments. While, treatment T_7 (150 ppm TIBA) was found at par with T_1 (control).

Ravichandran and Ramaswami (1991) in soybean and Reddy *et al.* (2009) in cowpea also reported increased seed yield with 50 ppm TIBA and decreased at higher concentration which may be due to toxic effects of TIBA.

Tripathi *et al.*(2007) studied the effects of TIBA (20 ppm), Alar [daminozide] (1000 ppm), Miraculan [triacontanol] (5 ppm), IAA (50 ppm), GA [gibberellic acid] (50 ppm), cytokinin (5 ppm), naphthoxyacetic acid [2-naphthoxyacetic acid] (NOA; 50 ppm), Planofix [NAA] (50 ppm), Mixtalol [triacontanol] (10 ppm) and CCC [chlormequat] (4000 ppm) on the incidence of flower drop and yield of chickpea (cv. Avrodhi). TIBA resulted in the highest seed yield (2767.8 and 2840.6 kg ha^{-1}) and productivity (18.37 and 18.74 grains day^{-1} ha^{-1}).

Tripathi *et al.* (2009) studied the effect of foliar application of TIBA (2, 3, 5-triiodobenzoic acid, 25 mg and 50 mg l^{-1}) on flower drop, growth and yield of pigeonpea variety 'UPAS-120'. Spraying of TIBA (50 mg l^{-1}) increased seed yield by 20.9 per cent over control.

Harvest index

Harvest index represents the ultimate partitioning of dry matter between seed (economic yield), vegetative parts (biological yield) and the data of which are given in table 2.

Harvest index was significantly influenced by different treatments. The range of harvest index recorded was 31.77-35.47 %. Treatment T_3 (50 ppm TIBA) followed by treatment T_2 (25 ppm TIBA) increased harvest index when compared with control and rest of the treatments. While, treatments T_4 (75 ppm TIBA) was also found significantly superior when compared with control and rest of the treatments under study. Treatments T_5 (100 ppm TIBA), T_6 (50 ppm TIBA) and T_2 (150 ppm TIBA) were found at par with T_1 (control).

Tripathi *et al.* (2009) studied the effect of foliar application of TIBA (2, 3, 5-triiodobenzoic acid, 25 mg and 50 mg l^{-1}) on flower drop, growth and yield of pigeonpea variety 'UPAS-120'. Spraying of TIBA (50 mg l^{-1}) increased harvest index of pigeonpea over control.

Harvest index is the proportion of biological yield represented by economic yield. It is the coefficient of effectiveness or the migration coefficient. Harvest index reflects the proportion of assimilate distribution between the economic and total biomass (Donald and Hamblin, 1976). Increase in harvest index might be the result of coordinated interplay of development characters.

Table1. Influence of growth retardant TIBA on chemical and biochemical parameters in chickpea

Treatments	Leaf chlorophyll content (mg g^{-1})			Leaf nitrogen content (%)			Leaf phosphorus content (%)			Leaf potassium content (%)			Protein content (%)
	45 DAS	65 DAS	85 DAS	45 DAS	65 DAS	85 DAS	45 DAS	65 DAS	85 DAS	45 DAS	65 DAS	85 DAS	
T_1 (Control)	1.50	1.58	0.99	1.90	2.35	2.12	0.658	0.718	0.704	0.76	0.98	0.85	19.50
T_2 (25 ppm TIBA)	1.85	1.99	1.90	2.31	2.98	2.72	0.698	0.793	0.780	1.25	1.38	1.31	21.73
T_3 (50 ppm TIBA)	1.98	2.10	2.02	2.43	3.20	2.79	0.710	0.805	0.791	1.33	1.50	1.41	21.90
T_4 (75 ppm TIBA)	1.78	1.94	1.85	2.24	2.90	2.66	0.683	0.778	0.760	1.19	1.34	1.26	21.56
T_5 (100 ppm TIBA)	1.71	1.87	1.77	2.18	2.82	2.60	0.676	0.770	0.753	1.15	1.27	1.21	21.30
T_6 (125 ppm TIBA)	1.65	1.82	1.71	2.15	2.78	2.54	0.670	0.764	0.748	1.10	1.22	1.14	20.95
T_7 (150 ppm TIBA)	1.58	1.75	1.60	2.08	2.69	2.43	0.661	0.753	0.741	1.01	1.15	1.08	20.70
SE (m) ±	0.044	0.047	0.045	0.062	0.095	0.081	0.011	0.016	0.015	0.047	0.052	0.051	0.446
CD at 5%	0.132	0.140	0.133	0.184	0.282	0.241	0.032	0.047	0.044	0.139	0.154	0.150	1.324

Table 2. Influence of growth retardant TIBA on yield and yield contributing parameters of chickpea

Treatments	No. of pods $plant^{-1}$	No. of unfilled pods $plant^{-1}$	100 seed weight (g)	Seed yield $plant^{-1}$ (g)	Seed yield $plot^{-1}$ (kg)	Harvest index (%)
T_1 (Control)	37.50	12.75	21.90	4.98	1.20	31.77
T_2 (25 ppm TIBA)	45.50	6.25	24.40	6.10	1.46	34.75
T_3 (50 ppm TIBA)	46.90	5.25	25.10	6.80	1.63	35.47
T_4 (75 ppm TIBA)	44.10	7.00	23.90	5.90	1.42	33.59
T_5 (100 ppm TIBA)	43.60	8.00	23.60	5.70	1.37	33.24
T_6 (125 ppm TIBA)	42.90	8.50	23.18	5.60	1.34	32.43
T_7 (150 ppm TIBA)	41.80	9.00	22.80	5.40	1.30	32.08
SE (m) ±	1.149	0.466	0.590	0.175	0.046	0.547
CD at 5%	3.413	1.386	1.754	0.519	0.138	1.626

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HALF SIB RECURRENT SELECTION STUDIES FOR YIELD IN SAFFLOWER (*Carthamus tinctorius* L.)

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ABSTRACT

The 80 half-sib families along with four checks Bhima, A1, AKS-207 and PKV Pink were evaluated in *rabi* 2013 in the experimental farm of College of Agriculture, Nagpur with the objectives to determine the expected genetic gain for seed yield and its components from half-sib selection method, to estimate the correlation and to assess the frequency of half-sib families significantly superior over checks. Mean, range, variance and heritability estimates revealed the significance of plant height, days to 50% flowering, number of seed capitilum^{-1}, seed yield plant^{-1} and number of capitulum plant^{-1} for selecting superior half-sib families. The narrow sense heritability estimates on family mean basis were high for oil content (0.90) followed by seed yield plant^{-1} (0.86), number of primary branches plant^{-1} (0.77), number of seeds capitulum^{-1} (0.75), 100 seed weight (0.71), days to 50 % flowering (0.67), number of capitula plant^{-1} (0.65), plant height (0.39), and days to maturity (0.19) respectively. Expected genetic advance was 56.91 per cent and 38.24 per cent at 10 per cent selection intensity over population mean and Bhima respectively for the seed yield plant^{-1}. Expected genetic advance was 56.91 per cent and 111.96 per cent at 10 per cent selection intensity over population mean and PKV Pink respectively for the seed yield plant^{-1}. 100 seed weight, number of capitula plant^{-1}, number of seeds capitulum^{-1} and number of primary branches plant^{-1} were positive and significantly correlated with seed yield plant^{-1} indicating the significance of these traits for indirect selection of high yielding families. This indicated that the half sib recurrent selection is effective in increasing population mean and extraction of superior recombination lines better than check varieties. Eight half sibs families i.e. (HS-60, HS-18, HS-21, HS-14, HS-15, HS-48, HS-71 and HS-41) were identified as promising half sibs for forwarding to the next cycle.

(Key words: Safflower, half sib, recurrent selection)

INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is one of the ancient oilseed crop of India. Out of 25 species in the genus *Carthamus* only *Carthamus tinctorius* (L.) (2n=24) is under cultivation. Safflower is usually considered to be a self-pollinated crop. Classen (1950), however, reported cross pollination ranging from zero to 100 per cent although in most of the plants he used, the detectable crossing ranged from 5 to 40 per cent. It contains 30% oil in Indian varieties. Safflower oil is preliminary used for cooking. The oil contains high amount of linoleic acid (76%), which is very useful for patients suffering from heart diseases. The unsaturated fatty acids of safflower lower the serum cholesterol (Nimbkar, 2002).

The safflower improvement programme in India was started in 1931 and N-630, the first variety was released in 1940. In India 25 varieties and five safflower hybrids were released in last four decades viz., DSH-129, MKH-11, NARINH-1, MRSA-521 and NARI-H-15. These varieties have the genetic potential to give yield of 15-20 q ha^{-1} with oil content of about 30% under optimal condition. However, attempts to further improve the yield and oil content were not successful for the last four decades. Similarly there is no breakthrough in the improvement of oil content in the last seven decades. This is mainly due to the use of pedigree selection technique in population derived from two line crosses and negative correlation between seed yield and oil content. The conventional breeding methods have been very useful only for recombining simple inherited characters. Therefore, these conventional breeding methods have not been very efficient for improving quantitatively inherited characters like seed yield, oil content, tolerance to stresses and horizontal resistance to diseases and insects. Moreover, the crossing and record keeping procedure are often both money and time consuming for the rate of progress attained. Conventional method have several limitations such as limited use of available genetic variability resulting in the development of varieties with a narrow genetic base, successive loss of genes in the segregating generation with no chance of recombination for genes linked for yield and oil content (Jensen, 1970). These limitations can be over come by application of recurrent selection method in self pollinating crops and hence this study was undertaken in safflower.

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MATERIALS AND METHODS

The F_1's were raised in 2009 in different research stations and equal amount of F_1seeds were mixed and base population was constructed. The base population was raised in 2010 and composited to form random mating population. Half sib seed were harvested from individual male sterile plants. 105 families were developed from random mating population, and raised in 2011. These half sib 105 families were evaluated in replicated trial for testing and half sibs superior over checks were selected for recombination. The reported work is the continuation of the above research. The selected plants from the above 105 half sib families were composited and raised in *rabi* 2012 for recombination. The total number of plants grown were 2000. At flowering stage 102 male sterile plants were identified, tagged and harvested separately as half sibs, out of which 80 half sibs were selected on the basis of visual observation for sowing in *rabi* 2013 and simultaneously their sufficient seed were kept as remanant for next recombination cycle. The 80 half sib families selected along with check *viz.,* Bhima, A1, AKS-207 and PKV Pink were evaluated in Randomized Block Design with two replications in *rabi* 2013. Observations were recorded on days to 50% flowering, days to maturity, plant height, number of primary branches plant^{-1}, number of capitula plant^{-1}, number of seeds capitulum^{-1}, 100 seed weight, seed yield plant^{-1} and oil content. The data were then subjected to statistical and biometrical analysis suggested by Panse and Sukhatme (1954) and Hallauer and Miranda (1989).

RESULTS AND DISCUSSION

The mean squares due to half-sib families as observed from table 1 were significant for all the characters except days to 50% flowering, days to maturity and plant height indicating the existence of substantial genetic variability among half-sib families for six characters i.e. number of primary branches plant^{-1}, number of capitula plant^{-1}, number of seeds capitulum^{-1}, 100 seed weight, seed yield plant^{-1} and oil content after one cycle of recurrent selection. Maximum, minimum, range and mean values of agronomic characters were measured on 80 half-sib families and data are presented in table 2. Number of primary branches plant^{-1}ranged from 5.60 to 9.50 with mean of 7.00. Number of capitula plant^{-1} ranged from 8.70 to 21.60 with mean of 15.18. Number of seeds capitulum^{-1} ranged from 11.74 to 34.02 with 21.25 mean. 100 seed weight ranged from 3.77 to 6.06 g with 4.84 g mean. Seed yield plant^{-1} ranged from 6.32 to 20.94 g with 12 g mean. Oil content ranged from 21.13 to 30.94 % with 25.32 % mean oil content.

The maximum range was recorded by plant height (42.10 cm) followed by days to 50% flowering (28),number of seeds capitulum^{-1}(22.28), seed yield plant^{-1} (14.62 g), number of capitula plant^{-1} (12.90), oil content (9.81%), number of primary branches plant^{-1}(3.90) and 100 seed weight (2.29 g) indicating considerable amount of genetic variance in random mating population which will facilitate selection of superior families. These results revealed that characters like plant height, days to 50% flowering and days to maturity showing maximum range in the 80 half-sib families studied which can be considered as traits for selecting superior families, providing these traits exhibit high heritability and genetic advance. In accordance to these results Awchar (2011) and Kurhade (2013) also reported the importance of plant height and days to 50% flowering for selecting superior families based on means and range in safflower crop.

The estimates of half- sib family components of variance and heritability for each agronomic trait were calculated and data are presented in table 3. For recurrent selection programme, significant and large genetic variation among half-sib families is prerequisite. The genetic variance among half- sib families ($\sigma^2_{H.S.}$) and additive variance ($\sigma^2_{A.}$) was high for days to 50 % flowering (191.08 and 47.77) followed by days to maturity (41.22 and 164.88), number of seeds capitulum^{-1} (31.53 and 126.12), plant height (27.56 and 110.24), seed yield plant^{-1} (17.33 and 69.32), number of capitula plant^{-1} (9.55 and 38.2), oil content (7.22 and 28.88), number of primary branches plant^{-1} (1.32 and 5.28) and 100 seed weight (0.37 and 1.48) respectively. The high genetic variance among half-sib families were also reported by Awchar (2011) and Kurhade (2013) in random mating population of safflower.

Estimates of heritability in safflower populations segregating for genetic male sterility are useful in determining the best method of selection to improve the population for specific traits and expressing the reliability of the phenotypic value as a guide to the breeding value. In the present study the narrow sense heritability estimates on family mean basis were high for oil content (0.90) followed by seed yield plant^{-1} (0.86), number of primary branches plant^{-1} (0.77), number of seeds capitulum^{-1} (0.75), 100 seed weight (0.71), days to 50 % flowering (0.67), number of capitula plant^{-1} (0.65), plant height (0.39), and days to maturity (0.19) respectively. High estimates of heritability were also reported in random mating population of safflower for several agronomic traits like days to 50 % flowering, plant height, days to maturity, number of primary branches plant^{-1}, number of capitula plant^{-1}, number of seeds capitulum^{-1}, 100 seed weight and seed yield plant^{-1} by Gawande (2010), Awchar (2011) and Kurhade (2013) in safflower.

The data regarding expected genetic advance per cycle from single trait selection using half-sib family selection and expected genetic advance expressed as per cent of population mean are presented in table 4. The expected genetic advance from single trait selection at 5 and 10 per cent of half-sib families was high for days to 50 % flowering (11.69 and 9.99 respectively), followed by number of seeds capitulum^{-1} (10.05 and 8.59), seed yield plant^{-1} (7.99 and 6.83), days to maturity (6.82 and 5.83), oil content (5.56 and 4.75), plant height (6.25 and 5.34), number of capitula plant^{-1} (5.15 and 4.40), number of primary branches plant^{-1} (2.08 and 1.78) and 100 seed weight (1.05 and 0.90).

The expected genetic advance expressed as per cent of population mean at 5 and 10 per cent was highest for seed yield plant^{-1} (66.58 and 56.91) followed by number of seeds capitulum^{-1} (47.29 and 40.42), number of capitula plant^{-1} (33.92 and 28.98), number of primary branches plant^{-1} (29.71 and 25.42), oil content (21.95 and 18.75), 100 seed weight (21.69 and 18.59), days to 50% flowering (11.47 and 9.80), plant height (6.97 and 5.95) and days to maturity (4.67 and 3.99). The expected genetic advance expressed as per cent over Bhima at 5 and 10 per cent selection intensity was highest for seed yield plant^{-1} (44.73 and 38.24) followed by number of capitula plant^{-1} (36.26 and 30.98), number of seed capitulum^{-1}(35.79 and 30.59), number of primary branches plant^{-1} (23.11 and 19.77), oil content (21.68 and 18.52), 100 seed weight (21.21 and 18.18), days to 50 % flowering (10.82 and 9.25,) plant height (6.81 and 5.82), and days to maturity (4.63 and 3.96) respectively.

The expected genetic advance expressed as per cent over PKV Pink at 5 and 10 per cent selection intensity was highest for seed yield plant^{-1} (130.98 and 111.96) followed by number of capitula plant^{-1} (54.78 and 46.80), number of primary branches plant^{-1} (43.33 and 37.08), number of seeds capitulum^{-1} (36.36 and 31.07), 100 seed weight (28.76 and 24.65), oil content (22.19 and 18.96), days to 50 % flowering (10.72 and 9.16,) plant height (7.12 and 6.08)and days to maturity (4.45 and 3.81) respectively. The expected genetic advance from single trait selection, expressed as per cent of population mean and over check Bhima and PKV Pink revealed the importance of seed yield plant^{-1} and number of capitula plant^{-1} as they exhibited maximum genetic advance. The heritability in narrow sense for these two characters was 86 % and 65 % respectively. Hence, selection of 5 % or 10 % superior half-sibs based on seed yield plant^{-1} and number of capitula plant^{-1} will definitely result in improved performance in the next cycle.

In accordance to this study in safflower, Gawande (2010) reported that expected genetic advance was 28.88 per cent and 22.78 per cent at 10 per cent selection intensity over population mean and Bhima respectively for seed yield plant^{-1} and 8.86 per cent and 8.37 per cent for number of capitula plant^{-1} after third cycle of recurrent selection. Awchar (2011) reported 60.95, 52.10 and 41.40 per cent genetic advance in seed yield plant^{-1} and 16.65, 14.24 and 11.33 per cent in number of capitula plant^{-1} at 5, 10 and 20 per cent selection intensity for mean population respectively. The genetic advance over Bhima at 5, 10 and 20 per cent selection intensity were 46.22, 39.51 and 31.40 per cent respectively and for number of capitula plant^{-1} were 15.78,13.51 and 10.74 per cent respectively after third cycle of recurrent selection. Kurhade (2013) reported that expected genetic advance was 42.48 per cent and 48.23 per cent at 10 per cent selection intensity over population mean and Bhima respectively for the seed yield plant^{-1}.This clearly indicates the accumulation of favorable genes for yield and important yield component i.e. number of capitula plant^{-1}.

Table 1. Analysis of variance for experimental design

Sources of Variation	d.f.	Mean square								
		Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches plant^{-1}	No. of capitula plant^{-1}	No. of seeds capitula^{-1}	100 seed weight (g)	Seed yield plant^{-1} (g)	Oil content (%)
Replication	1	162.05	182.29	93.60	0.67	0.29	15.13	0.45	0.95	4.38
Genotypes (Half sibs + checks)	83	70.80	69.17	89.59	1.70**	14.57**	41.70**	0.52**	19.92**	8.04**
Error	83	23.03	41.61	48.37	0.38	5.02	10.17	0.15	2.59	0.82

** Significant at 1 % level

Table 2. Mean values of agronomic characters measured on half-sib families

Characters	Days to 50 % flowering	Days to maturity	Plant height (cm)	No. of primary branches plant^{-1}	No. of capitula plant^{-1}	No. of seeds capitula^{-1}	100 seed weight (g)	Seed yield plant^{-1} (g)	Oil content (%)
Maximum	116	160.00	117.00	9.50	21.60	34.02	6.06	20.94	30.94
Minimum	88	132.00	74.90	5.60	8.70	11.74	3.77	6.32	21.13
Range	28	28.00	42.10	3.90	12.90	22.28	2.29	14.62	9.81
Mean(H.S.)*	101.86	145.86	89.67	7.00	15.18	21.25	4.84	12.00	25.32
Check Varieties**									
Bhima	108	147.00	91.70	9.00	14.20	28.08	4.95	17.86	25.64
A1	120.50	164.50	74.90	4.20	6.00	18.54	4.51	8.60	24.35
AKS-207	101.50	145.50	76.50	7.40	15.40	22.46	5.24	10.10	22.43
PKV-Pink	109	153.00	87.70	4.80	9.40	27.64	3.65	6.10	25.05

* Mean performance of 80 half- sib families** Mean performance of 4 lines of checks

Table 3. Estimation of half-sib family components of variance and heritability for different agronomic traits

Half-sib family component	Days to 50% flowering	Plant height (cm)	Days to maturity	No. of primary branches plant^{-1}	No. of capitula plant^{-1}	No. of seeds capitula^{-1}	100 seed weight (g)	Seed yield plant^{-1} (g)	Oil content (%)
$\sigma^2_{H.S}$	47.77	27.56	41.22	1.32	9.55	31.53	0.37	17.33	7.22
$\sigma^2_A = 4\ \sigma^2_{H.S.}$	191.08	110.24	164.88	5.28	38.2	126.12	1.48	69.32	28.88
$\sigma^2_P = ¼\ \sigma^2_A + \sigma^2_e$	118.57	96.73	130.81	1.32	9.55	31.53	0.37	17.33	8.04
$h^2(n.s.) = \dfrac{y_4 s^2 A}{y_4 s^2 A + s^2 e}$	0.67	0.39	0.19	0.77	0.65	0.75	0.71	0.86	0.90

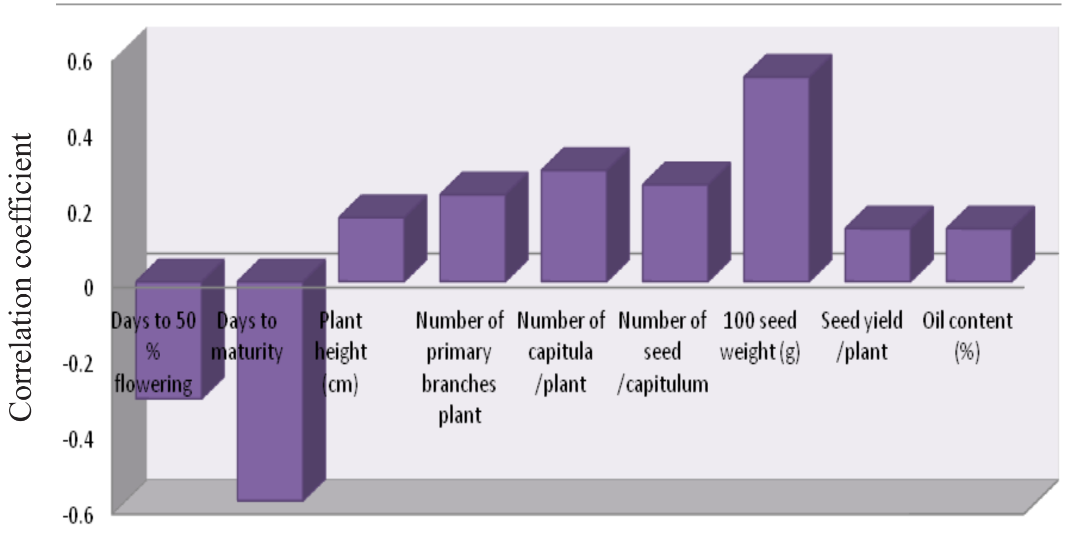

Fig 1. Correlation of different traits with seed yield plant^{-1}

Table 4. Expected genetic advance per cycle from single trait selection using half-sib family selection system

Unit of evaluation and selection	Generation cycle	(#) Selection intensity	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches $plant^{-1}$	No. of capitula $plant^{-1}$	No. of seeds $capitula^{-1}$	100 seed weight (g)	Seed yield $plant^{-1}$ (g)	Oil content (%)
Half-sib	2	5	11.69	6.82	6.25	2.08	5.15	10.05	1.05	7.99	5.56
		10	9.99	5.83	5.34	1.78	4.40	8.59	0.90	6.83	4.75
Expected genetic advance as per cent mean of population											
Half-sib	2	5	11.47	4.67	6.97	29.71	33.92	47.29	21.69	66.58	21.95
		10	9.80	3.99	5.95	25.42	28.98	40.42	18.59	56.91	18.75
Expected genetic advance as per cent mean over Bhima											
Half-sib	2	5	10.82	4.63	6.81	23.11	36.26	35.79	21.21	44.73	21.68
		10	9.25	3.96	5.82	19.77	30.98	30.59	18.18	38.24	18.52
Expected genetic advance as per cent mean over PKV pink											
Half-sib	2	5	10.72	4.45	7.12	43.33	54.78	36.36	28.76	130.98	22.19
		10	9.16	3.81	6.08	37.08	46.80	31.07	24.65	111.96	18.96

 # Response to selection of top 5 per cent (K=2.06), 10 per cent (K=1.76) of large number of families where K is standardized selection differential.

