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PRODUCTIVITY AND PROFITABILITY OF WET SEASON RICE (*Oryza sativa* L.) UNDER DIFFERENT METHODS OF CROP ESTABLISHMENT AND NUTRIENT MANAGEMENT

T.R.Mohanty[1], P.K.Roul[2], S.K.Maiti[3] and A.C.Dash[4]

ABSTRACT

Field experiment was conducted at North Central Plateau Zone of Odisha during 2009-10 and 2010-11 to evaluate three rice crop establishment methods viz., SRI, drum seeding and conventional transplanting under three nutrient management practices viz., RDN (80:40:40 N: P_2O_5: K_2O kg ha^{-1}) through inorganic fertilizers, integrated nutrient management (INM) i.e.50% of R.D.N. through inorganic fertilizers + 50% of R.D.N. through organic sources (based on nitrogen requirement) and organic management (OM) i.e. 100% of R.D.N. through organic sources (based on nitrogen requirement). System of rice intensification registered the highest productivity of 6655 kg ha^{-1} which was 15.2% and 20.5% higher compared to conventional transplanting and drum seeding respectively. Among the nutrient combinations, integrated nutrient management (INM) could register the highest grain yield of 6435 kg ha^{-1} which was significantly more than RDF and organic management by 10.6 and 16.1% respectively. SRI grown under INM recorded the highest rice yield of 7299 kg ha^{-1}. The highest gross return (Rs.77925 ha^{-1}), net return (Rs.43123 ha^{-1}) and return $rupee^{-1}$ invested (2.29) were obtained from SRI. Maximum net return of Rs.40720 ha^{-1} was obtained from the treatment with INM which was at par with RDF (Rs.40401 ha^{-1}). The return $rupee^{-1}$ invested (2.46) was the highest with R.D.F. followed by INM (2.17).

(Key words: SRI, drum seeding, conventional transplanting, nutrient management)

INTRODUCTION

Rice (*Oryza sativa* L.) currently feeds more than half of the world's population and demand for rice is expected to rise by almost 40% within 30 years due to population increase (Surridge, 2004). To sustain present level of food self sufficiency and to meet future food requirements, India has to increase its rice productivity by 3% $annum^{-1}$ (Thiyagarajan and Selvaraju, 2001). It is well documented that crop establishment techniques and systems of cultivation have profound effect on the growth, productivity and profitability of a crop in general and rice in particular. In the eastern part of India, which covers 43 per cent of rice area of the country, farmers grow rice either by conventional transplanting or by broadcasting seeds in puddled field in medium land condition. In either case the optimum plant stand is not maintained. Further, the unavailability and scarcity of labour and water as well during peak period of transplanting lead to delayed planting, which ultimately results in low productivity. There are evidences that cultivation of rice through the system of rice intensification (SRI) can increase rice yields by 2 to 3 fold compared to current yield levels while saving water and labour (Abu Yamah, 2002). Direct seeding of sprouted seeds on to puddled soil (wet seedling) holds special significance in the present day production systems by saving time, labour, energy and profitability to increase cropping intensity by reducing turn around period and to avoid arduous operations like nursery preparation and manual transplanting (Subbaiah and Balsubramanian, 2000).

Nutrient management provides an approach for feeding the plants with nutrients as and when required. Complementary use of organic and biological source of plant nutrient along with chemical fertiliser is of great importance for the maintenance of soil health and productivity, especially under intensive cropping system (Prasad, 1999). In this context a field experiment was conducted at the Instructional farm of Krishi Vigyan Kendra, Mayurbhanj, Shamakhunta, Odisha to evaluate the performance of different rice crop establishment methods under various nutrient management practices.

MATERIALS AND METHODS

Field experiments were carried out at the Instructional farm at KVK, Mayurbhanj, Shamakhunta during wet seasons of 2009 and 2010. The soil was sandy clay loam in texture with pH 5.63, organic carbon 0.46%, bulk density 1.55 g cm^{-3} and

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available N, P_2O_5 and K_2O of 221, 10.4 and 139.3 kg ha^{-1} respectively. The experiment was laid out in split-plot design with three replications. Three crop establishment methods, viz., System of rice intensification (SRI), line sowing of pre-germinated paddy seeds by drum seeder under puddled condition (DS) and conventional transplanting (CT) were randomly allotted in three main plots and three nutrient management practices, viz., 100% RDN (80:40:40 N: P_2O5: K_2O kg ha^{-1}) through inorganic fertilizers, OM *i.e.*100% of RDN through organic sources and INM *i.e.* 50% of RDN through inorganic + 50% of RDN through organic sources were allotted in sub plots . Each sub plot was 4 m x 3 m in size. Medium duration rice var. Pratikshya was studied as the test crop. Drum seeding and nursery sowing of SRI and CT were accomplished on the same date. Seeds were soaked in water for 24 hours and kept in gunny bags for 30-36 hours to obtain sprouted seeds. In drum seeding, the pre-germinated seeds were sown by using a four-row paddy drum seeder in a puddled soil with rows of 20 cm apart. 10 day old seedlings were transplanted with a spacing of 25 cm x 25 cm in SRI. The CT method used 25 day-old seedlings with a spacing of 20 cm x 15 cm. The organic sources comprised of 50% N through FYM, 25% N through vermicompost and rest 25% N through neem oilcakes based on the nitrogen requirement. The N content of FYM, neem oil cake and vermicompost used were 0.4, 3.78 and 1.16% during 2009 and 0.44, 3.84 and 1.20% during 2010, respectively. The P_2O_5 content was 0.20, 0.84 and 0.41% during 2009 and 0.26, 0.88 and 0.47% during 2010 for FYM, neem oilcake and vermicompost, respectively. Similarly the K_2O content was 0.45, 0.98 and 0.54% during 2009 and 0.47, 1.02 and 0.62% during 2010 for FYM, neem oil cake and vermicompost, respectively. Accordingly, the fertilizers applied for 100% RDN through chemical fertilizers were 140 kg urea, 87 kg DAP and 66.66 kg MOP, for OM were 10 t FYM, 533 kg neem oil cake and 1724 kg vermicompost and for INM were 70 kg urea, 43.5 kg DAP, 33.33 kg MOP, 5 t FYM, 266.7 kg neem oil cake and 862 kg vermicompost. All the organic manures were incorporated at the time of final land preparation of the respective treatments. Full dose of phosphorus and potassium and one-fourth of nitrogen were applied as basal and remaining nitrogen was top dressed twice – half at maximum tillering stage and one-fourth at panicle initiation stage for all the treatments. At 25 and 50 days after drum seeding hand weeding was carried out twice and one hand weeding at 30 DAT was carried out for CT. Weeding was carried out three times using cono-weeder at 10-12 days intervals from the 12-15th day after transplanting for SRI plots. Immediately after the disappearance of standing water, irrigation at 5 cm depth was applied in CT and DS. In SRI, the plots were irrigated to 2.5 cm depth after the formation of hairline cracks on the soil surface from planting to panicle initiation. Stem borer and leaf folder were observed during the *kharif* seasons of 2009 and 2010. Monocrotophos @ 1.0 l ha^{-1} was applied on the crop during the incidence of the pest. No other incidence of insect pest and diseases were noticed in the crop. Growth and yield parameters were recorded as per standard procedures. Plants in the outer rows on each side of the plots were considered as border rows and therefore, the remaining central rows were selected for taking observation. Ten hills selected randomly from each sub-plot were peg marked as surface plants for recording biometric observations like plant height and tillers m^{-2} at maturity stage of the crop and post-harvest observations like panicles m^{-2}, filled spikelets $panicle^{-1}$, 1000 – grain weight, grain yield, straw yield and harvest index were also recorded. Days to 50% flowering was also recorded. Similarly, three hills from the earmarked area for destructive sampling in each sub-plot were uprooted for taking observations on root volume at 75 days after nursery sowing (DANS), plant dry weight and panicles m^{-2} at maturity stage of the crop. Economics was calculated based on the prevailing price of inputs and outputs.

RESULTS AND DISCUSSION

Data regarding growth parameters of rice as influenced by different methods of crop establishment and nutrient management practices are presented in table 1.Significantly higher plant height (125.9 and 126.8 cm) and root volume (59.89 and 66.62 cc $plant^{-1}$) at maturity were recorded under system of rice intensification (SRI) during both the seasons. However, the plant height was comparable with conventional transplanting (CT).The results corroborate the findings of Geethalakshmi *et al.* (2011) who recorded higher shoot length (85.2 and 86.6 cm) under SRI which was comparable with transplanted rice (86.4 and 86.6 cm) and drum seeded rice (82.7 and 81.2 cm) in both the years of experiment. Similar findings of higher root volume under SRI (85.1 cc plant^{-1}) than conventional transplanting (35.cc plant^{-1}) have been reported by Raju and Sreenivas (2008). The drum seeded (DS) plants took the least number of days (98) to 50% flowering followed by SRI (104.7). Plants under CT took the maximum days (110.8) to 50% flowering.

Among the nutrient management practices, INM treatment recorded significantly higher plant height, tillers m^{-2} and root volume during both the years of study. However, INM treatment was at par with RDF with respect to plant height during both the years. Organically managed plants took the longest time of 105.9 days to 50% flowering while other two treatments were at par during both the years.

Plant dry weight, filled spikelets panicle^{-1} and 1000 – grain weight were significantly higher under SRI method when compared with DS and CT methods during both the years (Table 2). However, as regards to production of panicles/m^2, all the treatments were at par. Among the nutrient management practices, INM treatment recorded significantly higher plant dry weight (1186 and 1229 g m^{-2}) followed by RDF (1110 and 1157 g m^{-2}) and DS (1062 and 1095 g m^{-2}).Maximum number of panicles m^{-2} was also recorded under INM treatment though it was comparable with RDF during both the years.

Pooled data of two years showed that SRI produced significantly higher grain yield (6655 kg ha^{-1}) which was 15.2% and 20.5% higher than the conventional transplanting and drum seeding respectively (Table 3a). Superior yield attributes such as filled spikelets panicle^{-1} and grain weight in SRI method of cultivation resulted in higher grain yield as compared to other methods of cultivation. Stoop *et al.* (2002) revealed that increased grain yield under SRI might be due to the synergistic effects of modification in the cultivation practices such as use of young and single seedlings hill^{-1}, limited irrigation, and frequent loosening of the top soil to stimulate aerobic soil conditions. Further, combination of plant, soil, water and nutrient management practices followed in SRI increased the root growth, along with increase in productive tillers, grain filling and higher grain weight that ultimately resulted in maximum grain yield (Uphoff, 2001). The results corroborate the findings of Geethalakshmi *et al*. (2011) who recorded higher grain yield (6014 and 6682 kg ha^{-1}) under SRI followed by transplanted rice (5732 and 6262 kg ha^{-1}) and wet seeded rice (5175 and 5500 kg ha^{-1}). Similar findings of higher grain yield under SRI by 15.5 and 18.8% over DS and CT respectively have been reported by Chandrapal *et al*. (2010). Nutrient management practices influenced the grain yield of rice significantly in both the years. The increase in grain yield (average of two years) with INM over 100% RDF and organic management was 11.9 and 19.2% respectively. Straw yield and harvest index followed the same trend with INM producing the highest straw yield (7612 kg ha^{-1}) followed by RDF (7407 kg ha^{-1}) and OM (7124 kg ha^{-1}) and harvest index of 45.68, 43.64 and 41.89% respectively. The results corroborate earlier findings of Singh *et al*. (2009) who found that application of 50% N (inorganic) + 50% N FYM + PK (inorganic and adjusted) produced higher grain yield (3.79 t ha^{-1}) and higher straw yield (4.54 t ha^{-1}) than 100% RDF (60:20:20) which produced grain and straw yields of 3.04 t ha^{-1} and 3.91 t ha^{-1} respectively. Similar findings have also been reported by Mankotia (2007) who found higher grain (3.23 t ha^{-1}) and straw yield (4.87 t ha^{-1}) under 50% NPK + 5 t FYM ha^{-1} than under 100% NPK through chemical fertilizers only which produced grain and straw yields of 2.84 and 4.7 t ha^{-1} respectively. This might be due to the favourable soil condition and synchronized release of nutrients throughout the crop growth period.

Among the interactions the highest grain yield of 7299 kg ha^{-1} was recorded under the SRI method of cultivation with integrated nutrient management (Table 3b).

The economics of production for rice showed significant variations in response to crop establishment methods and nutrient management practices. The highest net return of Rs.43123 ha^{-1} and return rupee^{-1} invested of 2.29 ha^{-1} was computed for SRI followed by CT and DS (Table 4). Similar findings have also been reported by Shekhar *et al.* (2009) who recorded higher net return of Rs. 39121 ha^{-1} and benefit : cost ratio of 1.98 ha^{-1} under SRI than conventional transplanting which recorded net return of Rs.33928 ha^{-1} and B:C of 1.75 ha^{-1}. Among the nutrient management practices INM recorded the highest net return of Rs.40720 ha^{-1} which was comparable to RDF but both were significantly

Table 1. **Effect of crop establishment methods and nutrient management practices on plant height and tillers m^{-2} at harvest, root volume at 75 DAS and days to 50% flowering in rice**

Treatm-ents	Plant height at maturity (cm)			Tillers m^{-2}(no.)at maturity			Root volume at 75 DANS (cc $plant^{-1}$)			Days to 50% flowering (no.)		
	2009	2010	pooled	2009	2010	pooled	2009	2010	pooled	2009	2010	pooled
Crop establishment												
SRI*	125.9	126.8	126.4	234.0	246.1	240.0	59.89	66.62	63.26	105.4	103.9	104.7
DS	115.1	115.0	115.0	246.8	263.9	255.4	23.55	25.76	24.66	98.2	97.8	98.0
CT	119.7	120.7	120.2	260.7	279.3	270.0	25.43	28.37	26.90	111.0	110.7	110.8
SE m(±)	1.85	2.07	1.39	7.3	11.6	6.8	0.78	0.83	0.57	0.8	0.6	0.5
CD (0.05)	7.3	8.1	4.5	-	-	-	3.06	3.25	1.86	3.1	2.4	1.6
Nutrient management												
RDF	121.9	122.5	122.2	248.2	268.1	258.1	35.27	39.12	37.20	104.0	103.0	103.5
OM	116.1	116.3	116.2	225.2	236.9	231.1	34.57	38.74	36.66	106.2	105.6	105.9
INM	122.7	123.8	123.3	268.1	284.2	276.2	39.04	42.88	40.96	104.4	103.8	104.1
SE m(±)	1.80	1.88	1.30	9.2	7.1	5.8	0.75	0.82	0.56	0.4	0.5	0.3
CD (0.05)	5.6	5.8	3.8	28.4	21.8	16.9	2.31	2.53	1.62	1.2	1.4	0.9

SRI = System of rice intensification; DS = Drum seeding; CT = Conventional transplanting; RDF (Recommended dose of fertilizer) = 80 kg N, 40 kg P_2O_5 and 40 kg K_2O; OM = Organic management (50% N through FYM + 25% N through vermicompost + 25% N through neem oil cake); INM = Integrated nutrient management (1/2 RDF + ½ OM), DANS = days after nursery sowing

Table 2. **Effect of crop establishment methods and nutrient management practices on plant dry weight, panicle length, filled spikelets panicle^{-1} and 1000 – grain weight of rice at harvest**

Treatm-ents	Plant dry weight at maturity (g m^{-2})			Panicles m^{-2} at maturity (no.)			Filled spikelets panicle^{-1} (no.)			1000 – grain weight (g)		
	2009	2010	pooled	2009	2010	pooled	2009	2010	pooled	2009	2010	pooled
Crop establishment												
SRI*	1203	1245	1224	227.0	239.5	233.3	171.7	172.5	172.1	23.37	24.48	23.92
DS	1067	1102	1084	241.0	256.9	249.0	139.6	138.0	138.8	21.71	22.40	22.05
CT	1088	1133	1111	252.9	271.8	262.3	142.8	140.0	141.4	21.80	22.44	22.12
SE m(±)	21	27	17	8.0	11.2	6.9	5.3	4.3	3.4	0.30	0.40	0.25
CD (0.05)	83	106	56	-	-	-	20.7	16.8	11.1	1.18	1.57	0.82
Nutrient management												
RDF	1110	1157	1133	242.5	260.0	251.3	150.6	149.1	149.9	21.90	22.56	22.23
OM	1062	1095	1078	220.1	231.3	225.7	149.1	149.6	149.3	22.70	23.43	23.07
INM	1186	1229	1207	258.3	276.9	267.7	154.5	151.9	153.2	22.28	23.33	22.80
SE m(±)	14	11	9	8.5	7.0	5.5	6.4	6.3	4.5	0.51	0.40	0.32
CD (0.05)	45	34	26	26.1	21.4	16.0	-	-	-	-	-	-

SRI = System of rice intensification; DS = Drum seeding; CT = Conventional transplanting; RDF (Recommended dose of fertilizer) = 80 kg N, 40 kg P_2O_5 and 40 kg K_2O; OM = Organic management (50% N through FYM + 25% N through vermicompost + 25% N through neem oil cake); INM = Integrated nutrient management (1/2 RDF + ½ OM)

Table 3a. Grain and straw yield (kg ha^{-1}) and harvest Index (%) of rice as influenced by crop establishment methods and nutrient management practices

Treatments	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Harvest Index (%)		
	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled
Crop establishment									
SRI*	6341	6969	6655	7636	7486	7561	45.30	48.17	46.74
DS	5080	5499	5289	7344	7286	7315	40.80	42.97	41.89
CT	5407	5876	5642	7262	7272	7267	42.54	44.56	43.55
SE m(±)	195.08	228.54	150.24	195.22	216.61	145.80	0.21	0.76	0.396
CD (0.05)	766	897	490	-	-	-	0.84	2.99	1.29
Nutrient management									
RDF	5506	5997	5751	7387	7427	7407	42.66	44.63	43.64
OM	5164	5635	5400	7183	7065	7124	41.57	44.12	42.84
INM	6158	6711	6435	7672	7552	7612	44.42	46.95	45.68
SE m(±)	112.37	131.14	86.34	112.69	126.55	84.730	0.158	0.264	0.154
CD (0.05)	346	404	252	347	390	247	0.49	0.81	0.45

Table 3b. Interaction effect of crop establishment methods and nutrient management practices on grain yield of rice

Crop Establishment	Nutrient management		
	RDF	Organic management	INM
SRI	6071	6596	7299
DS	5359	4775	5735
CT	5825	4829	6270
	SE m(±)	CD (0.05)	
Main x Sub	193.601	605	
Sub x Main	149.544	436	

SRI = System of rice intensification; DS = Drum seeding; CT = Conventional transplanting; RDF (Recommended dose of fertilizer) = 80 kg N, 40 kg P_2O_5 and 40 kg K_2O; OM = Organic management (50% N through FYM + 25% N through vermicompost + 25% N through neem oil cake); INM = Integrated nutrient management (1/2 RDF + ½ OM)

Table 4. Cost of cultivation, Gross return, net return and return rupee^{-1} invested as influenced by crop establishment methods and nutrient management practices

Treatments	Cost of cultivation	Gross return(Rs.)			Net return (Rs.)			Return rupee^{-1} invested		
	pooled	2009	2010	pooled	2009	2010	pooled	2009	2010	pooled
Crop establishment										
SRI*	34802	74595	81254	77925	39978	46268	43123	2.20	2.38	2.29
DS	34462	60739	65214	62977	26462	30568	28515	1.84	1.96	1.90
CT	35182	64210	69274	66742	29213	33908	31560	1.90	2.04	1.97
SE m(±)		2263	2568	1712	2263	2568	1712	0.07	0.08	0.05
CD (0.05)		8883	10082	5581	8883	10082	5581	0.27	0.30	0.17
Nutrient management										
RDF	27640	65377	70705	68041	37736	43065	40401	2.36	2.56	2.46
OM	41940	61520	66514	64017	19949	24206	22077	1.48	1.57	1.53
INM	34865	72649	78523	75586	37967	43473	40720	2.09	2.24	2.17
SE m(±)		1303	1504	995	1303.49	1504	995	0.04	0.05	0.03
CD (0.05)		4016	4634	2904	4016	4634	2904	0.12	0.14	0.09

SRI = System of rice intensification; DS = Drum seeding; CT = Conventional transplanting; RDF (Recommended dose of fertilizer) = 80 kg N, 40 kg P_2O_5 and 40 kg K_2O; OM = Organic management (50% N through FYM + 25% N through vermicompost + 25% N through neem oil cake); INM = Integrated nutrient management (1/2 RDF + ½ OM)

higher than OM. However RDF recorded significantly highest return rupee^{-1} invested (2.46) followed by INM (2.17) and OM (1.53) which might be due to premium cost of organic materials such as vermicompost and neem oil cake. SRI under INM recorded the highest gross return and net return of Rs.85216 ha^{-1} and Rs.50324 ha^{-1}, respectively.

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CROP RESIDUES INCORPORATION AND ITS IMPACT ON SOIL pH, SOIL ORGANIC CARBON AND N AVAILABILITY

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ABSTRACT

A study was undertaken in uncropped land during the period March to June in the year 2009 and 2010 for 90 days to monitor the changes of soil pH, organic carbon and available N status during decomposition of various crop residues incorporated into the soil environment @ 6 t ha^{-1} under field condition. Results have shown that soil p^{H} decreased upto 45th day and then increased at 90th day irrespective of residues. Organic carbon and available N content in soil increased cumulatively with period of residues incorporation. Horse gram residue decomposed at a faster rate within 30 days, sesamum, niger, toria and buckwheat at 45th day and wheat and rice residue at 60th day, then gradually declined to the period of 90 days. At 90th day, horse gram and rice residues significantly increased the mean soil organic carbon by 21.73% and wheat residue registered 17.82% mean soil organic carbon which was higher than initial (0.46%), while toria, buckwheat, niger, sesamum residue and control treatment contributed 16.52%, 16.08%, 15.65%, 11.73% and 2.61% higher value of soil organic carbon, respectively, but at par with initial. Mineralization of N was very fast and rapid from horse gram residue and attained maximum at 30th day, sesamum, niger, toria, buckwheat, wheat and rice residue caused N immobilization during initial period of incorporation, however, remineralization of immobilized N started from sesamum, niger, toria, buckwheat after 15th day and from wheat and rice residues after 30th day of incorporation. The maximum per cent N was recovered in soil from residues of horse gram at 30th day, sesamum, niger, toria and buckwheat at 45th day and wheat and rice residues at 60th day of incorporation.

(Key words: Crop residues, immobilization, mineralization, organic carbon, available N, soil pH)

INTRODUCTION

In the present days of energy crises, the importance of crop residues' incorporation for maintaining soil organic carbon and fertility has been increasingly realized due to deteriorating soil health day by day. The concept of soil quality is regarded as a tool for assessing the long-term sustainability of agricultural production that can be improved by adoption of proper crop residue management practices. Incorporation of crop residues into the soil environment influences consequent chemical changes in the soil that are important for meeting the soil quality. Crop residues are important natural resources and upon decomposition during incorporation may lead to improvement in soil physical, chemical and biological parameters and improves the overall ecological balance of the crop production system besides building up of Soil Organic Matter (SOM) and soil N, P and K (Mandal *et al*., 2004; Yadvinder-Singh *et al*., 2004 and Regar *et al*., 2009). Plant nutrient availability is governed by soil pH which may, however, be influenced strongly by crop residue management (Mandal *et al.,* 2004). Crop residues play important role in nutrient cycling in soil and during decomposition process, organic nitrogen contained therein is mineralized into inorganic plant usable forms by the activity of soil microorganisms. Of course, suitability of residues to be incorporated depends on its decomposability and nutrient mineralization pattern. Several works on N mineralization-immobilization have been carried out under laboratory conditions (Roy *et al*., 2011; Khalil *et al.,* 2005 and Mohanty *et al*., 2010). However, works on effect of decomposition of various crop residues on soil properties in field conditions are meagre in our region. Therefore, the present investigation was conducted to study the change of soil pH, organic carbon content and availability of N in soil upon incorporation of various crop residues in field condition without growing crops.

MATERIALS AND METHODS

A field experiment was conducted in uncropped land at Regional Agricultural Research Station, Assam Agricultural University, Gossaigaon, Assam for years, 2009 and 2010 during March to June to study the change of soil pH, organic carbon content and available N content in soil when various crop residues were incorporated in agricultural lands under field condition. In the month of March, pre monsoon starts and from March to June total rainfall varies from 36.6 to 506.4 mm and average maximum soil temperature (^{0}C) at 5 cm depth varied from 15.88 ^{0}C to 26.0^{0} C during both the years creating a

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congenial soil environment for crop residue decomposition. The experiment was laid out in RBD with three replications. The soil of the experimental site was sandy loam with pH of 5.34 having 0.46% organic carbon, low available N (225.80 kg ha^{-1}), P (8.20 kg ha^{-1}) and K (92.42 kg ha^{-1}). The bulk density of the soil was 1.31 g cc^{-1}. Initial soil moisture content was 17.67%. Crop residues from seven different crops were collected after threshing and spreaded over the respective experimental plot uniformly then incorporated into the soil by ploughing and considered as treatments along with one control plot, viz.; T_1= Sesamum (*Sesamum indicum*), T_2= Niger (*Guizotia abyssinica*), T_3= Toria (*Brassica campestris*), T_4= Buckwheat (*Fagopyrum esculentum* L.), T_5= Horse gram (*Dolichos biflorus* L.), T_6 = Wheat (*Triticum aestivum*), T_7= Rice (*Oryza sativa*) and T_8 = control. Total C and total N content of various crop residues used (Table 2) were determined by wet digestion method (Walkley and Black, 1934) and Kjeldahl method (Jackson, 1973), respectively. Each of the residues @ 6 t ha^{-1} as per treatments were uniformly spread over the surface of the soil and then incorporated into the soil with ploughing and allowed for decomposition. The Soil samples were drawn at 0-15 cm depth before starting the investigation and also from different plots under various treatments at intervals of 15 days regularly upto 90 days in each year were and estimation of soil pH by potentiometric method in a soil water suspension (1:2.5 ratio), residual status of organic carbon by wet digestion method (Walkley and Black, 1934) and available N content in soil by alkaline potassium permanganate ($KMnO_4$) method (Subbiah and Asija, 1956) during decomposition were estimated. The experimental plots were reploughed just after each sampling.

RESULTS AND DISCUSSION

The results on the comparison of soil pH in all the treatments indicate that pH decreased from initial pH level (5.34) to the level of soil pH 5.29 in case of sesamum and wheat residue, pH 5.27 (niger and toria), pH 5.25 (buckwheat), pH 5.24 (horse gram), pH 5.26 (rice residue) and pH value 5.30 in the control treatment after the period of 45^{th} day of residue incorporation and then increased upto 90^{th} day of crop residues incorporation irrespective of the treatments and recorded in the order of pH level 5.50, 5.48, 5.45, 5.44, 5.42, 5.41, 5.41 and 5.37 in respect of rice, wheat, toria, buckwheat, niger, sesamum, horse gram residue and control, respectively (Table 2). The decrease in soil pH at the starting of crop residues incorporation upto a period of 45 days may be referred to carbonic acid formation as well as production of weak organic acids during decomposition (Vimlesh and Giri, 2011). Decomposition of carbohydrates produces carboxylic groups which, after dissociation, may decrease soil pH. After a period of 45 days onwards carboxylic groups are decarboxylated due to biological decarboxylation of organic anions on further decomposition caused by microorganisms and may result a rise in soil pH (Yan *et al*., 1996). Maximum mean highest pH value of 5.50 was recorded at 90^{th} day in rice residues incorporated plots which may be due to higher K content in rice residues. Sharma *et al*.(2010) opined that increase in soil pH in later stage of decomposition of organic matter might be due to release of bases.

The organic carbon status of the soils was found to increase cumulatively with days of incorporation irrespective of residues (Table 3). Of the various sources of organic materials, the horse gram residues decomposed at a faster rate and attained higher per cent organic carbon (45.65%) at 30^{th} day than that of initial organic carbon content (0.46%). It can be inferred that the horse gram residues had a narrow C:N ratio (31.96) and high N content (Table 1) than the other residues. The addition of horse gram residues significantly increased the organic carbon content (21.73%) in soil over initial value (0.46%) at the end of the experiment. The residues like sesamum, niger, toria, buckwheat, wheat and rice decomposed initially at a slower rate as compared to horse gram residues but they had higher rate of decomposition at 45^{th} day contributing maximum per cent increase in organic carbon for sesamum (30.44%), niger (32.61%), toria (28.26%) and buckwheat (32.61%) residues, while wheat and rice residues showed maximum per cent increase in organic carbon content at 60^{th} day of incorporation which was 36.95% and 41.30%, respectively. Then it gradually declined till 90^{th} day irrespective of residues. The rate of residue decomposition increased linearly and attained maximum on 45^{th} day for sesamum, niger, toria and buckwheat residues, at 30^{th} day for horse gram materials and wheat and rice residues showed maximum rate of decomposition at a period of 60th day of incorporation. This indicates that C:N ratio of the different residues were responsible for maximum mineralization of native soil organic matter and added crop residues by increasing microbial activity in soil environment at the particular day of incorporation. At the end of the 90th day, horse gram and rice residues significantly increased the mean soil organic carbon and was 21.73% higher than the initial value (0.46%), wheat residue also recorded significant increase of 17.82% organic carbon content over initial (0.46%) while niger (15.65%), buckwheat (16.08%), toria (16.52%), sesamum (11.73%) and control treatment (2.61%) recorded higher value of organic carbon but were at par with initial value (0.46%). Of course, soil organic matter increases may depend on the amount of residue added, quality of the residue and the duration of addition (Mandal *et al*., 2004). Mbah and Nneji (2010) revealed that the equilibrium level of soil organic matter will depend upon the amount of organic materials added, management factors and the environment. The increase in organic carbon in soil after incorporation of residues may be due to carbon mineralization present there in. During the period of incorporation, the soil microorganisms utilized crop residues' carbon for building up of the cellular materials as well as accelerated decomposition of added organic materials and increased organic carbon in soil. Yadvinder Singh *et al*. (2004) observed that organic carbon content in soil increased from 0.41 to 0.59 g kg^{-1} soil after 7 years of rice residue incorporation before sowing wheat. In another study (Yadvinder-Singh *et al*., 2009), C sequestration in soil from straw mulch after 2.5 years was about 25% on both sandy loams and silt loams. The amount of C sequestration from straw incorporation under conventional tillage was lower at 17%. Thus, soil organic carbon can be accumulated by recycling the crop residues at appropriate quantities.

Incorporation of various crop residues significantly reduced the inorganic available N content in soil than initial level at 15th day except horse gram residues (Table 4). From 15th to 30th day, no net mineralization was observed with wheat and rice residues but irrespective of residues, cumulative inorganic available N status in soil increased significantly from 30th to 90th day of incorporation over initial. N mineralization was very fast in soil incorporated with horse gram residue and showed the maximum rate of mineralization at 30th day increasing available N level to 22.98% higher than that of initial level (225.8 kg ha^{-1}), after that there was decline in the rate with period of incorporation and available N content decreased to 8.72% at 90th day. Rapid mineralization of horse gram residue at 15th to 30th day might be due to narrower C:N ratio (31.96) which was less than 40 (Table 2) containing higher residue N (0.61%) which accelerated the biological activity for rapid and easy microbial decomposition on incorporation that resulted in increase in available N content as compared to other organic residues used. On the contrary, a remarkable decrease of available N in soil treated with the residues of sesamum, niger, toria and buckwheat was recorded at 15th day which may be due to wider C:N ratio and immobilization of soil N by soil microorganisms and thereafter, N mineralization surpassed that of immobilization estimating maximum at 45th day, then gradually declined upto the period of 90th day. At 45th day of residues incorporation, the maximum per cent increase of inorganic available N recovered in soil from sesamum, niger, toria and buckwheat residue was 19.57%, 21.57%, 22.85% and 23.73%, respectively, and was higher than initial value (225.8 kg ha^{-1}) and at 90th day, when available N content declined to 7.80%, 7.30%, 8.02%, and 6.11%, respectively (Table 5). Incorporation of wheat and rice residues resulted N immobilization upto the initial period of 30th day due to more wide C:N ratio as compared to other crop residue treatments and remineralization of immobilized N exceeded after 30th day and maximum rate of mineralization was found at 60th day and then declined at 90th day of incorporation. At 60th day higher per cent of available N recovered in soil was 26.74% and 27.95% from wheat and rice residues, respectively, as compared to that of initial datum (225.8 kg ha^{-1}). At 90th day of incorporation, the available N in soil decreased to 11.86% and 14.08% in case of wheat and rice residue, respectively. Rate of changes of available N content in soil was higher at 30th day for horse gram residue, at 45th day for sesamum, niger, toria and buckwheat and at 60th day for wheat and rice residues which might be due to the enhancement of soil and residues N mineralization caused by microbial activity on incorporation of crop residues. The average cumulative mean available N level for sesamum, niger, toria, buckwheat, horse gram, wheat, rice

Table 1. C:N ratio of crop residues before decomposition

Crop residues	C content (%)	N content (%)	C:N ratio	P content (%)	K content (%)
Sesamum	27.60	0.50	55.20	0.02	0.16
Niger	21.60	0.42	51.42	0.02	0.12
Toria	20.40	0.52	39.23	0.11	1.13
Buckwheat	18.30	0.45	40.67	0.12	0.21
Horse gram	19.50	0.61	31.96	0.03	0.05
Wheat	34.62	0.46	75.26	0.10	1.08
Rice	38.44	0.52	73.92	0.11	1.18
Control	0.52	0.09	5.77	-	-

residue treatments during the period of incorporation was estimated as 262.7 kg ha^{-1}, 275 kg ha^{-1}, 279.6 kg ha^{-1}, 293.6 kg ha^{-1}, 356 kg ha^{-1}, 270.2 kg ha^{-1} and 281 kg ha^{-1}, respectively, and was significantly higher than initial value (225.8 kg ha^{-1}) and control treatment (226.6 kg ha^{-1}). Maximum cumulative mean available N content (356 kg ha^{-1}) was found to be significantly higher with horse gram residues than that of initial (225.8 kg ha^{-1}) and all other treatments. This increasing content of available N may be referred to active microbial decomposition and accompanied by higher rate of N mineralization. Fosu *et al.* (2007) showed significantly highest initial N immobilization in cover crops amended soils, particularly with devil bean which occurred 4 days after residue incorporation. They also observed that residues with lower percentage cellulose and lower lignin / N ratio mineralized faster with lower N immobilization. Legumes with C/N ratio less than 20 and per cent N 1.7 may immobilize N. Hartz *et al.*(2000) measured net N mineralization at 4 (1996) or 8 weeks (1997) intervals, and reported an average of 16%, 7%, and 1% of organic N was mineralized in 12 weeks of incubation in 1996, and an average of 15%, 6%, and 2% in 24 weeks of incubation in 1997, in manure, manure compost, and plant residue compost, respectively. They also recorded the mineralization of manure C averaged 35% of initial C content in 24 weeks, while compost C mineralization averaged only 14% and within 4 (compost) or 16 weeks (manure), the rate of mineralization of amendment C had declined to the soil organic C level. However, Roy *et al.* (2011) reported that N mineralization surpassed immobilization 40^{th} day onwards.

Thus, it can be opined that crop residues are the good source for improving particularly acidic and poor fertile soil in terms of raising soil pH, increasing soil organic matter and nutrient availability to the growing plants and is also important to incorporate legume and cereals crop residues before 45 to 60 days of planting.

Table 2. Effect of crop residues on changes of soil pH during decomposition at different days of incorporation

Crop residues	Initial	15 days			30 days			45 days			60 days			90 days		
		2009	2010	Mean	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean
Sesamum	5.34	5.34	5.35	5.34	5.32	5.33	5.32	5.28	5.30	5.29	5.32	5.36	5.34	5.40	5.42	5.41
Niger	5.34	5.33	5.36	5.34	5.30	5.33	5.31	5.26	5.28	5.27	5.33	5.38	5.35	5.41	5.44	5.42
Toria	5.34	5.33	5.36	5.34	5.31	5.34	5.32	5.26	5.29	5.27	5.35	5.36	5.35	5.45	5.46	5.45
Buckwheat	5.34	5.32	5.35	5.33	5.30	5.31	5.30	5.24	5.26	5.25	5.33	5.35	5.34	5.42	5.46	5.44
Horse gram	5.34	5.30	5.35	5.32	5.28	5.30	5.29	5.24	5.25	5.24	5.34	5.38	5.36	5.38	5.45	5.41
Wheat	5.34	5.34	5.35	5.34	5.32	5.33	5.32	5.28	5.30	5.29	5.35	5.40	5.37	5.46	5.50	5.48
Rice	5.34	5.33	5.36	5.34	5.31	5.32	5.31	5.25	5.27	5.26	5.38	5.41	5.39	5.48	5.53	5.50
Control	5.34	5.33	5.35	5.34	5.31	5.34	5.32	5.30	5.30	5.30	5.30	5.33	5.31	5.36	5.38	5.37
SEm±	-	-	-	-	-	-	-	-	-	**0.005**	-	-	**0.01**	-	-	**0.016**
CD (5%)	-	-	-	-	-	-	-	-	-	**0.011**	-	-	**0.023**	-	-	**0.037**

Table 3. Cumulative increase of soil organic carbon content (%) during decomposition of residues in soil at different days of incorporation

Crop residues	Initial	15 days			30 days			45 days			60 days			90 days			
		2009	2010	Mean	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean	
Sesamum	0.46	0.47	0.51	0.49	0.49	0.56	0.52	0.60	0.68	0.64	0.66	0.72	0.69	0.70	0.76	0.73	0.61
Niger	0.46	0.49	0.52	0.50	0.54	0.58	0.56	0.69	0.74	0.71	0.74	0.80	0.77	0.80	0.84	0.82	0.67
Toria	0.46	0.50	0.55	0.52	0.54	0.61	0.57	0.69	0.72	0.70	0.76	0.80	0.78	0.82	0.86	0.84	0.68
Buckwheat	0.46	0.51	0.54	0.52	0.55	0.62	0.58	0.72	0.74	0.73	0.78	0.81	0.79	0.81	0.85	0.83	0.69
Horse gram	0.46	0.54	0.64	0.59	0.77	0.83	0.80	0.85	0.88	0.87	0.90	0.94	0.92	0.94	0.98	0.96	0.83
Wheat	0.46	0.47	0.55	0.51	0.52	0.61	0.56	0.56	0.68	0.62	0.73	0.85	0.79	0.82	0.92	0.87	0.67
Rice	0.46	0.47	0.56	0.52	0.54	0.63	0.58	0.66	0.72	0.69	0.82	0.94	0.88	0.95	0.97	0.96	0.73
Control	0.46	0.46	0.48	0.47	0.47	0.50	0.48	0.49	0.51	0.50	0.50	0.54	0.51	0.48	0.55	0.52	0.50
SEm±		0.025	0.034	0.023	0.038	0.036	0.073	0.052	0.037	0.115	0.043	0.045	0.125	0.041	0.068	0.162	0.034
CD (5%)		--	--	--	0.100	0.077	0.173	0.111	0.081	0.272	0.092	0.096	0.296	0.087	0.146	0.384	0.070

Table 4. Effect of crop residues on cumulative available N (kg ha^{-1}) content during decomposition at different days of incorporation

Crop residues	15 days			30 days			45 days			60 days			90 days		
	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean
Sesamum	196.4	203.3	199.8	218.8	236.4	227.6	264.3	278.6	271.8	296.3	300.4	298.4	317.5	314.5	316.0
Niger	208.2	214.4	211.3	233.3	241.4	237.6	286.2	286.5	286.3	314.7	308.4	311.6	333.6	322.6	328.1
Toria	214.9	218.6	216.7	244.9	240.6	242.3	300.2	287.2	293.9	321.9	305.3	313.6	343.2	320.1	331.7
Buckwheat	219.3	225.6	222.5	254.5	253.2	253.9	310.7	304.3	307.5	341.0	329.2	335.1	356.1	341.8	348.9
Horse gram	267.7	278.3	273.0	328.9	320.9	324.9	375.2	362.2	368.7	405.5	388.8	397.2	422.1	411.6	416.9
Wheat	184.3	192.2	188.3	222.7	217.7	220.2	271.6	258.5	265.1	335.4	315.5	325.5	361.4	343.2	352.3
Rice	193.7	201.4	197.6	225.7	218.8	222.3	280.0	271.4	275.7	342.5	335.1	338.8	376.6	364.5	370.6
Control	225.8	226.1	226.0	226.0	226.5	226.3	226.4	227.1	226.8	226.6	227.4	227.0	226.7	227.5	227.1
SEm±	6.10	5.41	2.17	3.56	5.04	5.94	4.02	2.92	8.42	4.66	5.43	11.60	3.81	4.12	5.64
CD (5%)	13.08	11.60	5.14	7.63	10.81	14.04	8.62	6.25	19.91	10.00	11.66	27.43	8.17	8.84	13.35

Table 5. Percent increase of available N (kg ha^{-1}) during decomposition of crop residues at different days (Mean of two years) of residue incorporation

Crop residues	15 days		30 days		45 days		60 days		90 days	
	Available N (kg ha^{-1})	% increase	Available N (kg ha^{-1})	% increase	Available N (kg ha^{-1})	% increase	Available N (kg ha^{-1})	% increase	Available N (kg ha^{-1})	% increase
Seasmum	- 26	-	27.8	12.32	44.20	19.57	26.60	11.78	17.60	7.80
Niger	- 14.50	-	26.3	11.65	48.70	21.57	25.30	11.20	16.50	7.30
Toria	- 9.10	-	25.60	11.34	51.60	22.85	19.70	8.72	18.10	8.02
Buckwheat	- 3.30	-	31.40	13.90	53.60	23.73	27.60	11.22	13.80	6.11
Horsegram	11.20	4.96	51.90	22.98	43.80	19.40	28.50	12.62	19.70	8.72
Wheat	- 37.50	-	31.90	-	44.90	19.88	60.40	26.74	26.80	11.86
Rice	- 28.20	-	25.70	-	53.40	23.65	63.10	27.95	31.80	14.04
Control	0.20	0.08	0.30	0.14	0.50	0.22	0.20	0.08	0.10	0.04

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STABILITY, EFFICIENCY AND SOIL FERTILITY PARAMETERS OF DIFFERENT CROPPING SYSTEMS IN WESTERN HIMALAYAN REGION

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ABSTRACT

The study was conducted from 2001 to 2007 at the farmers' fields in central and undulating plain zone region and south-western regions of Punjab state under "All India Coordinated Research Project on Cropping Systems" (on-farm research).The prime objective of this study was to investigate the fertility status, rice equivalent yield, system productivity, net return and profitability of five cropping systems over a period of six years. The results of our study revealed low range of OC (<0.40 %) and available N (<272 kg ha^{-1}) whereas, medium levels of available P_2O_5 (12.4-22.4 kg ha^{-1}) and K_2O (137-337 kg ha^{-1}). None of the cropping system was able to sustain its soil fertility parameters over a period of six years. The highest rice equivalent yield (144.80 q ha^{-1}), system productivity (39.7 kg ha^{-1} day^{-1}), stability index (0.88), net returns (Rs. 90444) and profitability (247.8 Rs. ha^{-1} day^{-1}) were found for rice-gobhi sarson-summer moongbean system in south western region. Similarly the rice equivalent yield (147.6 q ha^{-1}), system productivity (40.4 kg ha^{-1} day^{-1}), net return (Rs. 89860) and profitability (246.2 Rs ha^{-1} day^{-1}) were also found to be highest for rice-gobhi sarson- summer moongbean in central and undulating plain zone region. But the rice-wheat sequence was most stable in central undulating plain zone having a stability index of 0.92.

(Keywords: Economic viability, productivity, profitability, rice based cropping systems, stability)

INTRODUCTION

The rice-wheat system is one of the important and largest agricultural production systems in South Asia covering 13.5 million ha and about 1.3 billion or about 20% of the world population is dependent on the produce of this area (Timsina and Connor, 2001). The rice-wheat system is primarily irrigated and its 85% lies in the Indo- Gangetic Plains, encompassing Northern India, Pakistan, Nepal and Bangladesh and covering about 32% of the total rice area and 42% of the total wheat area in these four countries and accounted for between 1/4th and 1/3rd of total rice and wheat production in these countries (Timsina and Connor, 2001). Punjab, a small northern Indian state has developed particularly since the Green Revolution in the mid 1970s, to be a key agricultural area producing 13% of the food grains of India. Rice and wheat are the major crops cultivated by the farmers of Punjab. Rice followed by wheat is the main cropping system in the state. More than 60% of the total cultivated area in the state in the *kharif* season is occupied by rice. Increased productivity brought economic benefits to farmers and led to the establishment of Wheat-Rice Cropping Pattern (WRCP) as the main agricultural system of Punjab which more recently has become dependent on underground water resources, agricultural machinery, chemical fertilizers and pesticides. Despite enormous growth of this cropping system in the country during the past few years, reports of stagnation in the productivity of these crops, with possible decline in production in future, have raised doubts on its sustainability (Kumar and Mittal, 2006). With the passage of time, excessive use of chemical fertilizers and irrigation in rice and wheat to maintain their productivity has created an imbalance in soil fertility and threatened the sustainability of the most productive food grain belt in South Asia (Hobbs and Morris, 1996). Legumes are an effective source of reversing the process and can contribute significantly to achieving the twin objectives of increasing productivity and improving the sustainability of the rice and wheat- based cropping system (Ahlawat *et al.*, 1998; Lauren *et al.,* 1998 and Yadav *et al*., 1998). Legume crops (pulses and oilseeds) are popular for their suitability in different cropping systems. Oilseeds and pulses including vegetables are receiving more attention owing to higher prices due to increased demand. Inclusion of these crops in a sequence can change the economics of the cropping sequences (Tomar and Tiwari, 1990). Legumes such as mungbean,soybean and groundnut were considered as the crops which could benefit farmers

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and help in improved environments. Legumes also show favorable effect on soil fertility (Roy Bardhan *et al.,* 1999 and Kharub *et al.,* 2003). Short-duration legumes can fit well into the existing cropping systems such as rice-wheat, as they are drought-tolerant and adapted to low-input situations. With rice based system having legumes as the components, infestation of pest and disease of rice would be reduced and fertility of soil could be increased through N_2 fixation (Pookpakdi, 2000). Likewise economic yield of these legumes can help in elevating farmers' income. Thus, this study was planned in order to find a sequence providing the better productivity, stability and profitability from different rice based cropping systems in different areas of Punjab in Western Himalayan region.

MATERIALS AND METHODS

The study was conducted from 2001 to 2007 at the farmers' fields of Punjab state in Ludhiana-Moga- Fatehgarh Sahib-Nawanshahar (central and undulating plain zone region) and Faridkot-Ferozpur-Moga (south western region) under "All India Coordinated Research Project on Cropping Systems" (on-farm research).Characteristics and locations of the experimental regions are described in table 1. Five crop sequences viz., rice-wheat, rice-gobhi sarson, rice- gobhi sarson-summer moongbean, rice-gram-summer moongbean and rice-gram were evaluated at 24 locations at Faridkot-Ferozpur-Moga and Ludhiana-Moga- Fatehgarh Sahib-Nawanshahar every year during 2001-05 and 2004-07 respectively. For comparison between crop sequences the yield of all the crops were converted into rice grain equivalent yield on price basis. The stability index (SI) for individual crop and cropping systems was computed using the following formula as used by Gangwar *et al.* (2006).

$$SI = \frac{Y - S}{Y\,max}$$

Where,

Y= average yield of crop in sequence over a period of year and locations

S = standard deviation of yield of a crop in a period of year

Y max = maximum yield of a crop in a certain year

The system productivity (kg grain ha^{-1} day^{-1}) was calculated by dividing the rice equivalent yield by 365. Similarly, the profitability in terms of Rs ha^{-1} day^{-1} was worked out by dividing the average net returns over years by 365. The benefit: cost ratios for different sequences were calculated by dividing the gross returns with cost of cultivation in the system. The recommended agronomic packages of practices of the state were followed for raising different crops at both the regions over the locations and years.

Collection of soil samples and their analysis :

Soil samples from 0-15 cm depth were collected from all the cropping systems at two different locations. These soil samples were air dried, grinded, sieved and stored in plastic bags for laboratory studies. Rapid titration method (wet digestion method) was used for organic carbon determination (Walkley and Black, 1934). Available nitrogen, phosphorus and potassium were determined from the soil samples by the methods described by Subbiah and Asija (1956), Olsen *et al.,* (1954) and Merwin and Peech (1950) respectively.

Statistical analysis :

The statistical analysis was done with the help of method described by Panse and Sukhatme, (1985). Critical difference (CD) was used to compare the treatments effects at $P<0.05$.

RESULTS AND DISCUSSION

Effect of cropping systems on soil fertility parameters :

The data presented in table 2 reported low range (<0.4 %) of organic carbon (OC) in all the cropping systems at southwestern districts of Punjab. The OC varied from 0.32-0.38 per cent in all the cropping systems. Among all the cropping systems, the lowest per cent of OC was reported by nutrient exhaustive rice-wheat system at southwestern region of Punjab. On the other hand, same trend of OC was noted at central plain and undulating zone where OC ranged from 0.24-0.30 per cent. The OC value at central plain and undulating zone was quite low as compared to southwestern zone. The data further reported that rice based systems including leguminous crops were able to maintain OC levels

(0.38 %) close to its medium range (0.40-0.75 %). Bharambe and Tomar (2004) in rice-wheat system reported an increase in organic carbon with FYM application associated with organic fertilizers. Available nitrogen (N) in all the cropping systems varied from 168-182 kg ha^{-1} and the highest level of N was reported by rice-gram-summer moongbean cropping system (182 kg ha^{-1}) followed by rice-gobhi sarson-summer moongbean cropping system (180 kg ha^{-1}). Interestingly rice-wheat cropping system reported the minimum level of N (168 kg ha^{-1}).Same trend of observations on available N was reported at central plain and undulating zone where available N ranged from 136-148 kg ha^{-1}. Chapale and Badole (1999) reported that GM plus NPK fertilizers helped in release of more N in soil under rice crop.

The data presented in table clearly evinced the buildup of available P_2O_5 in all the cropping systems at both the locations. The available P_2O_5 in all the cropping systems varied from 20.2-22.4 kg ha^{-1}. The highest amount of available P_2O_5 was reported by rice-gram-summer moongbean cropping system (22.4 kg ha^{-1}). Same trend of observations was reported in all the cropping systems at central plain and undulating zone where the levels of available P_2O_5 ranged from 18.4-21.2 kg ha^{-1}. The buildup of available P_2O_5 in all the cropping systems at both the locations may be ascribed to the fact that farmers apply SSP and DAP fertilizers. Yaduvanshi (2001) reported low amount of available P which may be attributed to ammonia volatilization losses from integrated nutrient management in rice fields of alkali soils.In all the cropping systems the available K_2O reported in medium range (137-237 kg ha^{-1}) and these levels varied from 143-154 kg ha^{-1} at southwestern districts of Punjab. The highest level of available K_2O was reported by rice-gobhi sarson-summer moongbean cropping system (154 kg ha^{-1}) followed by rice-gram-summer moongbean cropping system (152 kg ha^{-1}). On the other hand the available K_2O at central plain and undulating zone reported low (<137 kg ha^{-1}) in all the cropping systems varying from 116-130 kg ha^{-1}. The depletion of K_2O level may be attributed to the fact that farmers didn't apply potassic fertilizers to their crops. Sharma *et al.* (2000) reported higher amount of available K in an inceptisol resulted from residue management under rice-wheat cropping sequence. Our results further concluded that fertility parameters depleted over a period of time and none of cropping systems were able to sustain the fertility status of soil with respect to OC, available N, P and K.