Table 5. Performance of promising half-sib families

Half-sib families	Number of capitula $plant^{-1}$	100 Seed weight (g)	Seed yield $plant^{-1}$(g)
HS-60	21.60****	5.48**	14.97***
HS-18	20.50****	4.42*	10.53*
HS-21	19.90****	4.80*	13.74***
HS-14	19.10***	4.58*	10.32*
HS-15	18.80***	4.31	8.50
HS-48	17.90**	6.06****	11.00
HS-71	14.10**	5.80***	15.91***
HS-41	13.90**	5.75***	11.44*
Bhima	14.20	4.95	17.86
A-1	6.00	4.51	8.60
AKS-207	15.40	5.24	10.10
PKV Pink	9.40	3.65	6.10
SE (d)±	2.24	0.38	1.61
CD 5 %	4.45	0.76	3.20

**** Significantly superior over AKS -207, Bhima, PKV Pink and A1.
*** Significantly superior over Bhima, A1 and PKV Pink for number of capitula $plant^{-1}$ and 100 seed weight and singnificantly superior over A1 and PKV Pink for seed yield $plant^{-1}$.
** Significantly superior over A1 and AKS-207
* Significantly superior over A1 for number of capitula $plant^{-1}$ and superior over PKV Pink for 100 seed weight and seed yield $plant^{-1}$.

The recurrent selection experiments are mainly designed and conducted for improving seed yield plant^{-1}. However, this does not mean that other traits are unimportant. The simple correlations of different traits with seed yield plant^{-1} is reported in figure 1. The correlation coefficient of seed yield plant^{-1} with different traits revealed that number of primary branches plant^{-1}, number of capitula plant^{-1},number of seeds capitulum^{-1} and 100 seed weight were positively associated with seed yield plant^{-1} while days to 50% flowering and days to maturity were negatively associated with seed yield plant^{-1}. Oil content and plant height had positive but non significant association with seed yield plant^{-1}. Usually quality characters like oil content were found to be negatively correlated with yield parameter. But in this study this type of association has been broken due to random mating and positive association though non significant was obtained between oil content and seed yield plant^{-1}. It can be concluded from the correlation studies that 100 seed weight exhibiting the maximum correlation coefficient with seed yield plant^{-1} followed by number of capitula plant^{-1},number of seeds capitulum^{-1} and number of primary branches plant^{-1}. Hence, these traits can be used for indirect selection to improve seed yield plant^{-1}in safflower. Deshmukh (2009) and Kurhade (2013) reported that days to 50 % flowering and days to maturity had negative correlation with seed yield plant^{-1} indicating breaking of positive correlation to negative correlation.

The objective of any recurrent selection method is to increase the frequency of desirable genes thereby increase the frequency of lines than check varieties. In the present study, when 80 half sib families were compared with check, it was found that none of the families were significantly superior over check Bhima (high yielding check) for seed yield plant^{-1}. Twenty three half-sib families were superior over three checks AKS-207, A1 and PKV Pink, thirteen over A1, PKV Pink and twenty eight over only PKV Pink for seed yield plant^{-1}. As none of the half sib families were observed to be significantly superior over all the four checks for seed yield plant^{-1}. In the present study selection of promising half sib families for forwarding to the next cycle was done considering the important yield component i.e. number of capitula plant^{-1} and 100 seed weight. These two traits were considered as they have exhibited maximum positive significant correlation coefficient with seed yield plant^{-1}. Based on this criteria, out of 80 half sib families three half sib families (HS-18, HS-21 and HS-60) significantly superior over all the four checks and two half sib family HS-14, HS-15 significantly superior over all the check except AKS-207, three half sibs HS-48, HS-41 and HS-71 were identified and found significantly superior over A1 and AKS-207 for number of capitula plant^{-1} (Table 5). All these eight half-sib families were superior over one or other check for seed yield plant^{-1}. Hence, the remnant seeds of all these eight selected half sib families is suggested to be used for recombination cycle in next cycle.

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UTILIZATION OF CARROT *(Dacus carota)* JUICE FOR PREPARATION OF FLAVOURED MILK

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ABSTRACT

The present investigation entitled "Utilization of carrot juice (*Dacus carota*) for preparation of flavoured milk" was undertaken during Dec. 2013-May 2014. Flavoured milk was prepared using standardized milk containing 3 per cent fat with constant level of sugar (8 per cent) and different levels of carrot juice viz, 2% (T_1), 4% (T_2), 6% (T_3) and 8% (T_4). The product was analyzed for chemical composition as well as for sensory attributes in completely randomized design. The cost of production was also calculated by considering the retail market prices of different ingredients used. The results showed that fat, total solids, solids not fat, and protein were significantly decreased with the increase in concentration of carrot juice flavoured milk. The fat content was decreased from 2.72 to 2.62 per cent, total solids content decreased from 19.20 to 18.81 per cent, protein content decreased from 3.35 to 3.18 per cent and SNF content decreased from 16.48 to 16.19 per cent. On the other hand, the titrable acidity and ash percentage were significantly increased with the increase in the levels of carrot juice. Titrable acidity increased from 0.14 to 0.21 per cent and ash content increased from 0.75 to 0.84 per cent respectively. The significantly highest scores for colour and general appearance (28 out of 30), taste (46 out of 50), acceptability (18.66 out of 20) and overall acceptability (92.66 out of 100) were obtained in flavoured milk containing 4 per cent of carrot juice. The cost of flavoured milk increased with the increase in the levels of carrot juice. It is inferred from the above results that acceptable quality flavoured milk can be produced by blending carrot juice to the extent of 4 per cent with cost of production of Rs. 51.09 l^{-1}.

(Key words: Flavoured milk, carrot juice, physicochemical parameters, sensory attributes, cost structure)

INTRODUCTION

Flavoured milks are the milks to which some flavours are added. The very common flavours that are added to the milk are cocoa and chocolate. Flavoured milk can be prepared and marketed for growing children and adults. Flavoured milk is refreshing drink and it is served as cold drink. This can be prepared and marketed in any season of the year as blending material such as different types of flavours i.e. rose, vanilla, cardamom, chocolate, orange and pineapple are also available throughout the year.

Carrot (*Dacus carota* L.) is inexpensive and highly nutritious as it contains appreciable amount of vitamins B_2 (0.04 mg), B_6 (0.02 mg) and B_{12} (0.2 mg), vitamin C (4 mg) besides being rich in carotene (5.33 mg) (Gopalan *et al.*,1991). Bose *et al*. (2003) reported that nutritive value of edible portion of carrot 100^{-1} g i.e. 86.0 g moisture, 0.9 g protein, 0.2 g fat, 10.6 g carbohydrate, 1.2 g fibre, 3150 IU vitamin A, 1.1 g minerals, 3.0 mg vitamin C, 80 mg calcium, 30 mg phosphorus, 2.2 m iron, 14 mg magnesium and 27 mg sulphur. High carotenoid intake is associated with lowering risk of many cancer diseases, especially the prostate cancer. Further, vitamin A (12000 IU) is an antioxidant which is key to the growth and repair of tissues and helps the body to fight with infections, keeps eyes healthy, nourish epithelial tissues in the lungs, as well as of the skin. Apart from being high in carotenoids, carrots are also high in dietary fibres (Singh *et al.*, 2006).

The use of carrot juice as the natural flavouring agent in the preparation of carrot juice flavoured milk may prove to be beneficial due to highly nutritious nature of carrot as compared to artifitial flavours used generally for preparation of flavoured milk. The carrot juice is not consumed as such because of its somewhat bitter taste and needs special treatment for its processing to develop an acceptable beverage. Ritu *et al*. (2011) prepared herbal flavoured milk using double toned milk and extract of 10 medicinal herbs viz, amla, ashwagandha, atibala, bael, brahmi, rasna, saptala, saunf, triphala, vacha. Repate *et al*. (2010) prepared a safflower flavoured milk by using milk which is standardized at 3 % fat and 9 % SNF and blended with different proportions of safflower milk. Singh *et al*. (2005) prepared carrot flavoured milk, their studies revealed that although all the combinations (10,20,30 per cent carrot juice containing flavoured milk) were found generally acceptable, flavoured milk containing 20 per cent carrot juice was highly acceptable. Dalim *et al*. (2012) evaluated chickoo and

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banana flavoured milk for the physico-chemical characteristics. It was inferred by them that chickoo flavoured milk based beverage was more acceptable than that of banana flavoured milk based beverage.

Therefore, it was planned to study on utilization of carrot juice in the preparation of flavoured milk.

MATERIALS AND METHODS

The present investigation entitled "Utilization of carrot juice (*Dacus carota*) for preparation of flavoured milk" was undertaken during the period Dec. 2013-May 2014.During the entire study fresh, clean, whole cow milk was obtained from the Section of Animal Husbandry and Dairy Science, College of Agriculture, Nagpur. The milk was strained through clean muslin cloth and transferred into well cleaned and sterilized flat bottom stainless steel vessel and standardized at 3 per cent fat. Carrot juice prepared from fresh carrots of local varieties available in the market was, used for preparation of flavoured milk. Clean crystalline sugar purchased from local market was used as a sweetening agent. The flavoured milk was prepared with constant level of sugar (8 per cent) and different levels of carrot juice viz, 2% (T_1), 4% (T_2), 6% (T_3) and 8% (T_4) were added in carrot flavoured milk.

Gupta *et al*. (2005) reported the nutritive value of carrot juice 100 ml^{-1} i.e. 90.51 g moisture,0.88 g protein,0.20 g fat,0.9 g ash,9.49 g total solids,1.01 g fibre,238.58 mg calcium,8.83 mg iron 539.57ug carotenoids and 464.13 ug β carotene and Salwa *et al*. (2004) reported that the average chemical composition of carrot juice is around moisture 92.85 %, fat 0.20 %, protein 0.88 %, total solids 7.15 %, ash 0.90 % and acidity 2.58 %.

Method of preparation of flavoured milk suggested by De (2003) was used. Sugar was weighed as per proportion (8%). At the same time milk was standardized to 3 per cent fat by using Pearson's Square method. The Milk was filtered and pre-heated to 35 to 40^{o}C. After standardization, boiling of milk was carried out. The sugar and carrot juice were added in milk in desired amount. The mixture was then pasteurized at 71^{0}C for 30 minutes. The mixture was then kept for cooling to room temperature and after cooling the same was transferred in the sterilized bottle and kept under refrigeration storage at until use.

Analytical grade chemicals were used for chemical analysis of carrot flavoured milk. Fat content in flavoured milk was determined by Gerber's method as prescribed in BIS bulletin no IS: 1224, Part 1(Anonymous,1977). The total solids percentage in flavoured milk was determined by using gravimetric method as described in BIS handbook of food analysis SP-18 part XI, Dairy products (Anonymous, 1981). The protein content in flavoured milk was determined by microkjeldahl method as per procedure recommended in IS 1479(part II) (Anonymous, 1961). SNF content was determined as per procedure recommended IS 1183 (Anonymous, 1965). Titratable acidity was determined as per the procedure recommended in BIS Handbook of food analysis, SP-18, (Part XI) Dairy products (Anonymous, 1981).

The quality of flavoured milk was judged by sensory evaluation in respect of flavour, body and texture, colour and appearance, by offering sample to panel of 5 judges in each trial separately with help of 100 point numeric score prescribed by Pal and Gupta (1985).

Sr. No.	Characters	Score
1	Colour and general appearance	30
2	Taste	50
3	Acceptability	20
	Total	100

The experiment was laid out in CRD with 4 treatments and five replications. The data were analyzed statistically according to method described by Snedecor and Corchan (1994).

RESULTS AND DISCUSSION

Chemical quality of carrot juice flavoured milk was evaluated with respect to fat, total solids, protein, titratable acidity and ash content and data are presented in table 1.

Fat content

Fat content of flavoured milk was significantly affected due to the addition of different levels of carrot juice. It was noticed that with the increase in proportion of carrot juice the fat content gradually decreased. Thus, significantly highest fat content (2.72 %) was noticed in 2 per cent carrot juice flavoured milk and the lowest fat content (2.62 %) was noticed in 8 per cent carrot juice flavoured milk.

The results of present investigation are in line with the findings of Shelke *et al.* (2008) who reported that fat content of rose, vanilla, cardamom, strawberry, kesar, pineapple and mango flavoured milks slightly decreased as compared to original milk.

Total solids content

Total solids content of flavoured milk was significantly affected due to the addition of different levels carrot juice. Significantly highest total solids content (19.20 %) was noticed in 2 per cent carrot juice flavoured milk and the lowest total solids content (18.81 %) was noticed in 8 per cent carrot juice flavoured milk. It indicated that total solids content in flavoured milk decreased with the increase in the level of carrot juice.

The results of present investigation are in general agreement with the findings of Singh *et al.* (2005). They reported that with increase in the level of carrot juice, there was proportionate decrease in the total solids content of carrot flavoured milk. Likewise Repate *et al.* (2010) also noticed that the increase of safflower concentration in flavoured milk during the manufacture of safflower flavoured milk, there was decrease in the total solids content in flavoured milk.

Protein content

Protein content of flavoured milk was significantly affected due to the addition of different levels of carrot juice. Significantly highest total protein content (3.35%) was noticed in 2 per cent carrot juice flavoured milk and the lowest protein content (3.18%) was noticed in 8 per cent carrot juice flavoured milk. It indicated that protein content in flavoured milk decreased with the increased level of carrot juice.

The results of present investigation were in general agreement with the findings of Repate *et al.* (2010) who noticed that with the increase in concentration of flavoring agents protein content of flavoured milk beverage gradually decreased.

SNF content

Average values of SNF content in flavoured milk prepared with different concentrations of carrot juice viz., 2% (T_1), 4% (T_2), 6% (T_3), and 8% (T_4) treatments were 16.48, 16.39, 16.30 and 16.19 per cent respectively. It indicates that with the addition of carrot juice in flavoured milk there was slight decrease in SNF content with the increase in carrot juice concentration in flavoured milk but the decreasing variations were not statistically significant.

The results of present investigation are in general agreement with the findings of Shelke *et al.* (2008). They observed that SNF content of different flavoured milk beverages was ranging from 17.02 to 17.13. Deore (2013) reported that solid not fat per cent decreased with increased fat content of pineapple flavoured milk.

Titratable acidity content

Titratable acidity content of flavoured milk was significantly affected due to the addition of carrot juice in different levels. Significantly highest acidity content (0.21 %) was noticed in 8 per cent carrot juice flavoured milk and the lowest acidity content (0.14 %) was noticed in 2 per cent carrot juice flavoured milk. It indicated that acidity content in flavoured milk increased with the increased carrot juice level in flavoured milk.

The results of present investigation are in agreement with the findings of Singh *et al.* (2005). They reported that with the increase in the level of carrot juice, there was proportionate increase in the acidity content of flavoured milk.

Ash content

Ash content of flavoured milk was significantly affected due to the addition of carrot juice in different levels. Significantly highest ash content (0.84 %) was noticed in 8 per cent carrot juice flavoured milk and the lowest ash content (0.75 %) was noticed in 2 per cent carrot juice flavoured milk. It indicated that ash content in flavoured milk increased with the increased carrot juice level.

The results of present investigation are in agreement with the findings of Jothylingam and Pugazhenthi (2013). They reported that ash content of dietic flavoured milk was ranging from 0.75 to 0.78 per cent.

Sensory evaluation of flavoured milk

The data with respect to sensory evaluation of carrot juice flavoured milk are presented in table 2.

Colour and general appearance score

While studying the effect of different levels of carrot juice on the colour and general appearance of flavoured milk, flavoured milk prepared by using 4 per cent of carrot juice scored the highest marks (28 out of 30), while the lowest score (23.33 out of 30) was secured by the flavoured milk prepared by 8 per cent carrot juice. Statistically, flavoured milk with 4 per cent of carrot juice was superior among all the treatments, which had pleasant colour and general appearance. It was followed by flavoured milk with 2, 6 and 8 per cent carrot juice.

Khandawe (2003) reported that colour and appearance of chocolate flavoured milk depends on chocolate levels.Whereas Shelke (2005) reported that mango flavour had scored the highest marks while strawberry flavour had scored the lowest marks for colour and appearance of flavoured milk.

Taste score

The taste score of flavoured milk seems to be mainly depending on levels of carrot juice addition. Flavoured milk prepared with 4 per cent of carrot juice scored the highest marks (46 out of 50), while the lowest score (41.33 out of 50) was secured by the flavoured milk prepared with 8 per cent carrot juice. Statistically, flavoured milk containing 4 per cent carrot juice was superior among all the treatments.

Repate *et al.* (2010) observed that sensory scores for taste attribute of safflower flavoured milk was decreased with the increase in concentration of flavouring agent i.e. safflower milk.

Acceptability score

The acceptability score of flavoured milk seems to be mainly dependent on levels of carrot juice. The highest score for acceptability was obtained (18.66 out of 20) by the flavoured milk prepared with 4 per cent of carrot juice , while the lowest score was secured (14.66 out of 20) by the flavoured milk prepared with 8 per cent carrot juice. Statistically, 4 per cent carrot juice flavoured milk was superior among all the treatments. The results from table 2 indicate that second best treatment was 2 per cent carrot juice containing flavoured milk. Thus, acceptability of flavoured milk declined beyond 4 per cent carrot juice containing flavoured milk.

Ramasamy *et al*. (2005) observed that flavoured milk with carrot and cardamom obtained the highest acceptability scores (8.5 out of 10) and flavoured milk while only beetroot flavoured milk obtained the lowest acceptability scores (3 out of 10).

Cost of production

Considering the cost structure of flavoured milk prepared from different treatment combinations, it was observed that the flavoured milk with 2.0 % carrot juice had the lowest cost of production i.e. Rs.50.67 l^{-1}. While, the highest cost of production Rs.51.93 l^{-1} was observed the flavoured milk with 8.0 per cent carrot juice. The cost of most acceptable flavoured milk at the 4% carrot juice level was Rs.51.09 l^{-1}.

Repate *et al*. (2010) who prepared the safflower flavoured milk with different proportion of cow milk blended with safflower milk and reported that the cost of flavoured milk could be minimized by using safflower milk and cow milk blended together and blending could be done to the maximum proportion of 50:50.

Table 1. Chemical composition of carrot juice flavoured milk (%)

Treatments	Fat	Total solids	Protein	SNF	Titratable acidity	Ash
T_1 (2 % carrot juice)	2.72[a]	19.20[a]	3.35[a]	16.48[a]	0.14[d]	0.75[d]
T_2 (4 % carrot juice)	2.69[b]	19.08[b]	3.31[b]	16.39[b]	0.16[c]	0.78[c]
T_3 (6 % carrot juice)	2.65[c]	18.95[c]	3.24[c]	16.30[c]	0.19[b]	0.82[b]
T_4 (8 % carrot juice)	2.62[d]	18.81[d]	3.18[d]	16.19[d]	0.21[a]	0.84[a]
SE(m)±	0.012	0.088	0.015	0.074	0.006	0.004
CD at 5%	0.036	0.262	0.046	0.223	0.018	0.012.

Values with different superscripts differ significantly (P<0.05)

Table 2. Sensory evaluation of flavoured milk as affected by different levels of carrot juice

Treatments	Colour and general appearance (Out of 30)	Taste (Out of 50)	Acceptability (Out of 20)	Overall score (Out of 100)
T_1 (2% carrot juice)	25.33[c]	42.00[c]	17.00[b]	84.33
T_2 (4% carrot juice)	28.00[a]	46.00[a]	18.66[a]	92.66
T_3 (6% carrot juice)	25.33[b]	42.66[b]	15.33[c]	83.32
T_4 (8% carrot juice)	23.33[d]	41.33[d]	14.66[d]	79.32
SE(m)±	0.12	0.20	0.074	
CD	0.35	0.59	0.22	

Values with different superscripts differ significantly (P<0.05)

Table 3. Cost of production of 1 litre carrot flavoured milk blended with various levels of carrot juice

Item	Treatments							
	T_1		T_2		T_3		T_4	
	Qty	Value (Rs)	Qty	Value (Rs)	Qty	Value (Rs)	Qty	Value (Rs)
Cow milk (ml) @ Rs 29 l^{-1}. (3 % fat/toned milk)	980	28.42	960	27.84	940	27.26	920	26.68
Carrot juice (ml) @ Rs 50 l^{-1}.	20	1.00	40	2.00	60	3.00	80	4.00
Sugar (gm) @ Rs 32 kg^{-1}	80	2.56	80	2.56	80	2.56	80	2.56
Fuel Charges LPG (g) Rs 450@14.2 kg^{-1}		1.69	53.5	1.69	53.5	1.69	27.66	1.69
Electricity charges @Rs. 5 $Unit^{-1}$		2.00	0.40	2.00	0.40	2.00	0.40	2.00
Total	-	50.67	-	51.09	-	51.51		51.93

T_1- Flavoured milk with 2 per cent carrot juice
T_2- Flavoured milk with 4 per cent carrot juice
T_3- Flavoured milk with 6 per cent carrot juice
T_4- Flavoured milk with 8 per cent carrot juice

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EFFECT OF PLANTING TIME AND NITROGEN ON GROWTH, YIELD AND QUALITY OF SPIDER LILY

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ABSTRACT

A field investigation was carried out at Satpuda Botanic Garden, College of Agriculture, Nagpur in 2013 to study the effect of planting time and nitrogen on growth, yield and quality of spider lily. It was revealed that, the vegetative growth *viz.,* plant height and leaf area, yield parameters *viz.*, flowers plant^{-1}, bulbs plant^{-1}, bulbs hectare^{-1} and offsets plant^{-1}, flowering span and length of flower bud in spider lily were influenced non-significantly due to different treatments of planting time. However, significantly maximum plant height, leaf area, flowers plant^{-1}, bulbs plant^{-1}, bulbs hectare^{-1}, offsets plant^{-1}, flowering span and length of flower bud were noted with the application of 400 kg N ha^{-1} (N_4), whereas, all these parameters were recorded minimum under the control treatment i.e. 0 kg N ha^{-1}. Interaction effect of planting time and nitrogen was found non-significant in respect of all vegetative, flowering, yield and quality parameters of spider lily except days for first flower bud emergence which was noted significantly minimum under 15th March planting with 0 kg N ha^{-1}, whereas, flower bud emergence was delayed under 15th January planting with 400 kg nitrogen ha^{-1}.