Effect of cropping systems on productivity :

The highest productivity in terms of rice equivalent yield was found to be the highest for rice-gobhi sarson- summer moongbean in both the regions and it was 144.80 q ha^{-1} and 147.6 q ha^{-1} for south western region and central and undulating plain zone region respectively (Table 3). The REY significantly varied from each other in all sequences studied in both the regions. The system productivity (kg grain ha^{-1} day^{-1}) was also the highest for rice- gobhi sarson-summer moongbean in both the regions i.e. 39.7 kg grain ha^{-1} day^{-1} in south western region and 40.4 kg grain ha^{-1} day^{-1} in central undulating plain zone region and this was followed by rice-gram- summer moongbean and rice -wheat in both the regions. Bhandari *et al.* (2000) conducted the on-farm research studies during 1991-94 on the different cropping systems under irrigated conditions in three districts of Punjab (Kapurthala, Jalandhar and Hoshiarpur) and revealed that growing of three crops in sequence like rice-gobhi sarson- summer moongbean, are the only alternatives for increasing and sustaining the productivity over a longer period of time.

Effect of cropping systems on stability index :

The stability index of all cropping systems varied in two regions under study. The stability index of different crops varied from 0.61 to 0.84 in southwestern region while it varies from 0.54 to 0.95 in central and undulating plain zone region (Table 3). The rice-wheat sequence was most stable in central and undulating plain zone region having stability index of 0.92 but in south western region the rice-gobhi sarson- summer moongbean sequence was most stable with stability index of 0.88.

Effect of cropping systems on economic viability:

The maximum net returns and profitability were obtained from rice-gobhi sarson-summer moongbean system in both the regions studied. This was due to high prices of mungbean (Table 3). The net

Table 1. Location and characteristics features of experimental regions

Characteristics	Regions	
	South western zone (Faridkot-Ferozpur-Moga)	**Central and Undulating plain zone (Ludhiana-Moga-Fatehgarh Sahib-Nawanshahar)**
Latitude	30°40' N	30° to 32°56' N
Longitude	74°48' E	75° to 76°52' E
Altitude	242	247
Ecosystem	Sub humid to semi arid	Semi-arid and sub-tropical

Table 2. Soil fertility parameters under different cropping systems at two locations

Sr. No.	Cropping Systems	OC (%)	Avail. N	Avail. P (kg ha^{-1})	Avail. K
South western region					
1	Rice-wheat	0.32	168	20.2	143
2	Rice-gobhi sarson	0.34	174	21.6	146
3	Rice- gobhi sarson-summer moongbean	0.38	180	22.0	154
4	Rice-gram-summer moongbean	0.38	182	22.4	152
5	Rice-gram	0.36	176	21.8	146
SE±		0.01	1.5	0.40	2.2
CD(0.05)		0.04	4.6	1.2	6.6
Central and undulating plain zone region					
1	Rice-wheat	0.24	136	18.4	116
2	Rice-gobhi sarson	0.26	140	19.2	121
3	Rice- gobhi sarson-summer moongbean	0.30	144	20.6	127
4	Rice-gram-summer moongbean	0.30	148	21.2	130
5	Rice-gram	0.26	142	19.6	123
SE±		0.02	1.1	0.3	2.0
CD(0.05)		0.06	3.3	1.0	5.8

Table 3. Productivity, stability and economic viability of various crop sequences at two regions in Punjab

Sequence	Pooled yield (q ha^{-1})			REY (q ha^{-1})	Productivity (kg ha^{-1}day^{-1})	Stability Index				Economic viability		
	K*	R*	S*			K	R	S	Sequence	Net return (Rs ha-^{1})	Profitability (Rs ha^{-1} day^{-1})	B:C ratio
South-western region												
Rice-wheat	62.8	51.8		122.5	33.5	0.84	0.83		0.87	78838	216.0	2.4
Rice-gobhi sarson	62.4	16.9		104.9	28.7	0.84	0.75		0.85	66264	181.5	2.3
Rice-gobhi sarson-summer moongbean	62.6	17.0	9.7	144.8	39.7	0.84	0.76	0.81	0.88	90444	247.8	2.3
Rice -gram-summer moongbean	62.8	10.2	9.7	127.8	35.5	0.85	0.61	0.80	0.84	68874	188.7	1.9
Rice-gram	62.6	10.1		88.1	24.1	0.84	0.64		0.83	45059	123.4	1.8
SE±				3.2								
CD (0.05)				9.6								
Central and Undulating plain zone region												
Rice-wheat	65.7	48.2		121.5	33.2	0.82	0.95		0.92	77764	213.0	2.4
Rice-gobhi sarson	65.9	12.2		104.0	28.4	0.82	0.84		0.81	57129	156.5	2.1
Rice-gobhi sarson-summer moongbean	65.7	15.0	10.1	147.6	40.4	0.82	0.87	0.84	0.88	89860	246.2	2.3
Rice- gram-summer moongbean	65.7	9.5	10.3	133.1	36.5	0.81	0.66	0.87	0.82	72833	200.0	2.0
Rice-gram	65.9	12.4		99.2	27.2	0.83	0.78		0.85	55162	151.1	2.0
SE±				2.1								
CD (0.05)				6.4								

*K-*kharif*, R- *rabi*, S-Summer
Price (Rs.q^{-1}) in two regions: Rice=1110, Wheat=1285, Gobhi Sarson= 2800, Gram= 2800, Moongbean= 4500

return was Rs. 90444 and profitability was Rs. 247.8 ha^{-1} day^{-1} for rice-gobhi sarson-summer moongbean in the south western region and the net return of Rs. 89860 and profitability of Rs 246.2 ha^{-1} day^{-1} was obtained for rice-gobhi sarson-summer moongbean system of central undulating plain zone region. But the benefit cost ratio of 2.4 was found to be the highest for rice-wheat system in both the regions. Gangwar *et al.* (2004) also reported that inclusion of pulses, oilseeds and vegetables in the system is more beneficial than cereals after cereals, and such inclusion in a sequence changes the economics of the crop sequences. Therefore, it revealed that with suitable rice-based crop sequences i.e. rice- gobhi sarson- summer moongbean the total productivity and profitability could be increased.

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IMPACT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH PARAMETERS, PHYSIOLOGICAL CHARACTERISTICS, YIELD AND YIELD ATTRIBUTES OF HYBRID RICE

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ABSTRACT

An investigation was conducted during *kharif* seasons of 2005-06 and 2006-07 at the Student Instructional Farm of Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Faizabad, Uttar Pradesh, India to study the impact of integrated nutrient management on growth parameters, physiological characters, yield attributes and yield of hybrid rice and also to explore the possibility of substituting fertilizer through green manuring and work out the dose of zinc sulphate for hybrid rice grown on partially reclaimed salt affected soils of eastern Uttar Pradesh. The plant growth, physiological characters, yield attributing characters and yield of rice were higher with combined application of green manuring and inorganic sources of nutrients as compared to sole application. The results showed that the highest yield and growth was observed with treatment having 75% recommended dose of fertilizer + green manuring followed by 100 % recommended dose of fertilizer. Among zinc sulphate levels, 40 kg $ZnSO_4$ ha^{-1} was found superior for growth, yield attributes and grain yield of hybrid rice grown on partially reclaimed salt affected soil. Study revealed that combined application of organic with inorganic fertilizers helped in increasing crop growth, physiological parameters, yield attributing characters and yield of the hybrid rice. 25% of inorganic fertilizer could be reduced by using dhaincha as green manure without any decrease in the growth and grain yield of hybrid rice.

(Key words: INM, hybrid rice, growth parameters, physiological character and yield)

INTRODUCTION

Integration of chemical and organic sources and their efficient management have shown promising results not only in sustaining the production but also in maintaining soil health (Aulakh, 2011). Rice (*Oryza sativa* L.), the prince among the cereals, is the premier food crop not only in India but in the World also. Our national food security system largely depends on the productivity of rice ecosystem. Hybrid rice technology is a new introduction to India especially in eastern Uttar Pradesh. Hybrid rice produces 15-20 per cent more grain yield than high yielding rice varieties. Its productivity varies largely with the climate, soil type, nutrient management, pest management etc. High productivity of hybrid rice cannot be sustained on the partially reclaimed salt affected soils of Uttar Pradesh unless the declining trend in soil fertility resulting from the huge nutrient removal by hybrid rice is replenished properly. Simultaneously, use of inorganic fertilizer alone is adversely affecting the soil productivity (Sutaria *et al.,* 2011). Zinc is an important micronutrient reported deficient in Indian soils and plays a significant role in various enzymatic and physiological activities of plant bodies (Singh and Singh, 2012).Wide spread deficiency of zinc in various districts of Uttar Pradesh (0.08 to 9.76 ppm) has also been reported by Tiwari and Dwivedi (1994). Zinc deficiency is often reported on rice crops growing in sodic soils (Singh *et al.,* 2009). Integrated nutrient management not only sustains the soil and crop productivity it also ensure environmental and ecological security. Taking these views into consideration, the present investigation was, therefore, undertaken to assess the impact of integrated nutrient management on growth, yield and yield attributes of hybrid rice and also to work out the suitable dose of zinc for hybrid rice for salt affected soils of Uttar Pradesh.

MATERIALS AND METHODS

The present investigation entitled "Impact of integrated nutrient management on growth parameters, physiological characteristics, yield and yield attributes of hybrid rice (*Oryza sativa* L.)" was conducted at the Student Instructional Farm of Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Faizabad, Uttar Pradesh, India during *kharif* (wet) seasons of 2005-06 and 2006-07. The experimental site falls under subtropical zone in Indo-Gangetic plains having alluvial calcareous soil and lies between 24.4^0 - 26.56^0 North latitude and 82.12^0 – 83.98^0 East longitude with an elevation of about 113 m from mean sea level. The district Faizabad falls under sub humid climate receiving mean annual rainfall of about 1200 mm. About 85% of the total rainfal is

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concentrated from mid June to end of September. The experiment was comprised of twenty treatment combinations of four fertility levels viz., green manure, 50% recommended dose of fertilizers + green manure, 75% recommended dose of fertilizers + green manure and 100% recommended dose of fertilizers and 5 levels of Zn sulphate (0, 10, 20, 30 and 40 kg zinc sulphate ha^{-1}). The integration of inorganic fertilizer was done with green manure. Dhaincha (*Sesbania aculeata*) was used as green manuring crop. Green manure crop was raised *in situ* as per treatment. The hybrid rice variety NDRH-2 was taken as test crop. The experiment was laid out in spilt plot design (SPD) with three replications. One seedling hill^{-1} was transplanted at 3 cm depth at the planting at a distance of 20 cm x 15 cm. Nitrogen, phosphorus and potash @ 150, 60 and 60 kg ha^{-1}, respectively were considered as recommended dose of fertilizer (RDF). One third of nitrogen and full dose of phosphorus, potassium and zinc sulphate were applied through urea, single super phosphate, muriate of potash and zinc sulphate, respectively, as per treatment as basal at the time of transplanting. Remaining two third part of nitrogen was top dressed into two equal splits; one at active tillering stage and other at panicle initiation stage. Plant height was recorded with the help of meter scale at harvest. The length between the base of stem touching the ground and the top most tip of the plant was considered as height of plant and averaged. The number of tillers hill^{-1} was counted at maximum tillering stage. The number of panicle m^{-2} in each plot was taken with help of quadrate (1 x 1m) at harvest and values were averaged. Five plants were collected from the tagged plants in each plot and the average length of panicle was recorded. Five panicles from each plot were taken at random at maturity stage for weighing, the weight of grains panicles^{-1} and averaged. 1000 grains were counted and weighed from the samples of grains drawn from each net plot and recorded as test weight. After taking the bundles weight of the harvested produce of each net plot, their grains were separated manually. The grains of each plot thus obtained were air dried, weighed and recorded in kg plot^{-1}. Finally it was converted into kg ha^{-1}. Total chlorophyll content was estimated according to method of Arnon (1949) and expressed as mg g^{-1} fresh weight of leaves. Data were analyzed statistically by the method of Analysis of Variance as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Integrated Nutrient Management in hybrid rice had significant influence on growth parameters of hybrid rice (Table 1). Maximum plant height and number of tillers hill^{-1} were observed with treatment receiving 75% RDF+GM followed by 100% RDF. The plant height and number of tillers hill^{-1} were also significantly affected by various levels of zinc sulphate. The maximum height of plant was recorded in plot having 40 kg zinc sulphate ha^{-1} which was at par with 30 kg zinc sulphate ha^{-1} and significantly superior over 0, 10 and 20 kg zinc sulphate ha^{-1}. Increase in growth parameters might be due to rapid growth caused by adequate nutrient supply to the crops, which resulted an increase in various metabolic processes and performed better mobilization of synthesized carbohydrates in amino acids and proteins which in turn stimulated the rapid cell division and cell elongation, thus allowed the plant to grow faster. Parasuraman (2005) reported that the integrated use of N fertilizer with dhaincha found to affect the growth and yield attributes, such as plant height, total dry matter production hill^{-1}, productive tillers hill^{-1}, panicle length and weight, number of filled grains panicle^{-1} and 1000 grain weight favourably.

The highest chlorophyll content (2.43 and 2.47 mg g^{-1} fresh weight), leaf area index (5.21 and 5.31), panicle length (29.90 and 30.10 cm), panicle weight (5.79 and 5.84 g) and test weight (25.80 and 25.90 g) (Table 1) were recorded under treatment having 75% RDF + GM followed by 100% RDF, whereas minimum were recorded in green manuring alone. Integrated nutrient management was found to have significant effect on chlorophyll content and leaf area index, panicle weight, panicle length and test weight. Singh *et al.* (2009) reported significant positive correlation of grain yield with leaf area index and panicle number. Green manure decomposed rapidly and supplied N to rice plants due to its narrow C: N ratio a few weeks after its application. Integration of organic and inorganic sources of nutrient might be attributed to well developed source and sink capacity of the plant which ultimately resulted in the higher yield attributing characters viz., number of panicle m^{-2}, length and weight of panicle, number of grains panicle^{-1} and 1000 grain weight.

Table 1. Impact of integrated nutrient management on growth parameters, physiological characters and yield attributes of hybrid rice

Treatments	Growth parameters				Physiological characters				Yield attributes					
	Plant height (cm)		Number of tillers $hill^{-1}$		Chlorophyll content (mg g^{-1} fresh wt.)		Leaf area index		Panicle length (cm)		Panicle weight (g)		Test weight (g)	
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
Fertility levels														
GM	108	109	7.50	7.60	1.61	1.64	4.62	4.68	25.10	26.20	4.88	4.91	24.50	24.40
50% RDF+GM	114	116	8.70	8.60	1.82	1.86	4.83	4.87	27.60	27.80	5.34	5.31	25.00	25.10
75%RDF+GM	123	124	9.60	9.80	2.43	2.47	5.21	5.31	29.90	30.10	5.79	5.84	25.80	25.90
100% RDF	120	121	9.50	9.60	2.25	2.30	5.15	5.21	29.00	29.20	5.62	5.68	25.60	25.60
SEm ±	2.79	2.83	0.19	0.19	0.04	0.04	0.11	0.11	0.61	0.62	0.12	0.12	0.57	0.57
CD (P=0.05)	9.67	9.79	0.66	0.66	0.14	0.15	0.38	0.38	2.12	2.16	0.41	0.41	0.31	0.31
Zinc Sulphate Levels (Kg ha^{-1})														
0 kg ha^{-1}	99	100	7.54	7.61	1.73	1.77	4.23	4.29	23.85	24.21	4.62	4.65	24.78	24.81
10 Kg ha^{-1}	107	108	8.17	8.24	1.88	1.91	4.59	4.65	25.84	26.23	5.01	5.03	24.88	24.90
20 Kg ha^{-1}	119	121	9.09	9.17	2.09	2.13	5.10	5.17	28.74	29.17	5.57	5.60	24.97	25.00
30 Kg ha^{-1}	125	127	9.56	9.64	2.20	2.24	5.36	5.43	30.21	30.67	5.85	5.88	25.67	25.69
40 Kg ha^{-1}	128	130	9.77	9.85	2.24	2.29	5.48	5.55	30.87	31.34	5.98	6.01	25.82	25.85
SEm±	1.55	1.57	0.11	0.11	0.02	0.02	0.06	0.06	0.34	0.35	0.07	0.07	0.31	0.31
CD (P=0.05)	4.48	4.53	0.31	0.31	0.07	0.07	0.18	0.18	0.99	1.00	0.19	0.19	0.89	0.89

Note : Interactions effect of fertility levels and zinc sulphate levels was found non-significant for these parameters

Table 2. Impact of integrated nutrient management on grain yield of hybrid rice (kg ha^{-1})

Fertility level	GM		50% RDF + GM		75% RDF+GM		100% RDF		Mean	
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
Zinc level										
0 kg zinc sulphate ha^{-1}	3338	3413	4745	4775	5244	5301	4838	4873	**4541**	**4591**
10 kg zinc sulphate ha^{-1}	3833	3919	5352	5386	5883	5948	5555	5595	**5156**	**5212**
20 kg zinc sulphate ha^{-1}	4245	4340	5960	5998	6523	6594	6063	6106	**5697**	**5760**
30 kg zinc sulphate ha^{-1}	4574	4678	6422	6464	7130	7208	6690	6738	**6204**	**6272**
40 kg zinc sulphate ha^{-1}	4616	4720	6451	6493	7194	7273	6720	6768	**6245**	**6313**
Mean	**4121**	**4214**	**5786**	**5823**	**6395**	**6465**	**5973**	**6016**		

	2005		2006	
	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)
Fertility level (F)	98	339	80	276
Zn level (Zn)	46	132	45	131
F x Zn	92	264	91	261

Similarly, Awan *et al.* (2000) observed that application of nitrogen fertilizer along with organic manure significantly increased the number of tillers plant^{-1}, number of spiklets panicle^{-1}, test weight and paddy yield than control.

Levels of zinc had also significant effect on chlorophyll content, leaf area index, panicle length, panicle weight and test weight. The maximum chlorophyll content (2.24 and 2.29 mg g^{-1} fresh weight), leaf area index (5.48 and 5.55), panicle length (30.87 and 31.34 cm), panicle weight (5.98 and 6.01g) and test weight (25.82 and 25.85 g) were found with 40 kg $ZnSO_4$ ha^{-1} followed by 30 kg $ZnSO_4$ ha^{-1} in the year 2005 and 2006, respectively (Table 1). Panda *et al.* (1999) reported that content of chlorophyll a and b increased with 50 mg Zn compared to control. Significant effect of zinc on yield contributing characters viz., panicle length, panicle weight and 1000 grain weight were increased significantly with increasing levels of zinc over control. However, maximum response of zinc was recorded where 40 kg zinc sulphate ha^{-1} applied. This is probably due to the fact that zinc is an essential component of several enzymic systems which regulate various metabolic activities in rice plant. Zinc is also necessary for the formation of auxin, growth promoting substances in plants.

Perusal of data (Table 2) showed that grain yield of rice crop was greatly affected by integrated nutrient management. The maximum grain yield (6395 and 6465 kg ha^{-1}) was recorded with treatment having 75% RDF + GM which was significantly superior over rest of the treatments in both the years. Inorganic fertilizers in combination with green manure influenced the grain yield of rice significantly over green manuring and inorganic fertilizers alone. Grain yield in combination with inorganic and organic manures gave better results, because of improved physical condition of the soil thereby improving the efficiency in utilization of native as well as applied nutrients which ultimately improved the yield attributing characters and yield of crop. Tripathi *et al.* (2005) reported that the rice yield was considerably higher due to the combined use of 75% RDF of NPK fertilizer and green manuring comparing yield obtained at 100% recommended rate alone. Yadav and Kumar (2009) reported that soil organic matter is known to serve as soil conditioners, nutrient resource, substrate for microbial activity, preserver of environment and major determinant for sustaining agricultural productivity.

Positive effects of zinc levels were observed on grain yield. The maximum grain yield (6245 and 6313 kg ha^{-1}) was recorded with 40 kg $ZnSO_4$ ha^{-1} which was at par with 30 kg $ZnSO_4$ ha^{-1} and superior over rest of the zinc levels during both the years 2005 and 2006. Application of zinc enhanced the grain yield may be due to positive effect of zinc application on yield attributing characters. Application of Zn produced the highest grain and straw yield were also reported by (Ravichandran *et.al.,* 2006). Interaction effect between integrated fertility combination and zinc levels was found significant for grain yield. The maximum grain yield (7194 and 7273 kg ha^{-1}) was found in combination of 75% RDF + GM and 40 kg $ZnSO_4$ ha^{-1} which was at par with treatment combination of 75% RDF + GM and 30 kg $ZnSO_4$ ha^{-1} in the years 2005 and 2006, respectively.

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EFFECT OF HETEROCYCLIC NITROGEN ON MORPHOLOGICAL, YIELD AND FIBER QUALITY TRAITS IN COTTON (*Gossypium hirsutum* L.)

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ABSTRACT

Field experiment was conducted with transgenic cotton hybrid RCH 134 Bt during 2009-10 on a loamy sand soil in the Department of Soil Science, Punjab Agricultural University, Ludhiana to study the bio-efficacy of Allwin Top (an organic fertilizer) in cotton. Six different combinations of organic source (Allwin Top) and inorganic fertilizers were evaluated. Significantly higher number of sympods plant^{-1} (28.0) and seed cotton yield (2561 kg ha^{-1}) were recorded in three sprays of Allwin Top (2.0 g l^{-1} of water) alongwith 100 per cent RDF, against 24.9 sympods and 2155 kg ha^{-1} seed cotton yield in 100% RDF only, (Control). This increase in seed cotton yield was mainly attributed to higher boll number (61.6) and boll weight (3.74 g). Higher ginning out turn (34.1%) and seed cotton yield (18.8%) observed in treatment with 3 sprays of Allwin Top (2 g l^{-1}) alongwith 100 % RDF resulted in significantly higher lint yield. Similarly, treatment receiving three foliar applications of Allwin Top @ 1.5 g l^{-1} of water alongwith 100 per cent RDF, resulted in significant increase in boll number plant^{-1} (58.3), boll weight (3.94 g) and seed cotton yield (2338 kg ha^{-1}) over the 100 % RDF treatment. The study suggested that three sprays of Allwin Top @2.0 g l^{-1} water can save 25% of the fertilizers with the same yield levels. To get higher yields, three sprays of Allwin Top (1.5 or 2.0 g l^{-1} of water) can be applied alongwith 100% RDF.

(Key words: Organic fertilizer, Allwin Top, yield and fiber quality traits, Bt hybrid)

INTRODUCTION

Soil health is a crucial factor for realizing higher yields of vegetables, pulses, cereals and fiber crops. Farmers use nitrogenous fertilizers to get high yield that drives modern agriculture. The excessive application of chemical fertilizers may affect the soil health. The use of nitrogenous fertilizers will continue to increase with the growing requirement of food due to increased population. Food and Agriculture Organization of the United States (FAO) suggests that under current conditions annual fertilizer use must increase from the 134 million tons average between 1995 and 1997 to about 180 million tons by 2030 (Anonymous, 2000). These fertilizers have negative effect on the environment, since most plants utilize less than half of the N fertilizers applied by growers. The remaining large portion of the fertilizers either leaches down to lower layers resulting in dead zones or volatizes in the form of N_2O which contribute to global green house gases.

The productivity of cotton in India is the lowest among the top ten cotton producers in the world (Anonymous, 2009). One of the important factors for low productivity is the unbalanced use of fertilizers (Khadi, *et al*., 2007). Seed cotton yield and quality in cotton has been found to increase with the use of growth regulators and micro-nutrients. The application of Biovita, an organic biofertilizer, has been found affective for enhancing sewed cotton yield, boll number and boll weight in American cotton (Gumber *et al*., 2007). Granular application of Biovita @ 20 kg ha^{-1} at sowing time followed by three foliar applications of liquid Biovita @ 500, 600 and 750 ml ha^{-1}at flowering, boll development and boll diversion stages alongwith RDF gave the highest seed cotton yield (Buttar and Kaur, 2010).

So, it is very important to search for possible alternate organic source that can sustain soil health and crop production. Scientists are concentrating on development of organic fertilizers and till date large number of such nutrients has been developed and is in use. The agricultural scientists at Channai have developed two patented plant nutrients, Allwin Wonder and Allwin Top, (Sundaresan, 2009). They claim that these plant nutrients can increase the yield of the crops like rice, wheat, pulses, cotton and vegetables upto 20 per cent. These nutrients stimulate the plant growth and make the plant to absorb most of the essential vital nutrients in the soil. Allwin Top (0.5% and 1.0%) supported the growth of plants in black gram, green gram, beans, karamani and paddy (Kalaichelvan, 2009). The present study was, therefore, undertaken to study the bio-efficacy of Allwin Top in cotton.

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MATERIALS AND METHODS

The field study was conducted during 2009-10 at Punjab Agricultural University, Ludhiana on a loamy sand soil. There were total of 6 treatments (Table 1) and the experiment was laid out in a randomized complete block design with three replications. The soil under study was non-saline with pH 7.78 (1:2, soil / water suspension) and 4.3 g kg^{-1} organic carbon (Walkley and Black, 1934), and available soil P (Olsen *et al.,*1954) and soil K (Helmke and Sparks, 1996) were medium, judged on the basis of Olsen- P(6.38 mg kg^{-1}) and NH4OAc-extractable K (63.3 mg kg^{-1}). In the control (T6) treatment no application of Allwin Top was made and only recommended dose of fertilizers (N150, $P_2O_5$30, K_2O30 and $ZnSO_4$@ 25 kg ha^{-1}) was applied. Treatments T_1 to T_3 consisted of application of 3 sprays of Allwin Top (1.0, 1.5 and 2.0 g $liter^{-1}$ of water) alongwith 100% RDF. Similarly, 3 foliar sprays of Allwin Top (1.5 and 2.0 g $liter^{-1}$ of water) were applied in treatment T4 and T5 receiving 75 % of the RDF, respectively. The first spray was made 25 days after sowing followed by two sprays at 50 and 75 days after sowing. All other agronomical practices were followed as per package and practices for *kharif* crops recommended by PAU, Ludhiana to raise a good crop. Allwin Top was evaluated in cotton for its nutrient saving, crop yield, crop quality and its optimum time of its application as foliar application after planting. Morpho-physiological and yield attributes were estimated from five randomly selected plants from each treatment. Fiber properties viz., span length, fiber strength, fiber fineness and uniformity ratio, were estimated with the help of Premier Art II machine (ICC mode) installed at Cotton Section, Department of Plant Breeding and Genetics, PAU, Ludhiana. The data were analyzed statistically using completely randomized block design and the differences were compared at probability level of $p< 0.05$(Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Morphological, yield and yield attributing traits :

The data revealed that application of three sprays of Allwin Top @ 2.0 g $litre^{-1}$of water at 25 days interval each alongwith 100 per cent recommended dose of fertilizers (RDF) resulted in significant improvement in almost all the morphological, yield and yield attributing characters except number of monopods $plant^{-1}$ in RCH 134 Bt cotton compared with RDF alone during *kharif* 2009-10 (Table 1). Significantly higher number of sympods $plant^{-1}$ (28.0) was recorded in treatment receiving three sprays of Allwin Top (2.0 gl^{-1} of water) alongwith 100 % RDF against 24.9 in 100% RDF only, (control). The significant increase in plant height (131.4 cm) in treatment receiving three sprays of Allwin Top (2.0 gl^{-1} of water) alongwith 100 % RDF over the control plot (122.3 cm) receiving 100 % RDF was also observed. Maximum seed cotton yield of 2561 kg ha^{-1} was recorded in treatment receiving three sprays of Allwin Top (2.0 gl^{-1} of water) alongwith 100 % RDF against 2155 kg ha^{-1} in 100% RDF only (control). This increase in seed cotton yield was mainly attributed to its component traits (boll number and boll weight) as higher number of bolls $plant^{-1}$ (61.6) and boll weight (3.74 g) was observed in treatment receiving three sprays of Allwin Top (2.0 gl^{-1} of water) alongwith 100 % RDF against 100 % RDF (control) with 54.9 bolls $plant^{-1}$ and 3.46 g boll weight. Seed index was also better in treatment receiving three sprays of Allwin Top (2.0 gl^{-1} of water) alongwith 100 % RDF. As the plants were taller with more number of sympods $plant^{-1}$ the stalk yield also increased significantly in treatment receiving three sprays of Allwin Top (2.0 gl^{-1} of water) alongwith 100 % RDF which ultimately affected the total biomass as compared to the application of 100% RDF only, (control). Therefore, the application of 3 sprays of Allwin Top (2.0 gl^{-1} water) increased the number of sympods $plant^{-1}$, plant height, number of bolls $plant^{-1}$, boll weight, seed cotton yield, seed index and stalk yield by 12.4, 7.4, 12.2, 8.1, 18.8, 12.0 and 16.2% over RDF alone (control), respectively. This indicated that application of Allwin Top @ 2.0 gl^{-1} water alongwith 100 per cent RDF was effective in improving the yield and yield contributing traits. Further, the yields obtained with the application of 75 % of the RDF alongwith three sprays (first spray after 25 days of sowing followed by two sprays i.e. at 50 and 75 days after sowing) of Allwin top @ 2.0 gl^{-1} of water were on par as compared to the application of 100 per cent of RDF. It suggests that three sprays of Allwin Top @ 2.0 gl^{-1} of water with 75% of RDF alone can save 25 per cent of the fertilizers with the same yield levels.

Table 1. Effect of Allwin Top on morpho-physiological and yield traits on RCH 134 Bt.

Treatments	Number of monopods plant^{-1}	Number of sympods plant^{-1}	Plant height (cm)	Number of bolls plant^{-1}	Boll weight (g)	Seed cotton yield (kg ha^{-1})	Seed index (g)	Stalk yield (kg ha^{-1})
Allwin Top @ 1.0 g litre^{-1} water + 100% RDF (T_1)	2.97	24.8	122.2	56.2	3.60	2221	7.03	4759
Allwin Top @ 1.5 g litre^{-1} water + 100% RDF (T_2)	2.90	25.1	123.8	58.3*	3.94*	2338*	7.23	4664
Allwin Top @ 2.0 g litre^{-1} water + 100% RDF (T_3)	2.85	28.0*	131.4*	61.6*	3.74*	2561*	8.04*	5430*
Allwin Top @ 1.5 g litre^{-1} water + 75% RDF (T_4)	2.85	23.8	120.4	52.6	3.10	1885	6.97	4114
Allwin Top @ 2.0 g litre^{-1} water + 75% RDF (T_5)	3.05	24.4	119.3	53.1	3.40	2061	7.17	4290
100% RDF (Control)(T_6)	2.90	24.9	122.3	54.9	3.46	2155	7.18	4674
SEm±	-	0.36	1.78	0.98	0.04	34.62	0.16	123.17
CD at 5 %	-	1.05	5.19	2.87	0.14	100.4	0.49	357.2

RDF - Recommended dose of fertilizers

Table 2. Effect of Allwin Top on lint yield and fibre quality traits in RCH 134 Bt.

Treatments	Lint yield (kg ha^{-1})	Ginning outturn (%)	Lint index (g)	2.5% span length (mm)	Fibre strength (g tex^{-1})	Fibre fineness (Mic value)	Uniformity ratio
Allwin Top @ 1.0 g $litre^{-1}$ water + 100% RDF (T_1)	707	33.22	3.52	27.3	21.4	3.92	52.2
Allwin Top @ 1.5 g $litre^{-1}$ water + 100% RDF (T_2)	743	33.79	3.82	26.8*	21.4	4.42	52.2
Allwin Top @ 2.0 g $litre^{-1}$ water + 100% RDF (T_3)	874*	34.11*	4.00*	27.8	22.0	4.47	52.7
Allwin Top @ 1.5 g $litre^{-1}$ water + 75% RDF (T_4)	662	33.13	3.45	26.6*	22.6	4.27	50.7
Allwin Top @ 2.0 g $litre^{-1}$ water + 75% RDF (T_5)	675	33.47	3.68	26.7	20.7	4.32	52.7
100% RDF (Control) (T_6)	743	33.29	3.69	27.6	20.9	4.17	52.1
SEm±	25.37	0.17	0.07	0.21	-	-	-
CD at 5 %	73.60	0.50	0.23	0.61	-	-	-

RDF - Recommended dose of fertilizers

Alongwith RDF, application of Allwin Top @ 1.5 gl^{-1} of water resulted in the significant increase in number of bolls $plant^{-1}$ (58.3), boll weight (3.94 g) and seed cotton yield (2338 kg ha^{-1}) over control, (Table 1). Further, the yields obtained with the application of 75 % of the RDF alongwith three sprays of Allwin top @ 1.5 gl^{-1} of water, were remained at par with control (100 per cent of RDF). Different yield and yield contributing characters were not influenced by Allwin Top when applied at 1.0 g $litre^{-1}$ of water with RDF over 100 % RDF alone. Application of three sprays of both 1.5 & 2.0 gl^{-1} of water with 100 per cent RDF produced significantly higher yields over the 100 per cent of RDF. It is interesting to note that there was an increase of 8.5 and 18.8 per cent increase in yield with the application of three sprays of 1.5 and 2.0 gl^{-1} of water of Allwin Top with 100 % of the RDF respectively, over the using 100 per cent of RDF.

Lint yield and lint quality attributes :

The lint yield depends upon the seed cotton yield and ginning outturn of the genotype. Significantly higher ginning outturn (34.11 %) was observed in treatment receiving three sprays of Allwin Top (2.0 gl^{-1} of water) alongwith 100 % RDF as compared to control. As seed cotton yield was also higher in treatment receiving three sprays of Allwin Top (2.0 gl^{-1} of water) alongwith 100 % RDF so lint yield was also recorded to be significantly higher (874 kg ha^{-1}) as compared to 743 kg ha^{-1} in control treatment. The estimation of lint index involves ginning outturn and seed index, and it mainly depends on the ginning outturn. In treatment receiving three sprays of Allwin Top (2.0 gl^{-1} of water) alongwith 100 % RDF the ginning out turn was significantly better than the control which ultimately affects the lint index. None of the fiber quality parameters showed improvement with the application of Allwin Top rather there was significant decrease in 2.5% span length when Allwin Top was applied @ 1.5 g $litre^{-1}$ of water both with 100% RDF (T_2) and 75% RDF (T_4). The fiber strength, fiber fineness and uniformity ratio remained unaffected with the application of Allwin Top as non-significant differences were observed among the treatments.

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ESTIMATION OF N P K STATUS OF THE SAMPLED SOIL OF *INCEPTISOL* FROM JANJGIR DISTRICT OF CHHATTISGARH

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ABSTRACT

A detailed study of *Inceptisol* of Akaltara block, Janjgir district of Chhattisgarh was undertaken to assess the fertility status in the year 2010. After systematic survey, surface (0-15cm) soil samples were collected from 79 villages in Akaltara block covering 1000 sites (10000 ha) using the GPS such that one sample represents each grid of 10 ha based soil area represented. The soils were strongly acidic to neutral in reaction and the electrical conductivity of the soils showed safe limits. Soil was low to medium in organic carbon, low in available N, P and medium in available K content. The nutrient index with respect to available N, P and K was also calculated on village basis. The available nitrogen content ranged from 100.35 to 338.69 kg ha $^{-1}$ with an average of 171.12 kg ha^{-1}. The available phosphorus content ranged from 4.04 to 20.38 kg ha^{-1} with an average of 8.61 kg ha^{-1}. The available K content ranged from 107.49 to 290.52 kg ha^{-1} with an average of 186.64 kg ha^{-1}. The samples of the study area were determined for pH and observed in the range of 4.8-6.70 with the mean value of 5.83. The Electrical conductivity of the soil water suspension ranged from 0.06 to 0.36 dS m^{-1} at 25^{o}C, with an average of 0.12 dS m^{-1}, in the soil samples of Inceptisol collected from different villages of Akaltara block. The organic carbon in all samples exhibited range of 0.23 to 0.66% with an average of 0.48%. Thus, the Inceptisol of Akaltara block are low in organic carbon content. The significant and positive correlations were observed between soil pH and available N, P and K. EC of the soils showed significant positive relationship with available P and K. Available N and P showed significant and positive correlation with organic carbon status. From the above, the farmers could be advised to use required quantity of lime to ameliorate soil acidity along with use of recommended dose of fertilizers especially nitrogenous and phosphatic fertilizers on soil test based values for obtaining maximum productivity of the crops.

(Key words : *Inceptisol* of Akaltara block, nutrient status)

INTRODUCTION

Inceptisol is locally called *Matasi*. This soil is immature with weakly developed profile features. The soil is light textured with shallow to moderate depth. The soil is marginally suited for upland crops due to lack of structural stability, tendency to surface sealing and hard setting on drying, high susceptibility to erosion and limited water holding capacity. Under this order, the dominating sub-groups are Typic Haplustepts and Vertic Haplustepts which have clayey texture with clay content varying from 48.0 to 55.0 per cent. Typic Haplustepts is sandy clay loam to clay in texture with clay content ranging from 33.2 to 50.4 per cent. Clay content in the soil generally increased with depth indicating movement of clay from surface to sub surface layers. Very high profile water storage capacity was observed in Vertic Haplustepts and high profile water storage capacity was observed in Typic Haplustepts. The district Janjgir is lying between 21.06^{0} to 22.04^{0} North latitude, 82.03^{0} to 83.02^{0} East longitude and 294.4 m. high from mean sea level and it is situated in the centre of the Indian state of Chhattisgarh, so it is considered as the Heart of Chhattisgarh, is a major contributor of food grains in the state of Chhattisgarh. The Hasdeobango irrigation project has been considered as life supporting canal for the area which irrigates 75% area. There is need of location specific research attention on delineation of NPK status of soils and their deficiency and toxicities affecting the crop growth. Such study is felt necessary now more than ever before. Hence, estimation of soil fertility status of Inceptisol of Janjgir district (C.G.) was undertaken. This system maintains soil fertility and plant nutrient supply from various sources through an integrated approach also.

MATERIALS AND METHODS

The investigation to evaluate the soil fertility status of *Inceptisol* in different villages of Akaltara block of Janjgir-Champa district of C.G was undertaken during the year 2010. In each village, mainly four types of soil are present, namely *Entisol, Inceptisol, Alfisol and Vertisol. Inceptisol* have been taken for systematic survey under study. Total 79 villages were included under the study. The villages were Chandaniya, Changori , Katnai, Ameri, Barbaspur, Latiya, Saraipali, Devarikhod, Suwarmal, Taga, Sonsari, Karumahu, Parsada (Leelagartir),

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Gadola, Akaltari, Sonadula, Pharada, Khisora, Jhiriya, Madhuva, Khaparidih, Amartal, Tarod, Lilawadih, Sondih, Darri, Mahuadih, Sajapali, Parsahi-Bana, Bana, Barpili, Karhidih, Buchihardi, Bhaistara-Damami, Padriya, Sankar, Murlidih, Dhanva, Kirari, Khod, Jhilmila, Amora, Kotgarh, Mahamadpur, Nariyara, Khatola, Arjuni, Rogda, Bamhani, Pondilalha, Pakriya, Pauna, Arasmeta, Banahil, Pachri-Khod, Parsahi-Podi, Katghari, Raseda, Mudpar, Pakriya, Amalipali, Barganwa, Kalyanpur, Birkoni, Piparda, Sondih, Parsada, Bhaistara-Malgujari, Tilai, Kotmi, Piparsatti, Kapan, Dalha-Damami, Nawapara, Akaltara and Hardi. The area to be mapped was divided into small systematic grids of whole agricultural land of each village. The village maps prepared by land revenue records was obtained from the concerned department. Once these maps were obtained in digital format, suitable soil sampling spots were precisely identified by overlaying systematic grids. The approach roads were overlaid on the map and the exact position of sampling spots (latitude, longitude) were obtained. Once the spots were fixed, they were navigated and the correct spot with the help of global positioning system (GPS) was finalised. The method of using these techniques for devising suitable soil sampling plan has been described by Polive and Aubert (1998). The application of soil sampling for spatial fertilizer recommendation is described recently by Grandzinski *et al.* (1998).

Systematic or grid sampling :

Sampling points were pre-determined across a field for a soil type under study at fixed interval systematically across a grid from each of 10 ha area. Within each of such sample point, five samples were randomly taken for further analysis, to represent the 10 hectares area selected under the *Inceptisol* soil.

Table work :

Land System maps published by Chhattisgarh InfoTech and Biotech Promotion Society (CIBPS) and Indian Space Research Organisation (ISRO) in 2004-05 at the scale of 1:4000 have been used as the cadastral maps for conducting the field survey works. Prior to the actual fieldwork, tentative sampling sites were fixed on the cadastral maps. These sampling sites were set and distributed in such a way that all the agriculturally important land system units are proportionately represented.

Field work:

Following the sampling sites fixed in the cadastral map, soil samples (15 cm) were collected from each grid point using soil auger and local spade with proper labels.

Laboratory work:

Soil samples collected from the study area were dried and crushed with the help of wooden rod and passed through 2 mm sieve and then used for the determination of soil pH, organic matter, macronutrients and micronutrients content by adopting standard laboratory methods.

Methods of analysis:

Available N was determined by alkaline $KMnO_4$ method as described by Subbiah and Asija (1956). Available phosphorus in the soil was extracted by 0.5M $NaHCO_3$ (pH 8.5) as described by Olsen *et al.* (1954) and phosphorus in the extract was determined by ascorbic acid method as described by Watanabe and Olsen (1965). Soil potassium was extracted by shaking with neutral normal ammonium acetate for five minutes at a constant temperature (25^0C) as described by Hanway and Heidel, (1952) and then K in the extract was estimated by flame photometer. Soil pH was determined by glass electrode pH meter in 1:2.5 soil water suspensions after stirring for 30 minutes as described by Piper (1967). The soil samples used for pH determination were allowed to settle down the soil particles for 24 hours. And the electrical conductivity of supernatant liquid was determined by Solu-bridge as described by Black (1965). Organic carbon was estimated by Walkley and Black's rapid titration method (1934) as described by Jackson (1967).

Statistical Analysis :

A Complete enumeration of all the sample points under the *Inceptisol* stratum was made for different soils variables of interest under different fertility groups. Standard statistical procedure including correlation studies was adapted to analyze the data.

RESULTS AND DISCUSSION

Available N, P and K status of soils :
Nitrogen :

The data of available nitrogen content of different soil samples of *Inceptisol* collected from different villages of Akaltara block are given in table 1. The results showed that the available nitrogen content ranged from 100.35 to 338.69 kg ha^{-1} with an average of 171.12 kg ha^{-1}. Considering the soil test rating for available N (<280 kg ha^{-1} as low, 280-560 kg ha^{-1} as medium and >560 kg ha^{-1} as high), majority of the sampled area (97.70 %) fall under low (<280 kg ha^{-1}) in available nitrogen content (Table 1). Only 2.30% soil samples were categorized under medium (280-560 kg ha^{-1}) in available nitrogen content. In this way, almost all the soil samples tested were found to be deficient in N. It is quite obvious that being a mobile nature and low uptake recovery due to its losses through various mechanism like NH_3 volatilization, nitrification, succeeding, denitrification, chemical and microbial fixation, leaching and runoff (De and Buresh,1989), residual/available N becomes poor in soil. Ramesh *et al.* (1994) reported that in soils of Guntur district of Andhra Pradesh, available content of nitrogen showed a variation from 85 to 282 kg ha^{-1}. Kumar *et al.* (2009) observed that an available N content of Dumka and Lachimpur series varied from 125 to 310 kg ha^{-1} with a mean of 216 kg ha^{-1} and 210 to 545 kg ha^{-1} with a mean of 401 kg ha^{-1} in soils of Santhal Paraganas region of Jharkhand.

Phosphorous :

The data of available phosphorus content of different soil samples of *Inceptisol* collected from different villages of Akaltara block are given in table 1. The results showed that the available phosphorus content ranged from 4.04 to 20.38 kg ha^{-1} with an average of 8.61 kg ha^{-1}. The range is quite large which might be due to variation in soil properties viz., pH, calcareousness, organic matter content, texture and various soil management and agronomic practices. Considering the soil test rating for available P (<12.5 kg ha^{-1} as low, 12.5-25 kg ha^{-1} as medium and >25 kg ha^{-1} as high), majority of the sampled area (91.10 %) fall under low status (<12.5 kg ha^{-1}) in available phosphorus (Table 1). Only 8.90% soil samples were categorized under medium (12.5-25 kg ha^{-1}) status in available phosphorus. In this way, almost all the soil samples tested were found to be deficient in available P. Ramesh *et al.* (1994) reported that the available P content ranged from 5.0 to 38 kg ha^{-1} in Psamment soils of Guntur district of Andhra Pradesh. Kumar *et al.* (2009) observed that an available P content in soils ranged from 5.60 to 14.20 and 7.00 to 13.40 kg ha^{-1} with mean value of 10.00 and 9.00 kg ha^{-1} in Dumka and Lachimpur series, respectively.

Potassium:

The data of available potassium content of different soil samples of *Inceptisol* collected from different villages of Akaltara block are given in table 1. The results showed that the available potassium content ranged from 107.49 to 290.52 kg ha^{-1} with an average of 186.64 kg ha^{-1}.Considering the soil test rating for available K (<135 kg ha^{-1} as low, 135-335 kg ha^{-1} as medium and >335 kg ha^{-1} as high), majority of the sampled area (94.10 %) fall under medium (135-335 kg ha^{-1}) in available potassium content (Table 1) and 5.90% soil samples were categorized under low (<135 kg ha^{-1}) in available potassium content. Adequate (medium) available K in these soils may be attributed to the prevalence of potassium rich minerals like *illite* and *feldspars.* Rajeswar *et al.* (2009) analyzed the available potassium in all the pedons varied from 110 to 389 kg ha^{-1} in soils of Garikapadu of Krishna district of Andhra Pradesh.

Soil reaction (pH):

The samples of the study area were determined for pH (Table 2) and were observed in the range of 4.8-6.70 with the mean value of 5.83. The pH estimated from total 1000 soil samples of Akaltara block covering about 76 villages showed that nearly 42.90% samples fall under moderately acidic (5.5-6.0), 29.80% under slightly acidic (6.0-6.5), 26.30 % under (<5.5) strongly acidic (Table 2) and only 1.00% samples were categorized under neutral soil reaction. The relative low pH of the soils is due to low base saturation and light textured soil. Kumar *et al.* (2009) characterized the soils of Santhal Paraganas region of Jharkhand. They reported that Dumaka soil series were found in low pH range (from 3.80 to 6.40) and Lachimpur series showed wide variation in pH (4.60 to 7.70).

Electrical conductivity (E.C.) :

Data regarding electrical conductivity of different soil samples of Inceptisol collected from different villages of Akaltara block are given in table 2. The results showed that the EC of the soil water suspension ranged from 0.06 to 0.36 dS m^{-1} at 25°C, with an average of 0.12 dS m^{-1}. The results showed that the soluble salt content was under (<1.0 dS m^{-1}) normal range (Table 2) and there was no deleterious effect on crop. The normal soil EC may be ascribed due to leaching of salts to lower horizons and its light textured nature. Sharma and Chaudhary (2007) reported that available EC status in the soil profiles of different soil series ranged from 0.09 to 0.40 dS m^{-1} in lower Shiwaliks of Solan district in North–West Himalayas.

Organic carbon :

The organic carbon in all samples exhibited range of 0.23 to 0.66% with an average of 0.48%. (Table 2). Thus, the *Inceptisol* of Akaltara block are low in organic carbon content. Distribution of soil samples with respect to organic carbon content also indicates (Table 2) that about 61% samples have low (<0.50 %) and 39 % medium (0.50-0.75%) organic carbon. Use of almost nil to very low amount of organic wastes like farm yard manure and chemical fertilizers in imbalanced manner are the main reasons for poor organic carbon and low productivity of the region.

Correlation studies of macronutrient
Nitrogen :

A significant positive correlation (r = 0.106**) was found between pH and available nitrogen (table 4). This result shows that available N increased with the increase in pH from acidic to near neutral range. Due to favourable microbial activity, the availability of nitrogen becomes maximum at neutral soil reaction. Jain (1997) reported a significant positive correlation between available nitrogen and pH in soils of IGKV farm, Raipur. No significant correlation (r = 0.025) was found between available nitrogen and electrical conductivity (Table 4). A significant positive correlation (r = 0.114**) was found between organic carbon and available nitrogen (Table 4). There is a definite relation of organic carbon with available nitrogen because organic matter can release the mineralizable nitrogen in the soil. Hence, organic carbon status of the soil can predict the available nitrogen which shows positive relationship. Kumar *et al.* (2009) showed that relationship between available N content was a highly significant and positive correlation with organic carbon (r = 0.838**) in Lachimpur series in soils of Santhal Paraganas region of Jharkhand.

Phosphorus :

Available P was positively and significantly correlated with pH (r = 0.758**) (Table 4). It is a fact that P availability is strongly regulated by pH and since the *Inceptisol* under study had the pH trend in to the moderately acidic to neutral range hence, available P might have increased with the increase in pH level up to neutral range. Electrical conductivity of these soils showed positive significant correlation (r = 0.479**) with available phosphorus (Table 4). A significant positive correlation (r = 0.119**) was obtained between organic carbon and available phosphorus (Table 4). This relationship might be due to the presence of high amount of organic phosphorus and after its decomposition, humus is formed which forms complex with Al and Fe present in soil as dominant level and that can cause a protective cover for P fixation with Al and Fe thus reduce phosphorus adsorption / phosphate fixation (Tisdel *et al.,*1997). The presence of organic matter itself may also be indicative for enhanced P availability. Waghmare *et al.* (2009) reported that a significant positive correlation (r = 0.34**) was observed between organic carbon and available phosphorus in some soils of Ausa tahsil of Latur district.

Potassium :

A significant and positive correlation (r = 0.282**) was observed between available K with pH (Table 4). This may be attributed due to fact that the solubility of soil K increased by pH increment. Pal and Mukhopadhyay (1992) reported that a significant and positive correlation between available K and pH in in *Inceptisol* of West Bengal.

Electrical conductivity of these soils had showed positive significant correlation (r = 0.132**) with available potassium (Table 4). No significant correlation (r = 0.058) was found between available

Table 1. Mean and standard deviation of available nitrogen, phosphorus and potassium of Akaltara block

Soil characteristics	Range	Mean	S.D
Available N (kg ha^{-1})	100.35-338.69	171.12	$\pm$38.61
Available P (kg ha^{-1})	4.04-20.38	8.61	$\pm$2.95
Available K (kg ha^{-1})	107.49-290.52	186.64	$\pm$34.76

Number and per cent soil samples under ratings

Available nitrogen			Available phosphorus			Available potassium		
Nitrogen (kg ha^{-1})	No. of samples analyzed	Per cent (%) of samples	Phosphorus (kg ha^{-1})	No. of samples analyzed	Per cent (%) of samples	Potassium (kg ha^{-1})	No. of samples analyzed	Per cent (%) of samples
Low (<280)	977	97.70%	Low (<12.5)	911	91.10%	Low (<135)	59	5.90%
Medium (280-560)	23	2.30%	Medium (12.5-25)	89	8.90%	Medium (135-335)	941	94.10%
High (>560)	0	0%	High (>25)	0	0.00%	High (>335)	0	0.00%
Total	1000	100%	Total	1000	100%	Total	1000	100%

Table 2. Mean and standard deviation of Soil pH, EC and Organic carbon of Akaltara block

Soil characteristics	Range	Mean	S.D
pH (1:2.5, Soil: water)	4.8-6.70	5.83	±0.38
E.C. (dS m^{-1})	0.06-0.36	0.12	±0.04
O.C. (%)	0.23-0.66	0.48	±0.06

Number and per cent soil samples under ratings

Soil Reaction	Soil pH: No. of samples analyzed	Soil pH: % of samples	E.C. (dS m^{-1})	EC: No. of samples analyzed	EC: % of samples	Organic carbon (%)	OC: No. of samples analyzed	OC: % of samples
<5.5 (strongly)	263	26.30%	No deleterious effect on crop (<1)	1000	100.00%	Low (<0.50)	606	60.60%
5.5-6 (moderately)	429	42.90%	Critical for germination (1-2)	0	0%	Medium (0.50-0.75)	394	39.40%
6-6.5 (slightly)	298	29.80%	Critical for salt sensitive crop (2-3)	0	0%	High (>0.75)	0	0%
6.5-7.5 (neutral)	10	1.00%	Injurious to most crops (>3)	0	0%			
Total	1000	100%	**Total**	1000	100%	**Total**	1000	100%

Table 3. Mean of various macronutrients in different categories of soil pH and O.C.