(Key words: Planting time, nitrogen, spider lily, offsets, bulbs)

INTRODUCTION

Spider lily (*Hymenocallis littoralis* L.) is native to South America and belongs to the family *Amaryllidaceae*. It is a bulbous ornamental plant which is 45-60 cm tall and has long, broad shaped green leaves. It is now emerging as an important commercial flower crop in Maharashtra. The flowers of spider lily are largely used in garlands and *gajra* making, *mandap*, marriages and social ceremonies and various flower decorations.

Nitrogen is one of the important nutrient which helps to increase yield and quality of flowers. It is also found that, production of flowers can be regulated by adopting proper time of planting of flower crops, so that, the produce can be made available in the market whenever there is a good demand of flowers. Considering the important role of planting time and nitrogen for increasing the profit and productivity of flower crops, the present investigation was proposed on effect of planting time and nitrogen on growth, yield and quality of spider lily.

MATERIALS AND METHODS

The investigation was carried out at Satpuda Botanic Garden, College of Agriculture, Nagpur during January, 2013 to September, 2013 in factorial randomized block design. The treatments comprised of three treatments of planting time i.e. 15th January, 15th February and 15th March and four levels of nitrogen i.e. 0 kg N ha^{-1}, 200 kg N ha^{-1}, 300 kg N ha^{-1} and 400 kg N ha^{-1} with three replications. The bigger and uniform sized bulbs of spider lily were selected and then planted at a spacing of 60 cm x 45 cm in the flat beds on different dates as per the treatment. At the time of land preparation, well-rotted FYM @ 20 t ha^{-1} was mixed uniformly in the soil before last harrowing. A recommended dose of phosphorus and potassium i.e. 100 and 50 kg ha^{-1}, respectively was applied to all the treatment plots as a full dose at the time of bed preparation before planting, while, the dose of nitrogen was applied as per the treatments. It was splitted in three equal splits and each was applied at the time of planting, one month after planting and two months after planting. The growth parameters *viz.,* plant height (cm) and leaf area (cm^2) were observed at 120 days after planting and quality parameters *viz.,* length of flower bud (cm) and yield parameters *viz.,* flowers plant^{-1} were recorded after 120 DAP. Similarly, bulbs plant^{-1}, bulbs hectare^{-1} and offsets plant^{-1} were recorded at the time of harvesting.

RESULTS AND DISCUSSION

Growth

The data presented in table 1 exhibited that, vegetative growth in terms of plant height and leaf area was influenced non-significantly by planting time.

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However, in respect of nitrogen levels, significantly the maximum plant height (95.16 cm) and leaf area (329.08 cm^2) were noticed under the treatment N_4 i.e. 400 kg N ha^{-1} and the plant height and leaf area were recorded minimum under the control treatment i.e. 0 kg N ha^{-1} (92.02 cm and 310.15 cm^2 respectively). In respect of plant height, the treatment N_4 i.e. 400 kg N ha^{-1} was found at par with the treatment N_3 i.e. 300 kg N ha^{-1} (94.04 cm). This might be due to general improvement in growth and development of plant by suitable dose of nitrogenous fertilizer as nitrogen is an essential part of nucleic acid which plays a vital role in promoting plant growth. These results are in close conformity with the results of Ghule *et al*. (2003) in spider lily who reported that, the height of spider lily plant increased significantly with the application of higher level of nitrogen (300 kg ha^{-1}). Similar results were also obtained by Siraj and Al-Safar (2006) in gladiolus. They found that, application of the highest dose i.e. 75 kg N ha^{-1} reported maximum leaf area (8.17 cm^2) in gladiolus.

Interaction effect of planting time and nitrogen was found to be non-significant in respect of plant height, however it was significant in case of leaf area. The data from table 2 revealed that, significantly maximum leaf area (330.60 cm^2) was recorded with the treatment combination of T_1N_4 (15th January with 400 kg N ha^{-1}) which was statistically at par with the treatment combination of T_2N_4 i.e. 15th February with 400 kg N ha^{-1} (328.90 cm^2) and minimum leaf area (309.40 cm^2) was recorded under the treatment combination of T_2N_1 (15th February with 0 kg N ha^{-1}). This might be due to the combined effect of planting time and nitrogen applied to spider lily crop.

Flowering

The data presented in table 1 indicated that, a day for first flower bud emergence in spider lily was significantly influenced by various planting time. 15th March planting recorded less number of days (125.66 days) for emergence of first flower bud, whereas, maximum days were required under 15th January planting (165.91 days). However, the flowering span in spider lily was influenced non-significantly due to different treatments of planting time. The flower bud emergence was delayed under 15th January (T_1) planting which might have been due to non-availability of required temperature and day length for flower bud initiation of spider lily due to which the juvenile phase of the plant might have been extended. Suman Kumari *et al*. (2011) obtained contrast results in gladiolus. They reported an early emergence of spike under the earliest planting date i.e. 25th October.

The data regarding the days for first flower bud emergence and flowering span (days) in spider lily showed significant differences amongst the different levels of nitrogen. It was observed that, the control treatment (0 kg N ha^{-1}) took significantly minimum period (137.66 days) for emergence of first flower bud which was followed by the treatment N_2 i.e. 200 kg N ha^{-1}(144.88 days), whereas, the treatment N_4 (400 kg N ha^{-1}) took maximum days for emergence of first flower bud (147.66 days). However, in respect of flowering span, significantly the maximum flowering span (30.55 days) was recorded with the treatment N_4 (400 kg N ha^{-1}) which was followed by the treatment N_3 i.e. 300 kg N ha^{-1} (28.24 days) and the control treatment recorded minimum (25.00 days) flowering span. Delay in flower bud emergence due to the highest dose of nitrogen might be due to encouraged vegetative growth of plant by nitrogen which might have prolonged the time required by the plant to enter into reproductive phase from vegetative phase. Increased total flowering span might be due to better turgidity of flowers as a result of application of higher dose of nitrogen. These results are in close conformity with the results of Devi and Singh (2010) in tuberose who noticed that, the highest level of nitrogen i.e. 220 kg N ha^{-1} recorded maximum duration of flower. They also reported that, flowering was advanced by control upto 40 kg N ha^{-1} and delayed by higher level of nitrogen in tuberose.

Interaction effect of planting time and nitrogen was found to be significant in respect of days for first flower bud emergence, however, it was found non-significant in respect of flowering span in spider lily. The treatment combination of T_3N_1 (15th March planting with 0 kg N ha^{-1}) recorded an earlier flower bud emergence (122.66 days) which was found at par with the treatment combinations of T_3N_2 (15th March planting with 200 kg N ha^{-1}), T_3N_3 (15th March planting with 300 kg N ha^{-1}) and T_3N_4 (15th March planting with 400 kg N ha^{-1}), however, it was found late under the treatment combination of T_1N_4 (15th January planting with 400 kg N ha^{-1}).

Table 1. Effect of planting time and nitrogen on growth, yield and quality of spider lily

Treatments	Plant height (cm)	Leaf area (cm^2)	Days for first flower bud emergence	Flowering span (days)	Length of flower bud (cm)	Flowers $plant^{-1}$	Offsets $plant^{-1}$	Bulbs $plant^{-1}$	Bulbs ha^{-1} (lakh)
Planting time (T)									
T_1 – 15th Jan.	94.11	320.80	165.91	28.25	28.08	17.25	8.09	8.35	2.82
T_2 – 15th Feb.	93.71	319.70	141.00	27.83	27.66	16.95	7.71	8.03	2.76
T_3 – 15thMarch	92.90	320.62	125.66	26.58	27.55	15.85	6.93	7.97	2.56
SE (m)	0.34	0.44	1.15	0.47	0.17	0.47	0.33	0.31	0.07
CD at 5%	-	-	3.39	-	-	-	-	-	-
Nitrogen (N)									
N_1 – 0 kg ha^{-1}	92.02	310.15	137.66	25.00	25.80	15.01	6.07	6.18	2.45
N_2 – 200 kg ha^{-1}	93.07	319.23	144.88	26.22	27.42	16.31	7.27	7.63	2.60
N_3 – 300 kg ha^{-1}	94.04	322.93	146.55	28.24	28.31	17.18	7.90	8.91	2.82
N_4 – 400 kg ha^{-1}	95.16	329.08	147.66	30.55	29.53	18.25	9.06	9.75	3.00
SE (m)	0.40	0.51	1.33	0.54	0.20	0.54	0.38	0.36	0.08
CD at 5%	1.17	1.51	3.92	1.60	0.59	1.60	1.13	1.07	0.24
Interaction (TXN)									
SE (m)	0.69	0.89	2.31	0.94	0.35	0.95	0.66	0.63	0.14
CD at 5%	-	2.62	6.79	-	1.02	-	-	-	-

Table 2. Interaction effect of planting time and nitrogen on growth, yield and quality of spider lily

Treatments combination	Leaf area (cm^2)	Days for first flower bud emergence (days)	Length of flower bud (cm)
T_1N_1	310.20	153.00	25.93
T_1N_2	318.73	168.66	27.53
T_1N_3	323.70	170.66	28.53
T_1N_4	330.60	171.33	30.33
T_2N_1	309.40	137.33	25.06
T_2N_2	320.10	141.00	27.63
T_2N_3	320.43	142.66	28.60
T_2N_4	328.90	143.00	29.36
T_3N_1	310.86	122.66	26.40
T_3N_2	318.86	125.00	27.10
T_3N_3	324.66	126.33	27.80
T_3N_4	327.08	128.66	28.90
SE (m)	0.89	2.31	0.35
CD at 5%	2.62	6.79	1.02

Yield

The data presented in table 1 revealed that, the yield of spider lily in respect of total number of flowers plant^{-1}, bulbs plant^{-1}, bulbs ha^{-1} and offsets plant^{-1} was non-significantly influenced by different planting time. However, different levels of nitrogen influenced all these yield parameters significantly.

Significantly the maximum number of flowers plant^{-1} (18.25), bulbs plant^{-1} (9.75), bulbs ha^{-1} (3.00 lakh) and offsets plant^{-1} (9.06) were counted with the treatment N_4 i.e. 400 kg N ha^{-1} which was statistically at par with the treatment N_3 i.e. 300 kg N ha^{-1} (17.18, 8.91, 2.82 lakh and 7.90, respectively), whereas, significantly minimum values were noted with the control treatment i.e. 0 kg N ha^{-1} (15.01, 6.18, 2.45 lakh and 6.07, respectively).

An increased yield of flowers with the highest dose of nitrogen might be due to adequate supply of nitrogen to the plants resulted in the proper development of required photosynthetic system which helps to increase the production of flowers. Nitrogen is one of the essential elements for growth and development of plants and sufficient levels of nitrogen provides better growth and development and helps in translocation of photosynthates from source to sink (bulbs) which might have been resulted into higher yield of bulbs. The results are in congruent with the findings of Khan *et al*. (2012) who reported that, the application of higher dose of nitrogen i.e. 60 kg ha^{-1} showed significant effect on number of spikes plant^{-1} and number of cormels plant^{-1} as compared to other treatments (0, 20 and 40 kg ha^{-1}) in freesia. Similar results were obtained by Devi and Singh (2010) who suggested that, higher dose of nitrogen (220 kg ha^{-1}) produced significantly maximum yield of bulbs in tuberose.

The interaction effect of planting time and nitrogen on flowers plant^{-1}, bulbs plant^{-1}, bulbs ha^{-1} and offsets plant^{-1} in spider lily was found to be non-significant (Table 1).

Quality

The data showed that, the length of flower bud in spider lily had influenced non-significantly due to different treatments of planting time. However, different levels of nitrogen significantly influenced the length of flower bud.

The treatment N_4 i.e. 400 kg N ha^{-1} noted significantly maximum length of flower bud (29.53 cm) which was closely followed by the treatment N_3 i.e. 300 kg N ha^{-1} (28.31 cm), whereas, the control treatment i.e. 0 kg N ha^{-1} produced minimum length of flower bud (25.80 cm). The improvement in length of flower bud due to higher dose of nitrogen might be due to an increased vigour of spider lily plant which provided maximum food material for development of spider lily flowers. These results are in accordance with the findings of Khalaj and Edrisi (2012) in tuberose. They recorded that, the highest dose of nitrogen resulted in maximum spike length (27.66 cm).

The interaction effect due to planting time and nitrogen on length of flower bud in spider lily was found to be significant (Table 2). The treatment combination of T_1N_4 (15th January with 400 kg N ha^{-1}) produced significantly maximum (30.33 cm) length of flower bud and it was found statistically at par with the treatment combination of T_2N_4 (29.36 cm) i.e. 15th February planting with 400 kg N ha^{-1}, however, the treatment combination of T_2N_1 (15th February with 0 kg N ha^{-1}) produced minimum length of flower bud (25.06 cm). An increased length of flower bud might be due to combined effect of earlier planting with the highest dose of nitrogen.

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GENETIC VARIABILITY CREATED THROUGH BIPARENTAL MATING IN MUSTARD (*Brassica juncea* L.)

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ABSTRACT

Biparental mating was attempted in the population F_2 of four intervarietal crosses Kranti x ACN-9, Seeta x Ashirwad, Bio-902 x Ashirwad and Vardhan x Kranti of mustard using NCD I mating model during *rabi* 2013. The analysis of variance for experimental design revealed that the BIP progenies obtained from the four crosses had substantial genetic variability among themselves for yield and most of the yield components, which allowed the further estimation of different parameters. The maximum range was observed for number of siliqua plant^{-1}, followed by plant height, days to maturity, days to first flower and seed yield plant^{-1} in the four crosses. Comparison of mean value of BIP with check varieties revealed that upper limit value of BIP progenies for days to first flower, plant height, number of primary branches plant $^{-1}$, number of siliqua plant^{-1} and seed yield plant^{-1} were higher than best check varieties for respective characters. Genotypic variance and phenotypic variance were found to be maximum for number of siliqua plant^{-1} followed by plant height in all the four crosses. High GCV and PCV were observed for seed yield plant^{-1} and number of primary branches plant^{-1} for all the four crosses. Selection of superior BIPs, were done on the basis of significant superiority of BIPs over check and their index score. Based on this criteria 8.59 %, 17.96 %, 7.8 % and 16.40 % of BIPs over total 128 BIPs evaluated were selected from the cross Kranti x ACN-9, Seeta x Ashirwad, Bio-902 x Ashirwad and Vardhan x Kranti respectively for forwarding next generation and selection should be based on progeny testing through rather half sib or full sib for improvement of number of siliqua plant^{-1} and seed yield till^{-1} homozygosity is attained.

(Key words: Biparental mating, variability, mustard)

INTRODUCTION

Mustard is one of the important oilseed crops of India. It is a self-pollinated crop. Autogamous species place a restriction on genetic recombination because of the fact selfing leads to rapid fixation of linked genes, precludes free exchange of favourable genes and also prevents emergence of desirable gene constellations, thereby limits variability. However, genetic variability is the most essential requirement for the success of any crop improvement programme. As such biparental mating systems (Comstock and Robinson, 1948, 1952) are suggested to overcome the defects of conventional methods of breeding, and help to create new populations with higher frequencies of rare combinations which can not be realized in small segregating populations. Though there are studies on the biparental mating and its impact on various aspects on crop likes wheat and barley, reports on sesame are scanty and hence, the present work was undertaken in mustard with four crosses viz., Kranti x ACN-9, Seeta x Ashirwad , Bio-902 x Ashirwad, Vardhan x Kranti.

MATERIALS AND METHODS

The F_2 generation of four crosses Kranti x ACN-9, Seeta x Ashirwad , Bio-902 x Ashirwad, Vardhan x Kranti of mustard were used to generate biparental progenies by adopting North Carolina Design I (Comstock and Robinson, 1952) during *rabi* 2012. Eight plants were randomly chosen from the F_2 generation of each cross and used as pollen (male) parents. From F_2 population of each cross 32 plants were randomly tagged to be used as female plants. Each of the eight pollen plants (males) were crossed to four different female plants. Resulting 32 progeny families were divided into two sets, each comprising of 4 male group. The seeds from each of the BIP crosses were harvested separately. Each set along with their six parents and check Pusa bold were planted during *rabi* 2013 in randomized block design with three replications at the experimental farm of Agricultural Botany section, College of Agriculture, Nagpur. Data were recorded on five randomly chosen plants from BIP progenies, parents and check for recording observations in each of five crosses. Observations were recorded on days to first flower, days to maturity, plant height, number of primary branches plant^{-1}, number of siliqua plant^{-1} and seed yield plant^{-1}. The data were subjected to statistical and biometrical analysis as per the method described by Panse and Sukhatme (1954), Burton and Devane (1953), and Sivasubramanian and Menon (1973).

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RESULTS AND DISCUSSION

The mean square due to genotypes (BIP progenies+ checks) as observed from table1 were highly significant for all the characters except number of primary branches plant^{-1} in the cross Kranti x ACN-9. Similarly it was highly significant for all the characters except days to first flower and days to maturity in the cross Seeta x Ashirwad, except days to first flower in Bio-902 x ACN-9 and significant for all the traits in the cross Vardhan x Kranti. This reveals that the BIP progenies obtained from the four crosses had substantial genetic variability among themselves for yield and most of the yield components which allows the further estimation of different parameters in the experimental materials. Similar to this result wide variability for seed yield plant^{-1} and yield contributing characters in mustard were also observed by Singh and Murty (2003) in mustard.

The maximum range (Table2) was recorded by number of siliqua plant^{-1}(117.8, 117.03, 108.46 and 111.14) followed by plant height (35.53, 38.53, 37.13 and 38.8), days to maturity (7.4, 5.73, 5.13 and 19.93) days to first flower (7.27, 4.67, 5.87 and 8.46) and seed yield plant^{-1} (4.6, 7.27, 5.02 and 6.97) in the four crosses Kranti x ACN 9, Seeta x Ashirwad, Bio-902 x Ashirwad and Vardhan x Kranti respectively. This indicated the presence of considerable amount of genetic variance in BIP progenies. These results revealed that characters like number of siliqua plant^{-1}, plant height and seed yield plant^{-1} showing maximum range in BIP progenies of four crosses can be consider as traits for selecting superior progenies. Such high proportion of mean values were also reported by Anuradha and Reddy (2004) in sesame, Kampli *et al*. (2002) in chickpea and Gowthami (2013) in mustard. Higher mean values of BIP generation could be attributed to the advantages of increase heterozygosity at many loci for the said characters, so also pushing the mean values towards the positive side could be of immense value in throwing superior segregants in advance generation (Anuradha and Reddy, 2004). Comparison of range indicated that in BIP progenies upper limit increased in recombination of latent variability that tends to remain locked under linkage.

Mean values of BIP progenies (Table 2) when compared with check varieties, upper limit value of BIP progenies for days to first flower, plant height, number of primary branches plant^{-1}, number of siliqua plant^{-1} and seed yield plant^{-1} were found to be higher than best check varieties for respective characters as observed from Figure1a and Figure1b. Days to maturity in most of the cases, the upper limit values of BIP progenies were higher, but in Kranti x ACN-9 and Bio-902 x Ashirwad were at par with the best check varieties. This indicates the availability of promising BIP progenies superior than check, hence the BIP progenies can be subjected to selection for superior progenies for the above mentioned traits like number of siliqua plant^{-1}, seed yield plant^{-1}, plant height, number of primary branches plant^{-1}, if these traits also record a good extend of heritability and genetic advance.

Variability parameters like σ^2g, σ^2p, GCV (%) and PCV (%) were estimated in BIP progenies of all the four crosses and data are presented in table 4. The estimates of σ^2g and σ^2p were low in the BIP progenies of all the four crosses for days to first flower, days to maturity, number of primary branches plant^{-1} and seed yield plant^{-1}. Genotypic variance and phenotypic variance were found to be maximum for number of siliqua plant^{-1} followed by plant height in all the four crosses. Wide differences between genotypic and phenotypic variance was observed for all the characters in BIP progenies of all the four crosses. This indicates influence of environment in the expression of different traits.