	Range	No. of Sample	Mean value of available macronutrient content (kg ha^{-1})		
			N	P	K
p H	<5.5	263	165.86	6.03	175.70
	5.5-6.0	429	169.91	8.26	182.21
	6.0-6.5	298	177.05	11.10	202.03
	6.5-7.5	10	184.71	16.94	205.81
OC	<0.50	606	166.22	8.40	183.68
	0.50-0.75	394	178.66	8.94	191.19
	>0.75	0	0	0	0

Table 4. Correlation coefficient (r) for physico-chemical properties of *Inceptisol* of Akaltara block

	pH	EC	OC	N	P	K
N	0.106**	0.025	0.114**			
P	0.758**	0.479**	0.119**	0.11**		
K	0.282**	0.132**	0.058	0.07*	0.248**	

*Significant at 5% level (0.062)

**Significant at 1% level (0.081)

K and organic carbon (Table 4). Kumar *et al.* (2009) showed that relationship between available K content was a non-significant and positive correlation with organic carbon (r= 0.136 and r = 0.124) in Dumka and Lachimpur series in soils of Santhal Paraganas region of Jharkhand.

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COMPARATIVE EFFICACY OF VARIOUS INHIBITORS AGAINST SPORE GERMINATION OF *Cercospora centellae* INCITING LEAF SPOT OF MANDUKPARNI (*Centella asiatica*)

N. Lakpale[1]

ABSTRACT

Mandukparni (*Centella asiatica*) is one of the important medicinal plants attacked by *Cercospora centellae* inciting leaf spot disease. In the present laboratory study, inhibitors of various origins were tested for their efficacy against spore germination of *C. centellae* during the year 2010-11. Findings revealed that systemic fungicides – Hexaconazole (500 ppm), Propiconazole (500 ppm), Tricyclazole (500 ppm), non- systemic fungicides – Mancozeb (1000 ppm) and Copper oxychloride (1000 ppm) were found the best in inhibiting spore germination i.e. complete inhibition of spore germination. Other fungicides also reduced the spore germination significantly as compared to control. Neem based botanical –Neem-gold (20 ml l^{-1}) was found superior in inhibiting spore germination i.e. complete inhibition of spore germination followed by Achook (5 ml l^{-1}) and Neem oil (5 ml l^{-1}). Among the medicinal plant leaf aqueous extracts tested- *Azadirachta indica* (10%), *Allium cepa* (10%) and *Curcuma amada* (10%) and isolates of fungal bio agent – *Trichoderma viride* isolates 3, 7 and 5 @ 5% were found most effective in inhibiting the spore germination. Isolates of bacterial bio agent were found less effective than fungal bio agent- *Pseudomonas fluorescens* in inhibiting the spore germination.

(Key words :- Indian pennywart, *Cercospora centellae*, Mandukparni (*Centella asiatica*) spore germination)

INTRODUCTION

The importance of plants as major source of therapeutic and other agents has assumed greater importance throughout the world. The tribal state Chhattisgarh is very rich in medicinal and aromatic herbs. These herbs are being used from centuries and generations together for therapeutic and other uses. Mandukparni or Indian pennywart (*Centella asiatica*) is one of the important medicinal plants. Its leaves have Asiaticoside,Saponines and Centic acid, which are being used in preparation of medicines for skin diseases, increasing memory and age**.** Like other crop plants, this crop is also attacked by biotic and abiotic factors. Among biotic factors, diseases have always been considered as a scourge and limiting factors for plant growth and production of quality products (active ingredients having medicinal and aromatic values). Mandukparni is primarily suffered by leaf spot disease incited by *Cercospora centellae.*

Typical symptoms of the disease are small spots on leaf lamina with grey centre and dark brown margin. In later stages, lesions increase in number, coalesce and give blighted appearance leading to drying of leaves.

In the present study, an attempt was made to know the efficacy of fungicides, botanical fungicides, plant extracts and bio-control agents on spore germination of causal organism under laboratory condition (*in vitro*) in order to screen out the effective inhibitors and resultant may be used in field conditions.

MATERIALS AND METHODS

Preparation of spore suspension of *Cercospora centellae* :

Unless and otherwise mentioned, in general spores of causal organism were taken from the infected Mandukparni leaves. Spore suspension was prepared in sterile water in culture tubes and standardized, so as to have above 20-25 spores microscopic field $^{-1}$ under 100 X magnification of compound microscope. This standardized spore suspension was used with different groups of inhibitors. In all the studies, cavity slides containing spore suspension of *C. centellae* mixed with solution of inhibitor(s) were incubated at 25± 1^0C in BOD incubator. Four replications for each treatment along with untreated control were maintained and observations were recorded for spore germination after 24 hrs of incubation.

Efficacy of fungicides :

In this study, systemic fungicides namely Triadimefon (25 WP), Propineb (70 WP), Carbendazim (50 WP), Hexaconazole (5E), Propiconazole (25 EC), Ediphenphos (50 EC), Epoxiconazole (12.5 SC), Chlorothalonil (75 WP), Carboxin (75 WP), Tricyclazole (75 WP), Flusilazole

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(25 WP) each at 500 ppm concentration and non-systemic fungicides like Mancozeb (75 WP), Captan (75 WP), Copper oxychloride (50 WP), Saaf super (Carbendazim 12% + Mancozeb 63% WP) each at 1000 ppm concentration were tested to know their efficacy on spore germination of *C. centellae*. One ml standardized spore suspension was mixed with one ml spore germination stimulant i.e. glucose (0.1%). Thereafter, 0.5 ml of this suspension was mixed with 2 ml solution of each fungicide individually. Two drops of this suspension were placed in each cavity of cavity slides (Anonymous, 1947). Cavity slides containing spore suspension without adding fungicidal solution served as control.

Efficacy of ready to use botanical fungicides :

The comparative efficacy of seven marketed botanical fungicides viz., Achook (5 ml l^{-1}), Neem azal T/S (3 ml l^{-1}), Neem gold (20 ml l^{-1}), Tricure (5 ml l^{-1}), Wanis (5 ml l^{-1}), Biotos (2.5 ml l^{-1}) and Neem oil (4 ml l^{-1}), were tested for spore germination. One ml standardized spore suspension was mixed with one ml spore germination stimulant i.e. glucose (0.1%). Thereafter, 0.5 ml of this suspension was mixed with 2 ml solution of each botanical individually. Two drops of this suspension were placed in each cavity of cavity slides (Anonymous, 1947). Cavity slides containing spore suspension without adding botanical solution served as control.

Efficacy of plant leaf extracts :

In vitro aqueous leaf extracts of different medicinal plants were evaluated for their antifungal activity against spores of causal agent. The fresh leaves of 25 medicinal plants namely Pudina (*Mentha arvensis*), Chitrak (*Plumbago zeylanica*), Kalmegh (*Andrographis paniculata*), Sadabahar (*Catharantus pusillum*), Kiwach (*Mucuna pruriens*), Tikhur (*Curcuma angustifolia*), Bawchi (*Psoralea corylifolia*), Citronella (*Cymbopogon winterianus*), Adusa (*Adhatoda vasica*), Brahmi (*Bacopa monnieri*), Aswagandha (*Withania somnifera*), Datura (*Datura stramonium*), Amahaldi (*Curcuma amada*), Vidhara (*Argyreia speciosa*), Neem (*Azadirachta indica*), Eucalyptus (*Eucalyptus citriodora*), Lemon grass (*Cymbopogon flexuosus*), Jangali-onion (*Allium cepa*), Patchouli (*Pogostemon patchouli*), Bhasmpatti (*Kalanchoe heterophylla*), Ghritkumari (*Aloe-vera*), Khas (*Vetiveria zizanoides*), Roja grass (*Cymbopogon martinii*), Tulsi (*Ocimum sanctum*), Sarpagandha (*Rauvolfia serpentina*) and Satawar (*Asparagus racemosus*) were evaluated for their antifungal activity against spores of the *C. centellae*. The fresh leaves of these medicinal plants were collected from medicinal plants' garden of IGKV, Raipur (C.G.). The extract of each plant species was prepared in water by taking leaf tissues and distilled water in 1:1 ratio (w/v), steamed in water bath for 30 minutes and extracted material was filtered through muslin cloth and filtrate was then passed through Whatman's filter paper no. 42. This filtrate was considered as stock solution. One ml of stock solution was mixed in 9 ml of distilled water to make extract of 10% concentration of each plant species. One ml standardized spore suspension was mixed with one ml spore germination stimulant i.e. glucose (0.1%). Thereafter, 0.5 ml of this suspension was mixed with 2 ml solution of each aqueous extract individually. Two drops of this suspension were placed in each cavity of cavity slides (Anonymous, 1947). Cavity slides containing spore suspension without adding aqueous extract served as control.

Efficacy of bio- agents :

For this study, isolates of fungal bio-control agent like *Trichoderma viride* (Tv_1, Tv_3, Tv_4, Tv_5 and Tv_7) and bacterial bio-control agent like *Pseudomonas fluorescens* (Pf_1 and Pf_2) were evaluated against spores of causal organism. Isolates of *T. viride* were multiplied on Potato Dextrose broth for 7 days and isolates of *P. fluorescens* were multiplied on King's B medium broth for 48 hrs, individually. Both agents were separated from broth through filtration and centrifugation. Thereafter, supernatant of individual isolate was further diluted to 5% concentration in sterilized water and used separately. One ml standardized spore suspension was mixed with one ml spore germination stimulant i.e. glucose (0.1%). Thereafter, 0.5 ml of this suspension was mixed with 2 ml solution of each aqueous extract individually. Two drops of this suspension were placed in each cavity of cavity slides (Anonymous, 1947). Cavity slides containing spore suspension without adding isolates of bio-agent served as control.

RESULTS AND DISCUSSION

Comparative efficacy of fungicides on spore germination of *C. centellae* :

Data presented in table 1 revealed that all the fungicides were found effective as they inhibited the germination of spores of *C. centellae* significantly as compared to that of control. Spore germination of *C. centellae* was not found in Hexaconazole, Propiconazole, Tricyclazole, Mancozeb and Copper oxychloride followed by Saaf super (Carbendazim + Mancozeb) (2.41%), Chlorothalonil (2.71%) and Carbendazim (4.57%). The findings of present study conforms the results about the efficacy of various groups of fungicides obtained by earlier workers against *Cercospora* sp. Briere *et al.* (2003) found Propiconazole effective against *C. beticola* while Mancozeb was not so much effective. Biswas and Singh (2005) observed that Carbendazim was the most effective to control the leaf spot of groundnut (*C. arachidicola*) followed by Propiconazole. Gururaj *et al.* (2005) reported efficacy of Hexaconazole, Difenoconazole and Propiconazole against foliar diseases caused by *Cercospora* sp. Mallesh *et al.* (2008) found Carbendazim and Mancozeb superior over other fungicide tested against *C. kikuchii*. Captan + Hexaconazole and Propiconazole were on par in controlling Cercospora leaf spot of cotton (Bhattiprolu, 2010). Jahagirdar and Hundekar (2010) recorded very low per cent disease index against frog eye leaf spot caused by *C. nicotianae* by Propiconazole and Carbendazim.

Efficacy of botanical fungicides on spore germination of *C. centellae* :

Data presented in table 2 clearly showed that all the botanicals tested were found to inhibit the germination of spores of *C. centellae* significantly as compared to that of control. Spore germination of *C. centellae* was not observed in Neem-gold followed by Achook (2.19%) and Neem-oil (10.62%). Statistically Achook and Neem-oil were at par with each other for inhibition of spore germination. Since these products are neem based, there efficacy might be due to presence of alkaloid – Azadirachtin.

Effect of medicinal plant leaf extracts on spore germination of *C. centellae* :

Data presented in table 3 clearly showed that all the tested medicinal plant leaf extracts were more or less able to inhibit the germination of spores of *C. centellae* as compared to that of control. Medicinal plant leaf extracts found best against spore germination of *C. centellae* were *Azadirachta indica* (19.08%) followed by *Allium cepa* (24.62%) and *Curcuma amada* (26.87%). These leaf extracts were statistically at par with each other for inhibition of spore germination. The effectiveness of extracts might to due presence of alkaloids like Azadirachtin in *Azadirachta indica* and Allacin in *Allium cepa*. Effectiveness of extracts of *Azadirachta indica* and *Allium* sp. against *Cercospora* sp. was also reported by various workers. Salaudeen and Salako (2007) found neem leaf extract and Mahogany bark extract effective in reducing severity of late leaf spot of groundnut (*C. personata*). Bdliya and Alkali (2010) reported that neem and garlic extracts reduced the *Cercospora* leaf spot of groundnut. Poornima *et al.* (2011) found plant extract of *Allium sativum* was best against *Cercospora beticola* followed by *A indica* and *Chromolena odoratum*. Efficacy of Datura extract against Cercospora sp. was reported by Natrajan *et al.* (2005). Thus, present findings support their findings in respect of efficacy of some leaf extracts.

Effect of bio-agents on spore germination of *C. centellae* :

Data presented in table 4 clearly indicate that all the tested isolates of bio-agents significantly inhibited the germination of spores of *C. centellae* as compared to that of control. Isolates of bio-agents found the best against spore germination of *C. centellae* were *Trichoderma viride* isolate 3 (18.83%) followed by *Trichoderma viride* isolate 7 (23.88%) and *Trichoderma viride* isolate 5 (29.82%) but these were statistically at par with each other. Bacterial isolates *Pseudomonas fluorescens* 1 and 2 also inhibited the spore germination significantly but as compared to fungal isolates (Tv), they were less effective. Several other workers also reported the effectiveness of the bio agent. Kishore *et al.* (2005) reported that strains of *Pseudomonas* sp. were found effective against *Cercospora* sp. Raghuchander *et al.* (2005) found that *Pseudomonas fluorescens* and *Bacillus subtilis* were as effective as Carbendazim fungicide in reducing the disease severity of *Cercospora* leaf spot. Mallesh *et al.* (2008) reported

Table 1. Comparative efficacy of fungicides against spore germination of *Cercospora centellae*

Sr. No.	Fungicides	Dose (ppm)	Spore germination (%)*
1.	Triadimefon (25 WP)	100	5.13 (13.06)**
2.	Propineb (70 WP)	500	9.30 (17.76)
3.	Carbendazim (50 WP)	500	4.57 (12.24)
4.	Hexaconazole (5 E)	500	0.00 (0.57)
5.	Propiconazole (25 EC)	500	0.00 (0.57)
6.	Ediphenphos (50 EC)	500	17.92 (25.03)
7.	Epoxiconazole (12.5 SC)	500	35.63 (36.63)
8.	Oxycarboxin (75 WP)	500	21.49 (27.63)
9.	Chlorothalonil (75 WP)	500	2.71 (9.46)
10.	Tricyclazole (75 WP)	500	0.00 (0.57)
11.	Flusilazole (25 WP)	500	15.61 (23.26)
12.	Mancozeb (75 WP)	1000	0.00 (0.57)
13.	Captan (75 WP)	1000	20.37 (26.84)
14.	Copper oxychloride (50 WP)	1000	0.00 (0.57)
15.	Saaf super (Carbendazim 12% + Mancozeb 63% WP)	1000	2.41 (8.91)
16.	Control	-	93.37 (75.00)
	SE(m) $\pm$		1.13
	CD (P = 0.05)		3.16

* Average of four replications
** Data in parenthesis are arc sin transformed values

Table 2. Efficacy of botanical fungicides on spore germination of *Cercospora centellae*

Sr.No.	Botanical fungicides	Dose l^{-1}	Spore germination (%)
1.	Achook	5 ml	2.19 (8.53)
2.	Neem-azal	3 ml	31.39 (34.08)
3.	Neem-gold	20 ml	0.00 (0.57)
4.	Tricure	5 ml	30.09 (33.27)
5.	Wanis	5 ml	17.83 (24.94)
6.	Biotos	2.5 ml	26.31 (30.84)
7.	Neem-oil	4 ml	10.62 (19.00)
8.	Control		93.37 (75.00)
	SE(m) $\pm$		2.07
	CD (P = 0.05)		5.29

Average of four replications
Data in parenthesis are arc sin transformed values

Table 3. Effect of medicinal plant leaf extracts on spore germination of *Cercospora centellae*

Sr.No.	Medicinal plants (each at 10% conc.)	Spore germination (%)
1.	Vidhara (*Argyreia speciosa)*	60.71 (51.18)
2.	Bawchi (*Psoralea corylifolia*),	70.43 (57.10)
3.	Patchouli (*Pogostemon patchouli*)	76.83 (61.21)
4.	Bhasmpatti (Kalanchoe *heterophylla*)	71.56 (57.73)
5.	Ghritkumari (*Aloe-vera*)	69.83 (56.66)
6.	Amahaldi (*Curcuma amada*)	25.90 (30.59)
7.	Tikhur (*Curcuma angustifolia*)	47.07 (43.34)
8.	Jangali-onion (*Allium cepa*)	24.62 (29.73)
9.	Lemon-grass (*Cymbopogon flexuosus*)	59.72 (50.59)
10.	Khas (*Vetiveria zizanoides*)	76.80 (61.21)
11.	Roja grass (*Cymbopogon martinii*)	73.41 (58.96)
12.	Tulsi (*Ocimum sanctum*)	31.76 (34.27)
13.	Sadabahar (*Catharantus pusillum*)	30.17 (50.13)
14	Aswagandha (*Withania somnifera*)	58.92 (26.87)
15.	Brahmi (*Bacopa monnieri*)	26.87 (31.24)
16.	Sarpagandha (*Rauvolfia serpentina*)	59.46 (50.42)
17.	Satawar (*Asparagus racemosus*)	71.33 (57.61)
18.	Kiwach (*Mucuna pruriens*)	74.05 (59.34)
19.	Neem (*Azadirachta indica*)	19.08 (25.92)
20.	Chitrak (*Plumbago zeylanica*)	77.13 (61.41)
21.	Kalmegh (*Andrographis paniculata)*	47.09 (43.34)
22.	Adusa (*Adhatoda vasica*)	55.13 (47.93)
23.	Pudina (*Mentha arvensis*)	38.78 (38.53)
24.	Citronella (*Cymbopogon winterianus*)	80.51 (63.79)
25.	Datura (*Datura stramonium*)	28.34 (32.14)
26.	Control	93.37 (75.00)
	SE(m) ±	1.95
	CD (P=0.05)	4.96

Average of four replications
Data in parenthesis are arc sin transformed values

Table 4 . Effect of bio-agents on spore germination of *Cercospora centellae*

Sr.No.	Bio-agents (each at 5% conc.)	Spore germination (%)
1.	*Trichoderma viride* 1	43.44 (41.21)
2.	*Trichoderma viride* 3	18.83 (25.70)
3.	*Trichoderma viride* 4	61.23 (51.47)
4.	*Trichoderma viride* 5	29.82 (33.09)
5.	*Trichoderma viride* 7	23.88 (29.27)
6.	*Pseudomonas fluorescens* 1	44.80 (42.02)
7.	*Pseudomonas fluorescens* 2	68.87 (56.04)
8.	Control	93.37 (75.00)
	SE(m) ±	2.94
	CD (P=0.05)	7.58

Average of four replications
Data in parenthesis are arc sin transformed values

effectiveness of *Trichoderma viridae* and *T. harzianum* against *Cercospora* sp. Promising antagonistic activity of *Pseudomonas fluorescens* and *Bacillus amyliquefaciens* against *Cercospora* sp. was also reported by Simonetti *et al.* (2012). Thus, the present results conform the findings of these workers.

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COMBINED EFFECT OF FLY ASH AND PAPER MILL SLUDGE ON AGRICULTURAL TOP SOIL

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ABSTRACT

India has a large and diverse agriculture and is one of the world's leading producers. The main sources of land pollution have been the industries like paper and pulp mills, power plants, iron and steel plants, oil refineries etc. Disposal of industrial solid waste affect the soil, thereby inhibiting the crop growth. The present study was carried out during the academic year 2009 with the aim of studying the combined effect of Fly ash and Paper Mill Sludge on Agricultural Top soil.

Individual application of fly ash to cotton crop indicated that the soil samples have an alkaline pH (8.0) with high calcium and aluminum content (2.44 and 24.17% respectively) and relatively lesser amount of potassium (1.6%). Bulk density was found to be as low as 1.48 g/cm^3 by the addition of fly ash. The individual results obtained by the addition of paper mill sludge to orange crop indicated that the soil samples have an alkaline pH (7.9) with high aluminum and potassium content (24.15 and 2% respectively) and relatively lesser amount of phosphorus (0.11%).

Combined addition of fly ash and paper mill sludge to wheat crop showed an effective increase in the nutrient uptake by plants, as compared to control soil. pH of soil showed a drastic increase from 7.6 to 12. Bulk density decreased from 1.56 g/cm^3 to 1.41 g/cm^3. Increase in N (0.05% to 0.12%) and available P (0.08% to 1.1%) and decrease in Zn (0.014% to 0.008%) and Cu (0.05% to 0.001%) content in soil were observed. Available K content of the soil was increased (1.6% to 2%) due to addition of fly ash and paper mill sludge. Ca and Mg values increased from 2.39% to 2.55% and 1.55% to 1.9% respectively.

(Keywords: Fly ash, paper sludge, wheat, cotton, orange, optimum dose)

INTRODUCTION

Scores of waste materials having vital plant nutrients are obtainable in vast quantities in these areas. These materials when applied at appropriate rates can augment the nutrient status in addition to other soil properties.

Flyash is the major solid waste produced in thermal power stations. The quantity of flyash produced annually by the thermal power plant under study is estimated to be 20-25 thousand tons. This flyash is disposed at a distance of 3-5 km from the power plant. Flyash contains plant nutrients and can be used for crop production (Kumar *et al.,* 1999). Yet another industrial solid waste suitable for crop production is the paper sludge or lime sludge as it is rich in crop nutrients.

Addition of paper mill sludge, consisting mainly of carbonates, silicates and organic matter to a heavy-metal polluted soil produces a decrease of available metal forms. The carbonate content plays a key role in the chemical stabilization of metals and consequently decreases the toxicity of soil. The least solutions have a non-toxic effect. The mild remediation by addition of sludge has a lasting effect. Keeping in mind the above mentioned facts, the present study was undertaken to study the combined effect of fly ash and paper mill sludge on agricultural top soil.

MATERIALS AND METHODS

For analysis purpose fly ash and paper sludge was collected from Koradi Thermal Power Station, Koradi and Apex Paper and Pulp Industry, Bazargaon respectively. Crops chosen for individual fly ash, paper mill sludge and combined analysis purpose were cotton, orange and wheat respectively. Soil samples were collected at a depth of about 10-15 cm from five different points on the fields and these grab samples were later mixed to form composite samples, respectively. The soil samples, collected in thick plastic bags were brought to the laboratory for further analysis. The sample was spread out on a tray for air drying. After drying, it was sieved over a 2 mm sieve and stored in air tight polythene bags.

In the present study, clayey black soil was mixed with farmyard manure (10% w/w) and amended with fly ash at 5%, 10%, 20% and 40% w/w, in the laboratory and added to selected site. The crop under study was cotton and wheat. The crop chosen to study the effect of paper mill sludge was orange. Soil was mixed with farmyard manure (10% w/w) and amended with paper mill sludge at 0.5%, 1%, 2% and 4% w/w, in the laboratory and added to selected site.

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In order to study the combined effect of fly ash and paper mill sludge, soil was mixed with 20% fly ash in combination with 10% paper mill sludge.

Physical soil parameters analyzed were pH, bulk density, moisture, water holding capacity and electrical conductivity. Chemical analysis included analysis of per cent organic carbon, silica, calcium, magnesium and aluminum as suggested by Black *et al.*(1965). Analysis of iron, potassium, sodium, titanium, phosphate, zinc, nitrate, copper and manganese were done by standard method prescribed by Jackson (1967).

RESULTS AND DISCUSSION

Industrial waste like fly ash is an important waste resource, having a potential of recycling in agricultural land. Fly ash is a waste product residue resulting from the combustion of pulverized coal in coal-fired power generating station. Physico–chemical analysis of fly ash has revealed the presence of both macro-micro nutrients, which can sustain plant growth. Its application in the agricultural land acts as a liming factor and improves crop growth by neutralizing the soil acidity, increasing the water availability for the plants and supplement of nutrients.

Short-term field studies had shown dose-based effect of coal fly ash on chemical properties of soil. An increase in pH, electrical conductivity, water holding capacity, calcium and aluminum was observed in the soil with increasing dose and time. Fly ash dose of 20% were found to be most suitable for the soil. An increasing dose of 40% was harmful for the soil nutrients and thus plant nutrient uptake. The presence of calcium, magnesium and iron in most of the fly ash samples were found to improve the quality of cotton crop produced. An increase in arsenic content from 0.002 to 0.008% was also observed. Observations of similar nature were done by Pandey *et al*. (2011). They reported that dumping of fly ash in open ash pond causes serious adverse environmental impacts owing to its elevated trace element contents, in particular the arsenic which causes ecological problems.

The residues produced by paper recycling industries, commonly known as paper mill sludge, present some constituents that can correct soil acidity and act as nutrients source, mainly calcium. However, these residues may also have heavy metals, which can cause environmental impact (Balbinot Jr. *et al.,* 2006). One of the best ways of managing this problem is the agricultural use of these wastes as organic amendments (Madejon *et al.,* 2003).

Field experiments were conducted to study the dose effect of paper sludge on crop productivity. An increase in P, K, Fe and Mn in the crops was observed. Total organic carbon significantly increased in soils treated by the addition of paper mill sludge. Similar results were observed by Madejón *et al.* (2003). Their results indicated that the repeated application to the soil of moderate amounts of organic amendment like paper mill sludge had positive effects on the chemical and biochemical properties of the soil. The optimum dose was found to be 2% for paper mill sludge.

Data on various soil parameters by the addition of fly ash and paper mill sludge are given in table 1.

A mixture of fly ash and paper mill sludge was tested. Field experiments were done on wheat crop. The results (Table 2) showed an effective increase in the nutrient uptake by plants, as compared to control soil. Soil pH increased from 7.6 to 12 while electrical conductivity and bulk density showed a decrease from 0.28 dS/m to 0.098 dS/m and 1.56 g/cm^3 to 1.41 g/cm^3 respectively. A noticeable increase in total N and available P (from 0.05% to 0.12% and 0.08% to 1.1% respectively) and decrease in Zn and Cu content (from 0.014% to 0.008% and 0.01% to 0.005% respectively) in soil was observed. Ca and Mg values increased from 2.39% to 2.55% and 1.55% to 1.9% respectively. A result of similar nature was observed by Poykio *et al*., (1998). Their results indicated an increased concentration of P, Ca, K and Mg in amended soil when compared to control soil.

Table 1. Changes in properties of soil on addition of fly ash and paper mill sludge individually

Physical properties	Initial value	Changed value (Fly ash)	Changed value (paper mill sludge)
pH	7.60	8.00	7.90
Electrical conductivity (dS/m)	0.28	0.32	0.31
Natural moisture content (%)	45.00	43.00	43.50
Bulk density (g/cm^3)	1.56	1.48	1.50
Water holding capacity (%)	63.50	65.00	64.55
Chemical properties			
% Organic carbon	0.62	0.60	0.65
SiO_2 (%)	63.10	64.00	63.50
Al_2O_3 (%)	24.07	24.18	24.15
Fe_2O_3 (%)	3.50	3.90	3.50
CaO (%)	2.39	2.43	2.42
MgO (%)	1.55	1.58	1.57
MnO_4 (%)	2.05	2.06	2.05
TiO_2 (%)	0.04	0.05	0.04
P_2O_5 (%)	0.08	0.10	0.11
K_2O (%)	1.60	1.75	2.00
NO_3N (%)	0.05	0.045	0.045
Na_2O (%)	0.38	0.37	0.38
As_2O_3 (%)	0.002	0.008	0.002
CuO (%)	0.01	0.013	0.015
ZnO (%)	0.014	0.018	0.017
ESP	5.00	3.00	3.50

Table 2. Changes in properties of soil on combined addition of fly ash and paper mill sludge

Physical properties	Initial value	Changed value
pH	7.60	12.00
Electrical conductivity (dS/m)	0.28	0.098
Natural moisture content (%)	45.00	40.50
Bulk density (g/cm^3)	1.56	1.41
Water holding capacity (%)	63.50	65.00
Chemical properties		
% Organic carbon	0.62	0.65
SiO_2 (%)	63.10	63.80
Al_2O_3 (%)	24.07	24.19
Fe_2O_3 (%)	3.50	3.70
CaO (%)	2.39	2.55
MgO (%)	1.55	1.90
MnO_4 (%)	2.05	2.9
TiO_2 (%)	0.04	0.04
P_2O_5 (%)	0.08	1.10
K_2O (%)	1.60	2.20
NO_3N (%)	0.05	0.12
Na_2O (%)	0.38	0.40
As_2O_3 (%)	0.002	0.003
CuO (%)	0.01	0.005
ZnO (%)	0.014	0.008
ESP	5.00	4.00

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CORRELATION AND PATH ANALYSIS IN GRAIN QUALITY CHARACTERS IN UPLAND RICE (*Oryza sativa* L.)

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ABSTRACT

In order to determine the associations among grain quality characters and their direct and indirect influence on grain yield plant^{-1} of rice, an experiment was conducted. For this purpose twenty four genotypes were evaluated. The genotypic and phenotypic correlations and path coefficient were estimated for the quality traits viz., L:B ratio, relative density, water absorption, gel consistency, protein content and amylose content with grain yield plant^{-1}. The character L: B ratio and relative density had shown positive and significant correlation with grain yield plant^{-1}. The study of path analysis revealed that quality characters viz., L:B ratio and amylose content exert highest direct effect on grain yield plant^{-1} (0.0450) and (0.0308) respectively and also showed maximum positive indirect effect via number of effective tillers plant^{-1} (0.2172) and (0.0254) followed by number of grains panicle^{-1} (0.1201). Residual effect was 0.4878. Genotypes PBNR 03-07, PBNR 03-10, PBNR 03-11, PBNR 03-20, PBNR 04-23, PBNR 08-01, PBNR 08-04 and PBNR 08-06 were found to be promising genotypes for most preferred grain quality parameters like amylose content and soft gel consistency and genotypes PBNR 03-11, PBNR 04-37 and PBNR 03-10 were found to be promising for protein content.

(Key words: Rice, correlation, path analysis, grain quality characters)

INTRODUCTION

Rice is the only cereal grain cooked and consumed mainly as a whole grains, hence quality considerations are much more important than any other food crop (Hossain *et al.,* 2009). Hence, quality wise performance testing of rice varieties, is an integral part of rice breeding programme, cooking quality in rice is primarily determined by water uptake, soft gel consistency and intermediate amylose content. Association of these characters and path coefficients analysis are prerequisites for improvement of any crop as it help for selection of superior genotypes. Partitioning of total correlation into direct and indirect effect by path coefficient analysis is utilized to have an idea of direct and indirect contribution of particular trait towards the yield. Keeping in view the above facts, the present investigation was undertaken to know correlation of grain yield with grain quality characters in twenty four rice genotypes. The correlation and path analysis were done by the methods suggested by Johanson *et al.*(1955) and Dewey and Lu (1959).

MATERIALS AND METHODS

The experimental material consisted of twenty two genotypes along with two checks i.e. 'Parag' and 'Avishkar'. An experiment was conducted using Randomized Block Design with three replications on experimental field at upland Paddy Research Scheme, MKV, Parbhani, during *kharif* 2011. A plot of 4.5 x 3m^2 was assigned to each genotype with 30 cm spacing between two rows. The recommended agronomic practices were adopted timely to raise the healthy crop, five randomly selected plants of each genotype in each replication were used for recording observations to study the correlation and direct and indirect effect of six grain quality characters viz., L:B ratio, relative density, water absorption, gel consistency, protein content and amylose content on grain yield plant^{-1}.

RESULTS AND DISCUSSION

The analysis of variance revealed highly significant differences for L:B ratio, relative density, water absorption, gel consistency, protein content and amylose content suggesting the presence of high genetic variability among the genotypes (Table 1).

Correlation study revealed that L:B ratio had positive and significant correlation with grain yield plant^{-1} (r_g =0.525, r_P =0.385) at both genotypic and phenotypic levels. Relative density had recorded positive and significant correlation with water absorption (r_g =0.544, r_P =0.283). Relative density had also shown positive correlation with grain yield plant^{-1} (r_g = 0.195, r_P =0.086) (Table 2).

Water absorption showed negative and non significant correlation with grain yield plant^{-1}

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Table 1. Analysis of variance for grain quality parameters

Source	Df	L:B ratio	Gel consistency	Relative density	Water absorption	Protein content	Amylose content
Replication	r-1 =2	0.0283	12.3889	0.0059	0.0000	0.6239	1.5000
Treatments (genotypes)	t-1 = 23	0.8047**	358.4831**	0.0166**	0.1456**	0.7365**	12.9176**
Error	= (r-1) (t-1) = 46	0.1424	18.7802	0.0069	0.0039	0.2623	1.7982

* and ** indicates significant at 5 and 1 per cent level, respectively

Table 2. Genotypic and phenotypic correlations amongst different quality characters in upland rice

Characters		Relative density (g/ml)	Water absorption (mg)	Gel consistency (mm)	Protein content (%)	Amylose content (%)	Grain yield plant^{-1} (g)
L:B ratio	(G)	0.848**	0.275*	0.290*	-0.632**	0.241*	0.525**
	(P)	0.333**	0.194	0.275*	-0.308**	0.170	0.385**
Relative density (g/ml)	(G)		0.544**	0.776**	-0.330**	0.622**	0.195
	(P)		0.283*	0.330**	-0.232	0.224	0.086
Water absorption (mg)	(G)			0.337	0.195	0.513**	-0.158
	(P)			0.314**	-0.107	0.400**	-0.130
Gel consistency (mm)	(G)				-0.117	0.529**	-0.035
	(P)				-0.148	0.402**	-0.026
Protein content (%)	(G)					-0.403**	-0.760**
	(P)					-0.275*	-0.444**
Amylose content (%)	(G)						0.045
	(P)						0.009

(G) – Genotypic, (P) - Phenotypic   *, ** = Significant at 5% and 1% level respectively

Table 3. Path analysis showing direct and indirect effects of various quality traits on yield (Genotypic)

Characters	L:B ratio	Relative density (g/ml)	Water absorption (mg)	Gel consistency (mm)	Protein content (%)	Amylose content (%)	yield plant^{-1} (g)
L:B ratio	**0.0450**	-0.0014	-0.0102	-0.0470	0.0252	0.0052	0.3847**
Relative density (g/ml)	0.0150	**-0.0042**	-0.0149	-0.0563	0.0190	0.0069	0.0858*
Water absorption (mg)	0.0087	-0.0012	**-0.0526**	-0.0536	0.0088	0.0123	-0.1301
Gel consistency (mm)	0.0124	-0.0014	-0.0165	**-0.1707**	0.0121	0.0124	-0.0261
Protein content (%)	-0.0139	0.0010	0.0057	0.0253	**-0.0817**	-0.0085	-0.4437*
Amylose content (%)	0.0076	-0.0009	-0.0210	-0.0686	0.0225	**0.0308**	0.0092

Residual effect = 0.4878

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

Table 4. Mean values of genotypes for quality characters of rice grain

Sr. No.	Genotypes	L:Bratio	Relative density (g ml^{-1})	Water absorption (mg)	Gel consistency (mm)	Protein content (%)	Amylose content (%)
1	PBNR 03-02	3.67	1.235	0.976	47.33	7.50	25.03
2	PBNR 03-07	3.94	1.192	0.78	57.00	6.54	24.33
3	PBNR 03-10	2.86	1.134	0.800	55.33	8.26**	20.94
4	PBNR 03-11	3.10	1.150	0.930	54.33	8.32**	21.88
5	PBNR 03-19	3.56	1.101	0.762	43.00	7.95	18.69
6	PBNR 03-20	3.32	1.141	1.192**	59.00	7.40	24.80
7	PBNR 04-23	3.76	1.207	1.185**	56.66	6.70	21.77
8	PBNR 04-24	3.33	1.162	0.922	46.33	8.12	24.23
9	PBNR 04-26	3.43	1.225	1.025	64.00	7.49	25.04
10	PBNR 04-27	3.59	1.070	0.910	42.33	7.92	21.43
11	PBNR 04-28	4.27	1.292	1.160**	65.33	6.84	24.67
12	PBNR 04-30	3.70	1.225	0.943	44.66	7.72	24.07
13	PBNR 04-32	3.40	1.287	1.022	70.66	7.85	22.61
14	PBNR 04-36	3.75	1.212	1.150**	67.33	7.05	24.96
15	PBNR 04-37	3.26	1.152	0.755	47.66	8.29**	18.98
16	PBNR 08-01	4.00	1.333	1.132**	55.33	7.48	22.17
17	PBNR 08-02	3.52	1.112	0.870	43.00	7.11	21.00
18	PBNR 08-03	3.01	1.243	0.712	72.33	7.78	24.66
19	PBNR 08-04	3.75	1.222	1.065	60.66	8.04	20.53
20	PBNR 08-05	3.44	1.119	0.972	45.33	7.41	21.97
21	PBNR 08-06	3.60	1.115	0.874	77.66	7.82	23.82
22	PBNR 08-07	3.61	1.131	0.130	44.00	7.20	19.40
23	Parag (ch)	4.48	1.302	0.942	68.00	7.39	21.09
24	Avishkar (ch)	5.37	1.310	1.022	70.00	7.45	24.89
	Mean	3.658	1.194	0.926	56.55	7.57	22.62
	SE	0.217	0.047	0.036	2.50	0.29	0.77
	CD 5%	0.619	0.135	0.103	7.11	0.84	2.20
	CV%	10.31	6.927	6.768	7.66	6.76	6.92

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

(r_g =-0.158, r_P = -0.130) at both genotypic and phenotypic levels. The gel consistency had positive and significant correlation with amylose content (r_g = 0.529, r_P = 0.402) and recorded negative association with grain yield plant^{-1} (r_g = -0.035, r_P = -0.026). Similar to this findings Deosarkar (1985) also reported that L:B ratio was significantly correlated with grain yield plant^{-1}.

Protein content had negative and significant correlation with grain yield plant^{-1} (r_g = - 0.760, r_P = -0.444) at both genotypic and phenotypic levels. Nayak (2007) also reported a negative correlation between yield and protein content.

Path analysis was carried out to find out the extent and nature of direct and indirect effects of different quality characters on grain yield and the results are presented in table 3.

L:B ratio had recorded significant positive direct effect (0.0450) on grain yield plant^{-1}. The character also showed maximum positive indirect effect (0.2172) via number of effective tillers plant^{-1} followed by number of grains panicle^{-1} (0.1201). These results are in conformity with the findings of Nandan and Singh (2010). They revealed that kernel length and breadth had maximum direct effect on grain yield plant^{-1}.

Relative density showed negative direct effect (-0.0042) on grain yield plant^{-1}. The character also exhibited low positive indirect effect (0.0573) through number of grains panicle^{-1} followed by number of tillers plant^{-1} (0.0528). Water absorption (-0.0526) and gel consistency (-0.1707) had recorded negative direct effect on grain yield plant^{-1}.

Protein content had recorded negative direct effect (-0.0817) on grain yield plant^{-1}. This character showed low positive indirect effect via gel consistency. Amylose content showed positive direct effect (0.0308) on grain yield plant^{-1}. The character also exhibited positive indirect effect (0.0254) through number of effective tillers plant^{-1}. Plant height had recorded negative direct effect (-0.1042) on grain plant^{-1}. This character also showed positive indirect effect (0.0722) on grain yield plant^{-1} through gel consistency.

These results are in conformity with the findings of Deosarkar (1985), who reported that qualitative characters viz., L:B ratio and amylose content exerted highest direct effect on grain yield plant^{-1}, but protein content showed negative indirect effect on grain yield plant^{-1} via number of effective tillers plant^{-1} and number of grains panicle^{-1}.

Based on the study of correlation and path analysis L:B ratio, relative density, amylose content, gel consistency and protein content these quality characters were used for identifying promising genotypes. On the basis of mean performance of genotypes for L:B ratio, all the genotypes had recorded slender grains except PBNR 03-10. The genotype PBNR 08-01 (1.333 gml^{-1}) was with highest relative density as compare to check Avishkar (1.310 gml^{-1}). The most preferred grain quality parameters like intermediate amylose content and soft gel consistency was recorded in genotypes PBNR 03-07, PBNR 03-10, PBNR 03-11, PBNR 03-20, PBNR 04-23, PBNR 08-01, PBNR 08-04 and PBNR 08-06. The maximum protein content was recorded in the genotypes PBNR 03-11 (8.32%), PBNR 04-37 (8.29%) and PBNR 03-10 (8.26%).

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PHYSIOLOGICAL RESPONSES OF FOLIAR APPLICATION OF HUMIC ACID THROUGH VERMICOMPOST WASH ON MORPHO-PHYSIOLOGICAL, YIELD AND YIELD CONTRIBUTING PARAMETERS OF MUSTARD (*Brassica juncea*)

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ABSTRACT

The effect of humic acid through vermicompost wash (100, 150, 200, 250, 300, 350, 400, 450, 500 ppm) on the morpho-physiological yield and yield contributing parameters of mustard cv. Pusa Bold was studied during *rabi* 2011-2012 at farm of Botany section, college of Agriculture, Nagpur. Experiment was conducted in RBD with three replications. Morpho-physiological parameters such as plant height, number of primary branches, leaf area and dry weight of plant at 35, 50, 65 and 80 DAS were recorded. RGR, NAR were calculated at 50-35, 65-50 and 80-65 DAS. Observations on yield and yield contributing parameters like 1000 seed weight, number of the siliqua plant^{-1}, seed yield ha^{-1} were recorded. All these above mentioned parameters were analyzed statistically, Considering the treatments under study two foliar sprays of 400 ppm followed by 350 ppm, 300 ppm and 250 ppm humic acid through vermicompost wash at 30 and 45 DAS were found to be most effective in improving morpho-physiological, yield and yield contributing parameters of mustard (cv. Pusa Bold) when compared with control. Hence, it can be inferred from the results that two foliar sprays of 400 ppm humic acid through vermicompost wash at 30 and 45 DAS significantly enhanced all parameters under study. The yield increased by this treatment was 28 per cent over control having B:C ratio of 2.75.

(Keywords: Mustard, humic acid,vermicompost wash,morpho-physiological yield and yield contributing parameters)

INTRODUCTION

Indian mustard (*Brassica juncea*) locally called as "rai" "raya" or "laha", is an important oilseed crop belonging to *Brassica* group.The English word "mustard" derives from the Anglo-Norman *mustarde* and Old Frence *mostarde*. Mustard (*Brassica juncea*) is a second important oil seed crop in India after groundnut in area and production. It belongs to family Cruciferae with chromosome number 2n = 36. Humic acid (HA) is as important components of soil organic matter, which could improve the soil properties and crop nutrition. Humic acids are intermediates in complexity between humins and fulvic acids persist in soil for a longer period so that to be useful to the crops.

HA with high molecular weight are not known to be assimilate while these with low molecular weight are said to be assimilate by the plant (Chandrasekaran, 1992). Between three humic substances, humic acid have received the most attention and has been extensively studied to find out its effect on several crop plants. Vermicompost wash is useful as foliar spray. It is transparent pale yellow biofertilizer. It is a mixture of excretory products and mucous secretion of earth worm *(Lampito mautrii* and *Eisenia fetida)* and organic micronutrients of soil, which may be promoted as "potent fertilizer" for better yield and growth (Shweta *et al*., 2005). Vermicompost wash is having approximately 1300 ppm humic acid, 116 ppm dissolve oxygen, 50 ppm inorganic phosphate, 168 ppm potassium and 121 ppm sodium (Haripriya and Poonkodi, 2005). Vermicompost wash is having N% 0.29, P % 0.042 , K % 0.143, Ca% 0.186 , Mg% 0.11 , S% 0.058 , Fe 0. 466 ppm, Mn 0.406 ppm ,Zn 0.11 ppm, Cu 0.18 ppm(Anonymous, 2007). Considering the importance of humic acid present investigation was carried out to study the effect of different concentrations of humic acid on morpho-physiological, yield and yield contributing parameters of mustard.

MATERIALS AND METHODS

Present study entitled "Physiological responses of foliar application of humic acid through vermicompost wash on mustard" was undertaken in experimental farm of Botany Section, College of Agriculture, Nagpur during 2011-12. Experiment was laid out in randomized block design. There were ten treatments replicated thrice. These treatments included different concentrations of vermicompost

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wash like T_1 (control), T_2 (100 ppm), T_3 (150 ppm), T_4 (200 ppm), T_5 (250 ppm), T_6 (300 ppm), T_7 (350 ppm), T_8 (400 ppm), T_9 (450 ppm) and T_{10} (500 ppm). Foliar sprays of humic acid through vermicompost wash were given at 30 and 45 DAS respectively. Yield and yield contributing parameters like 1000 seed weight, number of the siliqua plant^{-1}, seed yield ha^{-1} were recorded at the time of harvesting.RGR and NAR were also calculated at 50-35, 65-50 and 80-65 DAS. Similarly observations on morpho-physiological parameters viz.,plant height, number of primary branches, leaf area and dry weight of plant were recorded at 35,50,65 and 80 days after sowing.

RESULTS AND DISCUSSION

Morpho-physiological parameters :

Data regarding morpho-physiological parameters were recorded at 35, 50, 65 and 80 DAS. The morpho-physiological parameters as influenced by the foliar sprays of vermicompost wash are presented in table 1.

Plant height plant^{-1}

At 35 DAS and 50 DAS significantly maximum plant height was recorded in treatment of 400 ppm (T_8) humic acid through vermicompost wash followed by 350 ppm (T_7), 300 ppm (T_6), 250 ppm (T_5), 200 ppm (T_4) , in a descending manner when compared with control and remaining treatments . Treatments 150 ppm (T_3), 450 ppm (T_9), 100 ppm (T_2), and 500 ppm (T_{10}) were found at par with control (T_1). The per cent increase by treatment 400 ppm (T_8) over control was 43.85 at 35 DAS and 14.98 at 50 DAS.At 65 DAS significantly maximum plant was recorded in treatment of 400 ppm (T_8) humic acid through vermicompost wash followed by 350 ppm (T_7) , 300 ppm (T_6), 250 ppm (T_5) , 200 ppm (T_4), 150 ppm (T_3) and 450 ppm (T_9) in a descending manner when compared with control and remaining treatments i.e 100 ppm (T_2) and 500 ppm (T_{10}). Treatment T_2 (100 ppm) and T_{10} (500 ppm) were found at par with control (T_1). The per cent increase by treatment T_8 (400 ppm) over control was 15.27.At 80 DAS significantly maximum plant height was recorded by the application of 400 ppm (T_8) humic acid through vermicompost wash followed by 350 ppm (T_7) , 300 ppm (T_6), 250 ppm (T_5), 200 ppm (T_4) , 150 ppm (T_3), 450 ppm (T_9) and 100 ppm (T_2) in a descending manner when compared with control and treatment T_{10} (500 ppm). The per cent increase by treatment T_8 (400 ppm) over control was 15.97.The foliar application of humic acid through vermicompost wash was the most important factor affecting mustard growth. It has been reported that humic acid increase the number of roots thereby stimulating nutrient uptake and plant development. (Alvarez and Grigera, 2005). It appers that certain component in vermicompost wash or leachate, such as humic acid and plant growth regulators, stimulated plant growth (Arancon *et al.,* 2003). The vermicompost wash or leachate also contains nutrients that might have stimulated plant height in the present investigation.

Number of primary branches :

At 35 DAS significantly maximum number of primary branches were recorded in treatment T_8 (400 ppm) followed by T_7(350 ppm), T_6 (300 ppm), T_5 (250 ppm) and T_4 (200 ppm) in a descending manner when compared with control and rest of the treatments under study. Treatments T_3 (150 ppm), T_9 (450 ppm), T_2 (100 ppm) and T_{10} (500 ppm) were found at par with control (T_1).At 50 DAS significantly maximum number of primary branches were recorded in treatment T_8 (400 ppm) followed by T_7 (350 ppm), T_6 (300 ppm), and T_5 (250 ppm) and in a descending manner when compared with control and rest of the treatments under study. Treatments T_4 (200 ppm), T_3 (150 ppm), T_9 (450 ppm), and T_2 (100 ppm) were also found significantly superior over treatments T_{10} (500 ppm) and T_1 (control) in respect of primary branches.At 65 DAS significantly maximum number of primary branches were noticed in treatment T_8 (400 ppm) followed by T_7 (350 ppm), T_6 (300 ppm), T_5 (250 ppm), T_4 (200 ppm), T_3 (150 ppm) and T_9 (450 ppm) when compared with treatment T_1 (control) and rest of the treatments under study. Similarly treatments T_2 (100 ppm), and T_{10} (500 ppm) also gave significantly more number of primary branches over control (T_1). At 80 DAS significantly more number of primary branches were noticed in treatment T_8 (400 ppm) followed by T_7 (350 ppm), T_6 (300 ppm), T_5 (250 ppm), T_4 (200 ppm), T_3 (150 ppm), and T_9 (450 ppm) in a descending manner when compared with the control. Treatments T_2 (100 ppm),

T_{10} (500 ppm) and T_1 (control) were found at par with each other.