Comparison of genotypic and phenotypic variance between different characters in different progenies is not that much appropriate. Hence, they are expressed as percentage of mean i.e. in terms of co-efficient of variation. Therefore, genotypic co-efficient of variation and phenotypic co-efficient of variation were estimated and data are presented in table 3. The estimates of genotypic co-efficient of variation and phenotypic co-efficient of variation were low for days to first flower and days to maturity in the BIP progenies of all the four crosses studied. Genotypic co-efficient of variation was also observed to be low (< 10%) in BIP progenies of all the four crosses, whereas phenotypic co-efficient of variation was found to be low in BIP progenies of Seeta x Ashirwad and moderate in BIP progenies of Kranti x ACN-9, Bio-902 x Ashirwad and Vardhan x Kranti. Genotypic co-efficient of variation estimate were low for number of branches plant^{-1} in BIP progenies of Kranti x ACN-9 (5.74%) and Bio-902 x Ashirwad

Table 1. Analysis of variance for various traits in BIP progenies of four crosses

A) Kranti x ACN-9

Sources	df	Days to first flower	Days to maturity	Pl. height (cm)	No. of branches plant^{-1}	No.of siliqua plant^{-1}	Seed yield plant^{-1} (g)
Replications	2	21.245	25.791	359.154	0.183	637.336	0.556
Genotypes (Progenies + Checks)	35	5.203**	6.279**	263.152**	0.398	2785.559**	6.271**
Error	70	2.065	2.811	118.712	0.280	523.94	0.841

B) Seeta x Ashirwad

Sources	Df	Days to first flower	Days to maturity	Pl. height (cm)	No. of branches plant^{-1}	No. of siliqua plant^{-1}	Seed yield plant^{-1} (g)
Replications	2	50.50	4531.33	295.03	0.768	7898.74	34.94
Genotypes (Progenies + Checks)	35	3.55	249.73	249.73**	0.612**	2932.49**	12.64**
Error	70	2.44	171.02	50.37	0.200	928.08	2.83

C) Bio-902 x Ashirwad

Sources	df	Days to first flower	Days to maturity	Pl. height (cm)	No. of branches plant^{-1}	No. of siliqua plant^{-1}	Seed yield plant^{-1} (g)
Replications	2	16.86	6.82	1707.95	0.71	8624.64	16.97
Genotypes (Progenies + Checks)	35	8.76	7.01*	338.63**	0.42**	2444.91**	4.70**
Error	70	7.93	3.55	198.34	0.21	1347.86	2.74

D) Vardhan x Kranti

Sources	df	Days to first flower	Days to maturity	Pl. height (cm)	No. of branches plant^{-1}	No. of siliqua plant^{-1}	Seed yield plant^{-1} (g)
Replications	2	266.86	75.84	2492.09	1.57	399.68	219.05
Genotypes (Progenies + Checks)	35	19.91**	38.44**	338.43**	0.77**	2193.33**	8.69**
Error	70	10.05	5.72	131.12	0.29	375.73	4.75

*** Significant at 5% and ** Significant at 1% level**

Table 2. Mean and range for different traits in the BIP progenies of four crosses

Crosses	Characters	Days to first flower	Days to maturity	Plant height (cm)	Number of primary branches $plant^{-1}$	Number of siliqua $plant^{-1}$	Seed yield $^{-1}$ (g)
Kranti x ACN-9	Maximum	44.80	99.00	137.60	4.53	179.27	5.87
	Minimum	37.53	91.60	102.07	2.80	61.47	1.27
	Range	7.27	7.4	35.53	1.73	117.8	4.6
	Mean (BIPS)	38.81	93.70	119.58	3.51	124.64	3.42
Seeta x Ashirwad	Maximum	44.67	99.80	135.80	4.47	205.40	8.78
	Minimum	40.00	94.07	97.27	2.87	88.37	1.51
	Range	4.67	5.73	38.53	1.6	117.03	7.27
	Mean (BIPS)	42.30	96.55	121.99	3.73	151.54	5.24
Bio-902 x Ashirwad	Maximum	44.67	98.13	140.40	4.40	179.73	6.15
	Minimum	38.80	93.00	103.27	3.20	71.27	1.13
	Range	5.87	5.13	37.13	1.2	108.46	5.02
	Mean (BIPS)	40.42	95.21	119.58	3.63	124.00	3.20
Vardhan x Kranti	Maximum	47.73	102.73	142.13	4.87	188.47	8.20
	Minimum	39.27	82.80	103.33	2.80	77.33	1.23
	Range	8.46	19.93	38.8	2.07	111.14	6.97
	Mean (BIPS)	42.66	95.58	125.06	3.58	127.29	4.57
Average of checks	ACN-9	41.56	94.33	112.18	2.93	71.44	2.01
	Pusa bold	43.45	99.00	97.27	3.07	90.75	1.42

Table 3. Estimates of genetic variability parameters for different traits in BIP progenies of four crosses

Characters	Kranti X ACN-9				Seeta x Ashirwad				Bio-902 x Ashirwad				Vardhan x Kranti			
	^2g	^2p	GCV (%)	PCV (%)	^2g	^2p	GCV (%)	PCV (%)	^2g	^2p	GCV (%)	PCV (%)	^2g	^2p	GCV (%)	PCV (%)
Days to first flower	1.04	3.11	2.61	4.52	0.37	2.81	1.44	3.97	0.27	8.21	1.29	7.05	3.28	13.34	4.26	8.59
Days to maturity	1.15	3.96	1.14	2.12	26.23	197.25	4.26	11.67	1.15	4.70	1.13	2.27	10.90	16.62	3.44	4.25
Plant height	48.14	166.85	5.87	10.92	66.45	116.82	6.77	8.98	46.76	245.10	5.70	13.05	69.10	200.22	6.76	11.52
No.of branches plant^{-1}	0.03	0.32	5.74	16.37	0.14	0.34	10.14	15.91	0.07	0.28	7.24	14.80	0.16	0.45	11.41	19.13
No.of siliqua plant^{-1}	753.8	1277.82	22.84	29.73	668.14	1596.23	17.65	27.28	365.7	1713.55	15.75	34.10	605.86	981.60	19.96	25.41
Seed yield plant^{-1}	1.80	2.65	41.91	50.73	3.27	6.12	36.73	50.21	0.65	3.40	26.39	60.31	1.31	6.06	26.56	57.08

Table 4 .Selected BIP progenies from four crosses of mustard

Sr. No	Progenies	No. of siliqua plant^{-1}	Seed yield plant^{-1} (g)	Percentage of progenies selected over BIPs of each cross	Percentage of progenies selected over total BIPs
1	KAS1F6	167.60**	4.40*		
2	KAS1F9	179.27**	5.87**		
3	KAS1F10	161.67**	4.86**		
4	KAS1F15	158.20**	5.05**		
5	KAS1F16	151.40**	5.85**		
6	KAS2F1	144.87**	5.13**	34.37 %	8.59 %
7	KAS2F3	145.27**	5.45**		
8	KAS2F7	118.20*	4.68**		
9	KAS2F9	145.80**	4.48*		
10	KAS2F10	159.40**	4.55*		
11	KAS2F11	157.60**	5.50**		
12	SAS1F1	130.53*	4.81**		
13	SAS1F4	153.47**	5.22**		
14	SAS1F5	164.27**	6.20**		
15	SAS1F9	162.40**	6.56**		
16	SAS1F10	160.20**	4.99**		
17	SAS1F11	205.40**	8.78**		
18	SAS1F12	148.73*	7.75**		
19	SAS1F13	177.87**	9.33**		
20	SAS1F14	190.80**	7.62**		
21	SAS1F15	201.93**	8.38**		
22	SAS1F16	181.80**	6.31**		
23	SAS2F1	132.00*	4.25*	71.87 %	17.96 %
24	SAS2F2	138.07**	5.02**		
25	SAS2F3	119.60*	4.23*		
26	SAS2F6	139.67**	5.07**		
27	SAS2F8	184.87**	7.58**		
28	SAS2F9	155.23**	4.63*		
29	SAS2F10	161.83**	6.31**		
30	SAS2F12	171.00**	5.15**		
31	SAS2F13	170.03**	4.95**		
32	SAS2F14	150.07**	4.36*		
33	SAS2F15	178.27**	7.31**		
34	SAS2F16	166.73**	4.77**		
35	BAS1F1	154.47**	4.50*		
36	BAS1F4	153.73**	4.31*		
37	BAS1F6	136.73**	4.07*		
38	BAS1F7	123.40*	4.41*		
39	BAS1F11	167.07**	6.15**		
40	BAS1F12	147.80**	4.12*	31.25 %	7.8 %

Contd....

Sr. No	Progenies	No. of siliqua plant^{-1}	Seed yield plant^{-1} (g)	Percentage of progenies selected over BIPs of each cross	Percentage of progenies selected over total BIPs
41	BAS1F14	179.73**	4.61**		
42	BAS2F2	154.27**	4.93**		
43	BAS2F3	124.33*	4.31*		
44	BAS2F9	151.33**	4.55*		
45	VKS1F1	146.87**	5.59**		
46	VKS1F2	121.53*	4.50*		
47	VKS1F3	130.27*	7.86**		
48	VKS1F4	146.87**	8.20**		
49	VKS1F5	118.47*	7.81**		
50	VKS1F6	123.53*	5.97**		
51	VKS1F7	153.00**	4.41*		
52	VKS1F8	158.07**	6.63**		
53	VKS1F9	144.27**	5.47**		
54	VKS1F10	188.47**	6.17**		
55	VKS1F12	127.93*	5.08**		
56	VKS1F15	130.13*	4.25*	65.62 %	16.40 %
57	VKS1F16	119.87*	4.18*		
58	VKS2F3	146.80**	5.09**		
59	VKS2F4	125.87*	4.14*		
60	VKS2F8	144.93**	5.23**		
61	VKS2F9	155.33**	4.69**		
62	VKS2F10	132.80*	4.71**		
63	VKS2F12	137.80**	4.09*		
64	VKS2F13	126.20*	4.52**		
65	VKS2F15	129.00*	4.22*		
ACN-9 (Average)		71.44	2.01		
Pusabold (Average)		90.75	1.42		
CD (5%) (Average)		44.54	2.62		

(7.24%), whereas this estimate was moderate in BIP of Seeta x Ashirwad (10.14%) and Vardhan x Kranti (11.41%). On the other hand phenotypic co-efficient variation estimates were moderate in the BIP progenies of all the four crosses i.e. Kranti x ACN-9 (16.37%), Seeta x Ashirwad (15.91%), Bio-902 x Ashirwad (14.18%) and Vardhan x Kranti (19.13%). In case of number of siliqua plant^{-1} the estimate of genotypic co-efficient of variation were moderate in BIP progenies of all three crosses, Seeta x Ashirwad (17.65%), Bio-902 x Ashirwad (15.75%), Vardhan x Kranti (19.96%) and in the cross Kranti x Ashirwad this estimate was found to be high (22.84%). High (> 20%) estimate of phenotypic co-efficient variation were observed in BIP progenies of all the four crosses for this trait. The estimate of genotypic co-efficient of variation and phenotypic co-efficient of variation for seed yield plant^{-1} were high (>20%) in BIP progenies of all the four crosses.

Better scope for improvement through selection existed for different characters and was confined through genotypic co-efficient of variation and phenotypic co-efficient of variation. The results of the present study revealed that genotypic co-efficient of variation and phenotypic co-efficient of variation were either high or moderate for number of siliqua plant^{-1} and seed yield plant^{-1} in mustard. High genotypic co-efficient of variation and phenotypic co-efficient of variation in BIP progenies of all the four crosses observed for number of siliqua plant^{-1} and seed yield plant^{-1} offers more scope for selecting better segregants on the basis of these two traits. The results of Kampli *et al.* (2004) in chickpea, Naik *et al.* (2009) in safflower, Koli *et al.* (2012) in rice were also in agreement with the finding of this experiment. These workers have also reported the scope of exploiting BIP progenies for getting good segregants. They have also observed higher genotypic co-efficient of variation and phenotypic co-efficient of variation of biparental progenies for yield and important yield component traits, which were in accordance with our findings.

Hence, in this study priority were given for significant superiority of BIPs for seed yield plant^{-1} and number of siliqua plant^{-1}. Based on these criteria the BIPs were selected and performance of selected BIPs are presented in table 4. The proportion of BIPs selected also varied from cross to cross. Percentage of progenies selected over BIPs of each cross were 34.37% in Kranti x ACN-9, 71.87% in Seeta x Ashirwad, 31.2% in Bio-902 x Ashirwad and 65.62% in Vardhan x Kranti and the percentage of progenies selected over total of 128 BIPs evaluated were 8.59% in Kranti x ACN-9, 17.96% in Seeta x Ashirwad , 7.8% in Bio-902 x Ashirwad and 16.40% in Vardhan x Kranti. It is suggested that these selected BIP progenies should be forwarded to next generation and selection based on progeny testing through either half sib or full sib progeny should be followed for genetic improvement of seed yield plant^{-1} and number of siliqua plant^{-1} till homozygosity is attained.

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EFFECT OF ANTITRANSPIRANTS AND FREQUENCY OF IRRIGATIONS ON GROWTH, YIELD ATTRIBUTES AND YIELD OF INDIAN MUSTARD (*Brassica juncea* L.)

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ABSTRACT

A field experiment was conducted during *rabi* season of 2013-14 at College of Agriculture, Nagpur. The experiment was laid out in split plot design with four treatments of irrigation levels under main plot viz., I_0 - No irrigation, I_1 - One irrigation (at pod filling stage i.e. at 55 DAS), I_2 - Two Irrigations (at flowering i.e. at 35 DAS and at pod filling i.e. at 55 DAS), I_3- Three irrigations (at 35, 55 and 75 DAS) and three antitranspirants as sub plot treatments viz., A_0 - Control i.e. No antitranspirant, A_1 - Kaolin @ 6%(two sprays at 35 DAS and at 55 DAS) and A_2 – PMA (Phenyl mercuric acetate) @ 250 ppm (two sprays at 35 DAS and at 55 DAS) forming 12 treatment combinations replicated three times.

Growth contributing characters viz., mean plant height, mean number of branches plant^{-1}, mean leaf area plant^{-1}, mean dry matter accumulation plant^{-1} and yield contributing characters viz., number of siliqua plant^{-1}, number of seeds siliqua^{-1}, test weight, seed yield plant^{-1} and stover yield plant^{-1}, and seed and straw yield kg ha^{-1} were significantly more due to three irrigations at 35, 55 and 75 DAS as compared to no irrigation (control). Antitranspirant PMA @ 250 ppm recorded significantly more values of growth contributing characters viz., mean plant height, mean number of branches plant^{-1}, mean leaf area plant^{-1}, mean dry matter accumulation plant^{-1}. Yield contributing characters such as number of siliqua plant^{-1}, number of seeds siliqua^{-1}, test weight, seed yield plant^{-1}, stover yield plant^{-1}, seed yield kg ha^{-1} and straw yield kg ha^{-1} were significantly higher due to PMA @ 250 ppm as compared to no antitranspirant. However, Kaolin @ 6% was at par with PMA @ 250 ppm.

(Key words: Anti transpirauts, irrigaition, Indian mustard)

INTRODUCTION

In India area under mustard crop is 6.5 million hectares producing about 7.67 million tons of seeds with an average productivity of 1179 kg ha^{-1}. Area under mustard cultivation in Maharashtra was 7700 hectares and production was 3000 tons with the productivity of 383 kg ha^{-1} and in Vidarbha area under this crop was 2200 hectares with the production of 800 tons and productivity of 312 kg ha^{-1} (Anonymous, 2013).

Among the various natural resources, water is the most important resource for exploiting yield potential of selected crop. It is necessary to have proper planning for optimal use of water to maximize production of oilseed crops. This can be achieved by additional development, conservation and efficient management of available water resources. However, information on how many irrigations are required for higher yield is meagre. Spraying of antitranspirants like phenyl mercuric acetate (PMA) and kaolin can go a way in economizing water and making it available to the plant for growth and seed production. The application of antitranspirant PMA and Kaolin alone and in combination through foliar spray resulted in significant increase of all biometric parameters. In a three year study the increase in seed yield of 3.6, 6.93 and 9.4% and stalk yield of 5.67, 10.17 and 15.17% was recorded with PMA + Kaolin combined spray, followed by PMA and Kaolin respectively (Singh and Rana, 2006). Hence, the present study was conducted with the objective to find out the optimum frequency of irrigation required to mustard crop for better growth and yield and to study the effect of antitranspirant .

MATERIALS AND METHODS

A field experiment was conducted during *rabi* season of 2013-14 at college of Agriculture, Nagpur. The soil of the experimental field was clayey in texture, medium in nitrogen content (175.1kg ha^{-1}), medium in phosphorus (24 .2 kg ha^{-1}) and rich in potash (264.3kg ha^{-1}). Organic carbon content was medium (0.58 %), soil reaction was slightly alkaline in nature (pH 7.7). Field capacity was 31.1 %, permanent wilting point was 14.5 % and bulk density was 1.5 g cm^2. The experiment was laid out in split plot design with four treatments of irrigation levels under main plots viz., I_0 - No irrigation, I_1 - One

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irrigation (at pod filling stage i.e. at 55 DAS), I_2 - Two Irrigations (at flowering i.e. at 35 DAS and at pod filling i.e. at 55 DAS), I_3- Three irrigations (at 35, 55 and 75 DAS) and three antitranspirants as sub plot treatments viz., A_0 - Control i.e. No antitranspirant, A_1 - Kaolin @ 6%(two sprays at 35 DAS and at 55 DAS) and A_2 – PMA (Phenyl mercuric acetate) @ 250 ppm (two sprays at 35 DAS and at 55 DAS) forming 12 treatment combinations replicated three times.

The gross plot size was 4.5 m × 4.8 m and net plot size was 3.6 m × 4.2 m. The pusa bold variety of mustard was sown at spacing of 45 cm × 10 cm. The recommended fertilizer dose used was 50:40:00 kg NPK ha^{-1}. The growth observations on height of plant (cm) at harvest, number of branches $plant^{-1}$ at harvest, leaf area $plant^{-1}$ at 80 DAS were recorded on five plants and dry matter at harvest was recorded on two plants. The yield contributing characters viz., number of siliqua $plant^{-1}$, test weight (g), number of seeds $siliqua^{-1}$, seed yield $plant^{-1}$ (g), stover yield $plant^{-1}$ (g) were recorded on five observational plants. The yield ha^{-1} was calculated from the net plot yield.

RESULTS AND DISCUSSION

Growth attributes

Effect of irrigation frequency

Three irrigations recorded maximum and significantly more plant height at harvest, number of branches $plant^{-1}$ at harvest, leaf area $plant^{-1}$ at 80 DAS and dry matter production $plant^{-1}$ at harvest over other irrigation frequencies. These better growth characters due to three irrigations might be due to better availability of soil moisture leading to better utilization of nutrients. These results obtained during the investigation are in close accordance with the finding of Jadhav *et al*. (1995), who also reported more plant height due to three irrigations given at 35, 50 and 75 DAS to mustard crop. Nagdive *et al*. (2007) also reported maximum leaf area $plant^{-1}$ due to three irrigations applied at branching, flowering and siliquae development stages and Kantwa and Meena (2002) also reported more growth characters viz., plant height and dry matter plant $^{-1}$ due to three irrigations.

Effect of antitranspirants

PMA @ 250 ppm recorded maximum and significantly more plant height at harvest , number of branches $plant^{-1}$ at harvest, more leaf area $plant^{-1}$ (dm^2) at 80 DAS and dry matter production $plant^{-1}$ at harvest (12.71g) over the control, but kaolin 6 % recorded at par height with PMA @ 250 ppm. These results are in close accordance with the findings of Singh and Tejsingh (2006), also reported significantly more plant height, leaf area $plant^{-1}$, number of branches $plant^{-1}$ and dry matter production $plant^{-1}$ due to foliar spray of PMA and kaolin alone and in combination. Kantwa and Meena (2002) also reported more number of branches $plant^{-1}$ due to PMA @ 250 ppm. Thakuria *et al.* (2004) reported that kaolin 6% spray resulted in better dry matter production in sunflower which support the present findings.

Interaction effect

The Interaction effect due to irrigation levels and antitranspirant on height of plant and number of branches $plant^{-1}$ was found to be non-significant. The Interaction effect on mean leaf area $plant^{-1}$ at 80 DAS and dry matter $plant^{-1}$ at harvest was found significant. Three irrigations without any spray of antitranspirant (I_3A_0) recorded maximum and significantly more leaf area $plant^{-1}$ at 80 DAS over rest of the interactions except three irrigations with kaolin @ 6% (I_3A_1) and three irrigations with PMA @ 250 ppm (I_3A_2) which were at par. Three irrigations with PMA @ 250 ppm (I_3A_2) recorded highest dry matter $plant^{-1}$ at harvest (17.7 g) but was at par to three irrigations with no antitranspirant (I_3A_0).

Yield attributes

Effect of irrigation frequency

Maximum number of siliqua $plant^{-1}$(231.7), number of seeds $siliquae^{-1}$ (15.03), seed yield $plant^{-1}$ (3.73), stover yield $plant^{-1}$ and test weight (1000 seed) were recorded due to three irrigations which were significantly more over control, one irrigation and two irrigations. However, one irrigation and two irrigations also recorded significantly more values in respect of these parameters over no irrigation. The significant increase in these yield attributes due to increase in irrigation might be due to better plant height, number of branches, more leaf area and more dry matter which again might have due to better soil moisture availability at proper stage. These results are in conformity with the findings of Dudwal *et al.*

(2013), who also reported significant increase in stover yield plant^{-1} due to three irrigations over no irrigation. Nagdive *et al.* (2007) also recorded maximum values of test weight due to three irrigations one each at branching, flowering and siliquae development stages which supports the present findings.

Effect of antitranspirant

The number of siliqua plant^{-1}, number of seed siliquae^{-1}, seed yield plant^{-1}, stover yield (g) plant^{-1} and test weight (1000 seed) were significantly higher due to two sprays of PMA @ 250 ppm as compared to no antitranspirant (control). This might be due to more judicious use of water conserved in plant by controlling the transpiration due to PMA @ 250 ppm. The results obtained during the investigation are in close accordance with the findings of Singh and Rana (2006) who also reported significantly more seed yield plant^{-1} and test weight due to application of PMA antitranspirant.

Interaction effect

Three irrigations with PMA @ 250 ppm (I_3A_2) recorded highest number of siliquae plant^{-1} (247.33) and was significantly superior over all other interactions but three irrigations with kaolin @ 6% (I_3A_1) was found at par with it. The Interaction effect on number of seeds siliquae^{-1} was found non-significant.

The highest seed yield plant^{-1} (3.94 g) was recorded by three irrigations with PMA @ 250 ppm (I_3A_2) and was significantly superior over rest of the combinations but three irrigations with Kaolin @ 6% (I_3A_1) and two irrigations with PMA @ 250 ppm (I_2A_2) were at par with it.

Three irrigations with PMA @ 250 ppm (I_3A_2) recorded maximum and significantly more stover yield plant^{-1} (37 g) over rest of the treatments.

Three irrigations with kaolin @ 6% (I_3A_1) recorded maximum and significantly higher test weight (3.16 g) but found at par with three irrigations without antitranspirant (I_3A_0), three irrigations with PMA @ 250ppm (I_3A_2), two irrigations without antitranspirant (I_2A_0), two irrigations with kaolin @ 6% (I_2A_1) and two irrigations with PMA @ 250 ppm (I_2A_2).

Seed, stover yield (kg) ha^{-1} and harvest index(%)

Effect of irrigation frequency

The three irrigations recorded maximum and significantly higher seed and stover yield than rest of the treatments. The three, two and one irrigation increased 103.7%, 89% and 20% more yield over no irrigation. The significant seed and stover yield ha^{-1} due to three irrigations might be cumulative effect of growth and yield contributing characters. The results obtained in this investigation are in close accordance with the finding of Dudwal *et al.* (2013), who also reported significant increase in seed yield due to three irrigation over one irrigation, Meena *et al.* (2013) and Sharma *et al.* (2013) reported maximum seed and stover yield of mustard crop under three irrigations and significantly improved productivity over one and two irrigations. Two irrigations recorded higher harvest index over one and three irrigations.

Effect of antitranspirant

The mean seed yield (600 kg ha^{-1}) and stover yield ha^{-1} (2216 kg ha^{-1}) was maximum and significantly higher due to PMA @ 250 ppm over control. The kaolin @ 6% also given significantly higher yield over control. This might be due to cumulative effect of yield and growth parameters. These results are in close accordance with the findings of Singh and Rana (2006), who also reported significantly more seed yield due to foliar spray of PMA and kaolin alone and in combination. The harvest index was maximum due to no antitranspirant.

Interaction effect

Three irrigations with two spray of PMA @ 250 ppm (I_3A_2) recorded maximum and significantly higher seed yield (742 kg ha^{-1}) over rest of the treatments except three irrigations with two sprays of Kaolin @ 6% (I_3A_1) and two irrigations with two spray of PMA @ 250 ppm (I_2A_2) which recorded at par yield.

The two irrigations with PMA @ 250 ppm (I_2A_2) recorded maximum stover yield (215.5 kg ha^{-1}) and was significantly superior over rest of the interactions but three irrigations with PMA @ 250 ppm (I_3A_2) and three irrigations with Kaolin 6% (I_3A_1) were at par with it.

Table 1. Growth, yield attributes and yield of mustard as influenced by various treatments and interactions

Treatments	**Growth attributes**				Yield attributes					Yield (kg ha^{-1})		HI
	Plant height at harvest (cm)	**No. of branches $plant^{-1}$ at harvest**	**Leaf area at 80 DAS (dm^2)**	**Dry matter $plant^{-1}$ at harvest (g)**	**No. of siliquae $plant^{-1}$**	**Test Weight (g)**	**No. of seeds siliquae^{-1}**	**Seed yield $plant^{-1}$ (g)**	**Stover yield $plant^{-1}$ (g)**	**Seed**	**Stover**	**(%)**
Main-Irrigation frequencies												
I_0 - No irrigation	97.8	2.79	1.88	8.65	85	1.95	11.07	2.14	13.3	341	794	30.7
I_1 - One irrigation	107.8	3.62	2.15	11.16	122	2.42	12.51	2.52	16.9	427	1254	27.1
I_2 -Two irrigations	115.3	4.09	3.68	12.51	147	3.08	14.63	3.51	25.0	646	1871	33.4
I_3 -Three irrigations	127.3	4.76	5.12	15.56	232	3.09	15.03	3.73	33.3	695	2951	19.8
SE(m) ±	2.6	0.13	0.07	0.46	3.1	0.05	0.40	0.06	0.69	14.0	57	-
CD at 5%	8.9	0.45	0.25	1.58	10.6	0.18	1.37	0.22	2.38	48.4	198	-
Sub-Antitranspirants												
A_0 -Control	101.9	3.58	3.00	11.21	131	2.48	12.65	2.69	21.1	465	1225	31.7
A_1 - Kaolin @ 6%	113.7	3.86	3.20	12.00	144	2.65	13.46	2.93	22.1	517	1712	26.3
A_2 - PMA @ 250 ppm	120.5	4.00	3.42	12.71	166	2.77	13.83	3.30	23.2	600	2216	25.2
SE(m) ±	3.8	0.11	0.11	0.28	4.5	0.05	0.32	0.07	0.54	15.4	64	-
CD at 5%	11.4	0.33	0.32	0.83	13.4	0.16	0.95	0.21	1.61	46.3	193	-
Interactions												
I_0 x A_0	-	-	1.37	7.40	83	2.00	-	2.09	10.9	332	648	-
I_1 x A_0	-	-	1.68	9.70	93	1.70	-	2.06	14.2	324	1059	-
I_2 x A_0	-	-	3.71	11.10	140	3.10	-	3.20	27.1	579	644	-
I_3 x A_0	-	-	5.24	16.50	208	3.13	-	3.40	32.2	623	2551	-
I_0 x A_1	-	-	1.90	9.36	87	1.60	-	2.16	18.2	344	987	-
I_1 x A_1	-	-	1.80	14.80	109	2.74	-	2.31	21.6	382	1092	-
I_2 x A_1	-	-	3.93	11.36	138	3.10	-	3.40	17.9	623	1715	-
I_3 x A_1	-	-	5.16	12.40	240	3.16	-	3.84	30.4	721	3054	-
I_0 x A_2	-	-	2.36	9.18	87	2.25	-	2.16	10.8	348	746	-
I_1 x A_2	-	-	2.97	8.81	164	2.83	-	3.18	14.8	575	1613	-
I_2 x A_2	-	-	3.41	15.07	163	3.03	-	3.91	30.0	735	3254	-
I_3 x A_2	-	-	4.96	17.70	247	2.97	-	3.94	37.0	742	3249	-
SE(m) ±	7.6	0.22	0.22	0.56	8.9	0.10	0.64	0.14	1.07	30.9	128	
CD at 5%	-	-	0.66	1.67	26.7	0.31	-	0.42	3.22	92.5	385	

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EFFECT OF FOLIAR APPLICATION OF GA_3 AND NAA ON GROWTH FLOWERING, YIELD AND QUALITY OF AFRICAN MARIGOLD

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ABSTRACT

A field experiment was conducted at farm of Horticulture Section, College of Agriculture, Nagpur during winter season of 2013-2014 with view to study the effect of different concentrations of GA_3 (100, 200, 300 and 400 ppm) and NAA (50,100, 150 and 200 ppm) on growth, yield and quality in African marigold. The results revealed that, vegetative growth *viz.,* height of plant (43.56 cm), number of branches plant^{-1} (10.83), spread of plant at 50 % flowering stage E-W (24.77) and N-S (24.92) was recorded significantly maximum with the treatment of GA_3 at 400 ppm, whereas, stem diameter (1.27 cm) of plant was found maximum with the treatment NAA 50 ppm. As regards flowering parameters, *viz.,* days for first flower bud initiation (21.41 days), 50 % flowering (35.21 days) and first harvesting of flower (37.33 days) were found minimum in treatment of GA_3 at 400 ppm. Regarding yield contributing parameters, *viz.,* number of flowers plant^{-1}(48.66), flower yield plant^{-1} (254.00 g) and ha^{-1}(187.96 q) were recorded maximum at GA_3 400 ppm. In respect of quality parameters, *viz.,* length of pedicel (7.05 cm), shelf life (4.68 days) were found maximum with the treatment of GA_3 400 ppm whereas, treatment NAA 50 ppm had produced significantly maximum weight of flower (6.10 g) and diameter of fully opened flower (6.51 cm).

(Key words: Marigold, GA_3, NAA, foliar application)

INTRODUCTION

Marigold is one of the commercially exploited flower crops that belong to the family Asteraceae and genus *Tagetes*. Marigold is broadly divided into two groups, *viz*., *Tagetes erecta (*L.) and *Tagetes patula (*L.) which have their origin in Mexico and South Africa, respectively. *Tagetes erecta (*L.) is popularly known as "African marigold" while *Tagetes patula (*L.) as "French Marigold". Marigold, which is also known as "Tagetes" is of Indian origin, although it appears that its natural home is Mexico compared to other flowering annuals. Marigold is easily adaptable to various growing conditions. It is propagated by seeds and growth is well in all types of soil. *Tagetes erecta*, the African marigold is a hardy, about 90 cm tall, erect branched and flowers are generally large in size with bright shades, ranging from yellow to orange and are the best for combination in any flower arrangement.

Marigold is mostly grown for cut flowers as well as loose flowers for making garlands or grown as bedding flowering plant in garden display. The globular shaped flowers with long stalks are used for cut flower purpose.

Now a days the use of growth regulators play an important role by increasing, reducing or modifying the physiological process within plant and which ultimately affect the growth, flowering and yield. Gibberellins and NAA fall in growth promoter group of plant hormones. Gibberellic acid and NAA plays a vital role in improving the vegetative growth characters of the plants as it enhances the elongation and cell division by promoting the DNA synthesis in the cell. It reduced the juvenile phase due to increase in photosynthesis and respiration with enhanced CO_2 fixation in the plant. Gibberellic acid helps to produce the good quality flower and increased flower yield in marigold.

Therefore, present experiment was undertaken in order to study the effect of GA_3, NAA on growth and yield of African marigold.

MATERIALS AND METHODS

A field experiment was carried out at farm of Horticulture Section, College of Agriculture, Nagpur during *rabi* season of the year 2013-2014.The experiment was laid out in a Randomized Block Design with three replications. The experiment comprised with nine treatments *viz.,* T_1 - GA_3 100 ppm, T_2 - GA_3 200 ppm, T_3 - GA_3 300 ppm, T_4 - GA_3 400 ppm, T_5 - NAA 50 ppm, T_6 - NAA 100 ppm, T_7 - NAA 150 ppm and T_8 - NAA 200 ppm and T_9 - Control.

The African marigold variety F_1 hybrid seed was procured from local source. The seeds were sown after filling the mixture of 70% cocopeat, 15% perlite and 15% soil in protray under controled condition. The seed was sown on 27 September 2013. Four week old seedlings were used by transplanting. The

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transplanting was done at a spacing of 45 cm×30 cm distance. A recommended dose of fertilizers *viz*., 100 kg nitrogen, 50 kg phosphorus and 25 kg potassium ha^{-1} were applied through urea, single super phosphate and muriate of potash. Half dose of nitrogen and full dose of phosphorus and potash were applied at the time of transplanting in all treatment plots and the remaining half of nitrogen was applied as top dressing after 30 days of transplanting.

Regarding treatments of GA_3 at 100, 200, 300 and 400 ppm and NAA at 50,100,150,200 ppm were prepared as per treatment concentration with distilled water just before their use. Foliar application of GA_3 and NAA were applied twice at 15 and 30 days after transplanting as per treatment. Spraying was done in the morning hours on both the surface of the leaves and apical meristem. Various observations were recorded on five randomly selected plants in each treatment plot and in each replication on various growth parameters like, height of plant, Stem diameter (cm) and branches $plant^{-1}$ were recorded at 90 days of transplanting, spread of plant was recorded at 50 % flowering stage, flowering parameters like, days to first flower bud initiation, days to 50 % flowering and days to first harvesting were recorded at flowering stage and yield parameters like number of flowers, yield of flowers $plant^{-1}$ and ha^{-1} were recorded at the time of harvesting.

RESULTS AND DISCUSSION

Growth parameters

Data from table 1 revealed that, plant height (43.56 cm) was recorded significantly maximum under the treatment GA_3 400 ppm which was statistically at par with the treatments GA_3 300 ppm. Stem diameter was recorded significantly maximum under the treatment GA_3 400 ppm which was statistically at par with the treatments NAA100 ppm. Branches $plant^{-1}$ (10.83) were recorded significantly maximum under the treatment GA_3 400 ppm which was significantly superior over all the other treatments followed by treatment GA_3 300 ppm and GA_3 200 ppm. Spread of plant at 50 % flowering E-W (24.77 cm) and N-S (24.92 cm) were recorded significantly maximum under the treatment GA_3 400 ppm which was statistically at par with the treatments GA_3 300 ppm and GA_3 200 ppm.

As regards foliar application of NAA, plant height (38.68 cm), was recorded significantly maximum under the treatment NAA 50 ppm which was statistically at par with the treatments NAA 100 ppm. Stem diameter (1.27 cm) was recorded significantly maximum under the treatment NAA 50 ppm which was statistically at par with the treatments NAA 100 ppm. Number of branches $plant^{-1}$ (9.43) was recorded significantly maximum under the treatment NAA 50 ppm which was significantly superior over all other treatments followed by treatments NAA 100 ppm, NAA 150 ppm and NAA 200 ppm. Spread of plant E-W (22.34 cm) and N-S (22.76 cm) were recorded significantly maximum under the treatment NAA 50 ppm which was statistically at par with the treatments NAA 100 ppm, NAA 150 ppm and NAA 200 ppm in E-W and NAA 100 ppm in N-S. However, minimum plant height (31.69 cm), stem diameter (1.13), number of branches $plant^{-1}$ (8.34) and spread of plant E-W (31.69 cm) and N-S (24.68 and 24.71 cm) were recorded in control treatment.

From above results, it is showed that gibberellic acid 400 ppm and NAA 50 ppm had significantly increased vegetative parameters in African marigold *viz*., plant height, stem diameter, number of branches $plant^{-1}$ and spread of plant E-W and N-S. This might be due to the fact that, an application of gibberellic acid at different concentrations the growth of plant increased by increasing internodal length, cell division, cell enlargement and enhancement of apical dominance.

The results are in conformity with the findings of Yadav *et al.* (2013), they found that foliar application of GA_3 300 ppm significantly enhanced plant height and number of branches $plant^{-1}$ in African marigold. Pandey and Chandra (2008) reported that foliar application of GA_3 450 ppm significantly enhanced stem diameter in African marigold. Tyagi and Kumar (2006) reported that foliar application of GA_3 200 ppm significantly enhanced plant spread in African marigold.

Similarly, NAA plays a vital role in improving the vegetative growth characters of the plants might be due to the fact that NAA, being a member of auxin group promotes vegetative growth by active cell division and cell elongation. Kanwar and Khandelwal (2013) reported that foliar application of NAA 200 ppm enhanced plant height and number of branches $plant^{-1}$ significantly in

African marigold. Pandey and Chandra (2008) reported that foliar application of NAA 200 ppm significantly enhanced stem diameter in African marigold. Girisha *et al*. (2012) reported that foliar application of NAA 150 ppm significantly enhanced plant spread in Daisy.

Flowering parameters

Data from table 1 revealed that, minimum days required for first flower bud initiation (21.41 days) under the treatment GA_3 400 ppm which was statistically at par with the treatments GA_3 300 ppm, GA_3 200 ppm, NAA 50 ppm and NAA 100 ppm. Minimum days required for 50 % flowering (35.21 days) under the treatment GA_3 400 ppm which was statistically at par with the treatments GA_3 300 ppm. The treatment GA_3 400 took significantly minimum period for first harvesting (37.33 days) and it was statistically at par with the treatments GA_3 300 ppm and GA_3 200 ppm.

As regards foliar application of Naphthalene acetic acid, NAA 50 ppm took significantly minimum period for days to first flower bud initiation (23.66 days), 50 per cent flowering (44.86 days) and first harvesting (41.46 days) which was significantly superior over all the other treatments followed by treatments NAA100 ppm, NAA150 ppm and NAA 200 ppm. However, maximum days to first flower bud initiation (26.87 days), 50 per cent flowering (47.07 days) and first harvesting (43.68 days) were recorded in control treatment.

From above results, it is showed that gibberellic acid 400 ppm and NAA 50 ppm had significantly increased flowering parameters *viz*., minimum days to first flower bud initiation, 50 per cent flowering and first harvesting in African marigold. This might be due to the fact that, an application of gibberellic acid at different concentrations might have reduced the juvenile phase and the shoot apical meristem converted into the flower primordia instead of producing leaves due to which minimum days required for initiation of first flower bud as well as 50 per cent flowering and early harvesting.

Similarly, NAA plays a vital role in improving the flowering characters of the plants as it enhanced the cell division and rate of respiration, resulting in production of metabolic energy which would have been utilized by plants for cellular expansion and tissue growth resulting in the improvement on all flowering parameters.

The results are in conformity with the findings of Swaroop *et al*. (2007). They reported that foliar application of NAA 300 ppm significantly reduced days to bud initiation in African marigold. Girisha *et al*. (2012) reported that foliar application of NAA 25 ppm significantly reduced days for 50 % flowering. Pandey and Chandra (2008) reported that foliar application of NAA 100 ppm significantly reduced days for first harvesting.

Yield parameters

The data from table 2 revealed that, treatment GA_3 400 ppm recorded maximum number of flowers plant^{-1} (48.66) which was found to be at par with the treatment GA_3 300 ppm. The treatment GA_3 400 ppm recorded maximum yield of flower plant^{-1} (254.00 g) ppm and ha^{-1} (187.96 q) which was found to be at par with NAA 50 ppm. However, significantly minimum number of flowers plant^{-1} (29.33), yield of flower plant^{-1} (110.86 g) and ha^{-1} (82.09 q) were recorded in control treatment.

From above results, it is showed that gibberellic acid 400 ppm and NAA 50 ppm had significantly increased yield parameters in African marigold *viz*., number of flowers plant^{-1}, yield of flowers plant^{-1} and ha^{-1}. This might be due to the fact that, GA_3 spray might have helped to enhance the uptake of nitrogen, phosphorus and potassium by the plant and this better uptake of nutrient might have supported the vegetative growth *viz*., plant height and number of branches and finally might have increased the number of flowers plant^{-1}. Production and accumulation of more photosynthates which would have diverted to the sink resulting into flower yield plant^{-1} and yield of flowers ha^{-1} in African marigold.

The results are in conformity with the findings of Swaroop *et al*. (2007), they reported that foliar application of GA_3 300 ppm significantly enhanced maximum number of flowers plant^{-1} and yield of flowers plant^{-1} in African marigold. Kanwar and Khandelwal (2013) reported that foliar application of GA_3 200 ppm significantly enhanced yield of flowers ha^{-1} in African marigold.

Table 1. Effect of foliar application of GA_3 and NAA on growth and flowering in African marigold

Treatments	Height of plant (cm)	Stem diameter (cm)	Branches plant^{-1}	Spread of plant at 50 % flowering (cm)		Days to first flower bud initiation (days)	Days to 50 % flowering (days)	Days to first harvesting
				E-W	N-S			
T_1 – GA_3 100 ppm	38.73	1.17	9.45	22.68	23.19	24.16	41.55	41.21
T_2 – GA_3 200 ppm	39.10	1.18	9.49	24.19	24.66	23.06	41.38	38.28
T_3 – GA_3 300 ppm	41.85	1.19	9.81	24.68	24.71	22.19	37.47	37.37
T_4 – GA_3 400 ppm	43.56	1.20	10.83	24.77	24.92	21.41	35.21	37.33
T_5 – NAA 50 ppm	38.68	1.27	9.43	22.34	22.76	23.66	44.86	41.46
T_6 – NAA 100 ppm	34.62	1.26	9.41	21.41	22.24	23.92	45.05	42.39
T_7 – NAA 150 ppm	33.56	1.21	9.26	21.22	21.42	24.41	46.35	42.92
T_8 – NAA 200 ppm	32.82	1.21	9.20	20.95	21.20	24.27	46.29	43.24
T_9 – Control (Water spray)	31.69	1.13	8.34	19.32	20.61	26.87	47.07	43.68
SE (m) ±	1.46	0.01	0.27	0.68	0.44	0.86	1.87	1.23
CD at 5%	4.39	0.05	0.82	2.05	1.32	2.58	5.63	3.69

Table 2. Effect of foliar application of GA_3 and NAA on flower yield and quality in African marigold

Treatments	Number of flowers plant^{-1}	Yield of flowers plant^{-1} (g)	Yield of flowers ha^{-1} (q)	Weight of flower (g)	Diameter of fully opened flower (cm)	Length of pedicel (cm)	Shelf life (days)
T_1 – GA_3 100 ppm	42.33	180.45	133.64	4.23	5.36	6.16	2.08
T_2 – GA_3 200 ppm	43.00	180.34	133.33	4.38	5.53	6.30	2.13
T_3 – GA_3 300 ppm	46.66	214.63	158.95	4.60	5.56	6.84	3.26
T_4 – GA_3 400 ppm	48.66	254.00	187.96	5.22	5.64	7.05	4.68
T_5 – NAA 50 ppm	41.33	252.11	186.72	6.10	6.51	6.19	3.25
T_6 – NAA 100 ppm	39.33	210.80	155.86	5.36	6.31	6.17	2.12
T_7 – NAA 150 ppm	37.33	195.60	144.75	5.24	6.20	5.84	2.06
T_8 – NAA 200 ppm	35.33	157.57	116.66	4.46	5.63	5.72	2.03
T_9 – Control (Water spray)	29.33	110.86	82.09	3.78	4.58	4.52	2.02
SE (m) ±	1.58	11.38	6.86	0.28	0.28	0.25	0.14
CD at 5%	4.76	34.13	20.57	0.84	0.85	0.75	0.42

Similarly, NAA plays a vital role in improving the yield parameters of the plants as it enhanced the cell division and rate of respiration, resulting in production of metabolic energy which would have been utilized by plants for cellular expansion and tissue growth resulting in the improvement on all flowering parameters *viz*., number of flowers plant^{-1}, yield of flowers plant^{-1} and yield of flowers ha^{-1}. Pandey and Chandra (2008) reported that foliar application of NAA 450 ppm significantly enhanced maximum number of flowers plant^{-1} and yield of flowers plant^{-1} in French marigold. Kanwar and Khandelwal (2013) reported that foliar application of NAA 200 ppm significantly enhanced maximum yield of flowers ha^{-1} in African marigold.

Quality parameters

Data from table 2 revealed that, weight of flower (6.10 g) was recorded significantly maximum under the treatment NAA 50 ppm which was statistically at par with the treatment NAA 100 ppm. Diameter of fully opened flower (6.51 cm) was recorded significantly maximum under the treatment NAA 50 ppm which was statistically at par with the treatments NAA 100 ppm and NAA 150 ppm. Lengths of pedicel (7.05 cm) was recorded significantly maximum under the GA_3 400 ppm treatment which was statistically at par with the treatments GA_3 300 ppm and GA_3 200 ppm. Shelf life (4.68 days) was recorded significantly maximum under the treatment GA_3 400 ppm and it was significantly superior over all other treatments followed by GA_3 300 ppm and NAA 50 ppm. However, minimum weight of flower (3.78 g), diameter of fully opened flower (4.58 cm), Lengths of pedicel (4.52 cm) and Shelf life (2.02 days) were recorded in control treatment.

From above results, it is showed that gibberellic acid 400 ppm and NAA 50 ppm had significantly increased quality parameters in African marigold *viz*., weight of flower, diameter of fully opened flower, length of pedicel and shelf life. This might be due to the fact that, an application of naphthalene acetic acid noted maximum weight of flower in African marigold. The increase in these floral and yield characters might be due to the fact that NAA enhanced rate of respiration resulting in production of metabolic energy which would have been utilized by plants for cellular expansion and tissue growth resulting in the improvement in weight of flowers and diameter of fully opened flower. An application of gibberellic acid noted maximum length of pedicel due to the cell elongation and rapid cell stimulation. Foliar application of gibberellic acid recorded maximum shelf life of flower. This might be due to more vegetative growth, early initiation of flowering, increased pedicel length and more diameter of flower which might have helped the flower to last longer in ambient temperature.