Leaf area of plant :

At 35 DAS significantly maximum leaf area was noticed in treatment T_8 (400 ppm) followed by T_7 (350 ppm), T_6 (300 ppm), T_5 (250 ppm), T_4 (200 ppm) and T_3 (150 ppm) when compared with control and rest of the treatments under study. Treatments T_9 (450 ppm), T_2 (100 ppm) and T_{10} (500 ppm) were found at par with control (T_1).At 50 DAS significantly maximum leaf area was recorded in treatment T_8 (400 ppm) followed by T_7 (350 ppm), T_6 (300 ppm), T_5 (250 ppm) and T_4 (200 ppm) when compared with control and rest of the treatments. Similarly treatments T_3 (150 ppm), T_9 (450 ppm),T_2 (100 ppm) and T_{10} (500 ppm) were found at par with control.At 65 DAS significantly maximum leaf area was recorded in treatment T_8 (400 ppm) followed by T_7 (350 ppm) when compared with control and rest of the treatments under study. Treatments T_6 (300 ppm), T_5 (250 ppm), T_4 (200 ppm) ,T_3 (150 ppm), T_9 (450 ppm) and T_2 (100 ppm) were also produced significantly more leaf area over treatments T_{10} (500 ppm) and T_1 (control).At the 80 DAS significantly maximum leaf area recorded in treatment T_8 (400 ppm) followed by T_7 (350 ppm), T_6 (300 ppm), T_5 (250 ppm) and T_4 (200 ppm) when compared with the control and rest of the treatments. But treatments T_3 (150 ppm), T_9 (450 ppm), T_2 (100 ppm), T_{10} (500 ppm) were found at par with T_1 (control).Data revealed that leaf area increased from 35 to 65 DAS. But at 80 DAS leaf area decreased. It might be due to leaf fall at this stage.The range of leaf area was 1.41 dm^2 in control to 1.92 dm^2 in treatment receiving 400 ppm humic acid through VCW at the 35 DAS, 2.45 dm^2 to 3.35 dm^2 at 50 DAS, 7.07 dm^2 to 7.88 dm^2 at 65 DAS and 4.71 dm^2 to 5.81 dm^2 at 80 DAS respectively. The per cent increase over control was 36.17 at 35 DAS, 36.73 at 50 DAS, 11.45 at 65 DAS, and 23.35 at 80 DAS.

Hence, it can be inferred that when nutrient applied through foliar spray, might have accelerated the metabolic and physiological activities of plant and put up more growth by assimilating more amount of major nutrients and ultimately increased the leaf area of the plant in the present investigation.

Dry weight of plant :

At 35 DAS significantly maximum dry matter was noticed in treatment T_8 (400 ppm) followed by T_7 (350 ppm), T_6 (300 ppm), T_5 (250 ppm), and T_4 (200 ppm) when compared with control and rest of the treatments under observations. Treatments T_3 (150 ppm),T_9 (450 ppm), T_2 (100 ppm) and T_{10} (500 ppm) also gave significantly more dry matter when compared with treatment T_1 (control). At 50 DAS significantly more dry matter was observed in treatment T_8 (400 ppm) and less in treatment T_1 (control).Next to treatment T_8 (400 ppm) treatments were T_7 (350 ppm), T_6 (300 ppm), T_5 (250 ppm), T_4 (200 ppm) and T_3 (150 ppm) in a descending manner. These above mentioned treatments were significantly superior over rest of the treatments and control (T_1) also. Treatments T_9 (450 ppm), T_2 (100 ppm) and T_{10} (500 ppm) were found at par with treatment T_1 (control).At 65 DAS significantly maximum dry matter was recorded in treatment T_8 (400 ppm) followed by T_7 (350 ppm), and T_6 (300 ppm), and minimum in T_1 (control) followed by T_2 (100 ppm) and T_{10} (500 ppm). Treatments T_5 (250 ppm), T_4 (200 ppm), T_3 (150 ppm) and T_9 (450 ppm) also showed their significance in respect of dry matter production in this stage of observation.At 80 DAS significantly maximum dry matter was noticed in treatment T_8 (400 ppm) followed by T_7 (350 ppm), T_6 (300 ppm), T_5 (250 ppm), and T_4 (200 ppm) when compared with control and rest of the treatments under observations. Treatments T_3 (150 ppm), T_9 (450 ppm), T_2 (100 ppm) and T_{10} (500 ppm) were found at par with treatment T_1 (control).

The data showed that there was steep increase in dry weight of plant from 1st stage (35 DAS) to 2nd stage (50 DAS). But thereafter, rapid increase was noticed at 65 and 80 DAS. The treatment receiving foliar spray of nutrients in the form of VCW increased growth in terms of plant height, number of branches and leaf area and it might have contributed photosynthetic potential of plant and ultimately increased dry matter in the present investigation. The range of dry matter production at 35 DAS was 1.56 to 2.09 g, 3.57 to 5.07 g at 50 DAS, 22.50 to 31.57 g at 65 DAS and 46.03 to 50.03 g at 80 DAS in control and 400 ppm humic acid treatment through vermicompost wash respectively. The per cent increase in dry matter with respect to foliar application of 400 ppm humic acid through VCW were 33.97 at 35 DAS, 42.01 at 50 DAS, 40.31 at 65 DAS and 08.68 at 80 DAS. Celk *et al.* (2011) reported the effect of foliar application of humic acid on dry matter accumulation of maize grown under calcareous soil condition. Three foliar application of humic acid doses (0, 0.1, and 0.2%) sprayed at 20 and 35 days after emergence significantly increased dry weight of maize.Khalid and Fawy (2011) also noticed highest dry weight with the foliar application of 0.5% humic acid in corn.

Growth analysis :

The productivity of crop may be related with parameters such as relative growth rate (RGR) and net assimilation rate (NAR). Growth analysis is one of the measures of assessing the yield of plant. The physiological basis of yield difference can be measured through an evaluation of difference in growth parameters and their impact on yield. The data regarding RGR and NAR are given in table 2.

Relative growth rate :

The highest rate of RGR indicates the ability of maximum dry matter for development. The increment in RGR might be associated with maximum leaf area expansion and growth of stem and root. Increment in NAR is related with the increase in total dry weight of plant unit^{-1} of leaf area.

Considering all the treatments under study, significantly maximum RGR was noted in treatment 400 ppm of humic acid through VCW spray i.e 0.062 g g^{-1} day^{-1} at 50-35 DAS, 0.15 g g^{-1} day^{-1} at 65-50 DAS and 0.047 g g^{-1} day^{-1} at 80-65 DAS respectively. While it was lowest in control i.e 0.040 g g^{-1} day^{-1} at 50-35 DAS, 0.09 g g^{-1} day^{-1} at 65-50 DAS and 0.030 g g^{-1} day^{-1} at 80-65 DAS respectively.

At 50-35 DAS all the treatments gave significant variation in respect of RGR when compared with control. Significantly more RGR was recorded in treatment T_8 (400 ppm) followed by T_7 (350 ppm), T_6 (300 ppm), T_5 (250 ppm), T_4 (200 ppm), T_3 (150 ppm) and T_9 (450 ppm) over control (T_1). Treatments T_2 (100 ppm) and T_{10} (500 ppm) were also found significantly superior over the control (T_1). At 65-50 DAS all the treatments gave significant variation in respect of RGR when compared with control. Significantly more RGR was recorded in treatment T_8 (400 ppm) followed by T_7 (350 ppm), T_6 (300 ppm), T_5 (250 ppm), T_4 (200 ppm), T_3 (150 ppm) and T_9 (450 ppm) when compared with control and rest of the treatments under observation. But treatments T_2 (100 ppm) and T_{10} (500 ppm) were found at par with control (T_1). At 80-65 DAS all the treatments gave significant variation in respect of RGR when compared with control. Significantly more RGR was noticed in treatment T_8 (400 ppm) followed by T_7 (350 ppm). Treatment T_6 (300 ppm), T_5 (250 ppm), T_4 (200 ppm), T_3 (150 ppm), T_9 (450 ppm) and T_2 (100 ppm) were also found at par with each other but were found significant superior over control (T_1).

Net assimilation rate :

NAR was significantly maximum in treatment T_8 (400 ppm VCW) i.e. 0.081 g dm^{-2} day^{-1} at 50-35 DAS, 0.33 at 65-55 DAS, and 0.26 at 80-65 DAS, while the values under control were 0.051 g dm^{-2} day^{-1} at 50-35 DAS, 0.28 at 65-50 DAS and 0.17 at 80-65 DAS respectively. At 50-35 DAS, treatments T_8 (400 ppm) followed by T_7 (350 ppm), T_6 (300 ppm), T_5 (250 ppm), T_4 (200 ppm), T_3 (150 ppm), T_9 (450 ppm) and T_2 (100 ppm) were also found at par with each other but remained significantly superior over T_{10} (500 ppm) and T_1 (control).At 65-50 DAS treatments T_8 (400 ppm) was found significantly superior in respect of NAR followed by treatments T_7 (350 ppm), T_6 (300 ppm), T_5 (250 ppm), T_4 (200 ppm), and T_3 (150 ppm), in a descending manner when compared with control and remaining treatments under study. Treatments T_9 (450 ppm), T_2 (100 ppm) and T_{10} (500 ppm) were also found significantly superior in NAR over control (T_1).At 80-65 DAS NAR was significantly maximum in treatment T_8 (400 ppm) followed by treatment T_7 (350 ppm), and T_6 (300 ppm). Treatments T_5 (250 ppm), T_4 (200 ppm), T_3 (150 ppm), T_9 (450 ppm), T_2 (100 ppm) and T_{10} (500 ppm) in a descending manner also gave significantly more NAR over control. The range of the NAR at 50-35 DAS was 0.051- 0.081 g dm^{-2} day^{-1} at 65-50 DAS was 0.28- 0.33 and at 80-65 DAS was 0.17- 0.26 in control and 400 ppm humic acid vermicompost wash application respectively.

Table 1. Effect of humic acid through vermicompost wash on morphological parameters of mustard

Treatments	Plant height (cm)				No.of primary branches				Leaf area plant (dm^2)				Dry weight of plant(g)			
	35DAS	50DAS	65DAS	80DAS	35DAS	50DAS	65DAS	80DAS	35 DAS	50 DAS	65 DAS	80DAS	35 DAS	50 DAS	65 DAS	80DAS
T_1 (control)	35.73	122.97	127.06	127.67	1.87	4.00	4.33	4.40	1.41	2.45	7.07	4.17	1.56	3.57	22.50	46.03
T_2 (100 ppm)	36.33	125.93	134.13	137.13	1.93	4.40	4.80	4.93	1.52	2.62	7.11	4.93	1.68	3.63	23.73	46.32
T_3 (150 ppm)	43.40	128.73	139.87	140.00	2.00	4.87	5.07	5.40	1.63	2.80	7.22	5.15	1.84	4.43	26.57	46.77
T_4 (200 ppm)	44.40	134.00	140.66	143.00	2.07	4.87	5.20	5.40	1.74	2.91	7.40	5.32	1.99	4.53	26.80	47.86
T_5 (250 ppm)	46.00	136.47	143.20	145.00	2.20	4.93	5.20	5.47	1.76	2.92	7.42	5.34	2.03	4.77	28.37	47.93
T_6 (300 ppm)	48.53	138.00	143.43	145.47	2.27	5.07	5.20	5.53	1.77	3.11	7.44	5.36	2.05	4.83	28.43	48.84
T_7 (350 ppm)	49.33	140.87	145.53	147.13	2.27	5.17	5.53	5.80	1.89	3.27	7.75	5.41	2.08	4.87	29.43	49.12
T_8 (400 ppm)	51.40	141.40	146.47	148.07	2.33	5.47	5.67	5.87	1.92	3.35	7.88	5.81	2.09	5.07	31.57	50.02
T_9 (450 ppm)	39.27	126.40	132.60	137.03	1.93	4.53	5.20	5.33	1.43	2.57	7.11	4.86	1.67	4.27	25.10	46.37
T_{10} (500 ppm)	36.67	123.87	128.94	130.13	1.87	4.20	4.67	4.87	1.43	2.57	7.11	4.86	1.85	4.10	25.33	46.06
SE (m)±	2.68	4.13	4.39	4.07	0.09	0.18	0.24	0.29	0.10	0.16	0.10	0.18	0.06	0.24	1.06	0.86
CD at 5%	7.96	12.28	13.07	12.10	0.29	0.54	0.74	0.83	0.29	0.48	0.30	0.55	0.19	0.71	3.15	2.56

Table 2. Effect of humic acid through vermicompost wash on growth parameters, yield and yield contributing parameters of mustard

Treatments	RGR ($g\ g^{-1}\ day$)			NAR ($g\ dm^{-1}\ day^{-1}$)			Yield contributing parameters			
	50-35 DAS	65-50 DAS	80-65 DAS	50-35 DAS	65-50 DAS	80-65 DAS	No.of siliqua $plant^{-1}$	1000 seed weight (g)	Yield ha^{-1} (q)	B : C Ratio
T_1 (control)	0.040	0.09	0.030	0.051	0.280	0.17	202.60	3.23	7.09	2.08
T_2(100ppm)	0.053	0.11	0.034	0.070	0.300	0.20	204.67	3.30	7.40	2.13
T_3(150ppm)	0.055	0.130	0.038	0.072	0.310	0.21	206.70	3.33	7.59	2.16
T_4(200ppm)	0.055	0.132	0.039	0.073	0.313	0.21	209.49	3.37	7.90	2.23
T_5(250ppm)	0.056	0.137	0.039	0.073	0.315	0.22	209.66	3.40	8.70	2.43
T_6(300ppm)	0.058	0.141	0.040	0.075	0.317	0.23	211.61	3.41	8.95	2.48
T_7(350ppm)	0.059	0.146	0.044	0.076	0.320	0.24	218.14	3.41	9.10	2.50
T_8(400ppm)	0.062	0.150	0.047	0.081	0.330	0.26	224.91	3.44	10.09	2.75
T_9(450ppm)	0.054	0.127	0.035	0.071	0.300	0.20	205.30	3.32	7.49	2.02
T_{10}(500ppm)	0.052	0.10	0.034	0.066	0.290	0.19	202.95	3.28	7.39	1.97
SE (m) ±	0.0029	0.0083	0.0021	0.0044	0.0048	0.011	3.471	0.0212	0.391	-
CD at 5%	0.0087	0.024	0.0065	0.013	0.014	0.033	10.31	0.0630	1.163	-

Yield and yield contributing parameters :

Number of siliqua plant^{-1}

Significantly maximum numbers of siliqua plant^{-1} were recorded by treatment T_8 (400 ppm) and T_7 (350 ppm) when compared with control and rest of the treatments under study. Remaining treatments i.e. T_6 (300 ppm), T_5 (250 ppm), T_4 (200 ppm), T_3 (150 ppm), T_9 (450 ppm) and T_2 (100 ppm) and T_{10} (500 ppm) were found at par with each other and with control also. Azarpour *et al.* (2011) studied the effect of nitrogen fertilizer and foliar spraying of humic acid on yield and yield components of cow pea. Results showed that, the effect of humic acid spraying and also nitrogen fertilizer on all studied traits had significant differences in 5% significance level. Interaction effect of humic acid and nitrogen fertilizer on seed yield, number of pods plant^{-1} and number of seed pod^{-1} was significant at 5% level.

1000 seed weight :

Significantly maximum 1000 seed weight was recorded by treatment T_8 (400 ppm) followed by T_7 (350 ppm), T_6 (300 ppm), T_5 (250 ppm) and T_4 (200 ppm) in descending manner and these treatments were found significantly superior over treatment T_1 (control) and rest of the treatments under study. Treatments T_3 (150 ppm), T_9 (450 ppm), T_2 (100 ppm) and T_{10} (500 ppm) also gave significantly more 1000 seed weight when compared with treatment T_1 (control).

Seed yield hectare^{-1}

Seed yield is the economic yield which is final results of physiological activities of plants. Economic yield is that part of biomass that is converted into economic product (Nichiporvic, 1960). Seed yield is influenced by morpho-physiolgical factors such as plant height, total dry matter production, leaf area and are considered as yield contributing parameters. The treatments receiving humic acid through vermicompost wash significantly increased seed yield hectare^{-1} when compared with treatment T_1 (control). Significantly maximum seed yield was recorded in treatment T_8 (400 ppm) followed by T_7 (350ppm) and T_6 (300ppm) when compared with control and remaining treatments under study. Treatments T_5 (250 ppm), T_4 (200 ppm), T_3 (150 ppm) and T_9 (450 ppm) were also found significantly superior over the treatments T_2 (100 ppm), T_{10} (500 ppm) and T_1 (control). Sebastiano *et al*. (2005) and Kaya *et al*. (2005) reported that foliar application of humic acid and zinc alone or in combination have increased the grain yield of bread wheat. Santhi *et al.* (2003) reported that grain yield of rice increased over control due to application of HA. Tangavel *et al*. (2003) found that vermiwash and vermicast increased yield of paddy. Zekeriya Akman (2004) reported that humic acid added foliar fertilizer significantly increased grains ear^{-1} and yield of sweet corn.

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ISOLATION AND IDENTIFICATION OF PLANT GROWTH PROMOTING RHIZOBACTERIA FROM THE RHIZOSPHERE OF SOYBEAN

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ABSTRACT

An investigation entitled "Biochemical characterization of PGPR of soybean (*Glycine max* (L.) Merill)" was conducted to characterize the PGPR from rhizosphere of soybean and test antagonisms against selected soil borne pathogens at Plant Pathology Section, College of Agriculture, Nagpur *in vitro* during the year 2011-12. Plant growth promoting rhizobacteria were isolated from the rhizosphere of soybean plants by using King's B medium and *Enterobacter* on Eosin methylene blue agar medium. Morphological and biochemical characters viz., gram reaction, cell shape, H_2S production, gelatine liquefaction, starch hydrolysis, pyocynin test, fluorescence test, mobility, oxidase test and KOH test were performed. The *Pseudomonas* isolates designated as Pf1, Pf2, Pf3 and Pf4 were gram –ve and rod shaped. All these isolates exhibited +ve test for biochemical analysis. Four *Enterobacter* designated as A, B, C and D were gram –ve and rod shaped, mobility and siderophore were having +ve tests. All the *Pseudomonas* isolates showed phosphate solubilization activity and IAA production. Antagonism activities of PGPR were tested against *Fusarium oxysporum* f.sp. *ciceri, Rhizoctonia solani, Sclerotium rolfsii.* The entire PGPR isolate, showed enhancement in germination, shoot and root length and vigour index of soybean plants as compared to uninoculated control.

(Key words : PGPR, *Pseudomonas*,*Enterobacter*, *Fusarium oxysporum* f. sp. *ciceri*, *Rhizoctonia bataticola, Scleotium rolfsii)*

INTRODUCTION

Plant growth promoting rhizobacteria (PGPR) are group of soil bacteria that actively colonize plant roots and increase plant growth and yield. PGPR belong to a range of genera including *Pseudomonas, Azotobacter, Azospirillum, Bacillus* etc. The mechanisms by which PGPR can promote plant growth are not fully understood, but are thought to include: symbiotic nitrogen fixation (Dobbelaere *et al*., 2003), the ability to produce phytohormones (Egamberdieva ,2007) solubilization of phosphate (Catellan *et al.,* 1999) and production of IAA deaminase (Patten and Glick, 1996). Significant increases in growth and yield of agronomical important crops in response to inoculation with PGPR have been demonstrated by many researchers (Asghar *et al*., 2002, Bashan *et al*., 2004, Biswas *et al.,*2000).

In last few decades a large array of bacteria including species of *Pseudomonas, Azospirillum, Azotobacter, Klebsilla, Enterobacter, Alcaligens, Arthrobacter, Burkholderia, Bacillus* and *Serratia* have reported to enhance plant growth (Glick, 1995, Kloepper *et al*., 1989, Misko and Germida, 2002). Occurrence of species of *Pseudomonas* in the rhizosphere of different crop plants has been previously reported. Strains of *Pseudomonas putida* and *Pseudomonas fluorescens* were particularly effective in increasing root and shoot elongation in canola, lettuce and tomato and yield of potato, radish, sugar beet, tomato, lettuce, apple, citrus, bean, ornamental plants and wheat (Rodriguez and Fraga, 1999). Several reports indicating that *Pseudomonas* is dominant in the rhizosphere of rice and their inoculation can increase growth and yield production in different parts of the world. (Mahmoud Reza Ramezanpour *et al.,* 2010). Among the plant growth micro-organisms which are capable to produce herbal hormones are *Azotobacter, Pseudomonas, Azospirillum, Rhizobium, Bacillus, and Enthrobacter* and mycorrhizae fungus. Misko and Germida (2002) reported through an experiment that the *Pseudomonas* is the most abundant auxin producer micro-organism. Growth regulators especially IAA (Indole -3- Acetic Acid), often affects the root systematic features such as primary growth of roots, side- root formation and root hairs. Auxins are group of herbal hormones which IAA is the most important of them. IAA is a natural auxin with vast physiological effects which plays an important role in growth, increasing and distinction (Khakipour, 2008).

MATERIALS AND METHODS

Collection of soil samples for isolation of PGPR : Soil samples were collected from rhizosphere of soybean from Agronomy field, Entomology field, Soil Science field, and from Plant Pathology field of College of Agriculture, Nagpur, respectively.

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Isolation of plant growth promoting *Rhizobacteria*. The plant growth promoting rhizobacteria were isolated from soil samples collected from rhizosphere of soybean (*Glycine max*) by serial dilution method. For isolation of *Pseudomonas fluorescens* King's B medium was used (King *et al.,* 1954).

King's B medium

Peptone	-	20 g
Glycerol	-	10 ml
K_2HPO_4	-	1.5 g
$MgSO_4.7H_2O$	-	1.5 g
Agar –Agar	-	15 g
Distilled water	-	1000ml
Cyclohexamide	-	1 mg.

All the media were supplemented with antifungal compound Cyclohexamide 1mg to inhibit fungal growth.

Collection of soil samples and Isolation of PGPR *Pseudomonas fluorescens* Enterobacter *:* Soil samples were collected from rhizosphere of soybean (*Glycine max* L. Merill) from different farms of College of Agriculture, Nagpur and were processed in the laboratory for isolation of *Enterobacter* on Eosin methylene blue agar medium and *P. fluorescens* on King's B medium by serial dilution and pour plate method. After three days of incubation greenish yellow to whitish yellow colonies were obtained on King's B medium which were later picked streaked on fresh King's B medium for pure culture and used for investigation. These isolates were designated as *Pseudomonas fluorescens* as Pf1, Pf2, Pf3 and Pf4. The isolates of *Enterobacter* sp were designated as A, B, C and D.

Identification of culture: Bacterial isolates were identified according to Bergey's Manual of Systemic Bacteriology (Brenner *et al*., 2005). The morphological and biochemical tests including gram staining, determination of H_2S production, motility, oxidase activities, gelatine liquefaction, starch hydrolysis, pyocynin, flurescense and KOH tests were used for identification (Bossis *et al.,* 2000).

Siderophore production test was done by following methods given by Schwyn and Neilands (1987).

Phosphate Solubilizing Activity: Phosphate solubilization test was performed as per method described by Pikovaskaya (1948).

IAA production : The ability of isolates to produce IAA was assayed colorimetrically using chloride perchloric acid reagent ($FeCl_3HCLO_4$) (Gordan and Weber, 1951).

***In vitro* antibiosis:** The PGPR *Pseudomonas fluorescens* isolates were further tested for their antagonistic ability against three soil borne plant pathogens i.e. *Fusarium oxysporum, Rhizoctonia solani, Sclerotium rolfsii.* The bacterial isolates were screened by dual culture test as followed by Morton and Stroube (1955) and Ramnathan *et al.* (2002). The per cent inhibition of test fungus with each bacterial isolate was calculated. Three replicated plates were maintained for each isolate. Plates streaked with sterilized water in place of bacterial isolates were kept as control. The per cent growth inhibition was calculated by using following formula.

$$I = \frac{C - T}{C} \times 100$$

Where
T = per cent inhibition
C = Growth of fungus in control (mm)
T = Growth of fungus in treatment (mm)

Effect of PGPR on germination: It was assed based on the seedling vigour index by the standard roll towel method (ISTA, 1993). Seedling vigour index of soybean were recorded on 5^{th} day. Seedling vigour index was calculated by using following formula as described by Abdul Baki and Anderson (1973).

SVI = Percentage germination x {shoot length (cm) + root length (cm)}

Where
SVI = Seedling vigour index

RESULTS AND DISCUSSION

It can be seen from table 2 that all isolates were rod and gram negative in reaction. All isolates were found efficient to liquefy gelatin (Tiwari and Thrimurthy, 2007) and were found capable of H_2S production (Shinde, 2003). Among these all the isolates were able to hydrolyse the starch and showed positive test for starch hydrolysis (Plate 1 A), Pyocynin, Fluorescens, Motility, Oxidase and KOH test. These findings are in accordance with the characteristics published in Bergey's manual of determinative bacteriology (Breed *et al.,* 1957) and also with the earlier reports (Siddiqui and Shakeel, 2009). The isolates responded to the gram negative reaction and were rod shape that produced round to irregular colonies with the production of yellowish to dull yellowish and greenish yellowish water soluble pigment. This confirmed isolates as *P. fluorescens*. The biochemical tests i.e. gelatin liquefaction, H_2S production, starch hydrolysis, Fluorescens test, Pyocynin test, oxidase test and chrome-azurole S assay for siderophore production further confirmed to be *P. fluorescens* (Qing Ping hu and Jain - Guoxu, 2011; Bhattacharya 2010). However, variable reaction of *Pseudomonas fluorescens* has been reported by Mahesh(2007).

It can be seen from table 3 that all the isolates were rod shaped and gram negative in reaction and showed positive test for motility test and Siderophore production (Plate 1 C) while all the isolates showed negative test for H_2S production, gelatin liquefaction, oxidase test, phosphate solubilization, tryptophan deaminase and Indole production.

The findings presented in table 4 indicate growth promoting characteristics of *P. fluorescens* were able to chelate Fe^{3+} from chrome azurole agar medium. All isolates produced clear orange zone against dark blue background on King's B medium. Similar observation for siderophore production has been demonstrated earlier by Sayyed *et al.* (2010) indicating the plant growth promoting rhizobacteria (PGPR) produced siderophores which was detected via chrome azurole S assay which is general test for siderophores production. Development of pink colour upon addition of Kovac's reagent to culture supernatant of *P. fluorescens* strain confirmed IAA production. All the isolates showed positive test for IAA production. Production of IAA and some other auxins has also been reported in the culture of *P. fluorescens* isolated from rice (*Oryza sativa*) (Mahmoud Reza Ramezanpour *et al.,* 2010). The IAA production in presence of tryptophan (50 gm l^{-1}) in all isolates of *Pseudomonas* i.e. Pf1, Pf2, Pf3 and Pf4 was recorded within the range of 17.7 – 28.2 mg^{-1}. These observations are in line with the reports of Maleki *et al.* (2010) and Bhromsiri and Bhromsiri (2010). However, there was no IAA production in the isolates of *Enterobacter* (A, B, C & D) indicating that they did not possess the ability to produce IAA.

Phosphate solubilization by bacterial strains was found positive as they formed clear zone on Pikovaskaya's agar medium. All the four isolates produced clear zone (Plate 1B). Similarly two strains of phosphate solubilizing bacteria from soil sample were identified as *P. fluorescens* on the basis of their morphological, cultural and biochemical reactions. Their phosphate solubilizing efficiency confirmed on Pikovaskayas medium. Sharma *et al.*(2007), Siddiqui and Shakeel (2009) also observed clear zone produced by *Pseudomonas* on Pikovaskaya's medium by all twenty one isolates in respect of oxidase and mobility have been documented by Nathan *et al.* (2011).

On nutrient agar medium all isolates showed slow growth and produced dull yellowish coloured colonies. All the isolates produced round shaped colonies except Pf2 where they produced irregular colonies. Irregular colonies produced because of composition of media. It is observed from this study that growth of *P. fluorescens* was fast on King's B medium as compared to other medium. Most of the *P. fluorescens* produced greenish yellow coloured colonies on King's B medium.

Observations on average colony diameter at 3, 5 and 7th DAI and per cent growth inhibition was recorded. All isolates under the test showed their potentiality to check the mycelial growth of all three pathogens i.e. *Fusarium oxysporum*, *Sclerotium rolfsii* and *Rhizoctonia solani*.

The data presented in table 5 and Plate 1 D indicates that there were significant differences in radial mycelial growth due to various isolates over uninoculated control. Minimum radial mycelial growth was recorded by the isolate Pf2 (68.40 mm) and it was at par with all the isolates followed by Pf4 (69.60 mm) with per cent inhibition of 24.00 and 23.33% on 7th DAI respectively. All the four isolates produced antifungal compounds which might have inhibited the growth of *R. solani.* Earlier reports by Nagrajkumar *et al.* (2004) and Battu and Reddy (2009) showed the antifungal activity of *Pseudomonas* against *R. solani*.

Table 1. Isolation of PGPR

Isolate	*Pseudomonas fluorescens*	*Enterobacter* spp.
1	Pf1	A
2	Pf2	B
3	Pf3	C
4	Pf4	D

Table 2. Morphological and biochemical tests of *Pseudomonas fluorescens* isolates

Sr. No.	Characters	Reaction of isolates			
		Pf1	Pf2	Pf3	Pf4
	Morphological Properties				
1	Gram reaction	-ve	-ve	-ve	-ve
2	Cell shape	Rod	Rod	Rod	Rod
	Physical and Biochemical Properties				
3	H_2S Production	+	+	+	+
4	Gelatin Liquefaction	+	+	+	+
5	Starch Hydrolysis	+	+	+	+
6	Pyocynin Test	+	+	+	+
7	Fluorescens Test	+	+	+	+
8	Motility	+	+	+	+
9	Oxidase Test	+	+	+	+
10	KOH Test	+	+	+	+

Table 3. Morphological and biochemical tests for PGPR (*Enterobacter)* isolates

Sr. No.	Characters	Reaction of isolates			
		Pf1	Pf2	Pf3	Pf4
	Morphological Properties				
1	Gram reaction	-ve	-ve	-ve	-ve
2	Cell shape	Rod	Rod	Rod	Rod
	Physical and Biochemical Properties				
3	H_2S Production	-	-	-	-
4	Gelatin Liquefaction	-	-	-	-
5	Motility	+	+	+	+
6	Oxidase Test	-	-	-	-
7	Siderophore production	+	+	+	+
8	Phosphate solubilization	-	-	-	-
9	Tryptophan deaminase	-	-	-	-
10	Indole production	-	-	-	-

Table 4. Growth promotion activities of PGPR (*Pseudomonas fluorescens and Enterobacter spp.)* Isolates

Sr. No.	Isolates	Siderophore Production	P Solubilization Activity	IAA Production	Amount of IAA produced mg/l
1	Pf1	+	+	+	28.2
2	Pf2	+	+	+	17.7
3	Pf3	+	+	+	25.1
4	Pf4	+	+	+	21.1
5	A	+	-	-	-
6	B	+	-	-	
7	C	+	-	-	
8	D	+	-	-	

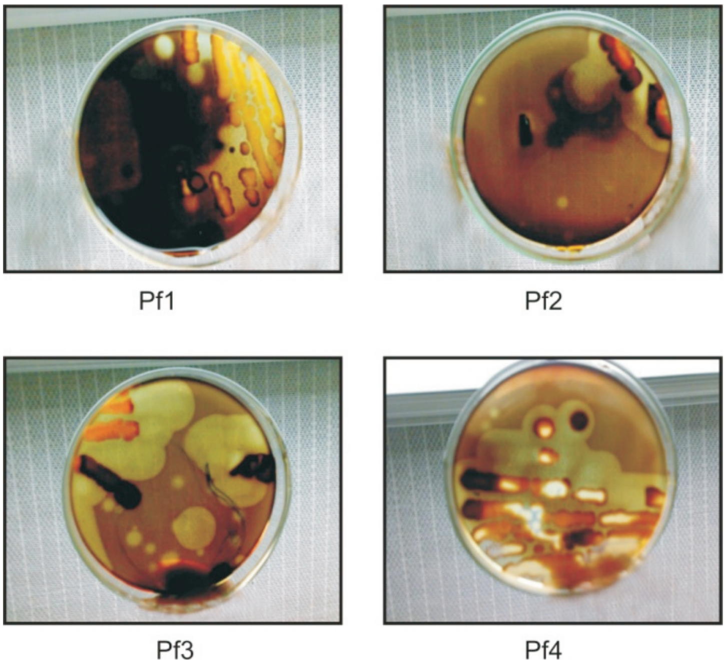
Table 5:. Effect of PGPR on growth of *Fusarium oxysporum* f. sp. *ciceri*, *Sclerotium rolfsii and Rhizoctonia solani* at different duration *in vitro*

Sr. No	PGPR Isolates	Mycelial Growth (mm) DAI			Growth Inhibition (%) DAI		
		Fusarium	Sclerotium	Rhizoctonia	Fusarium	Sclerotium	Rhizoctonia
1	Pf 1	63.30	66.60	74.90	29.66	26.00	16.77
2	Pf 2	64.90	66.90	68.40	27.88	25.66	24.00
3	Pf 3	64.70	65.10	70.60	28.11	27.66	21.55
4	Pf 4	67.60	66.70	69.60	24.88	25.88	23.33
5	Control	90.00	90.00	90.00	-	-	-
	SE(m)±	0.324	0.589	1.086			
	CD (P=0.01)	1.303	2.373	4.372			

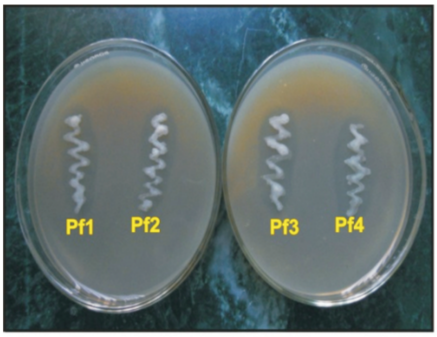
Table 6. Effect of PGPR isolates on germination percentage and vigour index

Sr . No.	PGPR Isolate	Germination Percentage	Mean Shoot Length (cm)	Mean Root Length (cm)	Vigour Index
1	Pf 1	77	9.27	15.11	1878.21
2	Pf 2	73	8.31	14.55	1646.28
3	Pf 3	74.66	9.13	14.21	1744.52
4	Pf 4	74.33	8.53	14.38	1704.40
5	Control	72.33	7.47	9.25	1275.74

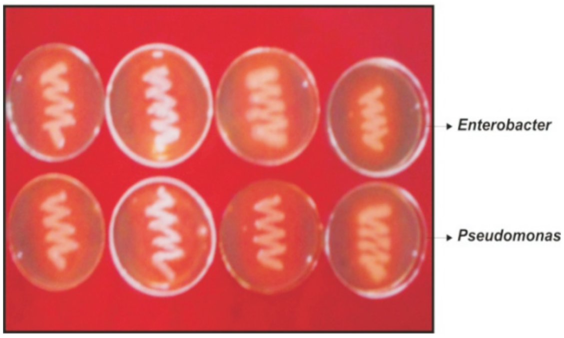
Plate 1. A. Starch hydrolysis B. Phosphate solubilization activity C. Siderophore production
D. Antagonism activity of PGPR isolates against *Fusariom oxysprum, Sclerotium rolfsil, Rhizoctonia solani*



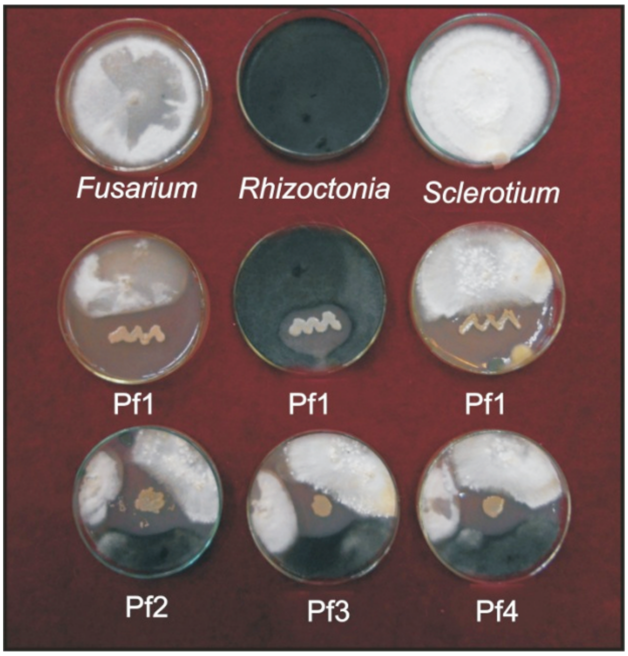
A



B



C



D

Similarly the antifungal activity of PGPR was tested against *Sclerotium rolfsii* and the data are presented in table 5. The observations were at various interval i.e.3, 5 and 7th DAI. It is revealed from the data that there were significant differences at all the intervals. Minimum radial mycelial growth was recorded by the isolate Pf3 (65.10 mm) and it was followed by Pf1 (66.60 mm) with maximum per cent inhibition of 27.66% and 26% respectively. All the isolates were at par with each other. Pf2 showed less per cent growth inhibition (25.66 %) at 7th DAI. These observations are in agreement with the findings of earlier workers Manjula *et al*. (2004) and Bhatia *et al*. (2005) they identified as *P. fluorescens* as bicontrol agents of groundnut stem rot and other soil borne diseases (Gholami *et al*., 2009; and Saharan and Nehra, 2011).

Data presented in table 5 indicates significant differences at 3, 5 and 7th DAI on radial mycelial growth of *F. oxysporum* f.sp. *ciceri* due to PGPR isolates. Minimum radial mycelial growth was recorded by Pf1 isolate (63.30 mm) followed by Pf 3 isolate (64.70 mm) with maximum per cent inhibition of 29.66 and 28.11% respectively. This might be due to the antibiotic production of PGPR. The observation recorded in the present investigation are in support with the findings of Rajeshwari and Kannabiran (2011). They reported the antagonistic activity of *Pseudomonas* strain against *Fusarium monoliformae*. The results showed that the plant growth promoting rhizobacteria *Pseudomonas fluorescens* can play an important role in bicontrol of soil borne diseases of rhizosphere.

The result with regard to effect of PGPR on germination percentage, shoot length, root length and vigour index are presented in table 6. Seed treatment with PGPR isolate Pf 1 exhibited higher germination i.e. 77% after 7 days respectively when tested by towel paper method. The seedling vigour index was maximum in PGPR isolate Pf1 1878.21 followed by Pf 3 1744.52. Maximum shoot length was observed in Pf1 i.e. 9.27 cm while maximum root length was in Pf1 (15.11 cm) as compared to control. Minimum shoot length was observed in control followed by Pf 2 (8.31 cm) and root length was in Pf 3 (14.21 cm). It indicates that PGPR isolates were effective for soybean as seed dresser for higher seedling vigour index and it does not have detrimental effect to other useful bioagents.

PGPR isolates were inoculated to soybean seeds and seedling vigour was recorded. The beneficial effects of rhizosphere micro-organisms has been studied by Naz *et al.* (2009) in soybean crop. The plant growth promoting activity of rhizobacteria such as *Azotobacter*, *Azospirillum, clostridium, Pseudomonas fluorescens* are well established (Kloepper *et al.,* 1980). PGPR promote plant growth or inhibit the soil borne pathogen include the production of extra cellular growth promoting chemical substances and from chelating siderophores. Seed treatment with PGPR, Pf 1 exhibited higher germination in soybean i.e. 77% as compared to control (72%) when tested by towel paper method. Similar results were confirmed the findings of reported that the treatment of rhizobacteria with soybean seed increased the germination of soybean. The seedling vigour index was maximum i.e. 1878.21 in PGPR Pf1 followed by 1744.52 in PGPR Pf3 root length and shoot length were also maximum in respective isolates. The present findings are in line with the reports published by Sayyed *et al.* (2005) and Begum *et al*. (2003). The results suggest the possible use of PGPR as seed dresser in soybean for seed germination, seed protection from seed borne and soil borne pathogen and plant growth promotion. Thus, it is inferred from the present investigation that the PGPR isolate (*Pseudomonas* spp.) can be used for controlling soil borne plant pathogens.

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HETEROSIS STUDIES FOR YIELD, YIELD CONTRIBUTING AND FIBRE TRAITS IN COTTON (*Gossypium hirsutum* L.)

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ABSTRACT

An experiment was carried out to study the heterosis of yield, yield contributing and fibre traits. Ten diverse genotypes of cotton viz., AKH-081, AKH-053B, AKH-9312, AKH-976, AKH-9913, BBP-9, AKH-1174 , LRK-516, 8660B, AKH-8828 were crossed in half diallel fashion to secure fourty five F_1s. This experiment was conducted during *kharif* 2007-08 at Botany Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. Observations were recorded on days to 50 % flowering, plant height (cm), chlorophyll content (mg g^{-1}), number of bolls $plant^{-1}$, seed cotton yield $plant^{-1}$, lint yield $plant^{-1}$ (g), ginning out turn (%), 2.5% span length (mm), Fibre strength (g tex^{-1}), uniformity ratio (%) and maturity co-efficient. The variation among the genotypes, parents and crosses, and parents *vs* crosses were found to be highly significant for all the characters studied. Highest magnitude of heterobeltiosis was observed for seed cotton yield (116.52%) followed by lint yield (98.43%), number of bolls $plant^{-1}$ (42.97%) and fibre strength (29.17%). Maximum useful heterosis was recorded by number of bolls $plant^{-1}$ (55.40%), followed by seed cotton yield (29.93%), fibre strength (27.72%) and lint yield (26.29%). The crosses AKH-081 x AKH-1174, AKH-053B x LRK-516, AKH-9312 x BBP-9, AKH-9931 x BBP-9, AKH-9913 x AKH-8828, BBP-9 x AKH-1174 and BBP-9 x AKH-8828 exhibited high significant standard heterosis for seed cotton yield and lint yield.

(Key words: Heterosis, *Gossypium hirsutum* L.)

INTRODUCTION

The manifestation of heterosis has received an increased attention from cotton breeders, although many workers studied it before. High heterosis has been reported in cotton at interspecific and intraspecific level, both in diploid and tetraploid cotton (Singh and Kalsy, 1983). The heterosis has been commercially exploited in *hirsutum* cotton and better yields have been obtained at intra and inter specific levels. In most of the earlier studies on the heterosis in cotton, the values over mid parent and better parent have been used as the criteria for assessing the superiority of a hybrid. Now a days useful or standard heterosis which is worked out on the basis of superiority over best commercial variety of the region is supposed to be good.

For the exploitation of heterosis in hybrid breeding programme the presence of dominance genetic effect is essential. Therefore, the nature and magnitude of gene action, particularly in quantitative characters such as yield is pre requisite. Selection of parents for crossing is the first and the most important task to evolve superior hybrids or strains. The selection of parents for hybridization is difficult task. Yield contributing and fibre traits in cotton are polygenically controlled and hence sensitive to environmental fluctuations. The initial selection of suitable parents is stated to be of immense importance for utilization of heterosis to its maximum extent. Higher yield along with better fibre quality in varieties and hybrids becomes a limitation as cotton is predominately self pollinated and often cross pollinated crop. The quality acceptable to fibre industry is must because cotton is an industrial crop.

The limited knowledge of gene effects and gene actions of important traits hinders the improvement in these traits. Hence, this study has a wide scope to identify promising crosses with high useful heterosis for their exploitation in hybrid development programme.

MATERIALS AND METHODS

The experimental material consisted of ten diverse genotypes viz., AKH-081, AKH-053B, AKH-9312, AKH-976, AKH-9913, BBP-9, AKH-1174 , LRK-516, 8660B, AKH-8828 crossed in half diallel fashion to secure fourty five F_1s. The crosses along with their respective parents were sown in randomized complete block design replicated thrice at the Farm of Department of Agricultural Botany, PGI, Dr.P.D.K.V., Akola during *kharif*, 2006 and 2007. Data were recorded on days to 50 % flowering, plant height (cm), chlorophyll content (mg g^{-1}), number of bolls $plant^{-1}$, seed cotton yield $plant^{-1}$, lint yield $plant^{-1}$ (g), ginning out turn (%), 2.5% span length (mm), fibre strength (g tex^{-1}), uniformity ratio

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(%) and maturity co-efficient. The statistical analysis was performed for analysis of variance as per the methodology suggested by by Fisher (1918) and the heterobeltiosis and useful heterosis of all F_1 hybrid was computed after Fehr (1987). Chlorophyll in leaves was estimated as per method suggested by Hiscox and Israelston (1979).

RESULTS AND DISCUSSION

The analysis of variance for various characters are presented in table 1. The variation among the genotypes, parents and crosses, were found to be highly significant for all the eleven characters studied, indicating, substantial amount of genetic variability for all the characters. However, the mean squares due to parents *vs* hybrids were highly significant for days to 50 per cent flowering, plant height, number of bolls plant^{-1}, ginning out turn, 2.5 per cent span length, fibre strength, uniformity ratio, maturity co-efficient , chlorophyll content, seed cotton yield (g) and lint yield (g). The significance of parents *vs* crosses observed for eleven characters satisfied the basic pre-requisites for comparing the expression of parents and crosses for different characters and for the estimation of heterosis. The wide variability for seed cotton yield and its components were also reported by Desai *et al.* (1982) and Khorgade *et al.* (2000).

Heterobeltiosis and standard heterosis were estimated as an increase or decrease of hybrid over better parent and standard check (AKH-8828) respectively. The phenomenon of heterosis was observed for all the eleven characters studied (Table 2). Highest magnitude of heterobeltiosis was observed for seed cotton yield (116.52%) followed by lint yield (98.43%), number of bolls plant^{-1} (42.97%) and fibre strength (29.17%). Maximum useful heterosis was recorded by number of bolls plant^{-1} (55.40%), followed by seed cotton yield (29.93%), fibre strength (27.72%) and lint yield (26.29%). The extent of heterosis obtained for maturity co-efficient, uniformity ratio, chlorophyll content were low as compared to other characters. These results indicated that the phenomenon of heterosis was of general occurrence, however, the magnitude varied with the characters. These results were in conformity with findings of Kaushik and Sastry (2011) and Kaushik and Kapoor (2013).

The extent of heterosis also gives us an idea of the genetic control of character. Heterosis by itself whether over mid-parent or better parent cannot tell us much about the superiority of hybrid over the check variety which is of practical value for plant breeding. Therefore, only heterosis over check variety is given more emphasis. The crosses AKH-081 x AKH-1174, AKH-053B x LRK-516, AKH-9312 x BBP-9, AKH-9931 x BBP-9, AKH-9913 x AKH-8828, BBP-9 x AKH-1174 and BBP-9 x AKH-8828 exhibited high significant standard heterosis for seed cotton yield and lint yield. Out of these five crosses besides seed cotton yield and lint yield AKH-9312 x BBP-9, also exhibited high significant useful heterosis in the desirable direction for fibre strength and days 50% flowering, the cross AKH-9913 x AKH-8828 also for fibre strength and 2.5% span length, the cross BBP-9 x AKH-1174 for number of bolls plant^{-1}, fibre strength, maturity co-efficient and uniformity ratio and chlorophyll content, and the cross BBP-9 x AKH -8828 for number of bolls plant^{-1} and fibre strength. These crosses besides having significant useful heterosis in desirable direction for different characters, also had high *per se* performance for respective characters.