The results are in conformity with the findings of Yadav *et al*. (2013). They reported maximum weight of flower and length of pedicel in African marigold by the application of GA_3 300 ppm. Pandey and Chandra (2008) reported that GA_3 300 ppm recorded maximum diameter of fully opened flower in French marigold. Tyagi and Kumar (2006) reported that GA_3 200 ppm recorded maximum length of pedicel in African marigold. Kumar *et al*. (2010) reported that GA_3 200 ppm recorded maximum shelf life of flower in African marigold.

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EFFECT OF LAND CONFIGURATION AND FERTILIZER MANAGEMENT IN *KHARIF* MAIZE (*Zea mays* L.)

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ABSTRACT

The experiment was carried out during the *kharif* 2012-13 at Agriculture College Farm, Nagpur. The experiment was laid out in split plot design replicated thrice with three land configuration treatments as main factor viz., L_1 -Broad bed method (The broad bed furrow prepared at sowing with distance of 120 cm with two rows of maize) , L_2 -Ridges and furrow (Ridges and furrow opened at the time of sowing with dibbling of seeds on ridge) and L_3-Flat bed and four nutrient management treatments as sub factor viz., F_1 -100% RDF (120:60:30 kg NPK ha^{-1}), F_2 -125% RDF (150:75:37.5 kg NPK ha^{-1}), F_3 -75% RDF (90:45:22.5 kg NPK ha^{-1})+25 % N through vermi-compost, F_4 - 75% RDF (90:45:22.5 kg NPK ha^{-1})+25 % N through FYM.

The ridges and furrow showed maximum and significantly higher plant height(201.9 cm), number of functional leaves(12.78), leaf area(105.13 dm^2), mean dry matter $plant^{-1}$(140.6 g $plant^{-1}$) , number of cobs $plant^{-1}$(1.51), number of grains cob^{-1}(399), grain weight cob^{-1}(85.35 g), test weight(21.76), grain yield $plant^{-1}$ (128.6) and grain yield ha^{-1}(56.69 q), straw yield $plant^{-1}$ (175.76 g) and straw yield ha^{-1} (70.56 q), gross monetary returns (Rs 71561), net monetary returns (Rs 44981) and benefit: cost ratio(2.76)over flat bed, followed by broad bed furrow method which also recorded significantly more over flat bed for above parameters.

The nutrient management practices 125% RDF (150:75:37.5 kg NPK ha^{-1}) recorded significantly higher plant height(201.8 cm), number of functional leaves(12.24), leaf area(106.38 dm^2), mean dry matter $plant^{-1}$ (139.1 g) number of cobs $plant^{-1}$(1.41), number of grains cob^{-1}(400), grain weight cob^{-1} (89.77), test weight(22.76), grain yield $plant^{-1}$ (127.76 g) and grain yield ha^{-1}(56.88 q), straw yield $plant^{-1}$(70.11 g) and straw yield ha^{-1}(70.11 q) over 100% RDF. The 75% RDF (90:45:22.5 kg NPK ha^{-1}) + 25% N through vermi-compost recorded at par values with 100% RDF but 75% RDF (90:45:22.5 kg NPK ha^{-1}) + 25% N through FYM recorded significant reduction over 100% RDF in respect of above parameters. Gross monetary returns (GMR) and net monetary returns (NMR) were highest (Rs 71761 and 48461 respectively) in treatment 125% RDF (150:75:37.5 kg NPK ha^{-1}) over 100% RDF. While 75% RDF + 25% N through vermi-compost and 75% RDF + 25% N through FYM recorded significantly lower GMR. Nutrient management treatment of 100% RDF registered higher B:C ratio over all other treatments. Interaction results were non significant.

((Key words : Maize, land configuration, fertilizer, growth, yield, economics)

INTRODUCTION

Maize crop can tolerate different environments and can be grown on variety of soils. It responds to various agronomic practices. Various factors of production deciding the maize productivity under rainfed condition are stress, plant density, fertilizer use and land configuration. Out of these factors, land configuration and fertilizer use have significance in stepping up the yield of maize during the *kharif* season or under irrigated condition.

The fertilizer management is of paramount importance in crop cultivation. Any variety of the crop for its high potential will require a optimum dose of nutrients. Plant nutrients are lost from the soil in different ways. Large quantities are removed from the soil through harvest of crop. Due to very expensive fertilizers, it is necessary to minimize the expenses on fertilizer and at the same time we can sustain the crop productivity by supplying organics manures. Arulkumar *et al.* (2005) with ridges and furrows recorded significantly maximum grain yield of maize over other practices and recorded increase in yield over normal sowing**.** Asghar *et al*. (2010) studied that too low or high NPK levels reduced the yield and yield parameters of maize crop. Treatment of 175:80:60 kg NPK ha^{-1} seems to be the most appropriate level to obtained maximum grain yield under the prevailing conditions. Application of NPK beyond treatment of 175:85:60 kg NPK ha^{-1} proved un-economical**.**

The land configuration not only improves soil drainage but also leads to efficient use of limited water for profitable crop production. For uniform distribution of irrigation water as well as rain water, broad bed furrow, ridges and furrow and flat-bed in standing crop may be required. With proper land layout or configuration, the fertilizer use and nutrient use efficiency might be enhanced.

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Among several factors responsible for crop production land configuration and nutrient management play an important role. The present investigation therefore was undertaken to study the response of maize to various land configuration and nutrient management treatment through different sources as well as their interaction under rainfed condition with the objective to study the effect of land configuration and fertilizer management on growth, yield and economics of *kharif* maize.

MATERIALS AND METHODS

The experiment was carried out during the *kharif* 2012-13 at Agriculture College Farm, Nagpur. The experiment was laid out in split plot design replicated thrice with three land configuration treatments as main factor viz., L_1 -Broad bed method (The broad bed furrow prepared at sowing with distance of 120 cm for two rows of maize), L_2 - Ridges and furrow (Ridges and furrow opened at the time of sowing with dibbling of seeds on ridge at 60 cm spacing) and L_3 -Flat bed and four nutrient management treatments as sub factor viz., viz., F_1 - 100% RDF (120:60:30 kg NPK ha^{-1}), F_2 -125% RDF (150:75:37.5 kg NPK ha^{-1}), F_3 -75% RDF (90:45:22.5 kg NPK ha^{-1})+25 % N through vermi-compost, F_4 - 75% RDF (90:45:22.5 kg NPK ha^{-1})+25 % N through FYM. The soil of experimental plot was clayey in texture, low in available nitrogen (263.60 kg ha^{-1}), medium in available phosphorus (20.32 kg ha^{-1}) and organic carbon (0.52 %), very high in available potassium (414.42 kg ha^{-1}) and slightly alkaline in reaction (pH 7.76). The permanent wilting point was 14.22 % and field capacity was 32.66 %.

The average annual precipitation is about 1022.4 mm. The total rainfall during growth period was 756.1 mm distributed in 49 rainy days. The gross and net plot sizes were 3.6 m × 3.6 m and 3.0 m × 3.0 m respectively with variety PKV-M Shatak sown on spacing of 60 cm × 20 cm. The sowing was done on 20.7.2012 and harvesting was done on 30.10.2012. The observations were recorded on various aspects of growth such as number of functional leaves at 90 DAS, leaf area at 90 DAS and leaf area index at 90 DAS, plant height, dry matter accumulation, number of cobs $plant^{-1}$, number of grain cob^{-1}, grain weight cob^{-1}, test weight, grain and straw yield $plant^{-1}$ and ha^{-1} at harvest. The yield ha^{-1} was recorded on net plot area while the growth and yield contributing characters were recorded on five observational plant from the net plot area as per the standard procedure.

RESULTS AND DISCUSSION

Growth attributes

Data regarding plant height (cm), number of functional leaves plant $^{-1}$, leaf area plant $^{-1}$, leaf area index and dry matter accumulation $plant^{-1}$ are presented in table 1.

Effect of land configuration methods

It is observed from the data that ridges and furrow method recorded maximum and significantly more plant height at harvest(201.9 cm), number of functional leaves $plant^{-1}$(12.78), leaf area $plant^{-1}$ (105.13 dm^2), leaf area index at 90 DAS(8.76) and dry matter accumulation $plant^{-1}$(140.6 g $plant^{-1}$) at harvest over flat-bed method. Broad bed furrow method also recorded significantly more in respect of above growth parameters over flat-bed method. Flat-bed recorded least values of growth parameters. This might be due to more favorable soil environment in ridges and furrow method followed by broad bed furrow method compared to flat-bed during *kharif* season. Ramakichenin *et al.* (2002) also reported significant increase in height, number of functional leaves $plant^{-1}$, leaf area $plant^{-1}$ and leaf area index due to ridges and furrow method. These result support the present findings.

Effect of nutrient management

Application of 125% RDF was found significantly superior over 100 % RDF in respect of plant height at harvest (201.8 cm), number of functional leaves $plant^{-1}$(12.24), leaf area $plant^{-1}$ at 90 DAS (106.38 dm^2), leaf area index at 90 DAS(8.86) and dry matter accumulation $plant^{-1}$ (139.1 g) at harvest. Other treatments 75 % RDF + 25 % N through vermi-compost was at par and 75 % RDF + 25 % N through FYM recorded significantly less plant height than 100% RDF at all the growth stages. This might be due to availability of nutrients, particularly nitrogen through 125% RDF as this crop require more nutrients. The full N might not be available for crop immediately when applied through FYM compare to vermi-compost and fertilizers therefore 75 % RDF + 25 % N through vermi-compost (F_3) might be at par and 75 % RDF + 25 % N through FYM might have recorded less height. The plant growth characters like plant height and number of leaves was fully reflected in the total dry matter accumulation plant^{-1}. Increased dry matter accumulation might be due to the adequate availability of nutrients and better growth with the application of 125% RDF. The results obtained during the investigation are in close accordance with the finding of Jayaprakash *et al*. (2004) in respect of dry matter accumulation who also reported higher dry matter accumulation plant^{-1} due to 125 % RDF.

Interaction effects

Interaction effects were found to be non-significant in respect of all the growth parameters studied.

Yield attributes

The data regarding number of cobs plant^{-1}, number of grains cob^{-1}, grain weight (g) cob^{-1}, test weight, grain yield plant^{-1} and straw yield plant^{-1} are presented in table 2.

Effect of land configuration methods

Maximum number of cobs plant^{-1}(1.51), number of grains cob^{-1}(399), grain weight (85.35 g) cob^{-1}, test weight(21.76 g), grain yield plant^{-1} (128.60 g) and straw yield plant^{-1} (175.75 g) were recorded in treatment ridges and furrow which was significantly more over flat-bed method. The broad bed furrow method also recorded significantly more in respect of these yield contributing characters over flat bed.

The higher number of grains cob^{-1} might be due to larger size cobs which again might be due to better growth condition provided by the ridges and furrow and broad bed furrow method. Gaur (2002) and Sakthivel *et al.* (2003) also found the higher number of grains cob^{-1} due to ridges and furrow and broad bed furrow method. These results are in close accordance with the present findings. The more grain weight cob^{-1} might be due to more number of grains cob^{-1}. Ramakichenin *et al.* (2002) also found maximum test weight with ridges and furrows method which resembles the present findings.

The data revealed that, ridges and furrow and broad bed furrow method recorded significantly higher grain yield plant^{-1}(128.6 and 111.1 g respectively) over flat-bed method (97.35 g). Gaur (2002) stated that ridging increased mean yield of maize grain yield over flat sowing. While Ramakichenin *et al.* (2002) reported that among the management practices, farming ridges and furrows resulted superiority in yield components. These results are in close accordance with the present findings.

The increase in straw yield might be due to more growth attributes in the treatments, like plant height, dry matter and number of leaves. The results obtained during the investigation are in close accordance with the finding of Gaur (2002) who also reported that the mean straw yield increased by ridging over the flat bed.

Effect of nutrient management

Application of 125% RDF recorded significantly higher number of cobs plant^{-1} (1.41), number of grains cob^{-1}(400), grain weight (g) cob^{-1} (89.77), test weight (22.76 g) grain yield plant^{-1} (127.26 g) and straw yield plant^{-1} (173.85 g) as compared to 100% RDF. However, 75% RDF + 25% N through vermi-compost was at par in respect of the above parameters, but 75% RDF + 25% N through FYM recorded significantly less than 100% RDF.

This might be due to comparatively higher availability of nutrient through 125% RDF and more or less similar availability of nutrient through 75% RDF + 25% N through vermi-compost treatment. Mithun and Mondal (2006) also reported more test weight with increasing RDF. These findings supports the present increase in test weight with more RDF(125%).

Interaction effects

Interaction effect of land configuration methods and fertilizer management was found non-significant in respect of various yield and yield contributing characters.

Yield study (qha^{-1})

The data regarding, seed yield (qha^{-1}), straw yield (qha^{-1}) and harvest index are presented in table 2.

Effect of land configuration methods

Treatment ridges and furrow recorded maximum seed yield (56.69 q ha^{-1}) followed by broad bed furrow (55.29 q ha^{-1}) and the two methods yielded significantly more over flat-bed method (52.60 q ha^{-1}). Thus, there was 7.66% and 5.11% increase in yield respectively over flat-bed method. The similar trend was also observed in case of straw yield where in treatment ridges and furrow recorded maximum straw yield (70.56 q ha^{-1}) followed by broad bed furrow (68.58 q ha^{-1}) and the two methods yielded significantly more over flat-bed method (67.44 qha^{-1}). The significant seed yield increase due to ridges and furrow method (7.66%) followed by BBF (5.11%) might be due to better drainage condition leading to ideal soil-air-moisture relationship of bed which subsequently reflected in increase in various yield attributes like number of cobs $plant^{-1}$, number of grain cob^{-1}, test weight, grain weight cob^{-1} and grain yield $plant^{-1}$. Gaur (2002) stated that ridging increased mean yield of maize grain over flat sowing. Ramakichenin *et al.* (2002) with farming ridges and furrows resulted superiority in yield components and grain yield of maize over other treatments. Sakthivel *et al.* (2003) with tied ridges recorded highest grain yield followed by ridges and furrow over flat beds in maize crop. Arulkumar *et al.* (2005) with ridges and furrows recorded significantly maximum grain yield of maize over other practices and recorded increase in yield over normal sowing. These results are also in line with the present findings.

The harvest index did not show more variation, though the broad bed method recorded higher harvest index (44.5) followed by ridges and furrow method(44.5).

Effect of nutrient management

Response of maize crop in respect of grain and straw yield (q ha^{-1}) to the different nutrient management treatments was significant. Application of 125% RDF to maize produced significantly higher grain and straw yield (56.88 and 70.11 q ha^{-1}) over 100% RDF (54.39 and 68.86 q ha^{-1}), 75% RDF + 25% N through vermi-compost (54.30 and 68.80 qha^{-1}) and 75% RDF + 25% N through FYM (53.87 and 67.67 q ha^{-1}). Jadhav *et al.* (2012) also found higher maize grain yield (51.46 q ha^{-1}) with higher fertilizer dose compared lower nutritional dose in the form of 75 percent RDN through chemical fertilizer + 25 per cent RDN through FYM (35.17 q ha^{-1}).These results support the present findings.

The harvest index of maize differed slightly with various nutrient levels to maize. Application of 125% RDF to maize recorded higher harvest index of (44.8%) followed by 75% RDF + 25% N through FYM (44.4%) and 75% RDF + 25% N through vermi-compost (44.1%).

Interaction effects

Interaction effects of land configuration methods and fertilizer management were non-significant.

Economic study of crop

The data in respect of gross monetary return (GMR), net monetary return (NMR) and benefit : cost ratio (B:C ratio) are presented in table 1.

Effect of land configuration methods

The data revealed that gross monetary returns was maximum and significantly higher in treatment ridges and furrow (Rs 71561 ha^{-1}) followed by treatment broad bed furrow (Rs 69773) which also recorded significantly higher over flat-bed (Rs 66492 ha^{-1}).

The data revealed that net monetary returns was maximum and significantly superior in ridges and furrow (Rs 44981 ha^{-1}) over flat bed (Rs 40652 ha^{-1}). However, land configuration with broad bed furrow recorded at par NMR with treatment ridges and furrow (Rs 43563 ha^{-1}) and both these were significantly superior over flat bed. This might be due to higher grain and straw yield.

Maximum benefit : cost ratio was recorded by broad bed furrow (2.76) followed by ridges and furrow (2.73). Flat-bed recorded the lowest B: C ratio (2.64).

Effect of fertilizer management

Data revealed that, gross monetary return was significantly influenced due to various fertilizer management levels. Treatment 125% RDF recorded significantly more gross monetary returns

Table 1. Mean growth and yield contributing characters, yield and economics as influenced by various treatments

Treatments	Mean growth contributing characters					Mean yield contributing characters						Yield study			Economics			
	Height (cm) at harvest	Number of leaves at 90 DAS	Leaf area (dm^2) at 90DAS	LAI at 90 DAS	DM $plant^{-1}$ at harvest (g)	No. of Cobs $plant^{-1}$	No. of grains Cob^{-1}	Grain wt. Cob^{-1} (g)	Test wt. (100 Seed) (g)	Grain Yield $plant^{-1}$ (g)	Straw Yield $plant^{-1}$ (g)	Grain Yield (q ha^{-1})	Straw Yield (q ha^{-1})	HI (%)	COC (Rs ha^{-1})	GMR (Rs ha^{-1})	NMR (Rs ha^{-1})	B : C ratio
Land Configuration																		
L_1 – Broad bed furrow	198.2	12.17	103.16	8.59	125.6	1.35	391	82.66	21.29	111.1	157.04	55.29	68.58	44.6	26210	69773	43563	2.73
L_2 – Ridges and furrow	201.9	12.78	105.13	8.76	140.6	1.51	399	85.35	21.76	128.6	175.75	56.69	70.56	44.5	26580	71561	44981	2.76
L_3 – Flat bed	196.8	11.50	101.11	8.42	112.9	1.26	382	77.32	20.43	97.35	141.16	52.60	67.44	43.8	26840	66492	40652	2.64
SE (m) ±	0.47	0.13	0.25	0.02	1.24	0.02	1.00	0.50	0.10	1.50	1.55	0.28	0.17	-	-	393	393	-
CD at 5%	1.86	0.50	0.98	0.08	4.86	0.06	3.94	1.94	0.39	5.89	6.08	1.11	0.65	-	-	1544	1544	-
Nutrient management																		
F_1 – 100 % RDF	198.5	12.34	103.47	8.62	124.4	1.37	390	79.94	20.83	109.73	155.45	54.39	68.86	44.1	22028	68705	46677	3.12
F_2 – 125 % RDF	201.8	12.76	106.38	8.86	139.1	1.41	400	89.77	22.76	127.26	173.85	56.88	70.11	44.8	23300	71761	48461	3.08
F_3 – 75 % RDF + 25 % N through vermi-compost	198.3	12.00	101.39	8.45	123.5	1.37	388	79.36	20.70	108.71	154.31	54.30	68.80	44.1	26756	68601	41845	2.56
F_4 – 75 % RDF + 25 % N through FYM	197.2	11.50	101.29	8.44	118.7	1.33	385	78.03	20.34	103.71	148.32	53.87	67.67	44.4	32756	68032	35276	2.08
SE (m) ±	0.23	0.07	0.22	0.02	0.68	0.01	0.77	0.41	0.06	0.81	0.85	0.08	0.11	0.49	-	120	120	-
CD at 5%	0.69	0.21	0.66	0.06	2.02	0.02	2.28	1.20	0.18	2.41	2.53	0.24	0.32	1.46	-	357	357	-
Interactions																		
SE (m) ±	0.40	0.12	0.39	0.03	1.18	0.01	1.33	0.70	0.11	1.40	1.47	0.14	0.19	0.85	-	208	1208	-
CD at 5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

DM: Dry matter, LAI : leaf area index , HI: harvest index, COC: Cost of cultivation, GMR: gross moneatary return, NMR: Net monetary return, Market rate Seed :Rs1200 q^{-1} straw Rs 50 q^{-1}

(Rs 71761 ha^{-1}) over 100% RDF (Rs 68705 ha^{-1}). However, 75% RDF + 25% N through vermi-compost (Rs 68601 ha^{-1}) and 75% RDF + 25% N through FYM (Rs 68032 ha^{-1}) showed lower gross monetary return as compared to 100% RDF. This might be due to higher yield in 125% RDF and less yield in other treatment.

Data revealed that, net monetary return was significantly influenced due to various fertilizer management levels. Treatment of 125% RDF recorded significantly more net monetary returns (Rs 48461 ha^{-1}) over treatment of 100% RDF (Rs 46777 ha^{-1}). However, 75% RDF + 25% N through vermi-compost (Rs 41845 ha^{-1}) and 75% RDF + 25% N through FYM (Rs 35276 ha^{-1}) showed lower net monetary return as compared to other treatment. This might be due to more GMR in 125% RDF and higher cost of vermi-compost and FYM application. Pawar *et al*. (2005) found significantly higher monetary returns with application of 125% RDF than the lower fertilizer doses. These results are in line with the present findings.

Treatment 100% RDF registered highest benefit: cost ratio (3.12) followed by treatment 125% RDF (3.08). The lowest benefit : cost ratio was recorded in 75% RDF + 25% N through FYM (2.08). This might be due to more cost of vermi-compost and FYM in comparison to 25% reduced RDF.

Interaction effects

Interaction effects of land configuration methods and fertilizer management was found to be non-significant in respect of gross monetary returns.

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STUDIES ON FEEDING PRACTICES OF BUFFALOES IN WARORA TAHSIL OF CHANDRAPUR DISTRICT

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ABSTRACT

The present investigation was carried out in Warora tahsil of Chandrapur district during the year 2013-2014, to know the feeding practices adopted by buffalo owners. Four villages from Warora tahsil were selected with 6 farmers each from small, medium and large category of farmers based on land holding. Thus, in all there were 72 respondent buffalo owners considered for the study through pre tested questionnaire. The information on feeding management was collected by personally contacting with each of the buffalo owner. Amongst the 72 respondents, 36.11, 23.61 and 20.83 per cent buffalo owners belonged to the age group of 41-50, 31-40 and 51-60 respectively. Thus, 80.55 buffalo owners belonged to the age group of 31 to 60. Only 15.27 and 4.17 belonged the old age (60 to70) and young age (21 to 30) respectively. It was observed that 58.13 and 41.86 per cent of small, 46.00 and 54.00 per cent of medium and 45.90 and 54.10 per cent of large category of buffalo owners had body weight 400 to 450 and 451 to 500. It was observed that 49.35 per cent buffaloes had the body weight in the range of 400-450 kg, while 50.68 per cent buffaloes had a body weight in the range of 451-500 kg with an average weight of 424.95 kg. The overall gap of feeding management practices in buffaloes was worked out to 12.30 and 63.30 per cent for green fodder and concentrates respectively. The dry fodder was fed in excess to the extent of 49.83 per cent in buffaloes over the recommended feeding practices. There was a small feeding gap in respect of green fodder and concentrates in buffalo farmers and the rearing of buffaloes was found profitable.