The level of heterosis observed in these crosses justified the development of commercial hybrids in cotton. Such potential of cotton crosses for commercial exploitation of heterosis have been reported by many cotton breeders like Khorgade *et al.* (2000), Verma *et al.* (2006), Kaushik and Sastry (2011) and Kaushik and Kapoor (2013). Thus, the present study on heterosis has clearly indicated that heterotic response for yield and its components resulted only in selected cross combinations indicating the pre-dominant role of non-fixable inter-allelie interactions. The crosses identified above i.e. AKH-081x AKH-1174, AKH-053B x LRK-516, AKH-9312 x BBP-9, AKH-9913 x AKH-8828, for seed cotton yield and lint yield and the crosses AKH-9913 x AKH-8828, BBP-9 x AKH-1174 and BBP-9 x AKH-8828 for seed cotton yield, lint yield and fibre strength along with some other additional one or the other characters like maturity co-efficient, uniformity ratio, number of bolls plant^{-1}, 2.5% span length etc. hold promise for further evaluation and commercial exploitation of heterosis. Also these hybrids by chain crossing may be composited to make a gene pool. This pool may be advanced for further generations to

Table 1. Analysis of variance for experimental design

Sources	d.f.	Mean squares										
		Days to 50% flowering	Plant height (cm)	No. of bolls plant^{-1}	Ginning out turn (%)	2.5% span length (mm)	Fibre strength (g tex^{-1})	Uniform-ity ratio (%)	Maturity co-efficient	Chlorophyll content (mg g^{-1})	Seed cotton yield plant^{-1} (g)	Lint yield plant^{-1} (g)
Replications	2	3.98	129.35	34.76	11.87	1.04	1.74	2.59	0.0006	0.01	13.72	27.58
Genotypes	54	12.77**	312.03**	24.25**	24.79**	9.07**	8.98**	7.71**	0.001**	0.06**	184.31**	28.99**
Parents	9	16.58**	628.45**	39.45**	38.30**	18.77**	9.57**	8.00**	0.0003**	0.04**	231.32**	29.57**
Crosses	44	11.75**	240.92**	21.03**	22.05**	6.91**	7.82**	6.78**	0.002**	0.06**	96.35**	16.01**
Parents vs. crosses	1	23.47**	592.91**	28.75**	23.57**	16.44**	54.57**	46.34**	0.0001*	0.14**	3631.57**	595.34**
Error	108	0.32	13.33	4.00	2.10	0.05	0.21	0.22	0.00003	0.0006	9.21	2.92

Note : *Significant at 5% ** Significant at 1%

Table 2. Heterobeltiosis and standard heterosis expressed by the crosses

Sr. No.	Crosses	Days to 50% flowering		Plant height (cm)		No. of bolls plant^{-1}		Ginning out turn (%)	
		H1	H2	H1	H2	H1	H2	H1	H2
1.	AKH- 081 x AKH-053B	-6.59**	-5.03**	18.70**	-3.88	-2.68	4.98	0.57	4.19
2.	AKH-081 x AKH-9312	-9.89**	-8.39**	-5.00	-6.34	-32.69	-27.67**	-16.87**	13.88**
3.	AKH-081 x AKH-976	-4.95**	-3.36**	-2.11	-1.76	-8.49	-19.82	2.73	6.43*
4.	AKH-081 x AKH-9913	-5.49**	-3.92**	-6.76*	-7.75*	-19.52*	-2.87	3.18	6.90*
5.	AKH-081 x BBP-9	-7.29**	-0.56	-14.95**	-9.86**	-22.43*	-15.69	8.11**	11.99**
6.	AKH-081 x AKH-1174	-8.24**	-6.71	17.79**	-13.74**	15.09	0.85	-11.32**	-4.53
7.	AKH-081 x LRK-516	-2.20**	-0.56	-15.53**	-21.48**	-15.09	-25.60*	-8.49**	1.67
8.	AKH-081 x 8660B	-8.24**	-6.71**	-3.61	-5.99	8.02	-5.35	-3.62	-0.15
9.	AKH-081 x AKH-8828	-2.20**	-0.56	-9.51**	-9.51**	-1.65	-1.63	6.34*	10.16**
10.	AKH-053B x AKH-9312	-7.73**	-6.71**	1.79	0.35	-3.07	4.57	-5.82	-10.61**
11.	AKH-053B x AKH-976	-6.63**	-5.59**	-7.02*	-6.69*	-19.16*	-12.79	-5.29	-10.10**
12.	AKH-053B x AKH-9913	-6.08**	-5.03**	-8.90*	-9.86**	-31.85**	-17.75	-4.52	-6.29*
13.	AKH-053B x BBP-9	-7.29**	-0.56	-9.97**	-4.58	-24.71**	-18.16	-8.53**	-13.18**
14.	AKH-053B x AKH-1174	-7.73**	-6.71**	11.74**	-9.51**	-6.90	0.43	4.09	12.06**
15.	AKH-053B x LRK-1516	0.55	1.67*	-6.82*	-13.38**	-11.11	-4.11	-11.90**	-2.12
16.	AKH-053B x 8660B	-6.08**	-5.03**	-2.89	-5.29	-20.31*	-14.03	0.71	-4.41
17.	AKH-053B x AKH-8828	-1.10	-0.01	-7.04*	-7.05*	-8.81	-1.63	15.21**	12.27**
18.	AKH-9312 x AKH-976	-2.21**	-1.12	14.74**	15.40**	-8.08	-1.22	4.46	-4.03
19.	AKH-9312 x AKH-9913	-5.56**	-5.03**	1.78	0.70	-27.40**	-12.38	-2.94	-4.74
20.	AKH-9312 x BBP-9	-9.90**	-3.36**	1.00	7.04*	-17.87	-10.73	-5.46	12.10**
21.	AKH-9312 x AKH-1174	4.68**	-0.01	-4.64	-5.99	-4.23	2.91	-11.40**	-4.62
22.	AKH-9312 x LRK-516	-1.12	-1.68*	4.29	2.81	-8.08	-1.22	-13.53**	-3.93
23.	AKH-9312 x 8660B	0.00	-0.01	13.21**	11.62**	-6.92	0.02	13.01**	-4.87
24.	AKH-9312 x AKH-8828	0.00	-0.01	20.42**	20.42**	-6.54	0.43	-1.93	-4.44
25.	AKH-976 x AKH-9913	-4.42**	-3.36**	-0.70	-0.36	-19.18*	-2.46	0.24	-1.62
26.	AKH-976 x BBP-9	-5.21**	1.67*	-3.32	2.46	-9.13	-1.22	6.36	-1.11
27.	AKH-976 x AKH-1174	-1.10	-0.01	-21.75**	-21.48**	16.87	-19.82	-2.47	5.00
28.	AKH-976 x LRK-516	-1.66*	-0.56	-12.28**	-11.97**	3.45	-13.21	-13.07**	-3.42
29.	AKH-976 x 8660B	1.66*	2.79**	-1.40	-1.06	6.32	-16.51	11.09**	2.05
30.	AKH-976 x AKH-8828	0.55	1.67*	-6.32*	-5.99	-9.92	-9.90	4.40	1.73
31.	AKH-9913 x BBP-9	-9.90**	-3.36**	-5.98*	-0.36	-7.88	11.18	4.94	2.99
32.	AKH-9913 x AKH-1174	-3.33**	-2.80**	-4.98	-5.99	-11.99	6.22	-12.69**	-6.00*
33.	AKH-9913 x LRK-516	-0.56	-0.01	-8.90**	-9.86**	-17.81*	-0.81	-15.88**	-6.55*
34.	AKH-9913 x 8660B	-1.11	-0.56	1.78	0.70	-21.58*	-5.35	-1.66	-3.49
35.	AKH-9913 x AKH-8828	-0.56	-0.01	3.52	3.52	0.34	21.10*	7.33*	5.34
36.	BBP-9 x AKH-1174	-6.77**	-0.01	-17.61**	-12.68**	42.97**	55.40**	-16.13**	-9.71**
37.	BBP-9 x LRK-516	2.08**	9.49**	-10.30**	-4.93	22.81*	33.50**	-15.81**	-6.46*
38.	BBP-9 x 8660B	-7.29**	-0.56	9.30**	15.84**	16.35	26.47*	0.61	-6.46*
39.	BBP-9 x AKH-8828	-5.21**	1.67*	1.66	7.74*	21.29*	31.85**	2.93	0.30
40.	AKH-1174 x LRK-516	1.69*	1.11	-19.70**	-25.35**	-15.27	-28.91**	-12.87**	-3.20
41.	AKH-1174 x 8660B	-2.23**	-2.24**	-7.22*	-9.51**	24.21*	-2.46	1.15	8.89**
42.	AKH-1174 x AKH-8828	-2.23**	-2.24**	-13.73**	13.74**	5.79	5.81	-1.60	5.93
43.	LRK-516 x 8660B	-6.70**	-6.71**	2.53	0.00	25.62*	5.39	-2.80	7.99**
44.	LRK-516 x AKH-8828	0.00	-0.01	-12.32**	-12.33	-12.81	-12.79	-5.38*	5.12
45.	8660B x AKH-8828	0.00	-0.01	0.35	0.35	-9.50	-9.49	0.04	-2.51
	SE(d)±	0.46	0.46	2.98	2.98	1.63	1.63	1.18	1.18
	CD (5%)	0.91	0.91	4.96	4.96	3.26	3.26	2.36	2.36

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Sr. No.	Crosses	2.5% span length (mm)		Fibre Strength (g tex^{-1})		Uniformity ratio (%)		Maturity co-efficient	
		H1	H2	H1	H2	H1	H2	H1	H2
1.	AKH- 081 x AKH -053B	0.57	6.92*	-7.10**	7.52**	2.84**	-1.36	-2.86**	-4.42**
2.	AKH-081 x AKH -9312	-16.87**	-11.62**	-10.95**	3.06	-0.69	-2.72**	1.21*	0.40
3.	AKH-081 x A KH-976	2.73	9.22**	-6.66**	8.03**	11.11**	2.04**	-2.86**	-4.42**
4.	AKH-081 x AKH -9913	3.18	9.70**	-8.28**	6.15**	0.71	-3.40**	-3.67**	-5.22**
5.	AKH-081 x BBP-9	8.11**	14.93**	-11.24**	2.72	-5.33**	-3.40**	-3.19**	-2.41**
6.	AKH-081 x AKH -1174	-11.32**	-2.02	-9.32**	4.95*	-2.78**	-4.76**	-3.67**	-5.22**
7.	AKH-081 x LRK-516	-8.49**	4.34	-10.21**	3.92*	0.71	-3.40**	1.22*	-0.40
8.	AKH-081 x 8660B	-3.62	2.47	-11.54**	2.38	1.43	-3.40**	-0.82	-2.41**
9.	AKH-081 x AKH -8828	6.34*	13.05**	-8.88**	5.46**	-5.44**	-5.44**	1.61**	1.20*
10.	AKH-053B x AKH -9312	-5.82	-8.26**	-6.47**	3.92*	-1.39	-3.40**	-3.24**	-4.02**
11.	AKH-053B x AKH -976	-5.29	-7.74**	3.45	7.86**	1.42	-2.72**	0.82	-0.80
12.	AKH-053B x AKH -9913	-4.52	-3.83	-1.15	3.06	1.42	-2.72**	-2.86**	-4.42**
13.	AKH-053B x BBP-9	-8.53**	-10.90**	-3.78*	0.33	-5.33**	-3.40**	1.20*	2.01**
14.	AKH-053B x AKH -1174	4.09	15.00**	-1.81	2.38	-0.69	-2.72**	-5.71**	-7.23**
15.	AKH-053B x LRK-1516	-11.90**	0.45	4.60*	9.06**	0.00	-4.08**	-3.67**	-5.22**
16.	AKH-053B x 8660B	0.71	-1.90	9.03**	13.68**	0.00	-4.08**	-1.22*	-2.81**
17.	AKH-053B x AKH -8828	15.21**	15.21**	-11.49**	-7.72**	0.00	0.00	2.82**	2.41**
18.	AKH-9312 x AKH -976	4.46	- 1.51	-19.57**	-10.63**	-1.39	-3.40**	1.21*	0.40
19.	AKH-9312 x AKH -9913	-2.94	-2.24	3.54*	15.05**	2.08**	0.00	-3.64**	-4.42**
20.	AKH-9312 x BBP-9	-5.46	-9.79**	12.79**	25.32**	-4.67**	-2.72**	0.80	1.61**
21.	AKH-9312 x AKH -1174	-11.40**	-2.12	14.95**	27.72**	0.00	-2.04**	-0.40	-1.20*
22.	AKH-9312 x LRK -516	-13.53**	-1.41	-9.24**	0.84	-4.17**	-6.12**	2.83**	2.01**
23.	AKH-9312 x 8660B	13.01**	-2.37	-2.16	8.71**	5.56**	3.40**	2.83**	2.01**
24.	AKH-9312 x AKH -8828	-1.93	-1.93	-4.62**	5.98**	-2.04**	-2.04**	-2.42**	-2.81**
25.	AKH-976 x AKH -9913	0.24	0.96	18.23**	21.04**	6.38**	2.04**	0.41	-1.20*
26.	AKH-976 x BBP -9	6.36	1.49	2.21	-5.15**	0.00	2.04**	-3.59**	-2.81**
27.	AKH-976 x AKH -1174	-2.47	7.75*	17.90**	9.40**	1.39	-0.68	-1.65*	-4.42**
28.	AKH-976 x LRK-516	-13.07**	-0.88	22.05**	18.47**	6.38**	2.04**	4.10**	2.01**
29.	AKH-976 x 8660B	11.09**	4.73	29.17**	22.07**	9.29**	4.08**	-2.88**	-5.22**
30.	AKH-976 x AKH -8828	4.40	4.40	7.19**	7.17**	2.04**	2.04**	-2.82**	-3.21**
31.	AKH-9913 x BBP -9	4.94	5.70	0.33	2.72	-4.67**	-2.72**	-8.37**	-7.63**
32.	AKH-9913 x AKH -1174	-12.69**	-3.53	9.53**	12.14**	5.56**	3.40**	2.86**	1.20*
33.	AKH-9913 x LRK -516	-15.88**	-4.09	17.89**	20.70**	4.26**	0.00	4.08**	2.41**
34.	AKH-9913 x 8660B	-1.66	-0.95	1.17	3.58	2.13**	-2.04**	-1.22*	-2.81**
35.	AKH-9913 x AKH -8828	7.33*	8.10*	14.05**	16.76**	3.40**	3.40**	0.81	0.40
36.	BBP-9 x AKH -1174	-16.13**	-7.34*	26.94**	14.54**	1.33	3.40**	1.20*	2.01**
37.	BBP-9 x LRK-516	-15.81**	-4.01	13.05**	9.74**	0.00	2.04**	-1.99**	-1.20*
38.	BBP-9 x 8660B	0.61	-4.01	5.98**	0.15	4.00**	6.12**	-3.98**	-3.21**
39.	BBP-9 x AKH -8828	2.93	2.93	9.93**	9.91**	0.00	2.04**	-0.40	0.40
40.	AKH-1174 x LRK -516	-12.87**	-0.66	6.88**	3.75	4.17**	2.04**	-4.92**	-6.83**
41.	AKH-1174 x 8660B	1.15	11.75**	4.71*	-1.04	1.39	-0.68	1.65**	- 0.80
42.	AKH-1174 x AKH -8828	-1.60	8.71**	3.77*	3.75	4.08**	4.08**	1.21*	0.80
43.	LRK-516 x 8660B	-2.80	10.82**	6.35**	3.24	0.71	-3.40**	-2.05**	-4.02**
44.	LRK-516 x AKH -8828	-5.38	7.88*	2.05	2.04	-4.08**	-4.08**	-2.02**	-2.41**
45.	8660B x AKH -8828	0.04	0.04	-3.94*	-3.95*	0.68	0.68	-3.23**	-3.61**
	SE(d) ±	1.18	1.18	0.37	0.37	0.38	0.38	0.0046	0.0046
	CD (5%)	2.36	2.36	0.74	0.74	0.76	0.76	0.0092	0.0092

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Sr. No.	Crosses	Chlorophyll content (mgg^{-1})		Seed cotton yield (g)		Lint yield (g)	
		H1	H2	H1	H2	H1	H2
1.	AKH- 081 x AKH -053B	-3.86**	-5.08**	43.12**	8.96	47.75**	1.19
2.	AKH-081 x AKH -9312	-7.68**	-12.22**	-5.55	-24.10**	-8.98	-37.66**
3.	AKH-081 x AKH -976	-7.04**	-16.19**	84.30**	10.60	77.30**	21.43*
4.	AKH-081 x AKH -9913	-4.58**	-13.97**	3.76	5.51	8.86	4.43
5.	AKH-081 x BBP-9	-14.17**	-15.40**	-4.77	1.84	0.83	-1.23
6.	AKH-081 x AKH -1174	-2.69**	-8.25**	116.52**	29.93**	84.40**	26.29**
7.	AKH-081 x LRK-516	7.75**	-2.86**	41.75**	-6.33	16.57	-17.43*
8.	AKH-081 x 8660B	-6.69**	-15.87**	19.75**	3.22	48.35**	1.60
9.	AKH-081 x AKH -8828	-14.76**	-14.76**	-1.94	-1.94	19.03*	19.00*
10.	AKH-053B x AKH -9312	-16.24**	-17.30**	38.30**	11.14	40.87**	-5.69
11.	AKH-053B x AKH -976	-17.68**	-18.73**	28.27**	-2.35	22.13*	-18.24*
12.	AKH-053B x AKH -9913	-7.07**	-8.25**	4.12	5.87	4.64	0.38
13.	AKH-053B x BBP-9	-17.36**	-18.41**	1.52	8.58	-0.41	-2.45
14.	AKH-053B x AKH -1174	-16.40**	-17.46**	51.53**	15.36*	71.70**	16.96*
15.	AKH-053B x LRK-1516	-1.77	-3.02**	54.50**	17.62**	43.43**	1.60
16.	AKH-053B x 8660B	-14.47**	-15.56**	20.03**	3.45	42.68**	-4.47
17.	AKH-053B x AKH -8828	-4.60**	-4.60**	9.55	9.56	4.05	4.03
18.	AKH-9312 x AKH -976	-14.19**	-18.41**	47.16**	18.25**	54.55**	3.22
19.	AKH-9312 x AKH -9913	-14.19**	-18.41**	-9.78	-8.26	-17.72*	-21.07*
20.	AKH-9312 x BBP-9	-14.81**	-16.03**	20.67**	29.05**	23.14**	20.62*
21.	AKH-9312 x AKH -1174	-10.52**	-14.92**	51.21**	21.51**	74.55**	16.78*
22.	AKH-9312 x LRK-516	-14.19**	-18.41**	30.95**	5.22	41.71**	0.38
23.	AKH-9312 x 8660B	-14.52**	-18.73**	16.40*	0.32	47.88**	-1.23
24.	AKH-9312 x AKH-8828	-11.27**	-11.27**	17.89**	17.90**	-4.45	-4.47
25.	AKH-976 x AKH -9913	-2.79**	-16.98**	10.57	12.43*	0.00	-4.07
26.	AKH-976 x BBP-9	-13.53**	-14.76**	6.10	13.48*	-0.83	-2.85
27.	AKH-976 x AKH -1174	-13.30**	-18.25**	32.95**	-21.10**	98.43**	2.00
28.	AKH-976 x LRK-516	-3.05**	-14.29**	39.64**	-7.72	32.00**	-6.50
29.	AKH-976 x 8660B	-6.16**	-17.78**	4.27	-10.13	39.19**	-16.62*
30.	AKH-976 x AKH -8828	-12.86**	-12.86**	-5.80	-5.79	-4.86	-4.88
31.	AKH-9913 x BBP-9	-10.79**	-12.06**	13.63*	21.52**	24.79**	22.24**
32.	AKH-9913 x AKH -1174	-2.19*	-7.78**	10.18	12.04*	13.92	9.29
33.	AKH-9913 x LRK-516	2.15*	-9.68**	3.48	5.22	12.66	8.08
34.	AKH-9913 x 8660B	-0.91	-13.17**	17.55**	19.53**	13.92	9.29
35.	AKH-9913 x AKH -8828	-2.54**	-2.54**	12.95*	14.85*	21.46**	21.43*
36.	BBP-9 x AKH-1174	5.96**	4.44**	17.71**	25.89**	23.14**	20.62*
37.	BBP-9 x LRK-516	-2.58**	-3.97**	21.21**	29.63**	14.46	12.12
38.	BBP-9 x 8660B	2.90**	1.43	14.40*	22.35**	18.60*	16.17
39.	BBP-9 x AKH-8828	-2.38**	-2.38**	15.98**	24.04**	21.86*	21.84*
40.	AKH-1174 x LRK-516	3.87**	-2.06*	27.99**	-15.42*	9.14	-22.69**
41.	AKH-1174 x 8660B	-8.25**	-13.49**	26.06**	8.66	89.19**	13.34
42.	AKH-1174 x AKH -8828	-0.63	-0.63	-11.65*	-11.64*	-7.69	-7.71
43.	LRK-516 x 8660B	-0.90	-12.38**	23.88**	6.77	56.00	10.50
44.	LRK-516 x AKH-8828	5.71**	5.71**	-3.51	-3.50	-1.62	-1.64
45.	8660B x AKH-8828	-18.25**	-18.25**	-8.88	-8.88	-10.93	-10.95
	SE(d) ±	0.019	0.019	2.48	2.48	1.39	1.39
	CD (5%)	0.038	0.038	4.96	4.96	2.78	2.78

devise and isolate lines with gene combinations for high seed cotton yield and lint yield.

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EFFECT OF IBA ON ROOTING OF ROOTSTOCK IN ROSE

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ABSTRACT

An investigation was conducted to study the effect of IBA on rooting of rootstock in Rose at Horticulture Section, College of Agriculture, Nagpur during July, 2011. The design of experiment was Complete Randomized Design (CRD). Four treatments viz., control (T_1), 500 ppm IBA (T_2), 1000 ppm IBA (T_3), 1500 ppm IBA (T_4) were tried in five replications. It is evident from the results that, the treatment of IBA 1000 ppm was proved to be significantly superior than other levels of IBA in respect of number of primary roots, secondary roots, root length, final survival percentage of rooted cuttings, sprouting percentage, number of leaves, as well as shoots and diameter of rootstock. However, the treatment of IBA 500 ppm showed early sprouting as well as rooting of rootstock cutting in rose.

(Key words: IBA, rootstock, rooting, rose, propagation)

INTRODUCTION

The genus *Rosa* is one of the most widely grown and best loved of all plant genera around the world. It belongs to the family 'Rosaceae'. Without roses the gardens are considered incomplete. The gardens exclusively for roses have been made in various parts of the world for showing respect to this flower. Great diversity in plant growth, colour of flowers, shape of flowers, fragrance, slow opening of flowers and good keeping quality made roses popular and commercially important. Roses are commercially propagated by cutting and budding. But success rate of cuttings is limited in most of rose varieties due to failure in root formation. For budding of rose varieties, *Rosa indica* Odorata is commonly used as rootstock.

Many research workers have reported that, IBA is the best rooting hormone for cuttings. Therefore, the investigation was carried out to study effect of IBA on rooting of rootstock cutting in rose and to find out suitable concentration of IBA for better rooting.

MATERIALS AND METHODS

The present experiment was conducted in Horticulture Section, College of Agriculture, Nagpur during July, 2011. The experiment was laid out in Complete Randomized Design (CRD) with four treatments and five replications. The four treatments comprised of different levels of IBA viz., control (T_1), 500 ppm IBA (T_2), 1000 ppm IBA (T_3) and 1500 ppm IBA (T_4). The semihard wood cuttings of 20 cm length and 0.6 to 0.7 cm diameter having good swollen buds were taken from the rootstock of rose i.e. *Rosa indica* Odorata. The solutions of different levels of IBA were prepared as per the treatment. The required quantity of IBA was first dissolved in small quantity of alcohol and then required quantity of distilled water to make the solutions of desired concentration. The lower portion of the cutting was treated with different concentrations of IBA for 20 minutes by dipping method. However, the untreated cuttings were placed in distilled water for the same period for control treatment. After treating with IBA cuttings were planted in plastic crates containing mixture of well decomposed FYM, sand and soil in the proportion of 1:1:1. Immediately after planting the cuttings were watered. Necessary plant protection measures were carried out as and when required. The data on rooting and growth performance of cutting in respect of days required to sprouting and rooting, number of primary roots and secondary roots, length of root, number of leaves, and shoots, diameter of rootstock, sprouting percentage and final survival percentage of rooted cuttings was recorded and statistically analyzed by the method given by Panse and Sukhatme (1954).

RESULTS AND DISCUSSION

Effect of IBA on rooting of rootstock cutting in rose :

The data (Table 1) revealed that, effect of different levels of IBA on days to root initiation, number of primary roots and secondary roots, length of root (cm) and final survival percentage of rooted cuttings was found to be significant. The minimum days to root initiation (20.48 days) were recorded in

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the treatment of IBA 500 ppm, whereas, maximum days (24.70 days) were required for root initiation under control treatment. This finding was in agreement with the result of Ulemale *et al.* (2004), who reported that, minimum days to root initiation (17.66 days) was recorded in 500 ppm IBA in rose. However, the treatment of 1000 ppm IBA was found to be significantly superior over rest of the treatments in respect of number of primary roots (65.80) and secondary roots (74.21), length of root (21.59 cm) and final survival percentage of rooted cutting (87.06 %). Treatment of 1000 ppm IBA was found to be significantly superior over all other treatments followed by treatment of 1500 ppm IBA in respect of number of primary roots (43.85) and secondary roots (62.84), length of root (18.74 cm) and final survival percentage of rooted cutting (82.06 %). Minimum values in respect of all parameters were recorded under control treatment. Maximum rooting of *Rosa indica* Odorata in this study was achieved under the treatment of IBA 1000 ppm, whereas, the concentrations above this level inhibited root initiation and development. The results were in agreement with the result of Hartmann *et al*. (2002), who stated that, IBA concentrations from 500 to 1500 ppm were found suitable for softwood cutting and any levels higher than those reduced rooting percentage as higher concentrations might have caused cell death. Similar results were also reported by Ulemale *et al.* (2004), who noticed that, IBA at 1000 ppm gave the highest number of primary roots rooted cutting^{-1} (40.66), total length of roots cutting^{-1} (145.66 cm), cuttings survival (85.55 %). Similar findings were also reported by Singh *et al*. (2010), who stated that, the cutting treated with 1000 ppm IBA were found superior with sprouting percentage (85.39 %), rooting percentage (75.46 %), number of primary roots (19.73) as well as secondary roots (28.8) cutting^{-1}, length of longest root (39.9 cm) and establishment (100 %) in bougainvillea. Similar results were also reported by Laubscher and Nadakidemi (2008), who reported that, IBA supplied at 1000 ppm produced greater root numbers when compared with all other treatments.

Effect of IBA on vegetative growth of rootstock cutting in rose :

The data (Table 2) indicated significant differences in respect of days to sprouting, number of leaves as well as shoots, diameter of rootstock and sprouting percentage due to different levels of IBA. The treatment of 500 ppm IBA recorded minimum days to sprouting (8.98 days), whereas, maximum days (11.39 days) were required for sprouting of cutting under control treatment. This finding was in agreement with the result of Ulemale *et al.* (2004), who reported that, minimum number of days required for sprouting (9.16 days) of cuttings in rose was recorded in 500 ppm IBA. However, significantly maximum sprouting percentage (91.07 %), number of leaves (53.30) as well as shoots (4.17) cutting^{-1} and diameter of rootstock (0.84 cm) were recorded due to the treatment of 1000 ppm IBA, while minimum sprouting percentage (62.93 %), number of leaves (40.06) and shoots (3.90) cutting^{-1}, diameter of rootstock (0.62 cm) were recorded under control treatment. Treatment of 1000 ppm IBA was found to be significantly superior over all other treatments followed by treatment of 1500 ppm IBA in respect of sprouting percentage (81.46 %), shoots (4.85) cutting^{-1} and diameter of rootstock (0.75 cm), however, it was found to be at par with treatment of 1500 ppm IBA in respect of number of leaves (51.60) cutting^{-1}. This might be due to production of maximum primary roots, secondary roots and longest root length under the treatment of 1000 ppm IBA which might have absorbed maximum nutrient and mineral from the media which was helpful for increasing vegetative growth of rose cutting. Similar observations were also recorded by Ulemale *et al.* (2004), who found more number of shoots (3.30) cutting^{-1}, survival percentage (85.55 %) in rose. Pivetta *et al*. (1999) also concluded that, maximum rooting percentage (95%) was obtained by the application of IBA at 1000 ppm. Swaroop and Raju (2008) conducted an experiment to find out the effect of IBA on hardwood cuttings of bougainvillea cultivars. They found that, cuttings treated with 1000 ppm of IBA gave more number of primary roots, branches plant^{-1} and highest rooting percentage.

It can be inferred from the present study that, IBA 1000 ppm was found to be the most suitable concentration for maximum and successful rooting as well as vegetative growth of rootstock in rose.

Table 1. Effect of IBA on rooting of rootstock cutting in rose

Treatments	Days required for root initiation(days)	Number of primary roots cutting $^{-1}$	Number of secondary roots cutting $^{-1}$	Total length of roots (cm)	Survival percentage of rooted cuttings (%)
Control	24.70	24.08	26.38	16.07	71.86
IBA 500 ppm	20.48	30.25	52.54	17.92	78.66
IBA 1000 ppm	21.92	65.80	74.21	21.59	87.06
IBA 1500 ppm	23.26	43.85	62.84	18.74	82.40
SE (m) ±	0.27	1.38	1.45	0.45	1.07
CD at 5%	0.82	4.18	4.41	1.37	3.24

Table 2. Effect of IBA on vegetative growth of rootstock cutting in rose

Treatments	Days required for sprouting (days)	Sprouting percentage (%)	Number of leaves cutting $^{-1}$	Number of shoots cutting $^{-1}$	Diameter of root stock (cm)
Control	11.39	62.93	40.06	3.90	0.62
IBA 500 ppm	8.98	72.13	42.98	4.49	0.69
IBA 1000 ppm	9.88	91.07	53.30	5.32	0.84
IBA 1500 ppm	10.54	81.46	51.60	4.85	0.75
SE (m) ±	0.25	2.59	1.32	0.11	0.01
CD at 5%	0.78	7.83	4.00	0.34	0.04

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COMBINING ABILITY ANALYSIS FOR YIELD CONTRIBUTING TRAITS IN NEWLY DEVELOPED *KHARIF* SORGHUM LINES

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ABSTRACT

A line x tester set of 40 hybrids along with 13 parents and one standard check i.e. CSH-9 was raised to estimate combining ability. These 40 hybrids were developed by crossing five diverse male sterile lines and eight testers in *rabi* 2009-10. The results indicated that, the lines *viz.,* MS 27A , MS 70A, AKMS 89A and testers *viz.,* AKR 456, AKR 422 and ICSR 43911-3 were found to be the good combiners with high gca effect for grain yield, number of grains panicle^{-1} and panicle length. Thus, they were identified as best general combiners for their further utilization in hybridization programme. The crosses AKMS 89A x AKR 422, MS 27A x AKR 456, MS 27A x ICSR 43911-3, MS 70A x AKR 492 and AKMS 30A x AKR 422 exhibited significant sca effects for grain yield, number of grains panicle^{-1}, fodder yield plant^{-1} and panicle breadth. These crosses possessed parents having either high X high, high X low or low X high gca effects of parents involved in these crosses and hence, these hybrids may be tested in multilocation trials on larger scale for their further evaluation and commercial exploitation.

(Key words: Sorghum, combining ability analysis,sca and gca)

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most widely cultivated grain crop in the world after Wheat, Maize, Rice and Barley and the third most important cereal crop in India. Besides grains, it is a chief source of palatable fodder for cattles in many parts of the country. But, presently yield levels have been saturated and hence, these newly developed diverse sorghum lines were evaluated to identify superior parents which can be further utilized in sorghum hybrid development programme for exploitation of their good general combining ability and superior crosses can be commercially exploited using heterosis breeding after its thorough evaluation in multilocation trials.

Combining ability studies helps in selection of parents and crosses which give highest improvement for the character under consideration. Breeders must have genetic information on the nature of combining ability of parents and their behavior and performance in hybrid combinations .Much information is already available in this respect in sorghum, but still additional information is necessary to help the breeder in developing better lines to suit changing environment and to meet present day needs. In view of this, combining ability of five male sterile and eight testers were estimated for grain yield and other important characters.

MATERIALS AND METHODS

The five diverse male sterile lines MS 27A, AKMS 30A, AKMS 42A, MS 70A and AKMS 89A were used as female parents for developing 40 F_1's using eight testers *viz.,* AKR 150, AKR 492, AKR 422, AKR 456, ICSR 43911-3, ICSR 43940, ICSR 43489 and ICSR 90006. The resulting 40 hybrids were planted along with thirteen parents and one standard check CSH-9 in randomized block design with three replications during *kharif* 2010 at Sorghum Research Unit, Dr. PDKV., Akola. Each entry was raised in four rows of 3 m length with recommended inter and intra row spacing of 45 cm x 15 cm, respectively. The data were recorded on five random plants for days to 50% flowering, days to maturity, plant height, panicle length, panicle breadth, number of primaries panicle^{-1}, 1000 seed weight, grain yield plant^{-1} and fodder yield plant^{-1}. The combining ability analysis for different traits was done through line x tester method of analysis developed by Kempthorne (1957).

RESULTS AND DISCUSSION

The analysis of variance for combining ability indicates that, mean sum of squares due to lines (female parents) were found significant for all the characters except panicle length. The mean sum of squares due to testers (male parents) were significant

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for plant height, panicle breadth, number of grains panicle^{-1} and grain yield plant^{-1} and non-significant for all other characters. The analysis of variance revealed that mean sum of squares due to lines x testers interactions were highly significant for all the characters except 1000 seed weight (Table 1).Mahdy *et al.* (2011) observed highly significant differences for all the characters under study for all the characters over two years for all the environments under study. The knowledge of combining ability coupled with mean performance of parents would be of great value in selecting suitable parents for hybridization programme. Among the lines, MS 70A and MS 27A recorded highest mean performance for grain yield plant^{-1} and also showed desirable mean performance for yield contributing traits like fodder yield, panicle length and days to 50% flowering.

Similarly, among the testers, ICSR 43489 and ICSR 43940 recorded highest mean performance for grain yield plant^{-1} and fodder yield. Similarly, other testers ICSR 43911-3 and AKR 456 showed maximum mean performance for grain yield plant^{-1}, fodder yield plant^{-1} and plant height.

Among the female parents, AKMS 89A was found to be good general combiner for early flowering, early maturity and grain yield plant^{-1}. The female line AKMS 30A was good general combiner for plant height, panicle length, panicle breadth and 1000 seed weight. The line MS 70A was found good general combiner for number of grains panicle^{-1}. However, the line MS 27A was good general combiner for number of primaries panicle^{-1} and fodder yield plant^{-1}**.**

Among the testers, ICSR 43940 and AKR 492 were recorded significant and negative gca effects for early flowering and early maturity. The testers, AKR 422 and AKR 456 were good general combiner for plant height, panicle length, panicle breadth, number of primaries panicle^{-1}, number of grains panicle^{-1}, grain yield plant^{-1} and fodder yield plant^{-1}. However, the tester, ICSR 43911-3 was good combiner for number of grains panicle^{-1} and grain yield plant^{-1} and hence, can be used as donor parents for hybridization programme. The tester ICSR 43489 recorded significant and positive gca effects for plant height and fodder yield plant^{-1} and hence, can be used as donor parent for increasing the fodder yield. Thus, these testers can be used in new hybrid development programme.

Wadikar *et al*. (2006) reported that parents were good general combiners and identified crosses had high sca for grain yield, Mukesh *et al*. (2007) in their combining ability studies pointed out male sterile lines *viz.,* ICS 4A, ICS 79A and tester IS 3289 were found as good general combiners for most of the traits.

From the available 40 hybrids, hybrid MS 70A x AKR 492 exhibited significant sca effects for days to 50% flowering, days to maturity, plant height, number of primaries panicle^{-1}, panicle length, panicle breadth, number of grains panicle^{-1}, grain yield plant^{-1} and fodder yield plant^{-1}and Biradar (Table 3). Patil *et al.* (2005) studied combining ability of newly derived restorers in *rabi* sorghum and identified two crosses viz.,1409A x RR-9830 and 104A x RR-9826 showing significantly high sca effects for grain yield plant^{-1} and number of grains panicle^{-1} with higher mean performance over the check CSH-19R. Wadikar *et al.* (2006) in their combining ability studies showed that the estimates of sca effects indicated the presence of higher non-additive gene action for all the characters studied.

It is revealed that, the testers showing high or average gca effects were also having higher or average mean values indicating the close relationship between gca and mean performance for most of the characters confirming the earlier reports of Kanawade *et al.* (2001). This may help in selection of parents on the basis of mean performance in absence of information on combining ability of testers. The parents MS 27A, MS 70A, AKMS 89A, AKR 456, AKR 422 and ICSR 43911-3, if used in breeding programme will provide an opportunity to generate more desirable transgressive segregants for grain yield and other component traits on the basis of specific combining ability effects. Specific combining ability is directly related to heterosis. The data regarding specific combining ability effects of promising cross combinations are presented in table 4. The data revealed that, from the available 40 hybrids, hybrid MS 70A x AKR 492 exhibited significant sca effects for days to 50% flowering, days to maturity, plant height, number of primaries panicle^{-1}, panicle length, panicle breadth, number of

Table 1. Analysis of variance for combining ability for different characters in sorghum

Source of variation	d.f.	Days to 50% flowering	Days to maturity (days)	Plant height (cm)	Panicle length (cm)	Panicle breadth (cm)	Number of primaries panicle^{-1}	Number of grains panicle^{-1}	1000 seed wt. (g)	Grain yield plant^{-1} (g)	Fodder yield plant^{-1} (g)
		Mean Sum of Squares									
Replications	2	5.01	9.66	11.13	5.80	1.72	7.20	3224.59	1.09	0.26	0.59009
Lines	4	319.62**	362.03**	1951.81	64.01	4.57**	586.38**	2670780.09**	16.35*	1786.90*	5546.21**
Testers	7	107.47	104.46	2942.28**	44.70	2.90	245.80	911569.87	3.47	1423.59*	1645.62
Line x tester	28	71.37**	83.96**	1243.41**	35.33**	1.21**	231.58**	327497.82**	4.94	521.91**	875.71**
Error	78	8.66	10.35	10.07	4.54	0.28	11.54	2531.86	3.14	2.16	2.70

Table 2. GCA effects of parents for ten characters in sorghum

Sr. No.	Parents	Days to 50% flowering	Days to maturity	Plant height (cm)	Panicle length (cm)	Panicle breadth (cm)	Number of primaries panicle^{-1}	Number of grains panicle^{-1}	1000 seed weight (g)	Grain yield plant^{-1} (g)	Fodder yield plant^{-1} (g)
	Females										
1	MS 27A	-2.14**	-1.12**	-0.63	0.03	0.39**	8.42**	-125.97**	0.25	6.18**	15.27**
2	AKMS 30A	-1.81**	-2.57**	12.57**	2.48**	0.51**	-1.02	-270.08**	0.74*	-5.17**	7.93**
3	MS 70A	3.61*	3.72*	4.75**	0.21	-0.12	-0.26	462.46**	-1.22	4.42**	-8.19**
4	AKMS 89A	-3.85**	-4.41**	-9.93**	-2.00	-0.29	-3.45	231.60**	0.67	7.26**	-22.48**
	SE ±	**0.60**	**0.66**	**0.65**	**0.43**	**0.11**	**0.69**	**10.27**	**0.36**	**0.30**	**0.33**
	Males										
1	AKR 492	0.41**	0.94**	-11.18**	-2.86*	-0.25	-2.66	-366.74**	-0.57	-7.35**	-10.42**
2	AKR 422	-1.46**	-1.52**	20.32**	1.69**	0.85**	8.50**	355.16**	0.33	9.44**	16.93**
3	AKR 456	-0.39**	-0.79**	11.42**	2.05**	0.24	3.75**	278.41**	0.63	16.19**	10.85**
4	ICSR 43911-3	2.54	3.01	-1.71	0.89	0.18	-2.05	214.99**	0.31	7.71**	0.19
5	ICSR 43940	4.34	4.01*	-9.26**	-1.35	-0.01	-2.43	-108.24**	-0.43	-10.08**	-2.77**
6	ICSR 43489	0.41	-0.32**	12.16**	0.65	-0.17	-0.41	-102.28**	-0.37	-2.55**	3.85**
	SE ±	0.76	0.83	0.82	0.55	0.14	0.88	12.99	0.46	0.38	0.42

Table 3. Top five crosses for important quantitative traits in sorghum

Sr. No.	Characters	Crosses	*per se* performance of crosses	sca effects of crosses	gca status of parents
1	Days to 50% flowering	AKMS 89A x AKR 422	61.00	-1.08**	H x H
		MS 27A x ICSR 43911-3	64.00	-3.79**	H x L
		MS 70A x AKR 492	69.33	-2.07**	L x L
		MS 27A x AKR 456	70.33	5.47**	H x H
		AKMS 30A x AKR 422	73.33	9.21**	H x H
2	Days to maturity	AKMS 89A x AKR 422	94.67	-1.06**	H x H
		MS 27A x ICSR 43911-3	102.00	-1.55**	H x L
		MS 70A x AKR 492	104.67	-1.65**	L x L
		AKMS 30A x AKR 422	105.33	7.77**	H x H
		MS 27A x AKR 456	105.67	5.92**	H x H
7	No. of grains panicle^{-1}	AKMS 30A x AKR 422	3979.47	571.56**	L x H
		AKMS 89A x AKR 422	3921.17	11.58	H x H
		MS 70A x AKR 492	3867.33	428.78**	H x L
		MS 27A x AKR 456	3533.33	38.06	L x H
		MS 27A x ICSR 43911-3	3527.83	95.99**	L x H
9	Grain yield plant^{-1}	AKMS 89A x AKR 422	99.70	14.88**	H x H
		MS 27A x AKR 456	99.17	8.67**	H x H
		MS 27A x ICSR 43911-3	98.07	16.05**	H x H
		MS 70A x AKR 492	96.60	31.41**	H x L
		AKMS 30A x AKR 422	88.53	16.14**	L x H
10	Fodder yield plant $^{-1}$(g)	MS 27A x AKR 456	137.00	7.23**	H x H
		AKMS 30A x AKR 422	125.63	-2.88**	H x H
		MS 27A x ICSR 43911-3	125.60	6.49**	H x L
		MS 70A x AKR 492	110.40	25.36**	L x L
		AKMS 89A x AKR 422	110.17	12.06**	L x H

grains panicle^{-1}, grain yield plant^{-1} and fodder yield plant^{-1}. In addition, the crosses AKMS 89A x AKR 422, MS 27A x AKR 456 and MS 27A x ICSR 43911-3 showed higher sca effect for grain yield plant^{-1} (g) and also recorded significant sca effects for fodder yield plant^{-1} (g) and other yield contributing traits. Kaul *et al.* (2003) screened two cms lines with seven restorers in line x tester mating design and reported high sca variances for flowering time, plant height, panicle length and number of branches panicle^{-1}, test weight and grain yield plant^{-1}.

From the study of general combining ability effects of parents and specific combining ability effects of crosses and *per se* performance for grain yield and its important components, the crosses, MS 70A X AKR 492, AKMS 89A X AKR 422, MS 27A X AKR 456, MS 27A X ICSR 43911-3 and AKMS 30A X AKR 422 appeared to be the most promising (Table 3). These crosses would provide transgressive segregants as these crosses involved good combiners for at least as one of the parents for grain yield.

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RESPONSE OF FOLIAR SPRAYS OF HUMIC ACID THROUGH COWDUNG WASH ON MORPHO-PHYSIOLOGICAL, YIELD AND YIELD CONTRIBUTING PARAMETERS OF GROUNDNUT

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ABSTRACT

An experiment was conducted during the *kharif* season of 2010-2011 at farm of Botany section, College of Agriculture, Nagpur. The experiment was laid out in randomized block design with ten treatments and three replications comprising of treatments control (T_1), 100 ppm humic acid through CDW (T_2), 150 ppm (T_3), 200 ppm (T_4), 250 ppm (T_5), 300 ppm (T_6), 350 ppm (T_7), 400 ppm (T_8), 450 ppm (T_9) and 500 ppm (T_{10}).The foliar application of humic acid through cow dung wash was given at two stages i.e. 20 DAS and 35 DAS on groundnut. Foliar sprays of humic acid showed their significance over control. Foliar sprays of 300 ppm followed by 350 ppm humic acid increased the plant height, number of branches plant^{-1}, dry matter production, leaf area, RGR, NAR, number of pods plant^{-1}, shelling percentage, weight of 100 kernels, pod yield plot^{-1} and hectare^{-1}.

(Key words: Groundnut. humic acid, cowdung wash, morpho-physiological parameters, yield)

INTRODUCTION

Groundnut 'the unpredictable legume' has originated in Brazil and South America. The botanical name of groundnut (*Arachis hypogea* L.) is derived from Greek word “Arachis” meaning a legume and “hypogea” meaning below ground referring to geographic nature of pod formation. Groundnut belongs to family leguminaceae, genus *Arachis* and has chromosome number 2n=40. It is also a day neutral plant, flowers are self pollinated. Groundnut is one of the leading field legume in India. Being an oil crop it plays an important role in country's agricultural economy, on account of its versatile use in domestic and industrial fields.

Humic acid is an important component of soil organic matter, which can improve the soil properties and crop-nutrition. Humic acid are intermediate in complexity between humins and fulvic acid and persist in soil for a longer period so as to be useful for the crop. Humic acid with high molecular weight are not known to be assimilable, while those with low molecular weight are said to be assimilable by the plants (Chandrasekharan, 1992).

Humic acid stimulate plant growth by assimilation of major and minor elements, enzyme activation and inhibition, changes in membrane permeability, protein synthesis and finally the activation of biomass production (Ulkon 2008). Humic acid are excellent foliar fertilizer, carriers and activators. Application of humic acid in combination with trace elements and other plant nutrients, as the foliar sprays can improve the growth of plant foliage, roots and fruits by increasing plant growth processes within the leaves and increase in carbohydrate content of the leaves and stem occurs. These carbohydrates are then transported down to the stem into the roots where they are in part released from the root to provide nutrients for various soil micro organisms on the rhizoplane and in the rhizosphere (Ghamry, 2009).

Cowdung wash is excellent liquid manure. It is good source of humic acid (approximately 1100 ppm), macronutrients (1.5% N, 1% P, 1% K) and also good amount of micro nutrient. Farmers who used biogas slurry reported to have obtained higher yield of many crops (Thomas and Ramesh, 2004). Hence, attempt was made to study the effect of foliar sprays of humic acid through cowdung wash on morpho-physiological, yield and yield contributing parameters of groundnut.

MATERIALS AND METHODS

Investigation on the response of foliar sprays of humic acid through cowdung wash on morpho-physiological parameters, yield and yield contributing parameters of groundnut was conducted at farm of Botany section, College of Agriculture, Nagpur during 2010-2011. Humic acid at different concentrations through cowdung wash like control (T_1), 100 ppm (T_2), 150 ppm (T_3), 200 ppm (T_4), 250 ppm (T_5), 300 ppm (T_6), 350 ppm (T_7), 400 ppm (T_8), 450 ppm (T_9) and 500 ppm (T_{10}) were tested.

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Groundnut seed of variety AK–303 was used for experiment in *kharif* season after receiving the sufficient rainfall in June 2010.Observations on morpho-physiological parameters and yield contributing parameters of groundnut were also recorded. Plant height (cm) and number of branches plant^{-1} were recorded at maturity. Leaf area and dry weight of plant were recorded at 20, 35, 50 and 65 DAS. Similarly RGR and NAR were calculated at 35-20, 50-35 and 65-50 DAS. Observations on number of pods plant^{-1}, shelling percentage, weight of 100 kernels, pod yield plant^{-1} and ha^{-1}were also recorded.

RESULTS AND DISSCUSSION

Morpho-physiological parameters :

Data regarding morpho-physiological parameters are presented in table 1.

Plant height at maturity :

Significantly maximum plant height was recorded in treatments 300 ppm humic acid through CDW (T_6) followed by 350 ppm (T_7), 250 ppm (T_5), 200 ppm (T_4), 150 ppm (T_3), 400 ppm (T_8), 450 ppm (T_9) and 500 ppm (T_{10}) when compared with control and rest of the treatments. Application of 100 ppm CDW also increased plant height significantly when compared with control. Humic sources (CDW) exert their influence on foliar transport in number of ways. The foliar application enhances the absorption of nutrients by the leaf at site of application. The above findings are in consonance with the findings of Chen and Solovitch (2003).They found that foliar application of HS enhanced shoot growth in different crops viz., wheat, maize, barely, bean etc. Humic acid is the source of major nutrients viz., N, P, K when these nutrients are applied they are quickly absorbed by the vegetative parts and remobilized to other parts. Nitrogen, phosphorus and potassium are concerned with different plant growth functions viz., cell enlargement, greater photosynthetic activity, formation of carbohydrates, translocation of solutes. These might be the reasons for increased plant height in the present investigation.

Number of branches plant^{-1} at maturity

Significantly maximum number of branches plant^{-1} was recorded in treatment of 300 ppm (T_6) humic acid through CDW followed by 350 ppm (T_7), 250 ppm (T_5), 200 ppm (T_4) and 150 ppm (T_3) in a descending manner when compared with control and remaining treatments. All the remaining treatments i.e. 400, 450, 500 and 100 ppm CDW in a descending manner also exhibited their significance over control in respect of number of the branches plant^{-1} at maturity. Similar results were also observed by Venkatramana *et al*. (2010). They reported that foliar application of VW and CDW proved effective in increasing the number of branches plant^{-1} in mulberry.

Leaf area of plant

Significant variations were recorded at 35, 50 and 65 DAS. At 20 DAS the data regarding leaf area was found non-significant, because foliar sprays of cowdung wash of different concentrations were given from this stage onwards (20 and 35 DAS). At 35 DAS treatment 300 ppm humic acid through CDW (T_6) showed significantly maximum leaf area followed by T_7 (350 ppm), T_5 (250 ppm), T_4 (200 ppm) and T_3 (150 ppm) when compared with control and rest of the treatments. Similarly treatments T_8 (400 ppm), T_9(450 ppm), T_{10} (500 ppm) and T_2 (100 ppm) showed significantly minimum leaf area but were at par with control. At 50 DAS treatment T_6 (300 ppm humic acid through CDW) showed significantly maximum leaf area followed by T_7 (350 ppm), T_5 (250 ppm), T_4 (200 ppm) T_3 (150 ppm) and T_8 (400 ppm) when compared with control and rest of the treatments. Treatments T_9 (450 ppm), T_{10} (500 ppm) and T_2 (100 ppm) showed significantly moderate leaf area however, minimum leaf area was recorded in treatment T_1. At 65 DAS treatment T_6 (300 ppm humic acid through CDW), T_7 (350 ppm) and T_5 (250 ppm) showed significantly maximum leaf area in a descending manner. While, treatments T_4 (200 ppm), T_3 (150 ppm) and T_8 (400 ppm) showed significantly moderate leaf area and minimum leaf area was observed in treatments T_9(450 ppm), T_{10} (500 ppm), T_2 (100 ppm) and T_1 (control). But treatments T_9 (450 ppm), T_{10} (500 ppm) and T_2 (100 ppm) also showed their superiority over T_1 (control). Ghadge (2008) reported that foliar application of humic acid through cowdung wash and vermicompost wash significantly increased leaf area in green gram.

Total dry matter production

Dry matter is an important criterion. It determines the source- sink relationship and depends upon the net gain in the processes on anabolism and catabolism of plant. At 20 DAS the data regarding dry matter production was found non-significant, because foliar sprays of cowdung wash of different concentrations were given from this stage onwards (20 and 35 DAS). At 35 DAS treatment T_6 (300 ppm humic acid through CDW) showed significantly maximum dry matter followed by T_7 (350 ppm), T_5 (250 ppm), T_4 (200 ppm) and T_3 (150 ppm) when compared with control and rest of the treatments. Treatments T_8 (400 ppm), T_9 (450 ppm), T_{10} (500 ppm) and T_2 (100 ppm) also gave significantly more dry matter when compared with treatment T_1 (control). At 50 DAS treatment T_6 (300 ppm humic acid through CDW) showed significantly maximum dry matter followed by T_7 (350 ppm), T_5 (250 ppm) and T_4 (200 ppm) when compared with control and rest of the treatments. Treatments T_3 (150 ppm), T_8 (400 ppm), T_9 (450 ppm), T_{10} (500 ppm) and T_2 (100 ppm) showed significantly moderate dry matter however, minimum dry matter was found in treatment T_1. All above treatments were found superior over T_1 (control). At 65 DAS treatment T_6 (300 ppm humic acid through CDW), T_7 (350 ppm) and T_5 (250 ppm) showed significantly maximum dry matter in a descending manner. While, treatments T_4 (200 ppm), T_3 (150 ppm), T_8 (400 ppm), T_9 (450 ppm) and T_{10} (500 ppm) showed significantly more dry matter as compared to treatment T_2 (100 ppm) and T_1 (control). Asharf *et al.* (2005) also reported that foliar application of humic acid derived from lakhara increased dry weight of plant significantly in mung beans. Khalid and Fawy (2011) also noticed highest dry weight with the foliar application of 0.5% humic acid in corn.

Growth analysis

Growth analysis is one of the measures for accessing the seed yield of the plant. The physiological basis of yield difference can measured through an evaluation of difference in growth parameters and their impact on yield. The productivity of crop may be related with the parameters such as RGR, NAR and partitioning of total photosynthates into economic and non-economic sink.

Relative growth rate (RGR)

Data regarding RGR are given in table 2. Considering all the treatments under study significantly maximum RGR and NAR were recorded in treatment receiving 300 ppm humic acid through CDW and minimum in control at 35-20, 50-35 and 65-50 DAS. During the first phase (35-20 DAS) significantly maximum RGR was noted in T_6 (300 ppm humic acid through CDW), followed by treatments T_7 (350 ppm), T_5 (250 ppm), T_4 (200 ppm), T_3 (150 ppm), T_8 (400 ppm), T_9 (450 ppm), T_{10} (500 ppm) and T_2 (100 ppm) in a descending manner when compared with T_1 (control) and rest of the treatments. During the second phase (50-35 DAS) RGR was significantly influenced by different treatments. At this stage treatment T_6 (300 ppm humic acid through CDW) showed significantly maximum RGR followed by T_7 (350 ppm), T_5 (250 ppm), T_4 (200 ppm), T_3 (150 ppm) and T_8 (400 ppm) when compared with control and rest of the treatments. Treatments T_9 (450 ppm), T_{10} (500 ppm) and T_2 (100 ppm) were also found significantly superior over T_1 (control). During the third phase (65-50 DAS) RGR was significantly influenced by different treatments. At this stage treatment T_6 (300 ppm humic acid through CDW) showed significantly maximum RGR followed by T_7 (350 ppm), T_5 (250 ppm) and T_4 (200 ppm) when compared with control and rest of the treatments. Treatments T_3 (150 ppm), T_8 (400 ppm) T_9 (450 ppm) and T_{10} (500 ppm) showed significantly moderate RGR. However, minimum RGR was found in treatment T_2 (100 ppm) and T_1 (control). All above treatments were found superior over T_1 (control).

Net assimilation rate (NAR) :

NAR is closely connected with photosynthetic 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 plant dry weight $unit^{-1}$ area of assimilatory tissues $unit^{-1}$ time. Data regarding NAR are given in table 2. Considering all the treatments under study, during the first phase (35-20 DAS) significantly maximum NAR was noted in T_6 (300 ppm humic acid through CDW) followed by treatments T_7 (350 ppm), T_5 (250 ppm), T_4 (200 ppm) and T_3 (150 ppm) in a descending manner when compared with T_1 (control) and rest of the treatments. Treatments T_8 (400 ppm), T_9 (450 ppm), T_{10} (500 ppm) and T_2 (100 ppm) also showed maximum NAR when compared with T_1 (control) in a descending manner. During the second phase (50-35 DAS) significantly maximum NAR was noted in T_6 (300 ppm humic acid through CDW), followed by treatments T_7 (350 ppm), T_5 (250 ppm) and T_4 (200 ppm) in a descending manner when compared with T_1 (control) and rest of the treatments. Similarly treatments T_3 (150 ppm), T_8 (400 ppm), T_9 (450 ppm), T_{10} (500 ppm) and T_2 (100 ppm) showed maximum NAR when compared with T_1 (control) in a descending manner. During the third phase (65-50 DAS) significantly maximum NAR was noted in T_6 (300 ppm humic acid through CDW), T_7 (350 ppm) and T_5 (250 ppm). Similarly treatments T_4 (200 ppm), T_3 (150 ppm), T_8 (400 ppm) and T_9 (450 ppm) showed significantly moderate NAR when compared with T_1 (control) and rest of the treatments. Treatments T_{10} (500 ppm) and T_2 (100 ppm) showed minimum NAR. All above treatments were found superior over T_1 (control).