(Key words: Warora tahsil, buffaloes, feeding practices)

INTRODUCTION

The role of dairy farming in the Indian rural economy is very outstanding. The significance is heightened by it's massive contribution of livelihood of India's rural population. Over 73 per cent of India's households have their own livestock. Grazing, feeding and milking cows and buffaloes is one of the largest source of productive employment in rural India (Ahirwar, 2010).

Buffaloes are the backbone of rural developing economy in many developing countries of the Asian region including India. Buffaloes occupy a prominent place in the social, economic and cultural life of Indian rural communities and are useful as a triple purpose animal for milk, meat and draft power (Kishore, 2013).

Buffalo is the main dairy animal of India, which provides economic stability to farmers through sale of milk and sale of animal due to uncertainties associated with crop farming in dryland/rainfed area, which is 70 per cent of arable land of India. Buffalo population of nearly 94 millons contributes about 56 per cent of total milk production as compared to that of nearly 218 million cattle population of the country (Sastry, 2003).

India ranks first in milk production in the world. It is estimated that milk production in India was around 127.9 metric tons during the year 2011-2012 (Anonymous, 2012).

The low productivity of milk in buffalo is mainly due to lack of proper knowledge for balanced feeding. Farmers from rural area feed their buffaloes with roughages and concentrates but, they do not have knowledge about quality and quantity of feed and also do not follow proper management practices which lead to dairy business uneconomical (Shitole, *et at.,* 2009).

Keeping these in mind, an attempt was made to study the feeding and management practices of buffaloes in Warora tahsil of Chandrapur district.

MATERIALS AND METHODS

This study was conducted in Warora tahsil of Chandrapur district during the year 2013-2014. Four villages viz., Wanoja, Chinora, Majara and Kondala were randomly selected. The list of buffalo owners was prepared for each village with the help of Gramsevak and Livestock Development Officers of Warora Panchayat Samiti. From each of the four villages, total buffalo owners based on land holding in the catagory of small (upto 2.00 ha), medium (upto 2 to 8.00 ha) and large (above 8 ha) were identified and

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then from each category 6 buffalo owners were selected. Thus, for all four villages 72 buffalo were considered for the study from 3 categories of buffalo owners. In the present study, general information viz., age, occupation and education, and following information were obtained from these selected buffalo owners through pre-tested questionnaire.

Information on feeding management practices information was obtained on the following aspects: 1. Feeding management viz., feeding of green fodder, dry fodder, concentrates and feed intake of buffaloes, body weight of buffalo and overall gap of feeding management practices over recommended practices in each category of farmers.

Plan of work

Following formula suggested by Prasad (1997) was used to determine the body weight of buffaloes owned by the selected farmers.

$$\text{Estimated live weight (kg)} = \frac{G^2 \times L \times 0.003}{2.2}$$

Where,

G = Girth of animal in inches
L = Length of animal in inches

Based on the body weight of individual buffaloes, recommended food intake was estimated and this recommended food intake was considered for finding the gap in feeding practices.

RESULTS AND DISCUSSION

General observations

Age

It was seen from table 1 that out of the 72 respondents, 36.11, 23.61 and 20.83 per cent buffalo owners belonged to the age group of 41-50, 31-40 and 51-60 respectively. Thus, 80.55 buffalo owners belonged to the age group of 31 to 60. Only 15.27 and 4.17 belonged the old age (60 to70) and young age (21 to 30) respectively. Bhatt (2006) observed that majority of the dairy farmers belonged to middle age group (52 per cent) followed by old age group (30 per cent) and the younger generation is less interested in taking up dairy farming as its occupation.

Occupation

Majority of the buffalo owners (76.39 per cent) were involved in farming occupation followed by business oriented buffalo owners (19.44 per cent). Only 4.17 per cent buffalo owners were found in the category of farmers whose family member is in service. Ravat and Chandavat (2011) reported that the majority of dairy farmers in Matur taluka of Kheda district were engaged in agriculture.

Education

It was seen from table 1 that 62.49 per cent buffalo owners had obtained seondary education whereas 20 per cent of them had primary education. Only 4.17 per cent buffalo owners possessed higher secondary education and 12.50 per cent buffalo owners were illiterate. Gour (2002) noticed that, 62 per cent of the dairy farmers had obtained secondary education, whereas 16 per cent of them had primary education. Only 4 per cent people had higher secondary education and 6 per cent of respondents were illiterate.

Land holding

Land holding is an important factor that determines the economic factor and potentially of dairy farmers for adoption of new practices in dairy farming. The average size of land holding in small, medium and large size group was 1.26, 4.02 and 10.35 ha respectively. The overall average size land holding was estimated to 5.21 ha. Durgga (2009) observed that, small dairy farmers were having 1 to 2 ha of land holdings.

Number of buffaloes owned by the different category of farmers

It was observed that, the small farmers had 43 buffaloes, medium category of farmers had 50 buffaloes and large category of farmers had 61 buffaloes. Thus, in all 154 buffaloes were considered for study.

Feeding practices

The data obtained on this respect are presented in table 2 and described as under.

Feed intake of buffaloes

It was revealed from table 2 that, farmers of large category fed 9.20 kg dry fodder day^{-1} buffalo^{-1} followed by medium (9.22 kg) and small (8.50 kg) categories of buffalo owners. It is also observed that, medium category of farmers fed more quantities of green fodder (9.22 kg) day^{-1} buffalo^{-1} followed by large (8.70 kg) and small (8.40 kg) categories of farmers. Similarly, the medium category of farmers fed more quantity of concentrate (1.95 kg) day^{-1} buffalo^{-1} followed by large (1.60 kg) and small (1.15 kg) categories of farmers. On an overall level, farmers fed 8.99 kg dry fodder, 8.77 kg green fodder and 1.56 kg concentrate with the total of 19.32 kg feed day^{-1} buffalo^{-1}. The medium category of farmers offered more feed (20.46 kg) than large (19.50 kg) and small (18.05 kg) categories of farmers day^{-1} buffalo^{-1}. Patil and Kamble (2002) suggested feed requirement for buffaloes as 6 to 7 kg dry fodder, 10 to 15 kg green fodder and 1 kg concentrates day^{-1} buffalo^{-1}.

Body weight of buffalo

It was observed from table 3 that, 58.13 and 41.86 per cent of small, 46.00 and 54.00 per cent of medium and 45.90 and 54.10 per cent of large category of buffalo owners had body weight 400 to 450 and 451 to 500 respectively. The average body weight of buffao in small, medium and large category of farmers were 421.64, 425.42, 427.79. It was observed that 49.35 per cent buffaloes had the body weight in the range of 400-450 kg while, 50.68 per cent buffaloes had a body weight in the range of 451-500 kg with an average weight of 424.95 kg.

Gap of feeding management practices over recommended practices in small category of buffalo owners

After going through the existing practices followed at dairy farmers level in case of small farmers, it is observed from table 4 that, small farmers fed dry fodder to the extent of 8.50 kg day^{-1} as against 6.00 kg day^{-1} recommended feed indicating 41.66 per cent more over recommended practices. Whereas, green fodder and concentrates were fed 8.40 and 1.15 kg day^{-1} as against 10.00 and 4.25 kg day^{-1} recommended feeds, respectively. Thus, a wide gap of 16.00 and 72.95 per cent in case of green fodder and concentrates respectively was observed at the small farmers level in case of feeding buffaloes. Patange *et al*. (2002) observed the nutrient availability of milch Marathawadi buffaloes reared by different categories of farmers in the Marathwada region of Maharashtra state. Overall ration of milch buffalo consisted of 6.60, 6.00 and 2.16 kg day^{-1} of green fodder, dry fodder and concentrate respectively.

Gap of feeding management practices over recommended practices in medium category of buffalo owners

It was observed from table 5 that, the existing feeding practices followed at the dairy farmers level in case of medium farmers worked out to 9.29, 9.22 and 1.95 kg day^{-1} animal^{-1} of dry fodder, green fodder and concentrates, respectively in case of buffaloes. While, the recommended quantities of feed were 6.00, 10.00 and 4.25 kg dry fodder, green fodder and concentrate day^{-1} respectively. The dry fodder was fed more to the extent of 54.83 per cent over recommendations. However, there was a wide gap in feeding of green fodder (7.80 per cent) and concentrates (54.12 per cent) in case of feeding buffaloes by medium category buffalo owners.

Gap of feeding management practices over recommended practices in large category of buffalo owners

It was observed from table 6 that, the existing feeding practices followed at the dairy farmers level in case of large farmers worked out to 9.20, 8.70 and 1.60 kg day^{-1} animal^{-1} of dry fodder, green fodder and concentrate, respectively. While in case of large farmer category indicating 53.33 per cent excess feeding of dry fodder over recommended practices in case of buffaloes. However, there was wide gap in feeding of green fodder 13.00 per cent and concentrates 62.36 per cent in case of feeding buffalo. Bainwad *et al.* (2007) from studies in Parbhani district of Marathwada region reported that the maximum green (8.69 kg), dry fodder (9.25 kg) and concentrates (1.25 kg) available to milch buffaloes was found in large farmers.

Overall gap of feeding management practices recommended practices in buffalo owners

The overall gap of feeding practices of three

Table 1. General information about the selected farmers

Sr. No.	Character	Group Distribution	Number of farmers	Percentage of farmers
		21-30	03	04.17
		31-40	17	23.61
		41-50	26	36.11
1	Age	51-60	15	20.83
		61-70	11	15.27
	Total		72	100.00
		Farming	55	76.39
2	Occupation	Farming + business	14	19.44
		Farming + Service	03	04.17
	Total		72	100.00
		Illiterate	09	12.50
		Primary school	15	20.84
		Middle school	22	30.55
3	Education	High school	23	31.94
		College	03	04.17
	Total		72	100.00

Table 2. Feed intake of buffaloes (kg day^{-1})

(On an average body weight of 425 kg)

Sr. No.	Category	Categories of farmers			Overall
		Small	medium	Large	
	Feed				
1	Dry fodder	8.50	9.29	9.20	8.99
2	Green fodder	8.40	9.22	8.70	8.77
3	Concentrates	1.15	1.95	1.60	1.56
	Total	18.05	20.46	19.50	19.32

Table 3. Distribution of frequency of body weight of buffalo (kg) with average body weight in different category of farmers

Sr. No.	Particular	Frequency	Category of farmers			Total
			Small	Medium	Large	
1	Buffalo	400-450	25 (58.13)	23 (46.00)	28 (45.90)	76 (49.35)
		451-500	18 (41.86)	27 (54.00)	33 (54.10)	78 (50.65)
	Total		43 (100.00)	50 (100.00)	61 (100.00)	154 (100.00)
	Average body weight		421.64	425.42	427.79	424.95

Table 4. Gap of feeding management practices over recommended practices in small category of buffalo owners

(On an average body weight of 425 kg)

Sr. No.	Feed items	Recommended Practices		Existing practices at dairy farmers level		Feed management gap	
		Quantity animal^{-1} day^{-1} (kg)	Value (Rs.)	Quantity animal^{-1} day^{-1} (kg)	Value (Rs.)	Quantity animal^{-1} day^{-1} (kg)	Value (Rs.)
1	Dry fodder	6.00 (100.00)	18.00 @ Rs. 3/kg	8.50 (141.66)	25.50	2.5 (41.66)	+7.5
2	Green fodder	10.00 (100.00)	35.00 @ Rs. 3.5/kg	8.40 (84.00)	29.40	1.6 (16.00)	-5.6
3	Concentrates	4.25 (100.00)	59.50 @ Rs. 14/kg	1.15 (27.05)	16.10	3.1 (72.95)	-43.40

Table 5. Gap of feeding management practices over recommended practices in medium category of buffalo owners

(On an average body weight of 425 kg)

Sr. No.	Feed items	Recommended Practices		Existing practices at dairy farmers level		Feed management gap	
		Quantity animal^{-1}day^{-1} (kg)	Value (Rs.)	Quantity animal^{-1} day^{-1} (kg)	Value (Rs.)	Quantity animal^{-1} day^{-1} (kg)	Value (Rs.)
1	Dry fodder	6.00 (100.00)	18.00 @ Rs. 3/kg	9.29 (154.83)	27.87	3.29 (54.83)	+9.87
2	Green fodder	10.00 (100.00)	35.00 @ Rs. 3.5/kg	9.22 (92.20)	32.27	0.78 (07.80)	-2.73
3	concentrates	4.25 (100.00)	59.50 @ Rs.14/kg	1.95 (45.88)	27.30	2.3 (54.12)	-32.2

Table 6. Gap of feeding management practices over recommended practices in large category of buffalo owners

(On an average body weight of 425 kg)

Sr. No.	Feed items	Recommended practices		Existing practices at dairy farmers level		Feed management gap	
		Quantity animal^{-1} day^{-1} (kg)	Value (Rs.)	Quantity animal^{-1} day^{-1} (kg)	Value (Rs.)	Quantity animal^{-1} day^{-1} (kg)	Value (Rs.)
1	Dry fodder	6.00 (100.00)	18.00 @ Rs. 3/kg	9.20 (153.33)	27.60	3.2 (53.33)	+ 9.6
2	Green fodder	10.00 (100.00)	35.00 @ Rs. 3.5/kg	8.70 (87.00)	30.45	1.3 (13.00)	-4.55
3	concentrates	4.25 (100.00)	59.50 @ Rs.14/kg	1.60 (37.64)	22.40	2.65 (62.36)	-37.10

Table 7. Overall gap of feeding management practices recommended practices in buffalo owners

(On an average body weight of 425 kg)

Sr. No.	Feed items	Recommended practices		Existing practices at dairy farmers level		Feed management gap	
		Quantity animal^{-1} day^{-1} (kg)	Value (Rs.)	Quantity animal^{-1} day^{-1} (kg)	Value (Rs.)	Quantity animal^{-1} day-1 (kg)	Value (Rs.)
1	Dry fodder	6.00 (100.00)	18.00 @ Rs. 3/kg	8.99 (149.83)	26.97	2.48 (49.83)	+8.97
2	Green fodder	10.00 (100.00)	35.00 @ Rs. 3.5/kg	8.77 (87.7)	30.69	1.23 (12.30)	-4.31
3	Concentrates	4.25 (100.00)	59.50 @ Rs.14/kg	1.56 (36.70)	21.84	2.69 (69.30)	-37.66

categories over recommended practices has been worked out and data are presented in table 7. The overall dry fodder, green fodder and concentrates were fed to the extent of 8.99, 8.77 and 1.56 kg day^{-1} buffalo^{-1} respectively. The dry fodder was fed more to the extent of 49.83 per cent over recommended practices. A wide gap was also noticed in feeding of green fodder to the extent of 12.30 per cent and in feeding concentrates to the extent of 69.30 per cent at the farmers level. Waykar *et al.* (2012) reported the small feeding gap in respect of green fodder and concentrates in buffalo farmers and the rearing of buffaloes was found profitable. Gujar *et al.* (2004) observed that there was large gap between existing and recommended feeding practices.

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ROLE OF FOLIAR SPRAYS OF ETHREL ON GROWTH AND YIELD OF SOYBEAN

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ABSTRACT

The present study examined the effectiveness of foliar sprays of ethrel on growth and yield of soybean (*Glycine max*). A field experiment was conducted at an experimental farm of Botany section, College of Agriculture, Nagpur by growing soybean during the *kharif* season in the crop area spanning from July 2013 – November 2013, using randomized block design. The effectiveness of foliar sprays of ethrel was studied as control (water spray) and with 5 different levels of ethrel (100, 150, 200, 250 and 300 ppm). Soybean plants were sprayed two times at 15 day intervals at 30 and 45 DAS with different concentrations of ethrel. Recorded data showed that all morpho-physiological parameters including plant height, number of branches, leaf area, dry matter production, RGR and NAR as well as yield ha^{-1} of soybean plants showed positive and significant responses with the foliar application of 150 ppm ethrel followed by 100 ppm ethrel when compared with control.

(Key words: Soybean, ethrel, growth and yield)

INTRODUCTION

Soybean (*Glycine max* L.) is one of the important oilseed as well as leguminous crop. Soybean is a diploid species having chromosome number 2n=40.It belongs to family "Leguminoseae" and subfamily "Papilionoidae". It is annual leguminous herbaceous plant.

Among, oilseeds soybean ranks fifth in the world. The important soybean growing countries in world are America, Brazil, Argentina, China and India. The largest soybean producing states in India are Madhya Pradesh, Maharashtra and Rajasthan. In India Maharashtra having Second rank in production.

Soybean is also known as "Gold of Soil" due to its various qualities such as ease in cultivation, less requirement of fertilizers and labour resulting in high cost : benefit ratio. Soybean being a legume crop is gifted naturally to fix atmospheric nitrogen in the root nodules with the help of *Rhizobium*. It fixes 69 to 168 kg of nitrogen ha^{-1} which helps in maintaining soil fertility.

Ethylene (ethrel) is a plant growth regulator involved in various aspects of growth and photosynthesis of plants at both whole plant and cellular levels (Abeles *et al.,* 1992; Fiorani *et al.,* 2002; Pierik *et al.,* 2006).

Ethylene released from ethrel (2-chloroethylphosphonic acid) could possibly be utilized for promoting pod growth as Abbas (1991) had shown that early pod development is related to higher ethylene levels, thus decreasing flower and pod shedding and thereby reducing abscission and improving better pod set.

Hence, an attempt has been made in the present investigation to asses the influence of foliar sprays of ethrel on morpho-physiological parameters and yield of soybean.

MATERIALS AND METHODS

A field experiment on soybean was conducted at an experimental farm of Botany section, College of Agriculture, Nagpur. The present investigation was undertaken during the *kharif* season of 2013-2014. The field experiment was laid out in Randomized block Design (RBD) with four replications consisting of six treatments with different concentrations of ethrel (100, 150, 200, 250 and 300 ppm). Spraying of ethrel was done two times at 30 and 45 DAS with hand sprayer. Observations on plant height, number of branches, leaf area and dry matter were recorded at different stages i.e. at 45, 60 and 75 DAS. RGR and NAR were recorded and calculated at 45-60 and 60-75 DAS. Seed yield ha^{-1} was also noted. The crop was kept free from disease and pest during the growth period. Harvesting was under taken after the crop attained maturity. Data was analysed by statistical method suggested by Panse and Sukhatme (1954).

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RESULTS AND DISCUSSION

Morpho-physiological observations

Observations on plant height plant^{-1}, number of branches plant^{-1}, leaf area plant^{-1}, and dry matter production plant^{-1} were recorded at 45, 60 and 75 DAS.

Plant height

Data regarding plant height were recorded at 45, 60, and 75 DAS. Significant variation was noticed at every stage of observation by the foliar sprays of ethrel. At 45 significantly maximum plant height was recorded in treatment T_4 (200 ppm ethrel) followed by the treatment T_3 (150 ppm ethrel) when compared with treatment T_1 (control) and remaining treatments under study. While, treatments T_6 (300 ppm ethrel) and T_2 (100 ppm ethrel) were found at par with treatment T_1 (control).

At 60 and 75 DAS significantly maximum plant height was recorded in treatment T_4 (200 ppm ethrel) followed by the treatments T_3 (150 ppm ethrel) and T_5 (250 ppm ethrel) when compared with treatment T_1 (control) and remaining treatments under study. While, treatments T_6 (300 ppm ethrel) and T_2 (100 ppm ethrel) were found at par with treatment T_1 (control).

Hamed (2003) carried out a field experiment to study the foliar spray of ethrel at different concentrations (250, 500 and 750 ppm) on maize hybrids S.C 10 and D.C. Taba at an interval of 15, 20 and 25 DAS. Foliar spray of ethrel at 250 ppm gave highest plant height.

Devi *et al.* (2011) conducted a field experiment in *kharif* season to study the response of soybean variety JS 335 to salicyclic acid (50 ppm), ethrel (200 ppm) and cycocel (500 ppm) applied as foliar spray at different stages. The study revealed that application of ethrel at 200 ppm gave highest plant height over control.

Number of branches plant^{-1}

Data regarding number of branches plant^{-1} were recorded at 45, 60 and 75 DAS and found statistically significant.

At 45 DAS significantly maximum number of branches were recorded in treatment T_4 (200 ppm ethrel) followed by T_3 (150 ppm ethrel) in a descending manner when compared with treatment T_1 (control) and remaining treatments under study. While, treatment T_6 (300 ppm ethrel) and T_2 (100 ppm ethrel) were found at par with treatment T_1 (control) in respect of number of branches plant^{-1}.

At 60 and 75 DAS significantly maximum number of branches were noticed in treatment T_4 (200 ppm ethrel) followed by the treatment T_3 (150 ppm ethrel) when compared with treatment T_1 (control) and remaining treatments under study. While, treatments T_5 (250 ppm ethrel), T_6 (300 ppm ethrel) and T_2 (100 ppm ethrel) were found at par with treatment T_1 (control).

Devi *et al.* (2011) conducted a field experiment in *kharif* season to study the response of soybean variety JS 335 to salicyclic acid (50 ppm), ethrel (200 ppm), cycocel (500 ppm) and control (water spray) applied as foliar spray at different stages i.e. flower-initiation (40 DAS), pod-initiation (60 DAS) and flower-initiation + pod-initiation stage. The study revealed that application of ethrel at 200 ppm gave the highest number of branches plant^{-1} in soybean.

Pahwa (2013) studied the effect of plant growth regulators on pigeonpea and found that 200 μg ml^{-1} ethrel increased the number of branches plant^{-1}.

Leaf area of plant

Data on leaf area plant^{-1} were recorded at three stages viz., 45, 60 and 75 DAS. Leaf area recorded at these stages gave significant results.

At 45 DAS significantly maximum leaf area was noticed in treatment T_4 (200 ppm ethrel) followed by treatments T_3 (150 ppm ethrel) T_5 (250 ppm ethrel) and T_6 (300 ppm ethrel) in a descending manner when compared with treatment T_1 (control) and remaining treatments under study. Treatment T_2 (100 ppm ethrel) was found at par with treatment T_1 (control).

At 60 DAS significantly maximum leaf area was noticed in treatment T_4 (200 ppm ethrel) followed by treatments T_3 (150 ppm ethrel) and T_5 (250 ppm ethrel) in a descending manner when compared with treatment T_1 (control) and remaining treatments under study. While, Treatment T_2 (100 ppm ethrel) was found at par with treatment T_1 (control).

At 75 DAS significantly maximum leaf area was noticed in treatment T_4 (200 ppm ethrel) followed by treatment T_3 (150 ppm ethrel) when compared with treatment T_1 (control) and remaining treatments under study. While, Treatment T_2 (100 ppm ethrel) was found at par with treatment T_1 (control).

Hence, it can be stated that the higher leaf area might be due to ethrel enhanced ethylene biosynthesis. The higher ethylene evolution led to higher leaf area and thus greater light interception and photosynthesis (Mir *et al.*, 2010).

Lone *et al.* (2010) studied the effect of ethrel (200 μ l l^{-1}) and nitrogen (0, 40, 80 and 120 kg N $ha.^{-1}$) on mustard. Ethrel treated with 200 $\mu l\ l^{-1}$ at flowering stage along with basal application of nitrogen at 80 kg ha^{-1} were recorded the highest leaf area.

Singh *et al.* (2011) reported that foliar application of ethrel at 200 ppm significantly increased leaf area in soybean.

Dry matter production

Data on dry matter production were recorded at the three growth stages i.e. 45, 60 and 75 DAS gave significant variation.

At 45 DAS significantly maximum dry matter was noticed in treatment T_4 (200 ppm ethrel) when compared with treatment T_1 (control) and remaining treatments under study. Also, treatments T_3 (150 ppm ethrel) T_5 (250 ppm ethrel), T_6 (300 ppm ethrel) and T_2 (100 ppm ethrel) were found significantly superior over treatment T_1 (control).

At 60 DAS significantly maximum dry matter was noticed in treatment T_4 (200 ppm ethrel) when compared with treatment T_1 (control) and remaining treatments under study. Also, treatments T_3 (150 ppm ethrel) and T_5 (250 ppm ethrel) found significantly superior over treatment T_1 (control). Treatments T_6 (300 ppm ethrel) and T_2 (100 ppm ethrel) were found at par with treatment T_1 (control).

At 75 DAS significantly maximum dry matter was noticed in treatment T_4 (200 ppm ethrel) followed by treatment T_3 (150 ppm ethrel) when compared with treatment T_1 (control) and remaining treatments under study. Also, treatments T_5 (250 ppm ethrel) and T_6 (300 ppm ethrel) were found significantly superior over treatment T_1 (control). Treatment T_2 (100 ppm ethrel) was found at par with treatment T_1 (control).

Significant increase in dry matter from 45-75 DAS might be due to increase in the leaf area and photosynthetic capacity.

Aurcharmal *et al.* (2008) reported that foliar spray of ethrel at 50 ppm significantly increased dry weight of a plant in urdbean.

Devi *et al.* (2011) observed that application of ethrel at 200 ppm increased dry weight of plant significantly in soybean.

Growth analysis

Growth analysis is one of the measure of assessing the yield of plant. The physiological basis of yield difference can be measured through an evolution of difference in growth parameters and their impact on yield. The productivity of crop may be related with parameters such as relative growth rate (RGR) and net assimilation rate (NAR).

Relative growth rate

Relative growth rate (RGR) represents total dry weight gained over existing dry weight in unit time. This was originally termed an "efficiency index" because it expresses growth in terms of a rate of increase in size per unit of size. As such, it permits more equitable comparisons between organisms than does absolute growth rate. Normally, relative growth rate deals with total dry weight $plant^{-1}$, though other measures of size have also been used. Data regarding RGR are given in table 2.

At 45-60 DAS significantly maximum RGR was observed in treatment T_4 (200 ppm ethrel) over treatment T_1 (control) and remaining treatments under study. While, treatments T_3 (150 ppm ethrel), T_5 (250 ppm ethrel), and T_6 (300 ppm ethrel) were found significantly superior over treatment T_1 (control). Treatment T_2 (100 ppm ethrel) was found at par with treatment T_1 (control).

At 60-75 significantly highest RGR was observed in treatment T_4 (200 ppm ethrel) followed by treatments T_3 (150 ppm ethrel) and T_5 (250 ppm ethrel) over treatment T_1 (control) and remaining treatments under study. Treatment T_6 (300 ppm ethrel) was found significantly superior over treatment T_1 (control). While, treatment T_2 (100 ppm ethrel) was found at par with treatment T_1 (control).

Aucharmal *et al.* (2008) carried out a field experiment to study the influence of different growth regulators on urdbean. They found that application of planofix at 40 ppm and ethrel at 50 ppm significantly increased RGR.

Pahwa (2013) carried out a field experiment to study the effect of plant growth regulators on pigeonpea and observed that application of ethrel at 100 µ ml^{-1} enhanced RGR.

Net assimilation rate

NAR is the rate of increasing the dry weight of a plant $unit^{-1}$ of active growing material. NAR is any attribute of the plant which is primarily concerned in carbon assimilation and thus has some claims to be taken as a measure of the internal factor for growth. NAR is closely associated with photosynthesis efficiency of leaves, but it is not a pure measure of photosynthesis. NAR depends upon the excess dry matter gained, over the loss in respiration. It is increase in plants dry weight $unit^{-1}$ area of assimilation tissues $unit^{-1}$ time.

At 45-60 DAS maximum NAR was observed in treatment T_4 (200 ppm ethrel) over treatment T_1 (control) and remaining treatments under study. While, treatments T_6 (300 ppm ethrel) and T_2 (100 ppm ethrel) were found at par with treatment T_1 (control).

At 60-75 DAS maximum NAR was observed in treatment T_4 (200 ppm ethrel) followed by the treatment T_3 (150 ppm ethrel) over treatment T_1 (control) and remaining treatments under study. While, treatment T_2 (100 ppm ethrel) was found at par with treatment T_1 (control).

Aucharmal *et al.* (2008) carried out a field experiment to study the influence of different growth regulators on urdbean and observed that application of planofix at 40 ppm and ethrel at 50 ppm significantly increased NAR.

Seed yield ha^{-1}(q)

Significantly maximum seed yield ha^{-1} was recorded in treatment T_4 (200 ppm ethrel) followed by treatments T_3 (150 ppm ethrel) and T_5 (250 ppm ethrel) when compared with control and remaining treatments under study. While, treatments T_6 (300 ppm ethrel) and T_2 (100 ppm ethrel) were found at par with treatment T_1 (control).

The use of plant hormone may prove its potential as it has been found to enhance growth and productivity of the crop plants. It also improve the crop manipulating source-sink relationship at pod development stage, several naturally occurring phytohormones ethylene influences about all aspects of plant growth and development as well as the induction of some plant defense responses. Ethrel involved in diverse array of cellular, developmental and stress released processes in plants. It reduces the problem of pod shattering by restricting the flower and pod abortions, Mir *et al.* (2010).

Devi *et al.* (2011) conducted experiment to study the effect of salicylic acid, ethrel and cycocel (50, 200 and 500 ppm) on soybean and observed that ethrel at 200 ppm gave highest number of pods $plant^{-1}$, 100 seed weight and seed yield ha^{-1}.

Sharma and Sardana (2012) tried ethrel and mepiquat chloride as foliar spray on groundnut and observed that IAA at 7.5 ppm + ethrel 25 ppm increased pod yield.

Table 1. Role of foliar sprays of ethrel on morpho-physiological parameters of soybean

Treatments	Plant height (cm)			Number of branches			Leaf area plant^{-1} (dm^2)			Total dry matter plant^{-1} (g)		
	45 DAS	**60 DAS**	**75 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**45 DAS**	**60 DAS**	**75 DAS**
T_1 (Control)	29.33	37.77	39.92	2.61	3.40	3.43	6.24	10.54	10.25	4.56	8.83	12.80
T_2 (25 ppm ethrel)	29.96	39.61	43.32	2.92	3.46	3.49	6.89	11.01	10.88	5.55	10.92	16.16
T_3 (50 ppm ethrel)	34.23	43.13	47.30	3.94	4.36	4.38	7.42	12.46	12.17	10.27	18.13	29.16
T_4 (75 ppm ethrel)	34.47	45.75	49.06	4.02	4.42	4.45	7.71	12.71	12.34	11.27	22.06	30.30
T_5 (100 ppm ethrel)	30.97	42.75	47.19	3.36	3.68	3.65	7.27	11.97	11.51	8.48	16.29	26.20
T_6 (125 ppm ethrel)	30.65	39.73	44.22	3.22	3.62	3.70	7.07	11.67	11.39	6.58	11.19	19.15
SE(m) ±	1.261	1.666	1.655	0.273	0.239	0.228	0.227	0.450	0.458	0.330	0.992	1.166
CD at 5%	3.623	4.786	4.754	0.784	0.669	0.656	0.651	1.293	1.315	0.947	2.850	3.350

Table 2. Role of foliar sprays of ethrel on RGR, NAR and yield of soybean

Treatments	RGR ($g\ g^{-1}\ day^{-1}$)		NAR ($g\ dm^{-1}\ day^{-1}$)		Seed yield $hectare^{-1}$ (q)
	45-60 DAS	60-75 DAS	45-60 DAS	60-75 DAS	
T_1 (Control)	0.0417	0.0250	0.0334	0.0288	17.34
T_2 (25 ppm ethrel)	0.0442	0.0258	0.0395	0.0316	19.49
T_3 (50 ppm ethrel)	0.0488	0.0328	0.0807	0.0599	21.19
T_4 (75 ppm ethrel)	0.0518	0.0338	0.1002	0.0639	22.02
T_5 (100 ppm ethrel)	0.0465	0.0321	0.0530	0.0520	20.81
T_6 (125 ppm ethrel)	0.0450	0.0310	0.0405	0.0398	19.79
SE(m) ±	0.00087	0.0052	0.0189	0.0087	0.764
CD at 5%	0.0026	0.0015	0.0537	0.00251	2.195

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EFFECT OF NIROGEN LEVELS AND CHLORMEQUAT ON GROWTH AND YIELD OF WHEAT

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ABSTRACT

A field experiment was conducted during *rabi* season of 2013-2014 at Agronomy Section, college of Agriculture, Nagpur. The experiment was laid out in split plot design with three treatments of nitrogen levels under main plot viz., N_1 - 100 kg N ha^{-1}, N_2 - 125 kg N ha^{-1}, N_3 - 150 kg N ha^{-1} and four chlormequat levels as sub plot treatments viz., C_0 – Control i.e. (no inoculation, no foliar application), C_1 - Seed inoculation of chlormequat @ 1000 ppm, C_2 - Foliar application of chlormequat @ 1000 ppm at maximum tillering stage and C_3 - Seed inoculation of chlormequat @ 1000 ppm + foliar application of chlormequat @1000 ppm at maximum tillering stage, forming 12 treatment combinations replicated three times. Growth contributing characters viz., mean plant height, mean number of leaves plant^{-1}, mean leaf area plant^{-1}, mean number of tillers plant^{-1}, mean dry matter accumulation plant^{-1} and yield contributing characters viz., length of spike, number of grains spike^{-1}, grain weight spike^{-1}, test weight, grain yield and straw yield (q ha^{-1}) were significantly more due to 150 kg N^{-1} ha as compared to 100 kg and 125 kg N ha^{-1}. Seed inoculation of chlormequat @ 1000 ppm + foliar application of chlormequat @1000 ppm at maximum tillering stage recorded significantly more values of growth contributing characters viz., mean number of leaves plant^{-1}, mean leaf area plant^{-1}, mean number of tillers plant^{-1}, mean dry matter accumulation plant^{-1} and found lowest value of plant height. Yield contributing characters viz., length of spike, number of grains spike^{-1}, grain weight spike^{-1}, grain yield and straw yield (q ha^{-1}) were significantly higher due to seed inoculation of chlormequat @ 1000 ppm + foliar application of chlormequat @1000 ppm at maximum tillering stage as compared to control and seed inoculation of chlormequat @ 1000 ppm but was at par with foliar application of chlormequat @1000 ppm at maximum tillering stage. Test weight found to be non significant with the application of chlormequat.

(Key words*:* Wheat, nitrogen, chlormequat, growth, yield)

INTRODUCTION

Wheat is one of the most important staple food crops of India grown in diverse agroclimatic conditions from 11°N- 35°N latitude and 72°E- 92°E longitudes. It is most widely cultivated as stable food crop of the world.

Indian soils are deficient in nitrogen. Deficiency of this major element is a limiting factor in crop production in this country. It is, therefore, required to be added in appropriate quantity to the soil at a time when it could be best utilized by the crop plant for their optimum responses for increasing yield of wheat.

Application of chlormequat before or during tillering may improve tiller production (Green, 1986). Meera and Poonam (2010) reported that application of cycocel @ 1000 and 2000 ppm significantly increased yield attributing characters in comparison to the untreated control in wheat crop. The highest yield was obtained when wheat was treated with 1000 ppm cycocel.

The outcome of present study will be useful for optimising the use of nitrogen with more productivity. Similarly the profitable use of any growth retardant will also be helpful for reducing the plant height, preventing lodging and reducing transpiration from plant.

MATERIALS AND METHODS

The field experiment was conducted in field No.15 at Agronomy farm, college of Agriculture, Nagpur during *rabi* season of 2013-2014. The topography of experimental site was fairly uniform and leveled. The soil analyzed in experimental site have loamy clayey in texture, medium in nitrogen content (206.98 kg ha^{-1}), low in phosphorus (16.15 kg ha^{-1}) and rich in potash (350.00 kg ha^{-1}) and soil reaction was slightly alkaline (pH 7.7) in nature.

The experiment was replicated thrice in split plot design with 3 levels of nitrogen, i.e. 100, 125 and 150 kg ha^{-1} and four levels of chlormequat, i.e. Control (no inoculation, no foliar application)(C_0), Seed inoculation of chlormequat @ 1000 ppm (C_1), Foliar application of chlormequat @ 1000 ppm at maximum (C_2) tillering stage and seed inoculation of chlormequat @ 1000 ppm + foliar application of chlormequat @1000 ppm at maximum tillering stage

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(C_3). After seed bed preparation, sowing was done by drilling.

The gross plot size was 4.5 m x 4.8 m and net plot size was 3.6 m x 4.2 m. The growth observations on plant height (cm) at harvest, number of tillers pant^{-1} at harvest, number of leaves and leaf area plant^{-1} at 90 DAS were recorded on five plants and dry matter at harvest was recorded on two plants. The yield contributing characters viz., spike length, number of grains spike^{-1}, grain weight spike^{-1}, test weight (g) were recorded on five plants. The yield ha^{-1} was calculated from the net plot yield.

RESULTS AND DISCUSSION

Growth attributes
Effect of nitrogen levels

Application of 150 kg N ha^{-1} recorded maximum and significantly more plant height at harvest, number of tillers plant^{-1} at harvest, number of leaves plant^{-1}, leaf area plant^{-1} at 90 DAS and dry matter production plant^{-1} at harvest over other nitrogen levels. These better growth characters due to 150 kg N ha might due to be vigorous vegetative growth of wheat plant, as proper nitrogen levels encourages plant growth and helps a plant to thrive well. Similar results were reported by Kumar and Sharma (2000), who reported more dry matter plant^{-1} and tillers plant^{-1} with the increasing nitrogen levels to wheat crop. Kumar *et al.* (2007) also reported maximum plant height plant^{-1}, leaves plant^{-1} and leaf area plant^{-1} due to increasing nitrogen levels in wheat crop.

Effect of chlormequat levels

Seed inoculation of chlormequat @ 1000 ppm + foliar application of chlormequat @1000 ppm at maximum tillering stage recorded maximum and significantly more number of leaves plant^{-1}, leaf area plant^{-1} at 90 DAS, number of tillers plant^{-1} at harvest, dry matter production plant^{-1} and lowest height at harvest over other treatments but was at par with foliar application of chlormequat @1000 ppm at maximum tillering stage. These results are in close accordance with the finding of Meera and Poonam (2010). They reported that foliar spray of cycocel 1000 and 2000 ppm on wheat significantly increased leaf area plant^{-1}, number of tillers plant^{-1} and dry matter plant^{-1} in wheat crop. Dastan *et al.* (2011) reported that the CCC application decreased plant height and stem length, but increased ear length and total tillers plant^{-1} as compared control in barley crop.

This might to be the source-sink relationship by way of pertaining of dry matter accumulation at later stage of growth instead at early phase of growth of wheat crop.

Interaction effect

The interaction effect due to nitrogen levels and chlormequat on plant height, number of leaves and leaf area plant^{-1} was found to be non significant. .The interaction effect on number of tillers plant^{-1} and dry matter plant^{-1} at harvest was found significant. Application of 150 kg N ha $^{-1}$ along with seed inoculation of chlormequat @ 1000 ppm + foliar application of chlormequat @1000 ppm at maximum tillering stage (N_3 x C_3) recorded higher number of tillers plant^{-1} (37.20) which was significantly superior over all the other treatment combinations. Application of 150 kg N ha $^{-1}$ along with seed inoculation of chlormequat @ 1000 ppm + foliar application of chlormequat @1000 ppm at maximum tillering stage (N_3 x C_3) recorded highest dry matter accumulation plant^{-1} (32.96 g) which was significantly superior over all other treatment combinations. However, it was at par with the application of 150 kg N ha^{-1} along with seed inoculation of chlormequat @ 1000 ppm + foliar application of chlormequat @1000 ppm at maximum tillering stage (N_3 x C_2) and application of 125 kg N ha^{-1} along with seed inoculation of chlormequat @ 1000 ppm + foliar application of chlormequat @1000 ppm at maximum tillering stage (N_2 XC_2).

Yield attributes
Effect of nitrogen levels

Maximum length of spike (6.58 cm), number of grains spike^{-1} (36.72), grain weight spike^{-1} (5.94), test weight (1000 seed) (38.50 g), grain yield q ha^{-1} (30.05) and straw yield q ha^{-1} (39.94) were recorded due to application of 150 kg N ha^{-1} which were significantly more over 100 kg N ha^{-1} and 125 kg N ha^{-1}. The significant increase in these yield attributes due to increase in nitrogen level might be due to better

Table1. Growth, yield attributes and yield influenced by various levels of nitrogen and chlormequat

Treatments	Growth characters					Yield characters					
	Plant height (cm)	No. of leaves $plant^{-1}$	Leaf area $plant^{-1}$	No. of tillers $plant^{-1}$	Dry matter $plant^{-1}$ (g)	Spike length(cm)	No. of grains $spike^{-1}$	Grain weight $spike^{-1}$ (g)	Test weight (g)	Grain yield q ha^{-1}	Straw yield q ha^{-1}
A) Nitrogen levels											
N_1 - 100 kg N ha^{-1}	69.86	8.99	1.46	8.95	8.45	5.28	29.81	1.72	37.27	25.49	34.59
N_2 - 125 kg N ha^{-1}	74.02	9.50	1.62	9.78	9.36	5.71	32.66	1.96	37.93	27.67	36.93
N_3 - 150 kg N ha^{-1}	79.88	11.41	1.82	10.84	10.62	6.58	36.72	2.23	38.50	30.05	39.94
SE(m)	0.99	0.17	0.06	0.15	0.41	0.07	0.88	0.08	0.23	0.73	0.93
CD at 5%	2.94	0.51	0.18	0.43	1.21	0.22	2.63	0.25	0.68	2.17	2.76
B) Chlormequat levels											
C_0 Control	79.80	8.82	1.50	8.93	8.47	5.13	29.09	1.63	37.13	25.43	34.94
C_1 Seed inoculation of chlormequat @ 1000 ppm	77.04	10.00	1.56	9.16	8.89	5.66	30.96	1.87	37.42	26.50	35.65
C_2 Foliar application of chlormequat @ 1000 ppm at maximum tillering stage	72.59	10.22	1.70	10.37	10.06	6.09	35.16	2.08	38.15	29.01	38.76
C_3 Seed inoculation of chlormequat @ 1000 ppm + foliar application of chlormequat @1000 ppm at maximum tillering stage	68.92	10.81	1.77	10.96	10.49	6.54	37.04	2.31	38.89	30.02	39.00
SE (m)	1.06	0.23	0.07	0.14	0.23	0.08	0.98	0.10	0.60	0.77	1.09
CD at 5%	3.16	0.68	0.20	0.43	0.69	0.23	2.90	0.29	-	2.29	3.25
C) Interaction											
SE(m)	1.84	0.39	0.12	0.25	0.40	0.13	1.69	0.17	1.04	1.33	1.89
CD at 5%	-	-	-	0.75	1.19	-	-	-	-	-	-

Table 2. Effect of interaction between nitrogen and chlormequat levels on number of tillers plant^{-1}

N x C	C_0	C_1	C_2	C_3
N_1	25.30	25.99	27.75	28.44
N_2	26.44	27.05	30.85	32.97
N_3	28.78	29.43	34.70	37.20
S E (m) ±			0.25	
C D at 5%			0.74	

Table 3. Effect of interaction between nitrogen and chlormequat levels on dry matter (g) plant^{-1}

N x C	C_0	C_1	C_2	C_3
N_1	22.00	22.55	26.30	30.60
N_2	23.80	25.80	31.85	30.84
N_3	30.45	31.69	32.35	32.96
S E (m) ±			0.40	
C D at 5%			1.19	

plant height, number of tillers, number of leaves and more dry matter which again might have due to more nitrogen availability at proper stage. These results are in conformity with the findings of Pol *et al.* (1989), they reported significant increase in length of spike, number of grains spike^{-1} and test weight due to increase in nitrogen levels. Deshmukh *et al.* (2007) also reported grain and straw yield (q ha^{-1}) significantly higher due to application of 150 kg N ha^{-1} over 0, 90 and 120 kg N ha^{-1}. Usadadiya *et al*. (2014) reported the highest grain and straw yield of wheat with the application of 120 kg N ha^{-1} over lower level of nitrogen (60 kg ha^{-1}).

Effect of chlormequat

The length of spike, number of grains spike^{-1}, grain weight spike^{-1}, grain yield q ha^{-1} and straw yield q ha^{-1} were significantly higher due to seed inoculation of chlormequat @ 1000 ppm + foliar application of chlormequat @1000 ppm at maximum tillering stage as compared to control (no inoculation, no foliar application) and seed inoculation of chlormequat @ 1000 ppm but was at par with foliar application of chlormequat @ 1000 ppm at maximum tillering stage. This might be due to source-sink relationship by way of pertaining of dry matter accumulation at later stage of growth instead at early phase of growth of wheat crop. These results obtained during the investigation are in close accordance with the finding of Meera and Poonam (2010) who reported that application of cycocel @ 1000 and 2000 ppm significantly increased yield attributing characters in comparison to the untreated control in wheat crop. The highest yield was obtained when wheat was treated with 1000 ppm cycocel.

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