Yield and yield contributing parameters :

Data in respect of yield and yield contributing parameters were recorded at harvesting stage and are presented in table 2.

Number of pods plant^{-1} :

Significantly more number of pods plant^{-1} were recorded in treatment T_6 (300 ppm humic acid through CDW) followed by treatments T_7 (350 ppm), T_5 (250 ppm), T_4 (200 ppm), T_3 (150 ppm) T_8 (400 ppm) and T_9 (450 ppm) when compared with T_1 (control) and rest of the treatments. Whereas treatments T_{10} (500 ppm), T_2 (100 ppm) and T_1 (control) showed minimum number of pods plant^{-1}. But treatments T_{10} (500 ppm) and T_2 (100 ppm) recorded more number of pods plant^{-1} when compared with T_1 (control). Ghadge *et al.* (2008) applied HA through VW and CDW as foliar sprays on green gram and observed increase in pods plant^{-1} with the application of 250 ppm VW and CDW.

Weight of 100 Kernels :

100 Kernels weight increased significantly and it was found maximum in treatment T_6 (300 ppm humic acid through CDW) followed by T_7 (350 ppm), T_5 (250 ppm), T_4 (200 ppm), T_3 (150 ppm), T_8 (400 ppm) and T_9 (450 ppm) in a descending manner when compared with control and rest of the treatments. Whereas treatments T_{10} (500 ppm), T_2 (100 ppm) and T_1 (control) showed minimum 100 kernel weight. But treatments T_{10} (500 ppm) and T_2 (100 ppm) recorded more 100 kernel weight as compared to T_1 (control).

Shelling percentage :

Shelling percentage was significantly highest in treatment T_6 (300 ppm humic acid through CDW) followed by T_7 (350 ppm), T_5 (250 ppm), T_4 (200 ppm), T_3 (150 ppm), T_8 (400 ppm) and T_9 (450 ppm) in a descending manner when compared with control and rest of the treatments. Whereas treatments T_{10} (500 ppm), T_2 (100 ppm) and T_1 (control) showed minimum shelling percentage. But treatments T_{10} (500 ppm) and T_2 (100 ppm) also showed their significance in shelling percentage over T_1 (control).

Yield contributing parameters mainly include number of pods and weight of 100 kernels in groundnut. From the data it is evident that all these two yield contributing parameters significantly increased in the treatments receiving two foliar sprays of CDW at 20 and 35 DAS over control. The uptake of N, P and K during reproductive stages greatly influenced the pod formation and quality aspects of seed. Photosynthetic rate at grain filling are also increased. Cheng *et al*., (1995) reported that spraying of humic acid increased thousand grain weight and retarded senescence in wheat.

Pod yield plot^{-1} and ha^{-1}:

Pod yield is a complex physiological character which is the sum total of all metabolic activities taking place in plant body. This includes various morphological aspects like increase in plant height, leaf size, leaf area, number of branches, dry matter, seed weight etc. These characters can be considered as yield contributing parameters. Significantly maximum grain yield plot^{-1}, ha^{-1} were recorded in treatment T_6 (300 ppm humic acid through CDW), T_7 (350 ppm), T_5 (250 ppm), T_4 (200 ppm) and T_3 (150 ppm) in a descending manner when compared with control and rest of the treatments. While, treatments T_8 (400 ppm), T_9 (450 ppm), T_{10} (500 ppm) and T_2 (100 ppm) were found at par with T_1 (control). Similar finding with respect to this parameter was also reported by Lende *et al*. (2007). They evaluated the effect of foliar sprays of vermicompost wash

Table 1. Effect of humic acid through cowdung wash on morpho-physiological yield and yield contributing parameters of groundnut

Treatments (ppm)	Plant height at maturity (cm)	Number of branches at maturity	Leaf area of plant (dm^2)				Total dry matter $plant^{-1}$ (g)				Number of pods $plant^{-1}$	Shelling (%)	Weight of 100 kernels (g)	Pod yield $plot^{-1}$ (kg)	Pod yield ha^{-1} (q)
			20 DAS	35 DAS	50 DAS	65 DAS	20 DAS	35 DAS	50 DAS	65 DAS					
T_1 (Control)	45.67	7.28	1.08	1.89	3.54	3.84	1.09	3.49	7.45	9.82	17.22	72.00	68.31	1.40	19.43
T_2(100)	47.25	7.31	1.09	1.91	3.75	4.02	1.11	3.57	7.78	10.32	17.40	72.92	70.64	1.42	19.63
T_3 (150)	51.48	7.77	1.12	2.03	4.21	4.45	1.15	3.78	8.57	12.00	18.28	74.48	72.94	1.49	20.78
T_4 (200)	51.86	7.80	1.12	2.10	4.34	4.63	1.18	3.99	9.10	12.96	18.34	74.62	73.96	1.51	20.96
T_5 (250)	52.64	8.20	1.13	2.15	4.40	5.01	1.19	4.14	9.51	13.54	18.39	75.01	74.26	1.51	21.00
T_6 (300)	53.28	8.37	1.15	2.15	4.56	5.26	1.20	4.21	9.87	14.43	19.00	75.79	76.50	1.61	22.32
T_7 (350)	53.16	8.32	1.15	2.17	4.51	5.12	1.20	4.20	9.71	14.05	18.42	75.62	75.89	1.53	21.27
T_8 (400)	50.91	7.64	1.12	1.96	4.15	4.32	1.13	3.69	8.34	11.66	18.21	73.89	72.63	1.47	20.38
T_9 (450)	50.73	7.59	1.11	1.92	3.98	4.12	1.13	3.65	8.09	11.09	18.06	73.80	72.42	1.45	20.18
T_{10} (500)	48.89	7.48	1.08	1.92	3.78	4.07	1.12	3.65	7.89	10.76	17.78	73.23	70.98	1.43	19.93
SE(m)±	1.611	0.226	0.01	0.06	0.14	0.16	0.02	0.15	0.33	0.41	0.328	0.723	1.485	0.036	0.467
CD at 5%	4.787	0.674	-	0.19	0.41	0.50	-	0.44	0.99	1.24	0.976	2.150	4.413	0.106	1.375

Table 2. Effect of humic acid through cowdung wash on RGR and NAR of groundnut

Treatments (ppm)	RGR (g g^{-1} day^{-1})			NAR (g dm^{-2} day^{-1})		
	35-20	50-35	65-50	35-20	50-35	65-50
T_1 (Control)	0.077	0.050	0.018	0.110	0.100	0.011
T_2(100)	0.078	0.052	0.019	0.112	0.102	0.011
T_3 (150)	0.079	0.054	0.022	0.115	0.106	0.012
T_4 (200)	0.081	0.055	0.023	0.120	0.110	0.013
T_5 (250)	0.083	0.055	0.023	0.124	0.113	0.014
T_6 (300)	0.084	0.057	0.025	0.125	0.117	0.015
T_7 (350)	0.083	0.055	0.024	0.124	0.115	0.015
T_8 (400)	0.079	0.054	0.022	0.114	0.106	0.012
T_9 (450)	0.078	0.053	0.021	0.114	0.104	0.012
T_{10} (500)	0.078	0.051	0.020	0.114	0.102	0.011
SE(m)±	0.0018	0.0013	0.0010	0.0034	0.0029	0.0004
CD at 5%	0.0053	0.0040	0.0029	0.0100	0.0087	0.0013

(VW) and cow dung wash (CDW) on yield and yield contributing parameters of soybean. The treatments tried were 100,150, 200 ppm HA through VW and CDW. Data showed that yield contributing parameters viz., number of pods plant^{-1}, pod weight, 100 seed weight and seed yield increased with the increasing concentration of VW and CDW.

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EFFECT OF FOLIAR APPLICATION OF GA_3 AND KNO_3 ON FLOWERING AND YIELD QUILITY OF AFRICAN MARIGOLD

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ABSTRACT

An experiment was undertaken to study the effect of foliar application of GA_3 and KNO_3 on flowering, yield and quality of African marigold in winter season, 2011-12. Experiment was laid out in randomized block design with three replications and 9 treatments of foliar application of GA_3 and KNO_3 with different concentrations alone and in combination viz., GA_3 200 ppm, GA_3 400 ppm, KNO_3 1%, KNO_3 2%, GA_3 200 ppm + KNO_3 1%, GA_3 200 ppm + KNO_3 2%, GA_3 400 ppm + KNO_3 1%, GA_3 400 ppm + KNO_3 2% and control (water spray). It is evident from experimental findings that, days to opening of flower from flower bud emergence, 50 per cent flowering and first harvesting from transplanting and maximum flowering span in marigold were obtained under treatment of foliar application of GA_3 200 ppm with KNO_3 1% . However, diameter of fully open flower, length of flower stalk, weight of flower and vase life of flower were found maximum under foliar application of GA_3 400 ppm with KNO_3 2%. Whereas, foliar spray of GA_3 at 200 ppm in combination with KNO_3 2% resulted in maximum flower yield ha^{-1}.

(Key words: GA_3, KNO_3, growth regulator, African marigold)

INTRODUCTION

Marigold (*Tagetes erecta*) belonging to the family 'Asteraceae' is a hardy annual with different flower colors ranging from lemon yellow to orange. It is mostly used as loose flower for making garlands. Due to essential oil present in different species of marigold, it is one of the source of perfume industry. The oil has a pronounce odour and it acts as a repellant to flies. It has been found that, the marigold plants are highly useful for suppressing the population of nematodes in the field. Infestation of fruit borer can be reduced by planting of marigold as an intercrop in other crops.

The horticulture science is much enriched with new tools and techniques during recent years. The research workers have reported that, flowering of many crops could be improved and enhanced by application of suitable growth substances. Plant growth substances like GA_3 and KNO_3 are known to coordinate and control various phases of growth and development including flowering at optimum concentrations.

It is generally accepted that, exogenously applied growth substances act through the alteration in the levels of naturally occurring hormones and modify the growth and development of the plant. Hence, the present study was undertaken to study the effect of foliar application of GA_3 and KNO_3 on flower yield and quality of African marigold.

MATERIALS AND METHODS

An investigation was carried out at Horticulture Section, College of Agriculture, Nagpur in winter season of the year 2011-12 in randomized block design with three replications and nine treatments of foliar application of GA_3 and KNO_3 with different concentrations alone and in combination. The treatments comprised of GA_3 200 ppm (T_1), GA_3 400 ppm (T_2), KNO_3 1% (T_3), KNO_3 2% (T_4), GA_3 200 ppm + KNO_3 1% (T_5), GA_3 200 ppm + KNO_3 2% (T_6), GA_3 400 ppm + KNO_3 1% (T_7), GA_3 400 ppm + KNO_3 2%(T_8) and control (T_9) as water spray. Growth substances were sprayed twice i.e. 20 and 40 days after transplanting. The field was prepared by ploughing and frequent harrowing. Flat beds of size 3.6 m x 1.8 m were prepared and transplanting of marigold seedlings was done at 3.6 m x 1.8 m spacing. Half dose of nitrogen (50 kg ha^{-1}) and full dose of phosphorus (50 kg ha^{-1}) and potash (25 kg ha^{-1}) were applied as a basal dose at the time of transplanting and remaining half dose of nitrogen (50 kg ha^{-1}) was applied 30 days after transplanting. Various observations viz., days to first flower bud emergence, days to 50 per cent flowering, days to first harvesting, flowering span, diameter of fully opened flower, length of flower stalk, weight of fully opened flowers, vase life of flower and flower yield were recorded. The data were statistically analyzed as per the method suggested by Gomez and Gomez (1984).

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RESULTS AND DISCUSSION

The data revealed that, significant differences were recorded among the treatments in respect of days to opening of flower from bud emergence, 50 per cent flowering from transplanting and flowering span. Significantly earlier opening of flower from bud emergence (6.00 days) and 50 per cent flowering (35.47 days) were observed with the treatment of T_5 (GA_3 200 ppm + KNO_3 1%) which was found to be at par with treatment T_1 (6.06 and 35.67days respectively GA_3 200 ppm). However, maximum days to opening of flower and 50 per cent flowering were required under the T_9 ((10.50 days and 41.33 days, respectively, control treatment). Similarly flowering span was found significantly maximum under the treatment of T_5 (42.75 days, GA_3 200 ppm + KNO_3 1%) which was found at par with the treatment T_1 (41.77 days, GA_3 200ppm),whereas, minimum flowering span was observed under T_9 (23.66 days, control treatment). However, significantly minimum days to first harvesting from transplanting were required under the treatment of T_5 (32.06 days, GA_3 200 ppm + KNO_3 1%) and it was followed by the treatment T_1 (33.40 days, GA_3 200 ppm) and T_4 (35.40 days, KNO_3 2%) and maximum days were required under the treatment T_9 (54.20 days, control treatment).

Significantly early flower opening after bud emergence, 50 per cent flowering and first flower harvesting might be due to role of GA_3 in stimulating the flowering and KNO_3 (1%) in inducing flowering as KNO_3 plays important role in providing nitrogen and potassium to the plant growth. Similarly, GA_3 (200ppm) in combination with KNO_3 (1%) resulted in increasing flowering span of African marigold which might be due to better photosynthesis and metabolic activities and uptake of nutrients from the soil due to application gibberellins and potassium. Kulkarni and Reddy (2003) also observed that, an application of GA_3 at 100 ppm and 200 ppm in chrysanthemum induced early flowering. Similarly, Katkar *et al.* (2005) sprayed the china aster plants with GA_3 (100, 150 and 200 ppm) and observed an earliness in flower bud (56.26 days) initiation and 50 per cent flowering (80.46 days) at 200 ppm GA_3. Mahajan *et al*. (2010) also observed minimum days for first spike initiation (98.00days) after spraying with 200 ppm GA_3 with 1.5% KNO_3 in tuberose.

The data from table 1 revealed that, weight of flower, diameter of fully open flower, length of flower stalk, vase life of flower and flower yield ha^{-1} in African marigold were significantly influenced by the different treatments of GA_3 and KNO_3 . The treatment of T_8 (6.30 cm, GA_3 400 ppm + KNO_3 2%) was found significantly superior over all other treatments in respect of diameter of fully open flower and it was found to be at par with the treatments T_7 (5.80 cm, GA_3 400 ppm + KNO_3 1%), T_8 (5.75 cm ,GA_3 200 ppm + KNO_3 2%) and T_7 (5.71 cm, GA_3 200 ppm + KNO_3 1%), whereas, significantly minimum diameter of fully open flower was found under control treatment (4.94cm). Similarly, the treatment T_8 (GA_3 400 ppm + KNO_3 2%) recorded significantly maximum length of flower stalk (10.87) and it was found to be at par with the treatment T_7 (1.083 cm, GA_3 200 ppm + KNO_3 1%), T_2 (10.60 cm, GA_3 400 ppm), T_6 (9.97 cm, GA_3 200 ppm +KNO_3 2%) and T_5 (8.63 cm, GA_3 200 ppm + KNO_3 1%). However, minimum length of flower stalk was found with treatment T_9 (5.87cm, control).

Maximum length of flower stalk and diameter of fully open flower in African marigold might be due to enhanced growth rate of vegetative plant parts due to physiological activities as influenced by higher concentration of GA_3 and KNO_3. GA_3 enhanced cell multiplication and cell elongation and additional KNO_3 might have provided N and K. Kumar *et al.* (2003) noticed that, the China aster plant sprayed with 200 ppm GA_3 produced maximum flower diameter. However, Shradha Wankhede *et al.* (2002) also found that foliar application of GA_3 200 ppm increased the diameter and length of fully open florate and length of rachis in tuberose.

In respect of vase life of African marigold flower it was observed that the treatment T_8 (9.26 days, GA_3 400 ppm + KNO_3 2%) was found significantly superior with maximum vase life of flower and it was at par with the treatments T_7 (9.13 days, GA_3 400 ppm + KNO_3 1%), T_2 (9.04 days, GA_3 200 ppm) and T_6 (9.03 days, GA_3 200 ppm + KNO_3 1%), however, minimum vase life of flower was recorded under the treatment T_9 (8.68 days, control).

Table 1. Influence of GA_3 and KNO_3 on flowering, yield and quality of African marigold

	Treatments	Days to opening of flower from bud emergence	Days to 50 per cent flowering	Days to first harvesting from transplanting	Flowering span (days)	Weight of flower (g)	Diameter of fully opened flower (cm)	Length of flower stalk (cm)	Vase life of flower (days)	Flower yield ha^{-1} (q)
T_1	GA_3 – 200 ppm	6.06	35.67	33.40	41.77	4.48	5.50	8.47	8.85	71.83
T_2	GA_3 – 400 ppm	9.33	39.14	45.13	30.10	4.43	5.17	10.60	9.04	77.30
T_3	KNO_3-1%	9.20	39.14	40.40	34.10	4.70	5.54	8.33	8.91	69.10
T_4	KNO_3 - 2%	6.86	37.83	35.40	39.03	4.67	5.45	7.93	8.98	76.67
T_5	GA_3 – 200 ppm + KNO_3 - 1%	6.00	35.47	32.06	42.75	4.78	5.71	8.63	9.00	85.92
T_6	GA_3 – 200 ppm + KNO_3 - 2%	7.20	37.87	37.27	37.44	4.97	5.75	9.97	9.03	92.57
T_7	GA_3 – 400 ppm + KNO_3 - 1%	8.00	38.20	38.47	36.00	5.13	5.80	10.83	9.13	103.89
T_8	GA_3 – 400 ppm + KNO_3 - 2%	9.00	38.80	40.86	33.33	5.27	6.30	10.87	9.26	121.55
T_9	Control (W.S.)	10.50	41.33	54.20	23.66	3.80	4.94	5.80	8.68	54.47
	SE (m) $\pm$	0.25	0.26	0.26	0.62	0.097	0.24	0.78	0.08	2.55
	CD at 5%	0.77	0.79	0.80	3.02	0.290	0.72	2.33	0.25	5.62

This might be due to enhanced activity of plant as a result of foliar spray of higher concentration of GA_3 and KNO_3 which might have accelerated growth promoting substances in flower stalk that might helped in prolonging vase life of cut flower by utilizing the accumulated substances during vase life period of cut flowers. These findings are in confirmity with the results obtained by Sharma and Singh (2007) who revealed that application of 40g per m^2 of nitrogen and 20g per m^2 of potassium increased vase life of spikes in gladiolus. Tyagi and Kumar (2006) also reported that application of GA_3 160 ppm significantly increased vase life in tuberose (13.85 days).

The results obtained in respect of flower yield are presented in table1. Significant differences were observed among the different treatments in respect of weight of flower and flower yield ha^{-1} in African marigold. Significantly the highest weight of flower and flower yield ha^{-1} were recorded with the treatment T_8 (5.27 g and 121.55 q ,respectively, GA_3 400 ppm + 2% KNO_3) which was closely followed by the treatment T_7 (5.13 g and 103.89 q, respectively, GA_3 400 ppm + 1% KNO_3) whereas minimum weight of flower (3.80 g) and flower yield ha^{-1} (54.47 q) were observed with the treatment T_9 (Control).

The weight of fully opened flower and flower yield increased with the increase in the concentration of GA_3 and KNO_3 which might be due to greater dry matter accumulation. The results are congruent with the result obtained by Varma and Arha (2004) who observed that, an application of GA_3 at the concentration of 200 ppm produced maximum flower yield $plant^{-1}$ and ha^{-1} as compared to control in African marigold. Moond and Gehlot *et al.* (2006) also reported that, an application of GA_3 significantly increased the diameter and weight of flower with the highest weight recorded due to application of GA_3 at 150 ppm in chrysanthemum.

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PHYSIOLOGICAL RESPONSES OF FOLIAR APPLICATION OF HUMIC ACID THROUGH COWDUNG WASH ON MORPHOPHYSIOLOGICAL PARAMETERS AND YIELD OF GREENGRAM

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ABSTRACT

The study was conducted to know the effectivety of humic acid through cowdung wash (100 ppm, 150 ppm, 200 ppm, 250 ppm, 300 ppm, 350 ppm, 400 ppm, 450 ppm and 500 ppm) on the morphophysiological parameters and yield of green gram cv AKM – 8802 during *kharif* 2011-2012. Field experiment was conducted at an experimental farm of botany, College of Agriculture, Nagpur. Data revealed that foliar sprays of CDW exhibited their significance over control. Two foliar sprays of 350 ppm followed by 300 ppm humic acid through cowdung wash at 20 and 35 DAS were found most effective to enhance morphophysiological parameters viz., number and dry weight of root nodules, plant height, leaf area, total dry matter, RGR and NAR and yield of green gram cv. AKM-8802. Yield was increased by 23 and 18% respectively over control by these two treatments and can be considered as the most effective and beneficial treatments (B:C ratio 2.23 and 2.10) in green gram.

(Key words: Green gram, humic acid, cowdungwash, morphophysiological parameters, yield)

INTRODUCTION

Green gram (*Vigna radiata*) is one of the pulse crop cultivated in India. Green gram have excellent source of high quality protein. Green gram is temperate crop which requires about 25 to 30ºC temperature with 60 to 75 cm rainfall with good humidity. Green gram is grown throughout the Southern Asia including India, Pakistan, Bangladesh, Srilanka, Thailand, Vietnam, Indonesia, Malysia and China etc. It is also grown in the parts of Africa and U.S.A. In India it is grown in Maharashtra, Rajasthan, Bihar, Andhra Pradesh, Gujrat, Orissa, Madhya Pradesh, Punjab and Uttar Pradesh. Green gram is rich source of high digestible protein, it contains about 25% protein. Green gram is leguminous crop having the capacity to fix atmospheric nitrogen symbiotically and is used as green manuring after removing the pods.

Cowdung wash is an excellent liquid manure. It is good source of humic acid (approximately 1100 – 1500 ppm), macronutrients (1.5% N, 1% P, 1% K) and also good amount of micronutrients. (Tamhane *et al*., 1965).

Considering the importance of cowdung wash, the present study was undertaken to enhance the yield of greengram through physiological manipulation such as foliar application of humic acid through source like cowdung wash.

MATERIALS AND METHODS

The field experiment was conducted in RBD with a ten treatments and three replications during *kharif* 2011-12 at experimental farm of Botany, College of Agriculture, Nagpur. Cowdung wash were sprayed twice at 20 and 35 DAS. The details of treatments are given in table 1. Plant height, leaf area and total dry matter production were recorded at 35, 50 and 65 days. The number and dry weight of root nodules were recorded at 30 and 40 DAS. NAR and RGR were calculated at 35-50 DAS and 50-65 DAS. Also yield ha^{-1} was recorded after harvesting.

RESULTS AND DISCUSSION

Plant height

Data in respect of plant height recorded at 35 and 50 DAS were found statistically significant. All treatments T_7 (350 ppm), T_6 (300 ppm), T_8 (400 ppm), T_9 (450 ppm), T_5 (250 ppm) and T_{10} (500 ppm) in a descending order increased plant height over treatment T_1 (control) significantly. Next to these treatments, treatments T_4 (200 ppm), T_3 (150 ppm) and T_2 (100 ppm) in a descending manner also significantly increased plant height over treatments control (T_1).

At 65 DAS significantly maximum plant height was noticed in treatment T_7 (350 ppm) humic acid application through cowdung wash followed by

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T_6 (300 ppm), T_8 (400 ppm) and T_9 (450 ppm) when compared with control and rest of the treatments under study. Next to these treatments, treatments T_5 (250 ppm), T_{10} (500 ppm), T_4 (200 ppm) and T_3 (150 ppm) in a descending manner also significantly increased plant height over treatments T_1 (control) and T_2 (100 ppm).

Humic sources (CDW) exert their influence on foliar transport in number of ways. The foliar application enhances the absorption of nutrients by the leaf at site of application. The above findings are consonance with the findings of Chen and Solovitch (2003).They found that foliar application of HS enhanced shoot growth in different crops viz.,wheat, maize, barely, bean etc.

Humic acid is the source of major nutrients viz., N, P, K when these nutrients are applied quickly absorbed by the vegetative parts and remobilized to other parts. Nitrogen, phosphorus and potassium are concerned with different plant growth functions viz., cell enlargement, greater photosynthetic activity, formation of carbohydrates, translocation of solutes. These might be the reasons for increased plant height in the present investigation.

Number and dry weight of root nodules :

The number of root nodules at 30 and 40 DAS ranged from 25.63 to 37.92 and 32.80 to 45.97 respectively.

At 30 DAS the treatment receiving 350 ppm (T_7) increased number of root nodules significantly over control (T_1) and other remaining treatments. Treatments T_6 (300 ppm), T_8 (400 ppm) and T_9 (450 ppm) gave significantly increased number of root nodules over control and rest of the treatments. Next to these treatments, treatments T_5 (250 ppm), T_{10} (500 ppm), T_4 (200 ppm) and T_3 (150 ppm) in a descending manner also significantly increased number of root nodules over treatments T_1 (control) and T_2 (100 ppm).

At 40 DAS significantly maximum number of root nodules was recorded in treatments T_7 (350 ppm humic acid through cowdung wash) followed by T_6 (300 ppm) and T_8 (400 ppm) when compared with treatment T_1 (control) and rest of the treatments. Treatments T_9 (450 ppm), T_{10} (500 ppm), T_4 (200 ppm), T_5 (250 ppm) and T_3 (150 ppm) also significantly increased number of root nodules over treatments T_1 (control) and T_2 (100 ppm).

In case of dry weight of root nodules at 30 and 40 DAS maximum dry weight was observed in treatment 350 ppm (T_7) i.e. 0.49 to 0.56 g and minimum in control 0.28 to 0.35 g respectively.

At 30 DAS significantly maximum dry weight of root nodules was noticed in treatment T_7 (350 ppm humic acid spray through CDW) followed by T_6 (300 ppm), T_8 (400 ppm), T_9 (450 ppm) and T_5 (250 ppm) when compared with control and rest of the treatments. Treatments T_{10} (500 ppm), T_4 (200 ppm) and T_3 (150 ppm) in descending manner also showed significance over treatments T_1 (control) and T_2 (100 ppm).

At 40 DAS significantly maximum dry weight of root nodules was recorded in treatment T_7 (350 ppm humic acid through CDW) followed by T_6 (300 ppm), T_8 (400 ppm) and T_9 (450 ppm) when compared with control and rest of treatments. Treatments T_5 (250 ppm), T_{10} (500 ppm), T_4 (200 ppm) and T_3 (150 ppm) also showed their significance in respect of dry weight of root nodules when compared with treatments T_1 (control) and T_2 (100 ppm).

Nodule development appeared to be dependent on source - sink relationship. This is a function of growth habit of legume crop. Treatments which produced and maintained more active photosynthesis are able to nodules well due to availability of adequate photosynthetic products.

Humic acid application had a definite input on the protein synthesis and nucleic acid synthesis. The high cation exchange capacity of humic acid prevents nutrient from leaching. It absorbs the nutrients from chemical fertilizer and these exchange of nutrients are slowly released to the plants. Foliar application of humic acid fastens the absorption of N and P through foliage and induces nodules formation and rhizobial activity.

Leaf area of plant

Data revealed that the leaf area increased from 35 to 65 DAS. At 35 DAS significantly maximum leaf area was noticed in treatment

T_7 (350 ppm) followed by T_6 (300 ppm) and T_8 (400 ppm) when compared with control and rest of the treatments under study. Treatments T_9 (450 ppm), T_5 (250 ppm), T_4 (200 ppm) and T_{10} (500 ppm) also increased leaf area significantly over control and rest of the treatments. Significantly lower leaf area was noticed in treatment T_1 (control) but this treatment was found at par with treatments T_3 (150 ppm) and T_2 (100 ppm) in a descending order.

At 50 DAS significantly maximum leaf area was recorded in treatment T_7 (350 ppm) followed by T_6 (300 ppm) and T_8 (400 ppm) when compared with control and rest of the treatments. Next to these treatments T_9 (450 ppm), T_5 (250 ppm), T_{10} (500 ppm) and T_4 (200 ppm) in a descending manner also significantly increased leaf area over treatments T_1 (control), T_2 (100 ppm) and T_3 (150 ppm). At 65 DAS treatment T_7 (350 ppm) exhibited significantly maximum leaf area followed by treatment T_6 (300 ppm) when compared with control and rest of the treatments. TreatmentsT_8 (400 ppm), T_9 (450 ppm), T_5 (250 ppm), T_4 (200 ppm), T_{10} (500 ppm) and T_3 (150 ppm) in a descending manner also found significantly superior over treatments T_1 (control) and T_2 (100 ppm).

Leaf area plant^{-1} was 2.44 dm^2 in control to 3.28 dm^2 in treatment receiving 350 ppm cowdung wash at 35 DAS, 3.07 to 4.62 dm^2 at 50 DAS and 4.09 to 6.21 dm^2 at 65 DAS respectively. The per cent increase over control was 57.03 at 20 DAS, 34.42 at 35 DAS, 50.48 at 50 DAS and 51.83 at 65 DAS.

Hence, it can be inferred that when nutrients applied through foliar spray, might have accelerated the metabolic and physiological activities of the plant and put up more growth by assimilating more amount of major nutrients and ultimately increased the leaf area plant^{-1} in the present investigation.

Ghadge (2008) reported that foliar application of humic acid through cowdung wash and vermicompost wash significantly increased leaf area in green gram.

Total dry matter production :

Total dry matter production plant^{-1} was recorded at 35, 50 and 65 DAS. Data regarding dry matter production plant^{-1} was found significant by the application of various treatments at all the stages of observations.

At 35 DAS significantly maximum dry weight were recorded in treatments T_7 (350 ppm) and T_6 (300 ppm) when compared with treatment T_1 (control) and rest of the treatments. Next to these treatments, treatments T_8 (400 ppm), T_9 (450 ppm), T_5 (250 ppm) were also found superior over control and rest of the treatments. Treatments T_4 (200 ppm), T_{10} (500 ppm), T_3 (150 ppm) in a descending manner also had significantly maximum dry matter over treatments T_1 (control) and T_2 (100 ppm).

At 50 and 65 DAS significantly maximum dry weight was recorded in treatment T_7 (350 ppm) humic acid through CDW followed by T_6 (300 ppm) and T_8 (400 ppm) when compared with control and rest of the treatments. Treatments T_9 (450 ppm) and T_5 (250 ppm) were found at par with each other. Similarly treatments T_4 (200 ppm) and T_{10} (500 ppm) were also found at par with other. Treatment T_3 (150 ppm) was also found significantly superior over treatments T_1 (control) and T_2 (100 ppm).

Data showed that there was gradual increase in dry matter of plant at 35 to 50 DAS and latter on at 65 DAS there was steep increase in dry matter production. The treatment receiving foliar spray of nutrients in the form of CDW increased growth in terms of plant height and leaf area and it might have contributed photosynthetic potential of plant and ultimately increased dry matter in the present investigation. Humic acid source (CDW) provides protoplasmic elements viz., N, P and K that assist in physiological functioning of plant such as chlorophyll and protein synthesis and their by increased dry matter production and yield.

The range of dry matter production was 3.10 to 4.45 g at 35 DAS, 4.43 to 7.00 g at 50 DAS and 6.68 to 11.71 g at 65 DAS in control and 350 ppm cowdung wash application respectively. The per cent increase in dry matter with respect to foliar application of 350 ppm CDW were 43.54, 58.01 and 75.29 over control at 35, 50 and 65 DAS respectively.

Asharf *et al*. (2005) also reported that foliar application of humic acid derived from lakhara increased dry weight of plant significantly in mung beans. Katkat *et al*. (2009) reported that humic acid raised the dry weight and N, P, K, Ca, Mg, Na, Fe, Cu and Mn uptake of plants at non limed pots and the amounts were found high at 0.1% dose of humic acid. Khalid and Fawy (2011) also noticed highest dry weight with the foliar application of 0.5% humic acid in corn.

RGR and NAR :

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 represents (RGR), total dry weight gained over existing dry weight in unit time. Whereas the net assimilation rate (NAR) depends upon the excess dry matter gained over the loss in respiration. It is the increase in plant dry weight $unit^{-1}$ leaf area of assimilatory tissue $unit^{-1}$ time.

At 35 to 50 DAS significantly maximum RGR was recorded in treatment T_7 (350 ppm). Next to this treatment, treatments T_6 (300 ppm) T_8 (400 ppm), T_9 (450 ppm), T_5 (250 ppm), T_4 (200 ppm), and T_{10} (500 ppm), in a descending manner also significantly increased RGR over treatment T_1 (control), T_2 (100 ppm) and T_3 (150 ppm).

At 50 to 65 DAS RGR was distinctly high in treatment sprayed with 350 ppm humic acid through cowdung wash. Rest of the treatments in a descending order viz., T_6 (300 ppm), T_8 (400 ppm), T_9 (450 ppm), T_5 (250 ppm), T_4 (200 ppm), T_{10} (500 ppm) and T_3 (150 ppm) were found significantly superior over treatments T_1 (control) and T_2 (100 ppm).

Net assimilation rate was maximum in treatment 350 ppm humic acid through cowdung wash (T_7) at 35- 50 DAS and 50-65 DAS.

At 35-50 DAS all treatments differed significantly over control and with each other. The treatment receiving 350 ppm humic acid through CDW was found best among all other treatments under study. Next to this treatment, treatments were T_6 (300 ppm), T_8 (400 ppm), T_9 (450 ppm), T_5 (250 ppm), and T_4 (200 ppm) when compared with control and rest of the treatments. Treatments T_{10} (500 ppm), T_3 (150 ppm), and T_2 (100 ppm) in a descending order were found superior over control and each other also.

At 50-65 DAS NAR was maximum in treatment 350 ppm humic acid application through CDW (T_7) followed by T_6 (300 ppm), T_8 (400 ppm), T_9 (450 ppm), T_5 (250 ppm), and T_4 (200 ppm) when compared with control and rest of the treatments. Next to these treatments T_{10} (500 ppm), T_3 (150 ppm) and T_2 (100 ppm) also showed their significance over control and over each other in a descending manner.

The highest rate of RGR indicates the availability of maximum dry matter for development and pod filling. The increment in RGR might be associated with rapid leaf area expansion and growth of stem and root. NAR increment is also related with increase in dry weight of plant $unit^{-1}$ of leaf area. Foliar application of nutrients might have resulted in more availability of N, P, K which caused improvement in RGR and NAR in the present study.

Seed yield :

Seed yield is the economic yield which is final results of physiological activities of plants. Economic yield is that part of biomass that is converted into economic product (Nichiporvic 1960). Seed yield is influenced by morpho physiological factors such as plant height, total dry matter production, leaf area and are considered as yield contributing parameters.

Source sink relation is key of the seed yield. The phloem loading at source (leaf) and unloading at sink (seed and fruit) by which the economic part will be getting the assimilates synthesized by photosynthesis. Partitioning of the assimilates in the plant during reproductive development is important for flower, fruit and seed crops. Thus, crop yield can be increased either by increasing the total dry matter production or by increasing the proportion of economic yield (HI) or both (Gardner *et al*., 1998).

The maximum seed yield ha^{-1} was observed in treatment receiving 350 ppm humic acid through CDW (T_7) when compared with control and rest of the treatments under study.

The maximum seed yield ha^{-1} was recorded

Table 1. Physiological responses of foliar application of humic acid through cowdung wash on plant height, number and dry weight of root nodules and leaf area

Treatments	Plant height $plant^{-1}$ (cm)			No. of root nodules $plant^{-1}$		Dry weight of root nodules $plant^{-1}$ (g)		Leaf area $plant^{-1}$ (dm^2)		
	35 DAS	50 DAS	65 DAS	30 DAS	40 DAS	30 DAS	40 DAS	35 DAS	50 DAS	65 DAS
T1 - Control (Water spray)	19.47	33.67	48.87	25.63	32.80	0.28	0.35	2.44	3.07	4.09
T2 - 100 ppm HA through CDW	20.30	34.50	49.13	27.40	37.92	0.29	0.40	2.48	3.26	4.58
T3 - 150 ppm HA through CDW	20.40	38.47	50.80	30.03	43.28	0.34	0.45	2.75	3.37	4.91
T4 - 200 ppm HA through CDW	20.47	38.60	51.89	35.02	44.41	0.39	0.46	2.80	3.74	4.99
T5 - 250 ppm HA through CDW	21.10	41.33	52.87	38.58	45.97	0.42	0.49	2.89	3.92	5.09
T6 - 300 ppm HA through CDW	21.33	42.87	54.48	43.47	51.16	0.48	0.53	3.07	4.43	5.86
T7 - 350 ppm HA through CDW	21.80	43.00	55.33	45.69	55.83	0.49	0.56	3.28	4.62	6.21
T8 - 400 ppm HA through CDW	21.20	42.00	53.40	41.69	50.19	0.45	0.51	3.06	4.34	5.39
T9 - 450 ppm HA through CDW	21.13	41.50	53.13	40.86	48.16	0.43	0.50	2.98	4.01	5.29
T10 - 500 ppm HA through CDW	20.80	40.87	52.73	37.92	45.16	0.40	0.47	2.79	3.75	4.98
SE(m)±	0.354	1.283	0.709	2.028	1.934	0.022	0.020	0.073	0.158	0.200
CD at 5%	1.052	3.813	2.105	6.026	5.747	0.064	0.059	0.216	0.471	0.593

Table 2. Physiological responses of foliar application of humic acid through cowdung wash on total dry matter production, RGR, NAR and seed yield ha^{-1}

Treatments	Total dry matter production $plant^{-1}$ (g)			RGR ($g\ g^{-1}\ day^{-1}$)		NAR ($g\ dm^{-2}\ day^{-1}$)		Seed yield ha^{-1} (q)
	35 DAS	50 DAS	65 DAS	35-50 DAS	50-65 DAS	35-50 DAS	50-65 DAS	
T1 - Control (Water spray)	3.10	4.43	6.68	0.0242	0.0274	0.0327	0.0426	5.04
T2 - 100 ppm HA through CDW	3.20	4.62	7.17	0.0245	0.0292	0.0333	0.0437	5.26
T3 - 150 ppm HA through CDW	3.45	5.03	7.84	0.0251	0.0296	0.0344	0.0460	5.46
T4 - 200 ppm HA through CDW	3.65	5.39	8.66	0.0266	0.0314	0.0359	0.0499	5.79
T5 - 250 ppm HA through CDW	3.86	5.77	9.31	0.0275	0.0320	0.0392	0.0528	6.19
T6 - 300 ppm HA through CDW	4.20	6.55	10.90	0.0296	0.0340	0.0422	0.0574	6.59
T7 - 350 ppm HA through CDW	4.45	7.00	11.71	0.0302	0.0348	0.0436	0.0596	6.97
T8 - 400 ppm HA through CDW	4.10	6.39	10.58	0.0296	0.0336	0.0417	0.0550	6.17
T9 - 450 ppm HA through CDW	3.87	5.91	9.58	0.0283	0.0322	0.0396	0.0528	5.77
T10 - 500 ppm HA through CDW	3.55	5.22	8.35	0.0257	0.0313	0.0344	0.0482	5.73
SE(m)±	0.082	0.106	0.203	0.0017	0.0018	0.0026	0.0035	0.230
CD at 5%	0.243	0.315	0.602	0.0050	0.0053	0.0078	0.0105	0.685

in 350 ppm humic acid CDW (T_7) i.e. 6.97q and minimum in control (T_1) i.e. 5.04 q respectively.

Next to treatment T_7 (350 ppm) maximum seed yield was recorded in treatment T_6 (300 ppm) when compared with control and rest of the treatments under study. Next to these treatments, treatments T_5 (250 ppm), T_8 (400 ppm), T_4 (200 ppm), T_9 (450 ppm) and T_{10} (500 ppm) in a descending manner also gave significantly more seed yield over treatments T_1 (control), T_2 (100 ppm) and T_3 (150 ppm).

Hu and Wang (2001) reported that komix humic acid containing organic fertilizer significantly increased seed yield plant^{-1} of spraying soybean.

Santhi *et al*. (2003) reported that grain yield of rice increased over control due to application of HA.

Zekeriya Akman (2004) reported that humic acid added foliar fertilizers significantly increased grains ear^{-1} and yield of sweet corn.

Boote *et al*. (1978) also reported that the foliar application of N, P, K enhances carbon balance and delay "self destructive mechanism" thus the plant resulting in increased yield of soybean. The increasing other yield attributing parameters viz., 100 seed weight and number of pods plant^{-1} might have helped in attaining better grain yield of green gram in the present investigation.

From the overall results it can be stated that foliar nutrition through humic sources such as CDW with different concentrations significantly improved morphophysiological parameters viz., plant height, number and dry weight of root nodules, leaf area, total dry matter, RGR and NAR etc. and ultimately increased seed yield.

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EFFECT OF PHOSPHOGYPSUM ON FERTILITY STATUS FOR GROWING SOYBEAN IN VERTISOL

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ABSTRACT

A field experiment was conducted at College of Agriculture Farm, Nagpur during *kharif* season of 2011-12. Eight treatments were studied in RBD with three replications, which comprises of 100% RDF alone, 200 kg phosphogypsum ha^{-1} alone and 100%, 75% RDF in combination with phosphogypsum @ 100, 150 and 200 kg ha^{-1}. The experimental site was medium black, slightly alkaline in reaction, clayey in texture, medium in organic carbon (5.82 g kg^{-1}), low in available N (206.98 kg ha^{-1}) medium in available P (19.53 kg ha^{-1}), high in available K (393.00 kg ha^{-1}), medium in available S. The significant increase in grain yield of soybean from 19.91 to 23.15 q ha^{-1} were recorded due to application of 100% RDF in combination with phosphogypsum @ 200 kg ha^{-1} which was found at par with 100 and 150 kg PG ha^{-1}. The significantly higher available N and P was noticed in 100% RDF + PG @ 200 kg ha^{-1} over rest of the treatments except T_3 100% RDF + PG @ 150 kg ha^{-1}. The availability of available K was also found highest in PG treated plots, however statistically found non significant. The available S content in soil increased with the increasing levels of PG applied with RDF. Maximum available S was noticed in 100% RDF + PG @ 200 kg ha^{-1}. Considering the yield and fertility status of soil for growing soybean on vertisols it is beneficial to use the cheapest multinutrient source i.e. phosphogypsum @ 100 kg ha^{-1} along with RDF.

(Key words: Soybean, phosphogypsum, vertisol)

INTRODUCTION

Soybean is a major oilseed crop of our country next only to groundnut, rapeseed and mustard. India ranks fifth in the world in area and production but the productivity is very low (less than 1000 kg ha^{-1}) than any other soybean producing countries. The predominant soybean growing states are Madhya Pradesh (74%), Maharashtra (5%) and Rajasthan (9%) (Mandal *et al.,* 2002). It also helps in maintaining soil fertility by fixing atmospheric nitrogen.

Most of the vertisols in Vidarbha are now a days found deficit in calcium, sulphur, phosphorus and zinc nutrients. These nutrients has to play a important role in the plant metabolisms and physiology of all oilseed crops. So, when the farmer has to provide these nutrients, he has to use independent sources which increases the input cost.

Sulphur and calcium are recognized as fourth and fifth major essential plant nutrients, respectively, for growth and development of plants. With the introduction of high yielding fertiliser responsive varieties and hybrids of crops in late sixties, the sulphur deficiency appeared in some intensively cultivated areas and currently 41% of the soil samples in the country (about 250 districts) are deficit in Sulphur (Biswas, and Sharma 2008).

Less than 10 % of phoshogypsum is being used for agricultural purposes (Somani, 1995). Since India is the net importer of S containing materials/ fertilizers. It is thus very important to use this material for improving productivity of the land resource.

Hence, here an attempt was made to identify a combined source having less cost i.e. phosphogypsum.

MATERIALS AND METHODS

The soil under the study area was medium deep and well drained. In order to study the physico-chemical characteristics, a composite soil sample was taken from of the whole field from 0 – 15 cm depth and analyzed to assess the initial fertility status of soil.

Initial Soil Fertility Status :

Avail. N (kg ha^{-1})	Avail. P_2O_5 (kg ha^{-1})	Avail. K_2O (kg ha^{-1})	Avail. S (kg ha^{-1})
06.98	19.53	393	13.4

The phosphogypsum was also analyzed in lab before its application to field to find out the nutrients present in it.

The phosphogypsum was broadcasted in plots as per the doses formulated for each plot along with basal dose of fertilizers in three replications having eight treatments and from the applied plots soil samples were collected and analyzed.

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Available nitrogen was calculated as by alkaline potassium permanganate method described by Subbiah and Asija (1956).Available phosphorus was estimated colorimetrically as per Jackson (1967).Available potassium was estimated by extracting the soil with 1 N NH_4OAc (pH 7.0) and concentration of K in the extract was measured using Flame photometer (Jackson, 1967).Available Sulphur was estimated by Morgan's extract with turbidity method using colorimeter as described by Chopra and Kanwar (1976).

Treatment details :

T1: RDF (30:75:0)
T2 : 100 % RDF + Phosphogypsum @ 100 kgha^{-1}
T3 : 100 % RDF + Phosphogypsum @ 150 kgha^{-1}
T4 : 100 % RDF + Phosphogypsum @ 200 kgha^{-1}
T5 : 75 % RDF + Phosphogypsum @ 100 kgha^{-1}
T6: 75 % RDF + Phosphogypsum @ 150 kgha^{-1}
T7 : 75 % RDF + Phosphogypsum @ 200 kgha^{-1}
T8 : Phosphogypsum @ 200 kgha^{-1}

RESULTS AND DISCUSSION

Grain yield of soybean :

The results obtained in respect of grain yield of soybean as influenced by phosphogypsum application are presented in table 2. The grain yield of soybean was significantly influenced due to application of different levels of phosphogypsum with two levels of RDF i.e. 100% RDF and 75% RDF.

From the data , it is revealed that significantly highest grain yield of soybean (23.15 q ha^{-1}) was obtained by the application of 100% RDF with 200 kg phosphogypsum ha^{-1} (T_4), over rest of the treatments. However, an application of 100% RDF in combination with 100 and 150 kg phosphogypsum ha^{-1} (22.50 and 22.92 q ha^{-1} respectively) *i.e.* T_2 and T_3 found at par with T_4.

Amongst various treatments, where, RDF applied with 3 levels of phosphogypsum, it can be stated that the grain yield was significantly influenced by the treatments (T_2 to T_4) *i.e.* 100% RDF applied with 100, 150 and 200 kg PG ha^{-1} over 75% RDF with 3 levels of PG. However, 75 % RDF applied with 100 and 150 kg PG ha^{-1} found remain at par with RDF applied alone(T_1).

From the above results, it can be stated that the treatments where PG applied with 100 % RDF significantly increased the yield over RDF and PG when applied alone.

The increase by the application of PG with valid reasons explained by Singh and Bajpai (1990) that PG increased the availability of Fe, Mn through a localized acidifying action around the roots and increased the availability of N, P and K along with Mg in calcareous soils.

Aulakh *et al.* (1990) also reported a significant increase in seed yield of soybean with application of sulphur. Piri and Sharma (2006) found that application of 15, 30 and 45 kg S ha^{-1} increased seed yield over control by 9, 15 and 23%, respectively. Similarly, Biswas and Sharma (2008) reported that the application of phosphogypsum significantly increased 26% yield over RDF in groundnut, 102% in sesamum and 23% in green gram. Phosphogypsum application significantly increased grain yield in rice (Rogerio and Carlos, 2008).

The increase in yield of grain also attributes to the facts explained by Agassi *et al.* (1990) who reported that application of PG in soil maintained high water infiltration, increasing water holding capacity of soil and reducing water runoff and soil aeration.

Morshed *et al.* (2008) reported that nitrogen application progressively and significantly increased the yield of soybean.

Effect of phosphogypsum on availability of nutrients after harvest of soybean :

The data pertaining to available N, P, K and S after harvest of soybean as influenced by different treatments are presented in table 2. From the data, it was revealed that the availability of nutrients in respect of N, P and S increased in soil at harvest with the application of 75% and 100% RDF when applied with 100, 150 and 200 kg ha^{-1} of phosphogypsum when compared with RDF and phosphogypsum when applied alone.

Table1.Elemental composition of phosphogypsum before its application

Ca %	S %	Mn ppm	Zn ppm	Mg %	Na %	Total P %	Total N %	Aval. P_2O_5%
22.30	11.7	4	2.8	3.9	0.27	0.46	0.51	1.33

Table2. Effect of PG on soil fertility status at harvest

	Treatment	Avail. N (kg ha^{-1})	Avail. P (kg ha^{-1})	Avail. K (kg ha^{-1})	Avail. S (kg ha^{-1})
T_1	100 % RDF (30:75:0)	242.51	11.14	439.2	17.12
T_2	100% RDF+ Phosphogypsum @ 100 kg ha^{-1}	303.20	16.37	442.3	26.26
T_3	100% RDF+ Phosphogypsum @ 150 kg ha^{-1}	316.88	18.90	452.2	28.20
T_4	100% RDF + Phosphogypsum @ 200 kg ha^{-1}	321.51	19.28	456.32	31.42
T_5	75 % RDF + Phosphogypsum @ 100 kg ha^{-1}	252.66	12.32	418.46	20.32
T_6	75 % RDF + Phosphogypsum @ 150 kg ha^{-1}	275.93	14.28	424.06	23.42
T_7	75% RDF + Phosphogypsum @ 200 kg ha^{-1}	280.51	15.67	430.24	27.08
T_8	Phosphogypsum @ 200 kg ha^{-1}	188.15	8.53	418.61	24.10
	SE(m)±	6.84	0.14	--	0.35
	CD at 5%	18.09	0.42	--	1.07

Table 3. Grain yield (q ha^{-1}) of soybean as influenced by phosphogypsum

	Treatments	Grain yield (q ha^{-1})
T_1	100 % RDF (30:75:0)	19.91
T_2	100 % RDF + Phosphogypsum @ 100 kg ha^{-1}	22.50
T_3	100 % RDF + Phosphogypsum @ 150 kg ha^{-1}	22.92
T_4	100 % RDF + Phosphogypsum @ 200 kg ha^{-1}	23.15
T_5	75 % RDF + Phosphogypsum @ 100 kg ha^{-1}	20.12
T_6	75 % RDF + Phosphogypsum @ 150 kg ha^{-1}	20.74
T_7	75 % RDF + Phosphogypsum @ 200 kg ha^{-1}	21.00
T_8	Phosphogypsum @ 200 kg ha^{-1}	9.77
	SE(m)±	0.309
	CD at 5%	0.917

The available N was significantly increased in soil at harvest with all the treatment combinations but statistically, a significant increase was observed in treatments T_2, T_3 and T_4 where, 100% RDF was applied with 100, 150 and 200 kg ha^{-1} phosphogypsum over rest of the treatments. The maximum available N (321.51 kg ha^{-1}) was recorded with the application of 100% RDF in combination with phosphogypsum @ 200 kg ha^{-1} (T_4). However, the treatment 100% RDF applied with phosphogypsum @ 100 and 150 kg ha^{-1} (303.20 and 316.88 kg ha^{-1} respectively) were found on par with T_4 and the lowest available N (188.15 kg ha^{-1}) was recorded in treatment phosphogypsum @ 200 kg ha^{-1} (T_8).

The available P increased with the various treatment combinations. A significant increase was observed in treatments T_2 , T_3 and T_4 , where 100% RDF was applied in combination with three levels (100, 150 and 200 kg ha^{-1}) of phosphogypsum. The highest available P was recorded in T_4 i. e. 100% RDF applied with 200 kg ha^{-1} of phosphogypsum (19.28 kg ha^{-1}) over rest of the treatment combinations except T2 (100 % RDF + Phosphogypsum @ 100 kg ha^{-1}) and T3 (100 % RDF + Phosphogypsum @ 150 kg ha^{-1}). The lowest value of available P was recorded in phosphogypsum @ 200 kg ha^{-1} (7.53 kg ha^{-1}).

The availability of soil K at harvest was influenced by the application of levels of RDF in combinations with three levels of phosphogypsum. It is noticed that T_4 (100% RDF applied with 200 kg ha^{-1} of phosphogypsum) was superior over rest of the treatment combinations. However, statistically found non significant.

The sulphur has great importance in oilseed crop and is found to be the chief constituent in influencing the nutrients and quality of grains. The phosphogypsum contained 14% S, the analytical data showed that soil sulphur was greatly influenced and statistically, a significant increase was found in all the treatments (T_2 to T_7) where 100, 150 and 200 kg ha^{-1} of phosphogypsum were applied in combination with 75% and 100% RDF over T_1 (RDF) and T_8 (Phosphogypsum @ 200kgha^{-1}). The highest available S (31,42 kg ha^{-1}) content was recorded in treatment 100% RDF + phosphogypsum @ 200 kg ha^{-1} and the lowest value of available S was recorded in the treatment phosphogypsum @ 200 kg ha^{-1} (17.12 kg ha^{-1}). Meena *et al.* (2006) also reported that the available sulphur status was found increased significantly due to application of S, Zn and Fe treatments.

Sulphur when supplied through Phosphogypsum, its availability is also ensured for longer period due to its low solubility in water and present in sulphate form. Most of the other sulphate salts that are supplied through fertilizers are highly water soluble and may be leached from soil before the plant could use it (Biswas and Sharma,2008).

Application of levels of phosphogypsum (100,150 and 200 kg ha^{-1}) with 75 % and 100 % RDF were compared with RDF and only PG treatments and observed that the application of 200 kg PG ha^{-1} along with 100% RDF showed significant increase in grain yield and also improved soil fertility status. However, found at par with 100 kg PG ha^{-1} and 150 kg PG kg ha^{-1} applied with 100 % RDF. Hence, the 100 % RDF applied with 100 kg PG kg ha^{-1} for soybean crop is proposed. Similarly, at harvest the availability of N,P and S were also found increased in soil.

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COMBINING ABILITY STUDIES FOR YIELD, YIELD CONTRIBUTING AND FIBRE TRAITS IN COTTON (*Gossypium hirsutum* L.)

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ABSTRACT

An experiment to study the combining ability of yield, yield contributing and fibre traits consisted of ten diverse genotypes of cotton viz., AKH-081, AKH-053B, AKH-9312, AKH-976, AKH-9913, BBP-9, AKH-1174 , LRK-516, 8660B, AKH-8828 crossed in half diallel fashion to secure fourty five F_1s. was conducted during *kharif* 2007-08 at Botany Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. Observations were recorded on days to 50 % flowering, plant height (cm), chlorophyll content (mg g^{-1}), number of bolls $plant^{-1}$, seed cotton yield $plant^{-1}$, lint yield $plant^{-1}$ (g), ginning out turn (%), 2.5% span length (mm), Micronaire value (mg $inch^{-1}$), Fibre strength (g tex^{-1}), uniformity ratio (%), maturity co-efficient and oil content (%). The mean squares due to GCA and SCA were significant for all the thirteen characters studied. The parents AKH-9913, BBP-9 and AKH-8828 were identified as the promising parents as they had high gca and additive genetic variance for yield and most of the yield contributing traits. Considering high *per se* performance, high positive significant sca effect and the extent of useful heterosis the crosses, AKH-9312 x BBP-9, AKH-9312 x AKH-1174 and BBP-9 x AKH-1174 were identified as the promising crosses for seed cotton yield, lint yield and fibre strength for their exploitation directly for heterosis breeding.

(Key words: Combining ability, diallel, *Gossypium hirsutum* L.)

INTRODUCTION

Yield is the most important economic character and is the product of multiplicative interaction of contributing characters. Progress in the genetic improvement of yield in any crop depends upon the genetic information available on inheritance of quantitative traits i.e. yield and yield component characters. To improve yield capacity with high fibre properties especially fibre strength due to the new spinning and weaving technology, has been a primary objective of cotton breeders. Therefore, knowledge of magnitude and type of genetic variance has a great importance for cotton breeders dealing with simultaneous improvement of fibre quality and lint yield. Most characteristics related to lint yield and fibre properties are quantitatively inherited in cotton. However, quantitative traits are difficult to study since: a) their expression is modified by environment expression and management fluctuation; b) each trait is a composite of many other traits and influenced by many genes; c) the expression of an individual gene is often modified by the expression of other genes; d) linkage blocks are difficult to breakup. e) the optimum genotype for any environment management system is likely to be different from that of another system. Thus, the purpose of all cotton breeders is to improve yield capacity with high fibre properties, especially fibre strength, in cotton by using simple genetic models and genetic parameters. The first step for successful breeding programme is to select appropriate parents. Selection of suitable parents is one of the most important criteria used to find the most promising crosses and to increase the efficiency of breeding programme. The concept of combining ability plays an important role in identification of superior parents and hybrids. Identification of superior parents is done on the basis of general combining ability and that selected parents are used in further breeding programme. Selection of superior crosses is done on the basis of specific combing ability. Allard (1960) pointed out that the common approach of selecting the parents on the basis of *per se* performance is not good identification of their superior combining ability. The choice of parents in any breeding programme has to be based on complete genetic information and knowledge of combining ability of the parents and not merely on the field performance of different genotypes. The diallel analysis provides systematic approach for the selection of appropriate parents and crosses superior for the investigated traits and understanding of genetic control of the trait. Also, it helps the plant breeders to choose the most efficient selection method by allowing estimation of several genetic parameters. Christopher *et al*. (2003) used combining ability analysis for the identification of superior combining parents, which were subsequently used in the breeding programme with good results. Braden *et al*. (2003) argued that combining ability analysis provides sufficient chance to cotton breeders to understand the basis on which certain parental lines

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could be exploited in the breeding program. The present research work was conducted to evaluate some cotton genotypes and their crosses for their relative performance regarding combining ability effects for quantitative and qualitative traits.

MATERIALS AND METHODS

The experimental material consisted of ten diverse genotypes viz., AKH-081, AKH-053B, AKH-9312, AKH-976, AKH-9913, BBP-9, AKH-1174 , LRK-516, 8660B, AKH-8828 crossed in half diallel fashion to secure fourty five F_1s (for studying combining ability). The crosses along with their respective parents were sown in randomized complete block design replicated thrice at the Farm of Department of Agricultural Botany, PGI, Dr.P.D.K.V. Akola during *kharif*, 2006 and 2007. Data were recorded on days to 50 % flowering, plant height (cm), chlorophyll content (mg g^{-1}), number of bolls $plant^{-1}$, seed cotton yield $plant^{-1}$, lint yield $plant^{-1}$ (g), ginning out turn (%), 2.5% span length (mm), Micronaire value (mg $inch^{-1}$), Fibre strength (g tex^{-1}), uniformity ratio (%), maturity co-efficient and oil content (%). Oil content was estimated by soxhlet method as suggested by Sankaran (1966).

The statistical analysis was performed for analysis of varience as per the methodology suggested by by Fisher (1918) and analysis for GCA and SCA effects by model I (Fixed effect model) and method 2 (Parents and one set of crosses excluding reciprocals) as described by Griffing's, 1956.

RESULTS AND DISCUSSION

The data regarding analysis of variance for combining ability for different characters are presented in table 1. The variation between crosses were partitioned into different components representing mean squares due to general combining ability and specific combining ability. The mean squares due to GCA and SCA were significant for all the thirteen characters studied. Thus, both GCA and SCA mean squares were important for the inheritance of various traits under study. The magnitude of GCA mean squares was higher than that of the SCA mean squares for all the characters except fibre strength which indicated the preponderance of additive gene action in the inheritance of these traits. Similar to this results significant mean squares for both gca and sca were also reported by Nadarajan and Elangovan (1982), Singh *et al*.(1987), Amalraj (1989) and Mendez-Natera *et al.* (2012) for different yield, yield components and quality traits in cotton.

Nature and magnitude of general combining ability effects of parents and specific combining ability effects of crosses provides guideline in identifying the better parents and their utilization. The estimates of GCA and SCA effects among the parents and crosses showed wide variation in the level of significance for different characters. None of the parents nor crosses had high and significant GCA and SCA effects in the desirable direction for all the characters studied. Variation among the parents and crosses for significant GCA and SCA effects were also reported by Ahuja and Tuteja (2000), Rao and Reddy (2001), Verma *et al.* (2006), Bagade *et al.* (2009) and Mendez-Natera *et al.* (2012) in cotton.

Data regarding mean performance and GCA effect of parents are presented in table 2. The GCA effects of the parents revealed that the parent AKH-9913 was found to be the good general combiner in the desirable direction for days to 50% flowering, plant height, number of bolls $plant^{-1}$, 2.5% span length, fibre strength, uniformity ratio, seed cotton yield and lint yield. Similarly the parent BBP-9 was found to be a good general combiner for plant height, number of bolls $plant^{-1}$, 2.5% span length, uniformity ratio, maturity coefficient, chlorophyll content, seed cotton yield and lint yield. The parent AKH-8828 was also found to be the good general combiner for plant height, number of bolls $plant^{-1}$, ginning out turn, uniformity ratio, maturity co-efficient , chlorophyll content, seed cotton yield and lint yield. Thus, from this study the parents AKH-9913, BBP-9 and AKH-8828 were identified as the good general combiners and also showed high mean performance for yield and most of yield contributing traits.

Specific combining ability effects is the index to determine the usefulness of particular cross in the exploitation of heterosis. The significant SCA effect observed in different crosses for different characters (Table 3) had the combination of either high x high, high x low, low x high and 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

Table 1. Analysis of variance for combining ability

Sources	d. f.	Mean squares												
		Days to 50% flowering	Plant height (cm)	Chlorophyll content (mg g^{-1})	No. of bolls $plant^{-1}$	Seed cotton yield $plant^{-1}$ (g)	Lint yield $plant^{-1}$ (g)	Ginning out turn (%)	2.5% span length (mm)	Micronaire value (µg $inch^{-1}$)	Fibre strength (g tex^{-1})	Uniformity ratio (%)	Maturity co - efficient	Oil content (%)
GCA	9	10.84**	440.4**	0.05**	15.4**	92.48**	11.44**	19.97**	11.03**	0.24**	1.96**	4.85**	0.0005**	3.65**
SCA	45	2.94**	36.73**	0.01**	6.62**	55.23**	9.31**	5.92**	1.42**	0.09**	3.20**	2.12**	0.0005**	0.65**
Error	108	0.11	4.44	0.0002	1.33	3.07	0.98	0.70	0.02	0.001	0.07	0.08	0.00001	0.03
Predictability ratio			0.88		0.88	0.77	0.79		0.87	0.94	0.85	0.55	0.82	0.92

Note : *Significant at 5%, ** Significant at 1%

Table 2. Mean performance and general combining ability effects of parents for various characters in cotton

Parents	Days to 50% flowering		Plant height (cm)		Chlorophyll content (mg g^{-1})		No. of bolls $plant^{-1}$		Seed cotton yield $plant^{-1}$ (g)		Lint yield $plant^{-1}$ (g)	
	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA
AKH - 081	60.67	-0.82**	69.33	-6.08**	1.89	-0.01**	14.13	-1.06**	25.31	-2.50**	11.28	-0.17
AKH - 053B	60.33	-0.73**	76.67	-3.25**	2.07	0.01**	17.40	-0.05	32.10	0.41	11.03	-0.58*
AKH - 9312	55.00	-1.29**	93.33	7.86**	2.00	-0.07**	17.33	0.12	33.89	0.45	11.00	-0.87**
AKH - 976	60.33	0.52**	95.00	2.03**	1.79	-0.11**	11.07	-1.62**	25.03	-3.25**	8.47	-1.25**
AKH - 9913	60.00	-0.34**	93.67	2.00**	1.79	-0.03**	19.47	1.04**	42.88	2.57**	15.80	1.02**
BBP - 9	64.00	1.74**	100.33	5.47**	2.07	0.06**	17.53	2.27**	45.10	6.02**	16.13	1.86**
AKH - 1174	57.00	-0.62**	54.33	11.56**	1.98	0.05**	7.47	-0.65**	18.72	-2.28**	7.80	0.00
LRK - 516	59.33	0.88**	88.00	-4.25**	1.86	0.06**	13.53	-0.55	27.87	-1.94**	11.67	-0.57*
8660B	59.67	-0.15	92.33	4.61**	1.84	-0.06**	12.67	-0.34	36.35	-0.04	9.87	-0.41
AKH - 8828	59.67	0.82**	94.67	3.17**	2.10	0.10**	16.13	0.84**	42.17	0.55	16.47	0.95**
SE (g_i) ±		0.09		0.58		0.004		0.32		0.48		0.27

Continued....

Parents	Ginning out turn (%)		2.5% span length (mm)		Micronaire value (µg $inch^{-1}$)		Fibre strength (g tex^{-1})		Uniformity ratio (%)		Maturity co-efficient		Oil content (%)	
	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA
AKH - 081	40.51	1.49**	28.73	0.73**	3.47	0.12**	22.53	0.20**	45.00	-1.13**	0.82	-0.004**	20.27	-0.29**
AKH - 053B	37.11	-0.41	27.17	0.32**	3.17	-0.08**	20.30	-0.24**	47.00	-0.74**	0.82	-0.005**	19.10	-0.53**
AKH - 9312	32.61	-2.63**	29.43	1.35**	3.63	-0.01	21.63	0.63**	48.00	0.36**	0.82	0.009**	21.47	0.54**
AKH - 976	35.92	-0.19	28.07	1.03**	2.70	-0.28**	18.07	0.01	44.67	0.17*	0.81	-0.003**	21.45	0.75**
AKH - 9913	38.37	-0.05	26.07	0.23**	3.20	-0.02	19.93	0.70**	47.00	0.17*	0.82	0.003**	20.86	-0.12**
BBP - 9	36.35	-1.05**	27.33	0.22**	3.03	0.03**	17.57	-0.36**	50.00	0.89**	0.84	0.007**	21.22	0.04
AKH - 1174	42.09	1.13**	22.03	-1.76**	3.43	0.17**	16.87	-0.20**	48.00	0.51**	0.80	-0.006**	18.92	-0.96**
LRK - 516	43.44	0.88**	24.03	-0.62**	2.90	0.13**	18.90	0.05	47.00	-0.36**	0.81	0.002*	21.63	0.41**
8660B	32.91	-0.62**	22.80	-0.84**	3.57	0.20**	18.40	-0.41**	46.67	0.23**	0.81	-0.005**	21.30	0.53**
AKH - 8828	38.10	1.45**	25.87	-0.67**	3.23	-0.02	19.47	-0.39**	49.00	0.62**	0.83	0.009**	20.84	-0.37**
SE (g_i) ±		0.23		0.03		0.01		0.07		0.07		0.0009		0.04

Note : *Significant at 5% , ** Significant at 1%

Table 3. Mean performance and specific combining ability effects of crosses for various characters in cotton

Crosses	Days to 50% flowering		Plant height (cm)		Chlorophyll content (mg g^{-1})		No. of bolls $plant^{-1}$	
	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA
AKH- 081 x AKH-053B	56.67	-0.583*	91.00	10.545**	1.99	0.120**	16.93	2.482*
AKH-081 x AKH-9312	54.67	-2.028**	88.67	-2.899	1.84	0.048**	11.67	-2.951**
AKH-081 x AKH-976	57.67	-0.833**	93.00	7.268**	1.76	0.004	12.93	0.055
AKH-081 x AKH-9913	57.33	-0.306	87.33	1.629	1.81	-0.030*	15.67	0.127
AKH-081 x BBP-9	59.33	-0.389	85.33	-3.843*	1.78	-0.151**	13.60	-3.173**
AKH-081 x AKH-1174	55.67	-1.694**	81.67	9.518**	1.93	0.016	16.27	2.410*
AKH-081 x LRK-516	59.33	0.472	74.33	-5.121	2.04	0.119**	12.00	-1.951*
AKH-081 x 8660B	55.67	-2.167**	89.00	0.684	1.77	-0.041**	15.27	1.105
AKH-081 x AKH-8828	59.33	0.528	85.67	-1.205	1.79	-0.170**	15.87	0.521
AKH-053B x AKH-9312	55.67	-1.111**	95.00	0.601	1.74	-0.082**	16.87	1.243
AKH-053B x AKH-976	56.33	-2.250**	88.33	-0.232	1.71	-0.073**	14.07	0.182
AKH-053B x AKH-9913	56.67	-1.056**	85.33	-3.205**	1.93	0.067**	13.27	-3.279**
AKH-053B x BBP-9	59.33	-0.472	90.33	-1.677	1.71	-0.238**	13.20	-4.579**
AKH-053B x AKH-1174	55.67	-1.778**	85.67	10.684**	1.73	-0.201**	16.20	1.338
AKH-053B x LRK-516	60.67	1.722**	82.00	-0.288	2.04	0.093**	15.47	0.510
AKH-053B x 8660B	56.67	-1.250**	89.67	-1.482	1.77	-0.058**	13.87	-1.301
AKH-053B x AKH-8828	59.67	0.778**	88.00	-1.705	2.00	0.020	15.87	-0.484
AKH-9312 x AKH-976	59.00	0.972**	109.00	9.323**	1.71	0.012	15.93	1.882
AKH-9312 x AKH-9913	56.67	-0.500	95.33	-4.316*	1.71	-0.069**	14.13	-2.579**
AKH-9312 x BBP-9	57.67	-1.583**	101.33	-1.788	1.76	-0.110**	14.40	-3.545**
AKH-9312 x AKH-1174	59.67	2.778**	89.00	2.907	1.79	-0.069**	16.60	1.571
AKH-9312 x LRK-516	58.67	0.278	97.33	3.934*	1.71	-0.153**	15.93	0.810
AKH-9312 x 8660B	59.67	2.306**	105.67	3.407	1.71	-0.046**	16.13	0.799
AKH-9312 x AKH-8828	59.67	1.333**	114.00	13.184**	1.86	-0.042**	16.20	-0.318
AKH-976 x AKH-9913	57.67	-1.306**	94.33	0.518	1.74	0.001	15.73	0.760
AKH-976 x BBP-9	60.67	-0.389	97.00	-0.288	1.79	-0.044**	15.93	-0.273
AKH-976 x AKH-1174	59.67	0.972**	74.33	-5.927**	1.72	-0.100**	12.93	-0.357
AKH-976 x LRK-516	59.33	-0.861**	83.33	-4.232*	1.80	-0.026*	14.00	0.616
AKH-976 x 8660B	61.33	2.167**	93.67	-2.760	1.73	0.013	13.47	-0.129
AKH-976 x AKH-8828	60.67	0.528	89.00	-5.982**	1.83	-0.036**	14.53	-0.245
AKH-9913 x BBP-9	57.67	-2.528**	94.33	-2.927	1.85	-0.068**	17.93	-0.934
AKH-9913 x AKH-1174	58.00	0.167	89.00	8.768**	1.94	0.040**	17.13	1.182
AKH-9913 x LRK-516	59.67	-0.528	85.33	-2.232	1.90	0.070**	16.00	2.616**
AKH-9913 x 8660B	59.33	0.167	95.33	-1.093	1.82	0.110**	15.27	1.671
AKH-9913 x AKH-8828	59.67	0.389	98.00	3.045	2.05	0.100**	19.53	2.093*
BBP-9 x AKH-1174	59.67	-0.250	82.67	-1.038	2.19	0.205**	25.07	7.882**
BBP-9 x LRK-516	65.33	3.917**	90.00	-1.010	2.02	0.019	21.53	4.255**
BBP-9 x 8660B	59.33	-1.056**	109.67	9.795**	2.13	0.245**	20.40	2.910**
BBP-9 x AKH-8828	60.67	-0.694*	102.00	3.573*	2.05	0.012	21.27	2.593**
AKH-1174 x LRK-516	60.33	1.278**	70.67	-3.316	2.06	0.076**	11.47	-2.895**
AKH-1174 x 8660B	58.33	0.306	85.67	2.823	1.82	-0.051**	15.73	1.160
AKH-1174 x AKH-8828	58.33	-0.667*	81.67	0.268	2.09	0.066**	17.07	1.310
LRK-516 x 8660B	55.67	-3.861**	94.67	4.518*	1.84	-0.038**	17.00	2.332*
LRK-516 x AKH-8828	59.67	-0.833**	83.00	5.705**	2.22	0.190**	14.07	-1.784
8660B x AKH-8828	59.67	0.194	95.00	-2.566	1.72	-0.201**	14.60	-1.462
SE(m)±	0.33	0.27	2.11	1.74	0.014	0.01	1.15	0.95
CD(5%)	0.92		5.90		0.04		3.23	

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Crosses	Seed cotton yield plant^{-1} (g)		Lint yield plant^{-1} (g)		Ginning out turn (%)		2.5% span length (mm)	
	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA
AKH- 081 x AKH-053B	45.95	5.147**	16.67	1.438	40.74	1.120	27.67	-0.209*
AKH-081 x AKH-9312	32.01	-8.839**	10.27	-4.674**	33.67	-3.725**	27.03	-1.872**
AKH-081 x AKH-976	46.64	9.498**	20.00	5.442**	41.61	1.768*	28.60	0.008
AKH-081 x AKH-9913	44.49	1.527	17.20	0.370	41.80	1.816**	27.07	-0.725**
AKH-081 x BBP-9	42.95	-3.470**	16.27	1.402	43.79	4.807**	26.87	-0.909**
AKH-081 x AKH-1174	54.79	16.680**	20.80	4.992**	37.33	-3.834**	27.10	1.305**
AKH-081 x LRK-516	39.50	1.047	13.60	-1.641*	39.75	-1.155	27.07	0.128
AKH-081 x 8660B	43.53	3.175*	16.73	1.337	39.04	-0.373	27.70	0.980**
AKH-081 x AKH-8828	41.35	0.407	19.60	2.842**	43.07	1.595*	27.30	0.411**
AKH-053B x AKH-9312	46.87	3.114*	15.53	0.996	34.95	-0.544	27.20	-1.289**
AKH-053B x AKH-976	41.18	1.130	13.47	-0.688	35.15	-2.794**	26.87	-1.309**
AKH-053B x AKH-9913	44.65	-1.227	16.53	0.107	36.64	-1.440*	26.63	-0.742**
AKH-053B x BBP-9	45.79	-3.537*	16.07	-1.199	33.95	3.136**	26.70	0.659**
AKH-053B x AKH-1174	48.65	7.626**	18.93	3.529**	43.82	4.553**	26.70	1.322**
AKH-053B x LRK-1516	49.60	8.240**	16.73	1.896*	38.27	-0.738	27.23	0.711**
AKH-053B x 8660B	43.63	0.368	15.73	0.740	37.38	-0.135	28.80	2.497**
AKH-053B x AKH-8828	46.20	2.346	17.13	0.779	43.90	4.319**	26.73	0.261*
AKH-9312 x AKH-976	49.87	9.771**	17.00	3.133**	37.52	1.797*	28.70	-0.506**
AKH-9312 x AKH-9913	38.69	-7.233**	13.00	-3.139**	37.25	1.385*	30.67	2.261**
AKH-9312 x BBP-9	54.42	5.050**	19.87	2.889**	34.37	-0.495	27.83	-0.556**
AKH-9312 x AKH-1174	51.24	10.173**	19.20	4.083**	37.29	0.248	27.73	1.325**
AKH-9312 x LRK-516	44.37	2.967*	16.53	1.983*	37.56	0.773	29.30	1.747**
AKH-9312 x 8660B	42.31	-0.998	16.27	1.561	37.20	1.903**	25.97	-1.367**
AKH-9312 x AKH-8828	49.72	5.820**	15.73	-0.333	37.36	0.004	27.93	0.430**
AKH-976 x AKH-9913	47.41	5.197**	15.80	0.045	38.47	0.158	28.53	0.441**
AKH-976 x BBP-9	47.85	2.187	16.00	-0.594	38.67	1.355	28.20	0.125
AKH-976 x AKH-1174	33.27	-4.090**	16.80	2.067*	41.05	1.561*	26.23	0.139
AKH-976 x LRK-516	38.98	1.210	15.40	1.233	37.76	-1.473*	27.73	0.494**
AKH-976 x 8660B	37.90	-1.701	13.73	-0.589	39.90	2.163**	27.07	0.047
AKH-976 x AKH-8828	39.73	-0.470	15.67	-0.017	39.78	-0.029	29.40	2.211**
AKH-9913 x BBP-9	51.25	-0.244	20.13	1.267	40.27	2.823**	29.33	2.058**
AKH-9913 x AKH-1174	47.25	4.059**	18.00	0.995	36.75	-2.874**	24.10	-1.195**
AKH-9913 x LRK-516	44.37	6.670**	17.80	3.633**	36.54	-2.697**	26.23	-1.006**
AKH-9913 x 8660B	50.41	10.805**	18.00	3.678**	37.74	-0.004	27.13	0.114
AKH-9913 x AKH-8828	48.43	2.97*	20.00	2.045*	41.19	1.245	26.03	-0.356**
BBP-9 x AKH-1174	53.09	6.449**	19.87	2.022*	35.30	-3.327**	25.37	0.089
BBP-9 x LRK-516	54.67	7.690**	20.07	1.189	36.57	-1.802*	26.67	0.244*
BBP-9 x 8660B	51.59	2.718	19.13	1.700*	36.57	-0.306	26.73	0.530**
BBP-9 x AKH-8828	52.31	2.836	18.47	1.272	39.22	0.272	25.30	-1.072**
AKH-1174 x LRK-516	35.67	-3.007*	12.73	-2.683**	37.85	-2.705**	24.00	-0.442**
AKH-1174 x 8660B	45.82	5.248**	18.67	3.095**	42.58	3.517**	24.87	0.644**
AKH-1174 x AKH-8828	37.26	-3.907**	15.20	-1.733**	41.42	0.295	23.73	0.659**
LRK-516 x 8660B	45.03	4.115**	18.20	3.195**	42.22	3.419**	26.80	1.433**
LRK-516 x AKH-8828	40.69	-0.814	16.20	-0.167	41.10	0.234	24.53	-1.003**
8660B x AKH-8828	38.43	-4.979**	14.67	-1.855*	38.12	-1.257	24.33	-0.984**
SE(m)±	1.75	1.45	0.99	0.82	0.84	0.69	0.13	0.10
CD(5%)	4.91		2.76		2.34		0.35	

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Crosses	Micronaire value (µg inch^{-1})		Fibre strength (g tex^{-1})		Uniformity ratio (%)		Maturity co-efficient		Oil content (%)	
	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA
AKH- 081 x AKH -053B	3.13	-0.123**	20.93	0.378	48.33	1.854**	0.79	-0.012**	19.23	-0.637**
AKH-081 x AKH -9312	3.13	-0.198**	20.07	-1.358**	47.67	0.798**	0.83	0.014**	20.11	-0.820**
AKH-081 x AKH -976	3.73	0.668**	21.03	0.231	50.00	2.604**	0.79	-0.014**	21.22	0.071
AKH-081 x AKH -9913	3.40	0.077**	20.67	-0.819**	47.33	-0.063	0.79	-0.021**	19.57	-0.697**
AKH-081 x BBP-9	3.47	0.093**	20.00	-0.428	47.33	-0.785**	0.81	-0.008**	21.26	0.832**
AKH-081 x AKH -1174	3.27	-0.243**	20.43	0.158	46.67	-1.063**	0.79	-0.018**	20.05	0.615**
AKH-081 x LRK-516	3.33	0.118**	20.23	-0.603**	47.33	0.465*	0.83	0.014**	21.40	0.590**
AKH-081 x 8660B	3.40	-0.137**	19.93	-0.447*	47.33	-0.119	0.81	0.004	21.16	0.243
AKH-081 x AKH -8828	3.07	-0.257**	20.53	0.128	46.33	-1.508**	0.84	0.021**	19.50	-0.528**
AKH-053B x AKH -9312	3.03	-0.090**	20.23	-0.753**	47.33	0.076	0.80	-0.022*	21.19	-0.494**
AKH-053B x AKH -976	2.80	-0.057**	21.00	0.636**	47.67	-0.119	0.82	0.017**	21.09	0.175
AKH-053B x AKH -9913	2.77	-0.348**	20.07	-0.981**	47.67	-0.119	0.79	-0.013**	19.17	-0.866**
AKH-053B x BBP-9	3.20	0.035	19.53	-0.456*	47.33	-1.174**	0.85	0.030**	21.11	0.910
AKH-053B x AKH -1174	3.13	-0.168**	19.93	-0.219	47.67	-0.452*	0.77	-0.034**	18.85	-0.354**
AKH-053B x LRK-1516	3.33	0.327**	21.23	0.836**	47.00	-0.258	0.79	-0.025**	21.59	1.017**
AKH-053B x 8660B	2.90	-0.429**	22.13	2.192**	47.00	-0.841**	0.81	0.002	21.38	0.697**
AKH-053B x AKH -8828	3.73	0.618**	17.97	-2.000**	49.00	0.770**	0.85	0.032**	19.42	-0.370**
AKH-9312 x AKH -976	2.63	-0.298**	17.40	-3.833**	47.33	-0.841**	0.83	0.013**	22.47	0.492**
AKH-9312 x AKH -9913	2.57	-0.623**	22.40	0.483*	49.00	0.826**	0.79	-0.027**	21.65	0.548**
AKH-9312 x BBP-9	3.37	0.127**	24.40	3.542**	47.67	-1.230**	0.84	0.013**	21.19	-0.077
AKH-9312 x AKH -1174	3.37	-0.010	24.87	3.844**	48.00	-0.508*	0.82	0.003	21.22	0.947**
AKH-9312 x LRK-516	3.13	0.052	19.63	-1.633**	46.00	-1.646**	0.85	0.021**	22.08	0.445**
AKH-9312 x 8660B	3.90	0.496**	21.17	0.356	50.67	2.437**	0.85	0.028**	21.56	-0.189
AKH-9312 x AKH -8828	2.87	-0.323**	20.63	-0.203	48.00	-0.619**	0.81	-0.026**	19.60	-1.257**
AKH-976 x AKH -9913	2.90	-0.023	23.57	2.272**	50.00	1.298**	0.82	0.012**	21.55	0.235
AKH-976 x BBP-9	2.67	-0.307**	18.47	-1.769**	50.00	0.576*	0.81	-0.012**	21.23	-0.243
AKH-976 x AKH -1174	3.23	0.124**	21.30	0.900**	48.67	-0.369	0.79	-0.012**	20.80	0.321*
AKH-976 x LRK-516	2.67	-0.148**	23.07	2.422**	50.00	1.826**	0.85	0.034**	22.08	0.232
AKH-976 x 8660B	3.07	-0.071*	23.77	3.578**	51.00	2.242**	0.79	-0.019**	21.06	-0.905**
AKH-976 x AKH -8828	2.97	0.043	20.87	0.653**	50.00	0.854**	0.80	-0.017**	22.18	1.111**
AKH-9913 x BBP-9	3.47	0.235**	20.00	-0.919**	47.67	-1.758**	0.77	-0.052**	19.90	-0.700**
AKH-9913 x AKH -1174	3.50	0.132**	21.83	0.750**	50.67	1.631**	0.84	0.034**	19.42	-0.187
AKH-9913 x LRK-516	3.33	0.518**	23.50	2.856**	49.00	0.826**	0.85	0.037**	21.11	-0.745**
AKH-9913 x 8660B	3.10	-0.037	20.17	-0.022	48.00	-0.758**	0.81	0.001	22.19	0.225
AKH-9913 x AKH -8828	3.73	0.552**	22.73	1.836**	50.67	1.520**	0.83	0.013**	19.78	-0.410**
BBP-9 x AKH -1174	3.70	0.282**	22.30	2.275**	50.67	0.909**	0.85	0.031**	18.78	-0.988**
BBP-9 x LRK-516	2.80	-0.323**	21.37	1.097**	50.00	1.104**	0.82	-0.004	18.91	-2.227**
BBP-9 x 8660B	3.63	0.188**	19.50	-0.314	52.00	2.520**	0.80	-0.014**	21.79	0.539**
BBP-9 x AKH -8828	3.40	0.168**	21.40	1.561**	50.00	0.131	0.83	0.003	21.38	1.029**
AKH-1174 x LRK-516	3.33	0.074**	20.20	-0.233	50.00	1.492**	0.77	-0.037**	18.98	-1.160**
AKH-1174 x 8660B	3.93	0.352**	19.27	-0.711**	48.67	-0.424	0.82	0.020**	21.15	0.889**
AKH-1174 x AKH -8828	3.07	-0.301**	20.20	0.197	51.00	1.520**	0.84	0.019**	18.99	-0.368**
LRK-516 x 8660B	3.47	0.179**	20.10	-0.122	47.33	-0.896**	0.80	-0.015**	21.74	0.114
LRK-516 x AKH-8828	2.67	-0.407**	19.87	-0.381	47.00	-1.619**	0.81	-0.015**	21.35	0.617**
8660B x AKH-8828	3.20	-0.196**	18.70	-1.092**	49.33	0.131	0.80	-0.018**	19.23	-1.614**
SE(m)±	0.03	0.03	0.27	0.22	0.27	0.23	0.003	0.003	0.16	0.13
CD(5%)	0.09		0.74		0.76		0.009		0.44	

did not involved one or both the parents as good general combiners for the concerned trait. This indicated that non additive type of gene action, which are not fixable were involved in these crosses. It was also inferred that all the crosses which exhibited high mean did not necessarily have significant SCA effect indicating the non-correspondence between *per se* performance and SCA effect .

Out of forty five crosses studied the 12 F_1 crosses viz., AKH-081 x AKH-1174, AKH-053B x AKH-1174, AKH-053B x LRK-516, AKH-9312 x AKH-976, AKH-9312 x BBP-9, AKH-9312 x AKH-1174, AKH-9312 x LRK-516, AKH-9913 x LRK-516, AKH-9913 x 8660B, BBP-9 x AKH-1174, AKH-1174 x 8660B and LRK-516 x 8660B exhibited significant positive SCA effects for seed cotton yield and lint yield. Out of these crosses besides seed cotton yield and lint yield the cross AKH-081 x AKH-1174 also exhibited significant SCA effect for plant height, number of bolls plant^{-1}, 2.5% span length and oil content. Similarly, AKH-0538 x LRK-516 besides yield also recorded significant positive SCA effects for fibre fineness, 2.5% span length, fibre strength, oil content and chlorophyll content, AKH-9312 x BBP-9 for fibre fineness, fibre strength and maturity co-efficient, AKH-9312 x AKH-1174 for 2.5% span length, fibre strength and oil content, AKH-9913 x LRK-516 for number of bolls plant^{-1}, fibre fineness, fibre strength, uniformity ratio, maturity co-efficient and chlorophyll content and BBP-9 x AKH-1174 for number of bolls plant^{-1}, fibre fineness, fibre strength, uniformity ratio, maturity co-efficient and chlorophyll content. On the basis of SCA effect these six crosses AKH-081 x AKH-1174, AKH-053B x LRK-516, AKH-9312 x BBP-9, AKH-9312 x AKH-1174, AKH-9913 x LRK-516 and BBP-9 x AKH-1174 were identified as superior crosses. These crosses also showed high mean performance for yield and yield contributing traits. As positive significant SCA effect is the indication of dominance genetic component along with the *per se* performance which are the prerequisite for hybrid breeding, these five crosses were identified to be suitable for direct use in hybrid production in order to exploit hybrid vigour expressed in F_1 instead of selecting segregants in advance generation.

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METROGLYPH ANALYSIS FOR MORPHOLOGICAL AND AGRONOMICAL TRAITS VARIATION IN MUSTARD (*Brassica juncea* L.)

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ABSTRACT

An experiment was conducted during *rabi* 2011-2012 to study the pattern of variation for nine agronomical and sixteen morphological characters of 20 local collections and 9 promising varieties of mustard by metroglyph and index score method. All the 29 genotypes were represented by open circle. Two most variable biometrical characters, seed yield plant^{-1} and number of siliquae plant^{-1} were selected for X and Y axis respectively. Scatter diagram revealed that maximum number of genotypes (15) were found in group III recording medium seed yield and number of siliquae plant^{-1} followed by group V with 6 genotypes recording medium seed yield plant^{-1}and high number of siliquae plant^{-1}.The highest index score of 20 was observed for two genotypes ACNM 2 and ACNM 12 and an index score of 19 for four genotypes ACNM 1, ACNM 8, ACNM 10 and Vardhan. Based on the distribution pattern of local collections and promising varieties of mustard in the scatter diagram the local collections ACNM12, ACNM1, ACNM3, ACNM20, ACNM8, ACNM16, ACNM10, ACNM2, and ACNM22 belonging to group IV,V,VI were identified to be crossed with promising varieties belonging to group III for harnessing maximum variability. Morphological characters like leaf hairiness, dentation of leaf margin, siliqua surface texture and seed colour were observed to exhibit significant variations among the genotypes and hence these characters were also identified to be considered as the marker traits in the identification of genotypes.

(Key words: Mustard local collection, metroglyph, morphological characters)

INTRODUCTION

Rapeseed – mustard crops in India are grown in diverse agro climatic conditions ranging from north eastern / north western hills to south under irrigated / rainfed, timely / late sown, saline soils and mixed cropping. Globally India account for 21.7% and 10.7% of the total acreage and production (Annonymous, 2010). Soybean, groundnut and rapeseed – mustard are the major oilseed crops in India contributing nearly 79 % and 88 % to its total acreage and production, respectively. The contribution of rapeseed – mustard to the total oilseed acreage and production were 23.7% and 26.0% respectively. During 2009 – 10, rapeseed – mustard contributed 25.9% and 22.0 % to the total oilseeds production and acreage (Annonymous, 2010). For the success of any breeding programme existence of variability is a prerequisite. Total variability is a metric trait which is divided into genotypic variability and phenotypic variability. The assessment of genetic variability for yield and its components is the basic need for improvement of the crop to desired level. The knowledge of nature and magnitude of genetic variation present in the population is desirable for improvement of yield. Local materials are supposed to be the storehouse of variability which can be exploited in a systematic manner. Greater the genetic variation, greater the chances of bringing about sustainable improvement through selection. Heritability estimated provides information about the extent to which a particular genetic character can be transmitted to the successive populations. Hence, this research work was carried out to evaluate 20 local lines of mustard collected from different regions of Vidharbha for the presence of variability.

MATERIALS AND METHODS

The present study was carried out during *rabi* 2011- 2012 with 29 genotypes consisting of 20 local collections viz., ACNM 1,ACNM 2, ACNM 3, ACNM 4,ACNM 5, ACNM 6, ACNM 8, ACNM 22, ACNM 10, ACNM 11, ACNM 12, ACNM 13, ACNM 14, ACNM 15, ACNM 16, ACNM 17, ACNM 18, ACNM 19, ACNM 20 and ACNM 21 and 9 promising varieties of mustard viz., Geeta, RH-819, Rohini, BioYSR, Kranti, Shatabdi, Bio 902, Pusa Bold and Vardhan at research farm of Botany section, College of Agriculture, Nagpur. The genotypes were planted in a randomized block design replicated thrice with row length of 3 m and spacing between two rows 45 cm. Five plants were randomly selected from each genotype for recording morphological and biometrical observations. Data on 16 morphological characters viz., Leaf hairiness, leaf colour, leaf lobes, dentation of margin, leaf length, leaf width, growth

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habbit (angle between leaf and horizontal), colour of petals, length of petals, width of petals, production of pollens, siliqua length, length of beak, siliqua angle with main shoot, seed colour and siliqua surface texture and nine agronomical characters viz., days to 50% flowering, days to maturity, plant height, number of primary branches plant^{-1}, number of siliquae on main shoot, number of seeds siliqua^{-1},1000 seed size, number of siliquae plant^{-1}, and seed yield plant^{-1} were recorded. The analysis of variance for all the biometrical characters were carried out following RBD design. Metroglyph and index score method advocated by Anderson (1957) were used for analysis of agronomical characters. X axis co - ordinate for each circle being the seed yield plant^{-1} and Y axis co-ordinate for each circle being number of siliquae plant^{-1}. Remaining seven characters were represented by rays of different positions on the glyph and range by length of rays i.e. a genotype having low value with short ray, medium value with medium ray and high value with long ray. The index values were divided into three classes i.e.1- short ray, 2- medium ray and 3 - long ray. The total index values were taken by adding up the index scores of all the nine characters studied. The 16 morphological characters were recorded and data are presented as such in result as there were less variations among the genotypes.

RESULTS AND DISCUSSION

The data regardubg morphological characteristics of 29 genotypes are presented in table 1. From the table it is observed that leaf hairiness was absent in ACNM17 and this trait ranged from sparse to dense among other genotypes. The genotypes ACNM 1, ACNM 3, ACNM 5, ACNM 6, ACNM 22, ACNM 11, ACNM 13, ACNM 14, ACNM 15, ACNM 16, ACNM 18, ACNM 20, ACNM 21, RH-819, Rohini, Bio 902, Pusa Bold and Vardhan exhibited sparse and genotypes ACNM 2, ACNM 4, ACNM 8, ACNM 10, ACNM 12, ACNM 19, Geeta, BioYSR, Kranti, Shatabdi exhibited dense leaf hairiness. Leaf colour of the genotypes were either medium green or dark green. Leaf lobes were observed in all the 28 genotypes except ACNM 17. The observations recorded on dentation of margin showed variation among the genotypes, ACNM 17 exhibited entire dentation, ACNM 6, ACNM 22, ACNM 12, ACNM 13, ACNM 18, Kranti, Shatabdi and Bio902 recorded Lyrate dentation and genotypes ACNM1, ACNM2, ACNM3, ACNM4, ACNM5, ACNM8, ACNM10, ACNM11, ACNM14, ACNM15, ACNM16, ACNM19, ACNM20, ACNM21,Geeta, RH-819, Rohini, BioYSR, Pusa Bold, Vardhan recorded auriculate dentation. Leaf length was observed to be short in all the genotypes except ACNM1, ACNM5, Rohini, BioYSR, Bio 902, Pusa Bold and Vardhan. Except ACNM 1 (medium) all other genotypes exhibited narrow leaf width. Similarly except ACNM 3 (semi erect) all other genotypes recorded open growth habbit. The characters like colour of petals (yellow), width of petals (narrow), production of pollens (present) and siliqua angle with main shoot (open) did not show any variations among 29 genotypes. Length of petals was observed to be short for all the genotypes except BioYSR which recorded medium length of petal. Similarly siliqua length was found to be short for all the genotypes except ACNM 21, which had medium siliqua length. Length of beak was short for ACNM 2, long for ACNM 17 and medium for all other genotypes. Constricted siliqua surface texture was observed in Geeta while intermediate siliqua surface texture was observed in other genotypes. Like dentation of margin, seed colour was the another significant character which showed lot of variation among the genotypes studied. ACNM 17 exhibited yellow seed colour, ACNM 22, ACNM 14, Geeta exhibited black seed colour, ACNM 4 reddish brown and all other 24 genotypes exhibited brown seed colour. This study on morphological characters revealed the significance of characters like leaf hairiness, dentation of leaf margin, siliqua surface texture and seed colour as they exhibited significant variations among the genotypes and hence these characters can be used as the marker traits in the identification of genotypes. These characters except seed colour also showed significance in resistance towards pest and hence can be considered for selecting genotypes in breeding programme for making crossing along with other agronomical characters. Simillar to this study Bhargava *et al*. (2009) in *Chenopodium* spp., Dewan *et al*. (1992) in Indian mustard and Punitha *et al*. (2010) in sorghum germplasm collections also used morphological characters for representing variation among the genotypes.

The metroglyph scatter diagram prepared for nine agronomical characters to depict the variations among 29 genotypes are presented in fig. 1. The diagram allowed the grouping of 29 genotypes into 6 groups / clusters. These 6 clusters could be easily distinguished on the basis of variations recorded by the genotypes. The mean values for 9 characters are given in table 2. The index score and signs used for 9 characters in the metroglyph analysis are given in table 3. The group I was represented by one genotype (ACNM 17) with low seed yield and number of siliquae plant^{-1}. Simillarly group II had only 2 genotypes (ACNM 4 and ACNM 11) with low seed yield plant^{-1} and medium number of siliquae plant^{-1}. Group III was found to consist of maximum number of 15 genotypes (ACNM13, Shatabdi, ACNM19, Kranti, RH-819, BioYSR, ACNM 15, Rohini, Geeta, Pusa Bold, Bio902, ACNM 5, ACNM 18, ACNM 14, ACNM 21) forming the biggest cluster recording medium seed yield plant^{-1} and number of siliquae plant^{-1}. This group comprised of all the 8 promising varieties except Vardhan and 7 local collections. Days to 50% flowering of genotypes in this group was recorded to be early, medium and late while days to maturity was found to be only early and medium. All the genotypes in this group recorded medium score for plant height and number of primary branches plant^{-1}. Except Shatabdi other genotypes scored medium for number of siliquae on main shoot and for number of seeds siliqua^{-1}, these genotypes ranged from score 1 to score 2. Except ACNM 5 and ACNM 18 all other genotypes scored 1 for 1000 seed size.

Group IV consisted of two genotypes ACNM 3, ACNM 20 which were found to be high yielder with medium number of siliquae plant^{-1}. The second biggest cluster was group V with 6 genotypes (ACNM 6, ACNM 8, ACNM 16, ACNM 10, ACNM 22, ACNM 2) recording medium seed yield plant^{-1} and high number of siliquae plant^{-1}. Group VI was characterised by 3 genotypes (ACNM 1, ACNM 12 and Vardhan) with high seed yield and number of siliquae plant^{-1}. The genotypes in group IV and group VI recorded high seed yield plant^{-1} with either medium or high number of siliquae plant^{-1} included one promising variety Vardhan and four local collections i.e. ACNM1, ACNM 3, ACNM 12 and ACNM 20. The genotypes of this group recorded early and medium days to 50% flowering, days to maturity. All these genotypes scored 2 (medium) for plant height and number of siliquae on main shoot and 1 (low) for 1000 seed size. The score for number of primary branches plant^{-1} ranged from 3 to 2 and for number of seeds siliqua^{-1} from 2 to 1 among the above genotypes. Simillar to this result Dewan *et al*.(1992) studied morphological variations in 108 germplasm lines of Indian mustard collected from Bangladesh and India and using a metroglyph index, for yield and growth related traits classified the germplasm lines into one of three grades and finally grouped the genotypes into seven clusters which were not always completely distant from each other. Lines in number of the clusters were associated with high yield and were identified as promising material for further breeding programme by Dewan *et al*. (1992). Sachan *et al*. (2003) also carried out metroglyph analysis for yield and yield components for 16 cultivars of Indian mustard including lines resistant to Alternaria blight, white rust, downy mildew and 2 control (Kranti and Varuna). They classified the cultivars into 3 groups based on yield potential. Khan *et al.* (2005) also carried out metroglyph analysis for yield and quality related characters of eight accessions of *Brassica juncea* and grouped them into 6 clusters. Jha *et al.* (2011) also studied metroglyph analysis for morphological variations in 25 chickpea lines and 5 check varieties and grouped them into 8 clusters.

Majority of genotypes in this study showed medium seed yield plant^{-1} and medium number of siliquae plant^{-1}. In accordance to this result Jha *et al.* (2011) also reported that majority of genotypes recorded medium grain yield plant^{-1} and medium primary branches plant^{-1} in chickpea. The frequency diagram showing the index score values for all characters are presented in figure 2. The range of index score ranged from 12 to 20. Laiju *et al.* (2002) reported index score ranging from 12 to 23 in *Hordeum* species and Jha *et al*.(2011) reported index score ranging from 14 to 23 in chickpea lines. Maximum genotypes (7) had an index score of 18 followed by 6 genotypes having an index score of 16. Highest index score of 20 was observed for two genotypes, ACNM 12 and ACNM2 followed by index score 19 for four genotypes ACNM1, ACNM8, ACNM10 and Vardhan. Minimum frequency (1) occurred for index score 12, 14 and 15. Laiju *et al.* (2002) reported that minimum frequency (1) occurred for index score of 13,16,18, 21and 22 in Hordeum species and Jha *et al.*(2011) reported minimum frequency (1) for index score of 14,15 and 18 in chickpea.

Table 1. Morphological characters of mustard local collections and promising varieties

Sr. No	Genotypes	Leaf hairi-ness	Leaf colour	Leaf lobes	Dentation of margin	Leaf length	Leaf width	Growth habit	Colour of petals
1	ACNM 1	Sparse	Dark green	Present	Auriculate	Medium	Medium	Open	Yellow
2	ACNM 2	Dense	Med. green	Present	Auriculate	Short	Narrow	Open	Yellow
3	ACNM 3	Sparse	Dark green	Present	Auriculate	Short	Narrow	Semierect	Yellow
4	ACNM 4	Dense	Med. green	Present	Auriculate	Short	Narrow	Open	Yellow
5	ACNM 5	Sparse	Med. green	Present	Auriculate	Medium	Narrow	Open	Yellow
6	ACNM 6	Sparse	Dark green	Present	Lyrate	Short	Narrow	Open	Yellow
7	ACNM 8	Dense	Dark green	Present	Auriculate	Short	Narrow	Open	Yellow
8	ACNM 22	Sparse	Dark green	Present	Lyrate	Short	Narrow	Open	Yellow
9	ACNM 10	Dense	Med. green	Present	Auriculate	Short	Narrow	Open	Yellow
10	ACNM11	Sparse	Med. green	Present	Auriculate	Short	Narrow	Open	Yellow
11	ACNM12	Dense	Dark green	Present	Lyrate	Short	Narrow	Open	Yellow
12	ACNM13	Sparse	Dark green	Present	Lyrate	Short	Narrow	Open	Yellow
13	ACNM14	Sparse	Dark green	Present	Auriculate	Short	Narrow	Open	Yellow
14	ACNM15	Sparse	Dark green	Present	Auriculate	Short	Narrow	Open	Yellow
15	ACNM16	Sparse	Dark green	Present	Auriculate	Short	Narrow	Open	Yellow
16	ACNM17	Absent	Med. green	Absent	Entire	Short	Narrow	Open	Yellow
17	ACNM18	Sparse	Dark green	Present	Lyrate	Short	Narrow	Open	Yellow
18	ACNM19	Dense	Dark green	Present	Auriculate	Short	Narrow	Open	Yellow
19	ACNM20	Sparse	Dark green	Present	Auriculate	Short	Narrow	Open	Yellow
20	ACNM21	Sparse	Dark green	Present	Auriculate	Short	Narrow	Open	Yellow
21	GEETA	Dense	Dark green	Present	Auriculate	Short	Narrow	Open	Yellow
22	RH-819	Sparse	Dark green	Present	Auriculate	Short	Narrow	Open	Yellow
23	ROHINI	Sparse	Med. green	Present	Auriculate	Medium	Narrow	Open	Yellow
24	BioYSR	Dense	Dark green	Present	Auriculate	Medium	Narrow	Open	Yellow
25	KRANTI	Dense	Dark green	Present	Lyrate	Short	Narrow	Open	Yellow
26	SHATABDI	Dense	Dark green	Present	Lyrate	Short	Narrow	Open	Yellow
27	BIO902	Sparse	Dark green	Present	Lyrate	Medium	Narrow	Open	Yellow
28	PUSA BOLD	Sparse	Med. green	Present	Auriculate	Medium	Narrow	Open	Yellow
29	VARDHAN	Sparse	Dark green	Present	Auriculate	Medium	Narrow	Open	Yellow

Contd....

Sr. No.	Genotypes	Length of petals	Width of petals	Production of pollen	Siliqua length	Length of beak	Siliquae angle with main shoot	Seed colour	Siliqua surface texture
1	ACNM 1	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
2	ACNM 2	Short	Narrow	Present	Short	Short	Open	Brown	Intermediate
3	ACNM 3	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
4	ACNM 4	Short	Narrow	Present	Short	Medium	Open	Reddish Brown	Intermediate
5	ACNM 5	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
6	ACNM 6	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
7	ACNM 8	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
8	ACNM 22	Short	Narrow	Present	Short	Medium	Open	Black	Intermediate
9	ACNM 10	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
10	ACNM11	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
11	ACNM12	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
12	ACNM13	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
13	ACNM14	Short	Narrow	Present	Short	Medium	Open	Black	Intermediate
14	ACNM15	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
15	ACNM16	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
16	ACNM17	Short	Narrow	Present	Short	Long	Open	Yellow	Intermediate
17	ACNM18	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
18	ACNM19	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
19	ACNM20	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
20	ACNM21	Short	Narrow	Present	Medium	Medium	Open	Brown	Intermediate
21	GEETA	Short	Narrow	Present	Short	Medium	Open	Black	Constricted
22	RH-819	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
23	ROHINI	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
24	BioYSR	Medium	Narrow	Present	Short	Medium	Open	Brown	Intermediate
25	KRANTI	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
26	SHATABDI	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
27	BIO902	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
28	PUSA BOLD	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate
29	VARDHAN	Short	Narrow	Present	Short	Medium	Open	Brown	Intermediate

Table 2. Agronomical characters of mustard local collections and promising varieties

Sr. No.	Genotypes	Days to 50% flowering	Days to maturity (days)	Plant height (cm)	No. of primary branches plant^{-1}	No. of siliquae on main shoot	No. of seeds siliqua^{-1}	1000 seed wt. (g)	No. of siliquae plant^{-1}	Seed yield plant^{-1}
1	ACNM 1	36.33	82.00	121.86	5.20	40.33	11.07	3.03	159.00	6.28
2	ACNM 2	51.66	88.00	123.20	5.40	37.33	14.26	0.70	155.20	3.94
3	ACNM 3	35.33	79.60	137.33	4.46	38.13	15.73	2.97	141.00	4.82
4	ACNM 4	51.00	87.33	129.40	4.87	34.80	10.53	0.83	145.33	1.49
5	ACNM 5	35.00	79.33	123.10	3.47	45.66	08.93	4.86	108.40	3.48
6	ACNM 6	38.33	85.33	123.26	5.00	36.53	09.93	2.60	151.26	2.10
7	ACNM 8	54.66	87.66	134.06	5.47	35.33	14.93	1.03	177.80	2.49
8	ACNM 22	50.33	86.66	124.93	4.53	34.86	16.60	0.87	153.20	3.22
9	ACNM 10	46.33	81.33	132.13	5.13	39.73	16.33	1.13	168.60	3.28
10	ACNM11	52.00	84.66	124.13	4.80	36.60	18.00	1.06	152.00	1.96
11	ACNM12	44.33	87.00	131.73	5.47	40.33	13.86	2.80	171.60	4.49
12	ACNM13	51.00	85.66	123.73	4.40	36.13	09.00	1.63	123.13	2.19
13	ACNM14	51.66	87.33	122.70	4.40	36.53	13.06	1.00	128.40	3.65
14	ACNM15	47.00	82.00	105.80	4.13	31.46	11.07	1.17	113.26	3.08
15	ACNM16	44.66	88.00	116.20	5.13	46.20	15.73	1.03	164.13	2.79
16	ACNM17	39.66	79.33	062.73	2.40	27.00	12.13	2.37	35.00	1.76
17	ACNM18	47.33	85.33	115.13	4.30	34.40	11.93	4.00	115.53	3.59
18	ACNM19	51.33	87.33	125.66	4.40	38.33	10.86	1.30	122.33	2.53
19	ACNM20	47.33	87.00	124.26	3.80	38.60	11.00	2.87	115.73	6.15
20	ACNM21	51.33	89.33	124.13	4.46	32.13	15.13	3.10	143.46	3.26
21	GEETA	50.33	90.00	120.46	4.00	37.93	15.73	3.63	106.06	3.07
22	RH-819	32.00	78.00	109.33	3.73	39.80	9.47	3.70	98.00	2.77
23	ROHINI	44.33	86.66	125.66	4.20	35.66	12.06	2.97	114.20	3.09
24	BioYSR	53.00	91.00	119.66	3.60	35.00	7.26	2.30	105.06	2.70
25	KRANTI	37.66	83.33	103.00	3.47	35.50	9.80	2.83	99.67	2.73
26	SHATABDI	36.33	82.33	127.80	3.93	28.80	9.70	2.80	108.86	2.36
27	BIO902	41.66	86.33	126.06	4.13	34.93	11.53	3.23	106.13	3.48
28	PUSA BOLD	42.66	79.00	122.53	3.86	31.33	8.93	2.90	99.93	3.01
29	VARDHAN	49.66	87.33	131.33	5.20	39.46	10.86	3.30	164.07	4.98

Table 3. Index score and signs used for characters for metroglyph analysis of 29 mustard genotypes

Sr. No	Characters	Score 1		Score 2		Score 3	
		Value less than	Sign	Value between	Sign	Value more than	Sign
1	Days to 50% flowering	40		41-50		51	
2	Days to maturity	81		81-100		101	
3	Plant height (cm)	101		101-150		151	
4	No. of primary branches plant^{-1}	3		3-5		5	
5	No. of siliquae on main shoot	30		30-50		50	
6	No. of seeds siliqua^{-1}	11		11-20		20	
7	1000 seed size (g)	4		4-5		5	
8	No. of siliquae plant^{-1}	100		100-150		150	
9	Seed yield plant^{-1} (g)	2		2-4		4	

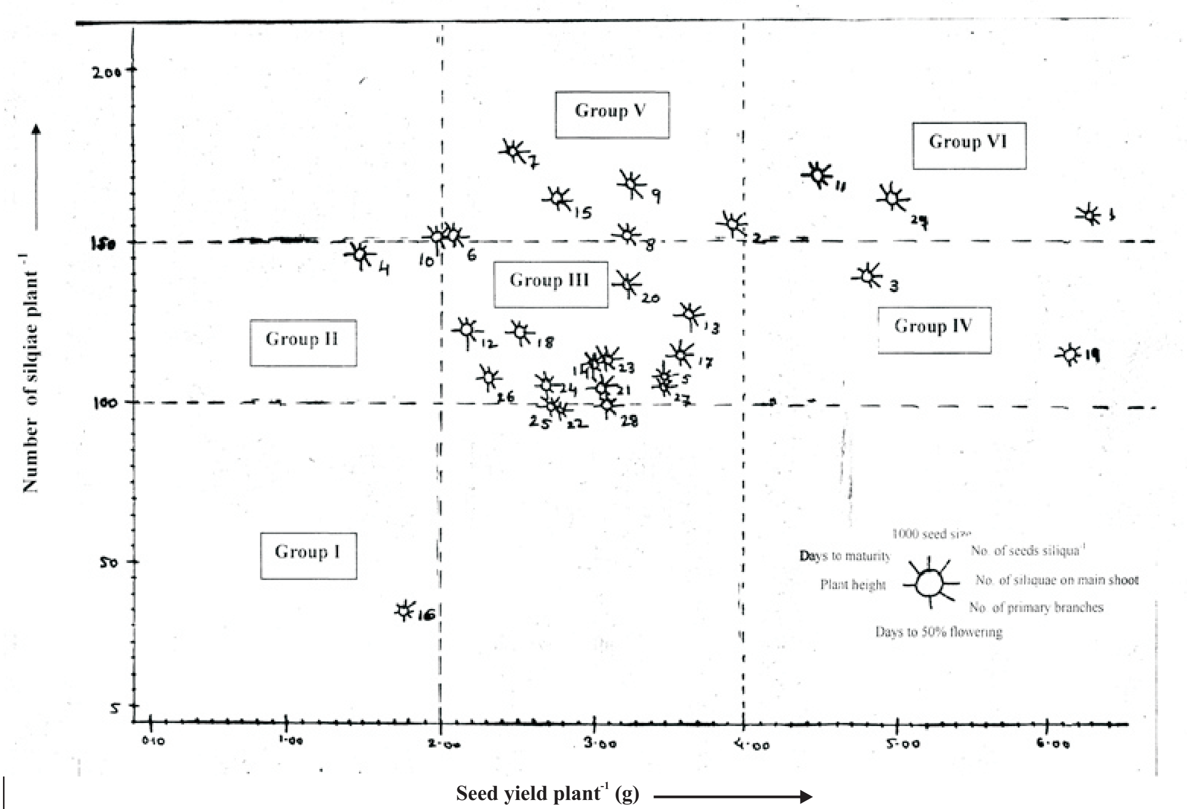

Fig. 1. Scatter diagram of metroglyph analysis of 20 local collections and 9 promising varieties

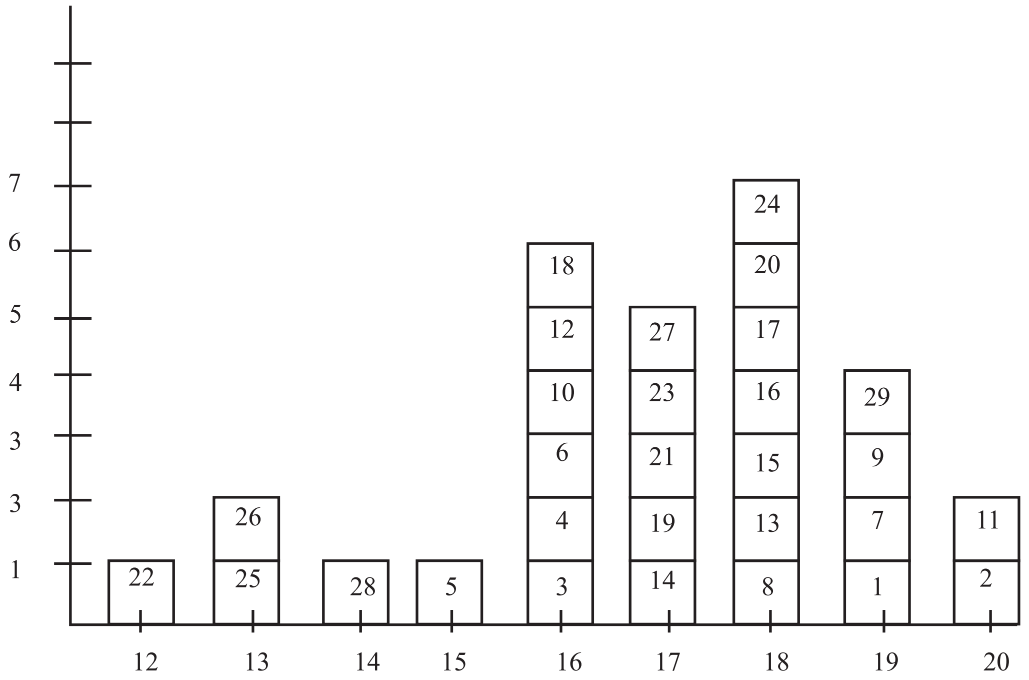

Fig 2. Pattern of distribution of 29 genotypes of mustard scored for 9 traits

The findings of the present study suggested that genotypes in different groups can be used for crossing programme for harnessing maximum variability of good combinations of characters and also helped to ascertain the diversity for various characters among the 29 genotypes. Looking into the distribution pattern of local collections and promising varieties of mustard in the scatter diagram the local collections ACNM12, ACNM1, ACNM 3, ACNM 20, ACNM 8, ACNM16, ACNM10, ACNM 2 and ACNM 22 belonging to group IV,V and VI can be crossed with promising varieties belonging to group III for exploiting maximum variability of good combinations of characters. Further morphological characters like leaf hairiness, dentation of leaf margin, siliqua surface texture and seed colour should also be considered while selecting parents from above groups for crossing.

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SUITABILITY OF INDUSTRIAL EFFLUENTS AND WELL WATER FOR IRRIGATION AROUND BUTIBORI INDUSTRIAL AREA OF NAGPUR

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ABSTRACT

The study was conducted during the year of 2010-11 to evaluate various industrial effuents of Butibori industrial estate near Nagpur city and to assess the seasonal variation in such effluents and underground water. A total of 5 industrial effluent mixed water samples and 5 well water samples were collected from the vicinity of the industrial area during pre monsoon and post monsoon season. These ten samples were analyzed for micronutrients and heavy metals content (Fe,Mn, Zn, Cu, Pb, Cd, Ni, Cr), bioloical oxygen demand (BOD) and chemical oxygen demand (COD). The BOD and COD of the effluent were beyond the permissible limits of National environmental quality standards (NEQS). Among the micronutrients and heavy metals (Fe, Mn, Cu, Zn, Pb, Cd, Pb, Ni and Cr) in effluents, Cd and Cr were beyond permissible limit for irrigation as per Ayers and Westcot (1976), whereas content of micronutrients and heavy metals in well water was within permissible limits. Therefore, these effluents need further elimination or reduction of chemical oxygen demand (COD) through pre-treatment methods before irrigation.

(Key words: Butibori industrial area, industrial effluents, heavy metals, micronutrients, suitability for irrigation)

INTRODUCTION

Various devastating ecological and human disasters of the last four decades implicate industries as a major contribution to environmental degradation and pollution. Environmental pollution due to increase of industrail activities are one of the most significant problems of the century. Pollution in soil and water is strictly related to human activities such as industry, agriculture, burning of fossil fuels, mining and metallurgical processes and their waste disposal. An industry which uses the large amount of water in their processes includes chemical manufactures, steel plants, metal processors etc. All types of effluents and most of by-products from any kind of industry create a most serious pollution to the water bodies and soil bodies. The contamination of soil is often a direct or indirect consequence of industrial activities. With the ever increasing demand on irrigation water supply, farmlands are frequently faced with utilization of poor quality irrigation water. Due to shortage of canal irrigation water farmers use industrial effluents which being discharged in canal. Since, the use of such effluents as irrigation water may introduce some metal ions, which may accumulate in the plants. Soil physico-chemical properties are adversely affected by high concentration of heavy metals, rendering contaminated soils unsuitable for crop production. Metals can also be transported from soil into groundwater resulting in to soil contamination and inhibiting growth of plants. Soils contaminated with toxic metals from point sources are potential exposure routes for surrounding population. The heavy metals accumulate in the plant material grown in these soils, which will ultimately go to human body through food chain directly or indirectly causing a number of physico-mental problems (Ladwani *et al.,* 2012).

Nagpur is rated as the fastest growing city in the entire Central India. A good number of industries of different types have been established in the Butibori area, near Napgur city, which has been loading the environment with ever increasing levels of pollutants. These pollutants may enter the soil and degrade the quality of groundwater. The groundwater and the pollutants that it may carry move with such a low velocity that it may take considerable time for the contaminants to move away from the souce of pollution. Once the groundwater is contaminated, it may remain in unusable or even hazardous condition for decades or even centuries (Mishra *et al.,* 2005).

Use of waste water in agriculture is gaining importance now a days, because of its value as a potential source of irrigation water a nutrient donor. Use of waste water for irrigation makes it possible to conserve the limited water resources for crop production and also prevent pollution of water bodies, as soil is a very good sink. Also application of waste waters to agricultural land may promote the growth of crops and conserve water and nutrients. But the indiscriminate use of the industrial effluents for irrigation to agricultural crops may cause soil and groundwater pollution problems in the long run when they are not properly handled before and after their

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application to land. The project was comprised of the study of contaminated water bodies during pre monsoon and post monsoon periods and the impact of effluent use for irrigation on soil and groundwater quality in the vicinity of Butibori industrial are in Nagpur district.

MATERIALS AND METHODS

A total of 10 water samples were collected to assess the quality of industrial effluents and well water from vrious sites in the vicinity of Butibori industrial area. The sampling locations were selected on the basis of effluent discharge outlets, cultivated area and irrigation sources. The exact location of sampling site was decided with the help of global positioning system (GPS).

Selection of water sampling sites :

To assess the iron and steel industry, textile industry effluent quality and ground water quality of the study area 5 samples of industrial effluents and 5 samples from well water were collected from 10 different locations. Sampling locations were selected after every 1-2 km approximately in order to study the overall impact.

The village selected from sampling were Butibori (20^0 55.048' N 078^0 59.516' E), Beldarsukdi (22^0 55.245' N 078^0 59.100'E), Mohgaon (20^0 58.216'N 079^0 01.334' E), and Bothali (22^0 60.271' N 079^0 0.133 E).

These 10 samples were collected and analyzed twice, during June 2010 (pre-monsoon) and September 2010 (post monsoon) to study the seasonal variation. These water samples were analyzed for micronutrient and heavy metals. The water samples were collected in polythene bottles directly from effluent carrying 2 samples from drain, 3 samples from river and 5 samples from dug wells. The collected water samples were stored in the dark at laboratory conditions for future uses. For the analysis of Chemical oxygen demand (COD) and heavy metals the preservatives used werer conc. H_2SO_4 and conc. HNO_3 (98%) respectively (Anonymous, 1975).

Water samples were analyzed for micro-nutrients (Fe, Mn, Zn and Cu) on atomic absorption spectrophotometer (Anonymous, 1975). Metal cations (cr, Cd, Ni, and Pb) of sewage and well water were estimated according to Jackson (1967). Effluent sample (250 ml) was treated with 0.1 N conc. HNO_3 and evaporated to dryness. Dried samples were then treated with aqua-regia and evaporated. Adding few drops of HNO_3 the treated samples were finally diluted to 50 ml. Metal cations contents of these solutions were determined using inductively Coupled Plasma Spectrometer (ICP-AES) (Model-JY24, Jobin, France), (Anonymous, 1975).

There are two demand parameters which were determined in the effluent i.e.

a) Chemical oxygen demand (COD) and
b) Biological oxygen demand (BOD)

The Chemical oxygen demand (COD) test determine the oxygen required for chemical oxidation of organic matter with the help of strong chemical oxidant. The organic matter gets oxidized completely by $K_2Cr_2O_7$ in the presence of H_2SO_4 to produce CO_2 + H_2O. The excess $K_2Cr_2O_7$ remaining after the reaction was titrated with Fe $(NH_4)_2(SO_4)_2$. The dichromate consumed gives the oxygen required for oxidation of the organic matter (Anonymous, 1975).

The Biological oxygen demand (BOD) test is based upon determination of dissolved oxygen; consequently accuracy of result is influenced greatly by the care given to its measurement. BOD may be measured directly by adjusting sample at 20^0c and aerated with diffused air to increase or decrease the dissolved gas content of the sample to near saturation. Two or more BOD bottles were filled with sample, at least one was analyzed for dissolved oxygen immediately and an other was incubated for 5 days at 20^0c. After 5 days the amount of dissolved oxygen remaining in incubated samples was determined and the 5^{th} day BOD was calculated by subtraction of 5^{th} day result from those obtained on zero days (Annonymous, 1975).

RESULTS AND DISCUSSION

Seasonal variation in micronutrient and heavy metal content in effluent and well water as influenced by industrial effluents :

The results obtainied on micronutrients (Fe, Mn, Zn and Cu) and heavy metals content (Pb, Cd, Ni and Cr) in various industrial effluents and well water near industrial area are depicted in table 1. The results showed that, the micronutrients (Fe, Mn, Zn and Cu) and heavy metals content (Pb, Cd, Ni and Cr) in effluent and contaminated water in pre monsoon ranged from 1.91 to 3.10, 0.17 to 1.25, 0.19 to 1.19, 0.025 to 1.09 and 0.030 to 0.26, 0.006 to 0.60, 0.002 to 1.20 and 0.045 to 1.65 mg l^{-1} respectively. These results were above the permissible limits (Anonymous, 2000). Similar findings also reported by Bansal (1992) that the main source of Fe in the effluent appeared due to iron and steel industries. Perhaps Ni in the industrial effluents was due to certain industries e.g. Kitchen appliances, surgical instruments, steel alloys and automobiles batteries. The high Cd in discharged effluent was due to marble, steel industries as well as mining and metal plating whereas the main sources of Cu was due to industrial wastes and agro-chemicals. Kanu and Achi (2011) also reported that industrial waste water entering a water body represent a heavy source of environmental pollution in Nigerian rivers. It affects both the water quality as well as the microbial and aquatic flora. Industrial effluents are characterized by their abnormal turbidity, conductivity, total suspended solids (TSS) and total hardness. Industrial wastes containing high concentration of microbial nutrients would obviously promote and after-growth of significantly high coliform types and othr microbial forms. They found that waste effluent rich in decomposable organic matter, is the primary cause of organic pollution.

Similarly, all micronutrients (Fe, Mn, Zn and Cu) and heavy metals (Pb, Cd, Ni and Cr) in well water during pre monsoon ranged from 0.18 to 1.50, 0.005 to 0.04, 0.015 to 0.18, 0.008 to 0.017 and 0.031 to 0.22, 0.002 to 0.05, 0.01 to 0.25 and 0.007 to 0.10 mg l^{-1} respectively. The results showed that all heavy metals content in well water were found within permissible limit for irrigation and may not pose any serious hazard (Ayers and Westcot, 1976).

Biological oxygen demand measures the biodegradable materials in water and helps in the development of bacteria and other organic byproducts (Minhas and Gupta, 1992). The biological oxygen demand in various industrial effluents ranged from 81.1 to 83.1 mg l^{-1}. Results showed that effluents had higher BOD values than the NEQS standards (80 mg l^{-1}) indicating that if such effluent mixed with rivers or stream water, it will have adverse effect on aquatic life due to depleted oxygen level in water. Similar conclusions were also drawn by Sharma *et al.* (2002). They studied ground water pollution by industrial effluent where they observed the nitrate content beyond its permissible limit of 45 mg l^{-1}. The BOD, which is generally not found in groundwater at greater depth, was also recorded in the village at the depth of more than 20 m in the range varying from 0.96 to 5.29 mg l^{-1}. The BOD in well water and river water ranged for 1.1 to 1.9 mg l^{-1} suggesting that all the underground water and river water samples were within safe limits compared with US-EPA standards (Bauer, 1974 and Anonymous, 1983). The indication of BOD in the ground water samples suggested that the industrial effluents might have contributed some organic carbon to such water, which is potential threat of water contamination in future.

The data regarding bilogical oxygen demand (BOD) and chemical oxygen demand (COD) of effluent samples and well water samples as influenced by industrial effluent are depicted in table 2. The COD of effluents had higher COD values ranging from 152 to 162 mg l^{-1} than NEQS (150 mg l^{-1}) standards. Therefore, these effluents need further elimination of COD through proper treatment methods before irrigation (Sial *et al.* 2006). The COD of well water and river water were ranged from 3.3 to 3.9 mg l^{-1} suggesting that all the well water and river water samples were within the safe limits compared with NEQS standards.

Table 1. Seasonal variation in micronutrient and heavy metal content in effluent and well water as influenced by industrial effluents

Sr. No.	Location	Seasons	Fe	Mn	Zn	Cu	Pb	Cd	Ni	Cr
			(mg l^{-1})							
1.	Effluent carrying stream	Pre monsoon	3.1	1.25	1.19	1.09	0.06	0.06	1.2	1.65
		Post monsoon	2.7	1.10	0.97	0.75	0.03	0.4	0.89	1.05
2.	Textile effluent	Pre monsoon	1.9	0.17	0.19	0.07	ND	0.01	0	1.27
		Post monsoon	2.0	0.14	0.14	0.04	ND	0.01	ND	0.87
3.	Vennariver flowing in industrial area	Pre monsoon	2.4	0.19	0.50	0.03	0.03	0.20	0.05	0.06
		Post monsoon	1.7	0.12	0.31	0.02	0.02	0.09	0.02	0.03
4.	Confluence of effluent carrying stream and river	Pre monsoon	2.1	0.17	0.30	0.03	0.26	0.01	0.05	0.05
		Post monsoon	1.7	0.11	0.17	0.02	0.15	0.01	0.02	0.02
5.	Venna 2-3 km away from industrial area	Pre monsoon	0.2	0.03	ND	ND	0.25	0.01	0.04	0.03
		Post monsoon	0.1	0.01	ND	ND	0.12	0	0.02	0.02
6.	Well adjoining effluent carrying stream	Pre monsoon	1.5	0.04	0.18	0.02	0.22	0.05	0.25	0.10
		Post monsoon	1.0	0.02	0.02	0.01	0.17	0.04	0.11	0.01
7.	Well 0.5 km away from industrial area	Pre monsoon	1.0	0.09	0.04	0.02	0.12	0.01	0.02	0.02
		Post monsoon	0.7	0.05	0.02	0.01	0.09	0	0.01	0.01
8.	Well 1 km from industrial area	Pre monsoon	0.7	0.07	0.03	0.01	0.06	0.01	0.02	0.01
		Post monsoon	0.5	0.02	0.03	0.01	0.04	0	0.01	0.01
9.	Well 2 km from industrial area	Pre monsoon	0.5	0.06	0.02	0.01	0.05	0	0.01	0.01
		Post monsoon	0.3	0.01	0.01	0.01	0.02	0	0.01	0.01
10.	Well 3-4 km from industrial area	Pre monsoon	0.2	0.01	0.02	0.01	0.03	0	0.01	0.01
		Post monsoon	0.1	0	0.01	0	0.01	ND	0	0
	NEQS		2.0	1.50	5.00	1.00	0.50	0.10	1.00	1.00

Table 2. Seasonal variation in oxygen demand parameter of water as influenced by industrial effluents

Sr. No.	Location	Seasons	COD (mg l^{-1})	BOD (mg l^{-1})
1.	Effluent carrying stream	Pre monsoon	152	81.2
		Post monsoon	145	45.2
2.	Textile effluent	Pre monsoon	162	83.10
		Post monsoon	155	51
3.	Vennariver flowing in industrial area	Pre monsoon	29	9.20
		Post monsoon	21	7.10
4.	Confluence of effluent carrying stream and river	Pre monsoon	171	57
		Post monsoon	165	53
5.	Venna 2-3 km away from industrial area	Pre monsoon	27.3	9.10
		Post monsoon	17.1	5.70
6.	Well adjoining effluent carrying stream	Pre monsoon	3.5	1.10
		Post monsoon	3.2	1.06
7.	Well 0.5 km away from industrial area	Pre monsoon	3.7	1.23
		Post monsoon	3.4	1.13
8.	Well 1 km from industrial area	Pre monsoon	3.9	1.30
		Post monsoon	3.3	1.20
9.	Well 2 km from industrial area	Pre monsoon	3.3	1.90
		Post monsoon	2.9	0.96
10.	Well 3-4 km from industrial area	Pre monsoon	3.6	1.50
		Post monsoon	3.3	1.30
	NEQS		**150**	**80**

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EXTENT OF ADOPTION OF BIOFERTILIZERS BY THE FARMERS IN MAJOR CROPS IN WARDHA DISTRICT

A. Srinivas[1] and D. N. Bhalekar[2]

ABSTRACT

The study was carried out during 2011-2012 in Deoli Taluka of Wardha district of Vidarbha region of Maharashtra state for ascertaining the adoption level of biofertilizers by selective 100 farmers. The study revealed that majority of the farmers (57.00%) had medium level of adoption of biofertilizers. Majority of them had highly favourable view towards attributes of biofertilizers and were medium in use of biofertilizers. 90.00 per cent of the respondents used biofertilizers only for the specified crops, 82.00 per cent of the respondents used 250g *Rhizobium* for 10 kg seeds and 81.00 per cent of the respondents had adopted practices like drying of the inoculated seeds under shade. Further, it was noted that majority of the respondents had adopted practices like, use of jaggery as sticking agent (80.00 %), use of biofertilizers before expiry date (80.00 per cent) and used 250g *Azotobactor* for 10 kg seeds (55.00 per cent). The findings of the study have shown that the farmers are not making use of PSB and composting biofertilizers. It is, therefore, essential to equip the farmers with requisite knowledge and skills connected with adoption of PSB and composting biofertilizers for preparation of compost from farm waste. Among selected variables age and education were non significantly related with adoption. Annual income, land holding, irrigation, cropping pattern, extension contact, scientific orientation, innovativeness, cosmopoliteness, knowledge were positively correlated with adoption at 0.01 level of significance.

(Key words: Adoption, biofertilizers, farmers, major crops)

INTRODUCTION

Agriculture production depends upon availability and use of quality and quantity of farm inputs. The chemical fertilizers are supposed to be essential inputs for boosting up of production of hybrids and high yielding crop varieties. It has played a significant role in increasing agricultural production in the country since 'Green Revolution'. The continuous use of chemical fertilizers however, has deteriorated the soil fertility, destroyed soil microbial activity, and disturbed environmental balance and ecological soundness.

This indicates a dire need to use such fertilizers that are eco-friendly, maintain soil fertility and increase crop production. Biofertilzers, most of which are nitrogen fixing microorganisms, are considered to be suitable alternative source of plant nutrition.

The use of biofertilizers is the recent attempt in increasing yield of different crop's productivity as well as soil fertility by way of fixing atmospheric nitrogen, solublising insoluble phosphate present in the soil biologically along with production of growth hormones, vitamins and also helps to improve soil structure, texture and water holding capacity.

The most prominent and contributing function of biofertilizers is substantial reduction in environmental pollution and improvement in agro ecological soundness. Biofertilizers are affordable to farmers because of low costs and they are very significant in making available nutrients like nitrogen and phosphorus to the crop plants (Pandy and Pandey, 1995).

Despite having various potential activities, biofertilizers yet did not get farmers acceptance adequately. The present investigation was therefore, aimed at ascertaining the adoption with the following specific objectives.

1. To find out the extent of adoption of biofertilizers by the farmers in major crops viz., wheat, soybean, gram and tur.
2. To study relationship between selected profile of farmers with adoption of biofertilizers.

MATERIALS AND METHODS

The present study was carried out in Deoli Taluka of Wardha district of Vidarbha region of Maharashtra state. Deoli taluka was selected purposively for study because this area is having multiple crops like Soybean, Tur, Wheat and Gram. Deoli taluka consist of 144 villages. Among these 10 villages were selected by simple random sampling method. 100 farmers were selected by proportionate random sampling method from selected 10 villages of this Taluka. These farmers were considered as

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respondents for the present study. On the basis of the objectives of study, an exhaustive interview schedule was designed and developed. Data were collected from these farmers by personel interview method.

The data about various aspects of adoption of biofertilizers were collected, tabulated, analyzed and interpreted.

Correlation coefficient was also determined for ascertaining relationship between selected profile of farmers with adoption of biofertilizers.

RESULTS AND DISCUSSION

For studying adoption, 12 practices related with biofertilizers were identified in consultation with the experts in this field. These practices were related to actual use of nitrogen fixing biofertilizers viz., *Rhizobium, Azotobacter* and *Azospirillum*, Phosphate Solublizing Bacteria (PSB), composting biofertilizers, sticking agents, precautions and storage of biofertilizers. The actual use of a particular practice was ascertained in terms of adoption as per recommendation, adoption not as per recommendation and no adoption with a score of 2, 1 and 0, respectively. The scores of all the practices were added together to work out adoption score of an individual farmer. These scores were then converted into an index as mentioned below.

$$\text{Adoption index} = \frac{\text{Maximum obtained adoption score}}{\text{Maximum obtainable adoption score}} \times 100$$

The farmers were then grouped into the following three levels on the basis of mean and standard deviation (X ± SD).

It reveals from table 1 that 30.00% of the farmers were found under low category of adoption of biofertilizers. The farmer belongings to medium categories of adoption were 57.00%. Whereas, only 13.00% of the farmers had high level of adoption of bio-fertilizers. Thus, majority of respondents belonged to medium level of adoption.

It leads to approval of the hypothesis (Bhople and Borkar, 2002) that the farmers did not adopt various practices associated with bio-fertilizers. Majority of the respondents has medium adoption (57.00%) of practices of bio-fertilizers. Marathe (2004) observed that majority of the farmers had medium level of adoption of biofertilizers.

It could be seen from table 2 that a great majority of the respondents (82.00 per cent) used the *Rhizobium* for inoculation to pulse crops like Gram and Tur. A sizeable percentage of the farmers (55.00 per cent) were found to use *Azotobacter* for cereal crops like wheat. This was followed, by 14.00 per cent of respondents who used PSB to crops like soybean and gram.

Practice wise adoption of various biofertilizers :

The adoption of various practices connected with use of biofertilizers by the respondent was further ascertained and the same have been reported in table 3, 90.00 per cent of the respondents used biofertilizers only for the specified crops, 82.00 per cent of the respondents used 250g *Rhizobium* for 10 kg seeds and 81.00 per cent of the respondents had adopted practices like drying of the inoculated seeds under shade. Further, it was noted that majority of the respondents had adopted practices like, use of jaggery as sticking agent (80.00 %), expiry date of biofertilizers before use (80.00 per cent), and used 250g *Azotobactor* for 10 kg seeds (55.00 per cent), storing of biofertilizers in cool and place (55.00 per cent) and considering incompatibility of biofertilizers with the chemical fertilizers (46.00 per cent). It is also noted that 3.00 per cent were using composting biofertilizers and 2.00 per cent of the respondents used PSB and *Rhizobium* in 1:1 proportion as per the recommendation.

The reasons for non adoption of composting biofertilizers and PSB might be the lack of awareness about these biofertilizers. The farmers should therefore, be equipped with detailed knowledge about these biofertilizers. They should be convinced about the effectiveness of biofertilizers in crop production through organization of demonstrations and meetings. Further, with a view to boost up the adoption of biofertilizers, it is essential to supply the different biofertilizers in time and that too at village level.

The above findings are in line with the finding of the Talape *et al.* (2011) who reported that majority of the farmers had medium level of adoption of biofertilizers.

Table 1. Distribution of respondents according to their adoption level of biofertilizers

Sr. No.	Adoption Level	Respondents (N=100)	
		Frequency	Percentage
1	Low	30	30.00
2	Medium	**57**	**57.00**
3	High	13	13.00

Table 2. Distribution of the farmers according to their adoption of various bio-fertilizers

Sr. No.	Biofertilizers	Respondents (N=100)	
		Frequency	Percentage
1	*Rhizobium*	**82**	**82.00**
2	*Azotobacter*	55	55.00
3	Phosphate solubalising bacteria	14	14.00
4	Composting biofertilizers	04	04.00

Table 3. Distribution of respondents according to practice wise adoption of various biofertilizers

Sr. No	Biofertilizer practices	Adoption (N=100)		
		As per recommendation	Not As per recommendation	Non adopti-on
A)	**Methods of application of biofertilizers**			
1	Recommended quantity of *Rhizobium* (250 g. 10^{-1} kg of seeds)	82 (82.00)	10 (10.00)	08 (08.00)
2	Recommended quantity of *Azotobacter* (250 g. 10^{-1} kg of seeds)	55 (55.00)	21 (21.00)	24 (24.00)
3	Recommended quantity of PSB (2 kg in 20 kg FYM ha^{-1})	14 (14.00)	4 (04.00)	82 (82.00)
4	Recommended quantity of composting biofertilizers (1kg ton^{-1} compost)	3 (3.00)	0 (0.00)	97 (97.00)
B)	**Precaution to be taken while use of biofertilizers**			
1	Consideration of expiry date of biofertilizers (Six months)	80 (80.00)	05 (05.00)	15 (15.00)
2	Use of biofertilizers only for specified crops	90 (90.00)	04 (04.00)	06 (06.00)
3	Storage of biofertilizers in cool and dry place	55 (55.00)	35 (35.00)	10 (10.00)
4	Use of jaggery as sticking agent	80 (80.00)	08 (08.00)	12 (12.00)
5	Drying of inoculated seeds under shade	81 (81.00)	17 (17.00)	02 (02.00)
6	Period within which inoculated seeds used for sowing (12 hrs.)	45 (45.00)	48 (48.00)	7 (07.00)
7	Incompatibility of biofertilizers and chemical fertilizers	46 (46.00)	28 (28.00)	26 (26.00)
8	Proportion of use of PSB and *Rhizobium* (1:1)	2 (2.00)	5 (5.00)	93 (93.00)

(Figures in parenthesis indicate percentage)

Table 4. Coefficient of correlation between selected profile of the respondents with their adoption

Sr. No.	Characteristics	`r` Value
1	Age	0.0848 NS
2	Education	-0.1019 NS
3	Annual income	0.6178**
4	Land holding	0.5449**
5	Irrigation	0.5064**
6	Cropping pattern	0.4028**
7	Extension contact	0.4611**
8	Scientific orientation	0.4114**
9	Innovativeness	0.4305**
10	Cosmopoliteness	0.4743**
11	Knowledge	0.5774**

** Significant at 0.01 % level of probability.
NS – Non Significant.

Relationship of selected profile of respondents with adoption.

Relational analysis :

The correlation coefficient of adoption with personal, situational, communicational and psychological characteristics of the respondents have been depicted in table 4.

A critical examination of table 4 revealed that those among selected variables, age and education were non significantly related with adoption.

Annual income, land holding, irrigation, cropping pattern, extension contact, scientific orientation, innovativeness, cosmopoliteness, knowledge were positively correlated with adoption at 0.01 level of significance.

Thus, efforts should be made by the extension agencies that along with the *Rhizobium* and *Azotobacter*, farmers should also be motivated to use biofertilizer viz., phosphate solubalising bacteria and composting biofertilizers. It is necessary to make a propaganda about these biofertilizers, as they are low cost, econfriendly and sustainable.

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EFFECT OF FOLIAR APPLICATION OF HUMIC ACID THROUGH COWDUNG WASH ON CHEMICAL, BIOCHEMICAL AND YIELD AND YIELD CONTRIBUTING PARAMETERS OF GREENGRAM

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ABSTRACT

An experiment was laid out to study the effect of foliar application of humic acid through cowdung wash (100 ppm, 150 ppm, 200 ppm, 250 ppm, 300 ppm, 350 ppm, 400 ppm, 450 ppm and 500 ppm) on the chemical, biochemical, yield and yield contributing parameters of green gram cv. AKM – 8802 during *kharif* 2011-2012. Field experiment was conducted at an experimental farm of Botany, College of Agriculture, Nagpur. Data revealed that foliar sprays of CDW exhibited their significance over control. Two foliar sprays of 150, 200, 250, 300, 350, 400, 450 and 500 ppm humic acid through cowdung wash significantly enhanced chemical, biochemical parameters viz., chlorophyll ,nitrogen, phosphorus and potassium content in leaf, protein content in seed and yield and yield contributing parameters viz., number of pods plant^{-1},100 seed weight, seed yield plant^{-1} and plot^{-1} over control. Considering the treatments under study two foliar sprays of 350 ppm humic acid through cowdung wash at 20 and 35 DAS was found most effective in improving chemical and biochemical, yield and yield contributing parameters of green gram cv. AKM-8802 and ultimately increased yield by 23% over control and can be considered as the most effective and beneficial treatment (B:C ratio 2.23)in green gram.

(Key words: Green gram, humic acid, cowdungwash,chemical,biochemical parameters, yield and yield contributing parameters)

INTRODUCTION

Green gram (*Vigna radiata*) is one of the pulse crop cultivated in India. Green gram is small herbaceous annual erect or semi erect 45 to 120 cm tall plant having chromosome number 2n = 24. It belongs to family "leguminoceae" and sub family "Papilionaceae". Green gram is ideal crop for spring and summer season. Green gram is grown in summer and *kharif* season in Northern India. In Southern India it is also grown in winter season.

The yield during summer season is much higher than those obtained during *kharif* season.

Green gram is rich source of high digestible protein, it contains about 25% protein, also contains 10.4% moisture, 1.3% fat, 3.5% minerals, 1.4% fiber, 56.7% carbohydrate and 25% protein and small amount of vit. B complex (Thiamine, Riboflavin etc.). It is rich in minerals like calcium (124 mg), phosphorus (326 mg) and iron (73 mg). 100 g green gram contains protein 22.1 g, fat 0.8 g, carbohydrate 59 g and heat 332 k. Cal. Green gram also contains phospholipid and starch. Chandrasekaran (1992) have reported the HA with high molecular weight are not known to be assimilable while those with low molecular weight are said to be assimilable by the plants.

Considering the importance of green gram from nutritional and production point of view it becomes necessary to cultivate the green gram crop with expectation of higher yield, which can be achieved by physiological approaches by co-ordinating plant process to synthesize the dry matter and yield of green gram may be increased through physiological manipulation such as foliar application of humic acid through source like cowdung wash.

MATERIALS AND METHODS

The field experiment was conducted in RBD with ten treatments and three replications during *kharif* 2011-12 at experimental farm of Botany, College of Agriculture, Nagpur. The details of treatments are given in table 1. Chemical and biochemical parameters like total leaf chlorophyll content, leaf nitrogen, leaf phosphorus, leaf potassium were estimated at 35, 50 and 65 DAS. Seed protein was also estimated. Total chlorophyll content of oven dried leaves was estimated by colorimetric method as suggested by Bruinsma (1982). Nitrogen content in leaves was determined by microkjeldahl's method as given by Somichi *et al*. (1972). Phosphorus content in leaves was determined by vanadomolybdate yellow colour method given by Jackson (1973). Potassium content in leaves was determined by flame photometer by di-acid extract

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method as given by Jackson, 1973. The protein content in seeds was estimated by microkjeldhls method suggested by Somichi *et al*. (1972). Firstly N content was estimated and then it was converted to protein by multiplying it with 6.25. Observations on yield and yield contributing paraments like number of pods plant^{-1}, 100 seed weight, seed yield plant^{-1}and plot^{-1} were also recorded after harvesting.

RESULTS AND DISCUSSION

Biochemical analysis :

The biochemical analysis studies with respect to chlorophyll and N, P, K content in leaves as well as protein content in seed estimated at various stages of observations have been presented here under.

Leaf chlorophyll content :

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 process which in turn is the major synthesis pathway operative in plants. Data regarding leaf chlorophyll content in leaves of green gram was recorded at 35,50 and 65 DAS.

At 35 DAS all the treatments showed their significance in leaf chlorophyll content and it was significantly maximum in treatment T_7 (350 ppm) followed by T_6 (300 ppm), T_8 (400 ppm) and T_5 (250 ppm) when compared with control and rest of the treatments. Treatments T_9 (450 ppm), T_{10} (500 ppm), T_4 (200 ppm), T_3 (150 ppm) and T_2 (100 ppm) in a descending order increased leaf chlorophyll content over treatment T_1 (control) significantly. At 50 DAS significantly maximum leaf chlorophyll content was noticed in treatment T_7 (350 ppm) followed by T_6 (300 ppm) and T_8 (400 ppm) when compared with control and rest of the treatments. Next to these treatments, treatments T_5 (250 ppm), T_9 (450 ppm), T_{10} (500 ppm), T_4 (200 ppm), T_3 (150 ppm) and T_2 (100 ppm) also gave significantly maximum leaf chlorophyll content over treatment T_1 (control). At 65 DAS the trend was totally different. All treatments T_7 (350 ppm), T_6 (300 ppm), T_8 (400 ppm), T_5 (250 ppm), T_9 (450 ppm), T_{10} (500 ppm), T_4 (200 ppm), T_3 (150 ppm) and T_2 (100 ppm) in a descending order increased leaf chlorophyll content over treatment T_1 (control) significantly.

The above data indicates that chlorophyll content in leaves was progressively increased at 35 DAS but thereafter, decreased gradually at 50 to 65 DAS. The green leaf pigment chlorophyll is a nitrogenous compound enables plant to use the energy of sunlight to form sugar from carbon dioxide and water. A higher concentration of N is found in young, tender plant tissues like tips of shoots and new leaves. The N present mostly as protein is constantly moving and undergoing chemical changes. In young stage plant may be uptake more nutrients from soil than that older one. The increase in chlorophyll content in the present study might be due to increased uptake of N and other nutrients in early stage of plant. The proper function of N in plant nutrition requires that the other essential elements particularly P, K, Ca and Mg be present in adequate supply. The foliar application of humic acid gave these additional nutrients to crop and this might have accelerated chlorophyll synthesis.

Foliar spray of CDW enhanced chlorophyll synthesis in the present investigation because the minerals like Mg required for chlorophyll synthesis was found adequate in quantity i.e. about 162 mg l^{-1} in CDW (Sivasubramaniam and Ganeshkumar, 2004).

Lende *et al*. (2007) reported that foliar sprays of cowdung wash significantly increased leaf chlorophyll content of soybean.Hu and Wang (2001) also reported that komix humic acid containing organic fertilizer significantly increased chlorophyll content of spring soybean.

Leaf nitrogen content :

Nitrogen is important constituent of protein and protoplasm. Also it is essential for normal cell division and plant growth. The maximum N found in areas like tip of shoots, buds and leaves.

Data pertaining to leaf nitrogen content in leaves of green gram was recorded at 35, 50 and 65 DAS.

The range of leaf nitrogen was 2.66, 1.76 and 1.23 per cent in control and 3.42, 2.32 and 2.21 per cent in foliar application of 350 ppm humic acid through cowdung wash at 35, 50 and 65 DAS respectively.

At 35 DAS significantly maximum leaf nitrogen content was recorded in treatment T_7 (350 ppm) followed by T_8 (400 ppm) and T_6 (300 ppm) when compared with control (T_1) and rest of the treatments. Treatments T_9 (450 ppm), T_5 (250 ppm), T_{10} (500 ppm) and T_4 (200 ppm) were also found significantly superior over treatments T_1 (control), T_2 (100 ppm) and T_3 (150 ppm) in a descending manner.

At 50 DAS the treatment receiving foliar spay of nutrients in the form of humic acid through cowdung wash increased leaf nitrogen content and it was found significantly maximum in treatment T_7 (350 ppm) followed by T_8 (400 ppm), T_6 (300 ppm) and T_9 (450 ppm) when compared with T_1 (control) and rest of the treatments. Next to these treatment, treatments T_5 (250 ppm), T_4 (200 ppm), T_{10} (500 ppm), T_3 (150 ppm) and T_2 (100 ppm) in a descending manner also gave significant results in respect of total nitrogen content in leaves when compared with control. At 65 DAS significantly maximum leaf nitrogen content was recorded in treatment T_7 (350 ppm) followed by T_8 (400 ppm) and T_5 (250 ppm) in a descending manner when compared with other remaining treatments and control. Treatments T_4 (200 ppm), T_{10} (500 ppm), T_3 (150 ppm) and T_2 (100 ppm) also found significantly superior over each other and control.

Leaf nitrogen content increased at 35 DAS and decreased at 50 and 65 DAS because leaf nitrogen was utilized for different growth processes and developing organs such as seeds do act as strong sink demand and may draw heavily the nitrogen from the leaves (Gardner *et al.,* 1988).

Neri *et al*. (2005) mentioned that it can be hypothesized that HA reduced the speed of dropet drying while there wetting action may enhance nutrient absorption. The result clearly indicated that humic can be use on foliage to make more efficient utilization of nutrients.

Poonkodi (2003) also stated that decrease in nitrogen content might be due to translocation and utilization of nutrients for flower and pod formation.

Nandakumar *et al*. (2004) reported that foliar application of HA in combination with NPK increased soil nutrients (N, P, K, Fe, Mn, Zn, Cu) availability at all growth stages (tillering, flowering and harvest) in rice.

Venkatramana *et al*. (2010) reported that foliar application of cowdung wash at 25 and 35 days after pruning of mulberry and found increase in leaf nitrogen content in mulberry leaves.

Leaf phosphorus content :

Data regarding leaf phosphorus content were recorded at three stages of observations i.e. 35, 50 and 65 DAS.

At 35 DAS significantly maximum leaf phosphorus content was noticed in treatments T_7 (350 ppm) followed by T_8 (400 ppm), T_6 (300 ppm), T_9 (450 ppm) and T_5 (250 ppm) when compared with treatment T_1 (control) and remaining treatments also. Treatments T_{10} (500 ppm), T_4 (200 ppm), T_3 (150 ppm) and T_2 (100 ppm) also found significantly superior over each other and control (T_1). At 50 DAS significantly more leaf phosphorus content was recorded in treatments T_7 (350 ppm), T_8 (400 ppm), T_6 (300 ppm), T_9 (450 ppm), and T_5 (250 ppm) in a descending order when compared with other remaining treatments and control. Next to these treatments, treatments T_{10} (500 ppm), T_4 (200 ppm), T_3 (150 ppm) and T_2 (100 ppm) also gave significantly more phosphorus over control and over each other.

At 65 DAS trend was totally different. Treatments T_7 (350 ppm), T_8 (400 ppm), T_6 (300 ppm), T_9 (450 ppm) and T_{10} (500 ppm) in a descending manner were found significantly superior in respect of phosphorus content in leaves when compared with other remaining treatments and control. Treatments T_5 (250 ppm) and T_4 (200 ppm) were found at par with each other. Similarly treatments T_3 (150 ppm) and T_2 (100 ppm) were also found at par with each other, but above four treatments were found significantly superior over control.

Phosphorus is an important constituent of protoplasm and nucleic acid and nucleio protein and also it is essential for the formation of grain. Phosphorus content in leaves was increased gradually up to 35 DAS and it decreased thereafter at 50 to 65 DAS.

The range of leaf phosphorus was 0.247,

0.148 and 0.107 per cent in control and 0.373, 0.273 and 0.230 per cent in foliar application of 350 ppm humic acid through CDW at 35, 50 and 65 DAS respectively.

Vaughan and Ord (1985) reported that, the higher P uptake by rice could be due to development of uptake capacity in plants through the stimulating effect of humic acid. In the presence of humates, the plants could use phosphate fertilizers fully at the humic molecules and the phosphate an ion compete on an almost equal basis.

Khalid and Fawy (2011) reported that foliar application of 0.1 and 0.2 % humic acids increased uptake of phosphorus in corn.

Leaf potassium content :

Data on potassium content in leaves of green gram found statistically significant at 35, 50 and 65 DAS.

At 35 DAS significantly maximum leaf potassium content were recorded in treatments T_7 (350 ppm), T_8 (400 ppm), T_6 (300 ppm), T_9 (450 ppm), T_{10} (500 ppm) and T_5 (250 ppm) in a descending manner when compared with remaining treatments and control. Treatments T_4 (200 ppm), T_3 (150 ppm) and T_2 (100 ppm) also showed their significance over control and over each other.

At 50 DAS treatments 350 ppm (T_7) and 300 ppm (T_6) showed their significance in respect of leaf potassium content when compared with control and rest of the other treatments under study. Treatments T_6 (300 ppm), T_9 (450 ppm), T_{10} (500 ppm) and T_5 (250 ppm) were found at par with each other. Similarly treatments T_4 (200 ppm), T_3 (150 ppm) and T_2 (100 ppm) were found at par with each other but showed their significance in leaf potassium content at this stage in a descending manner over control (T_1).

At 65 DAS trend was somewhat different, significantly maximum leaf potassium content was noticed in treatment T_7 (350 ppm) followed by T_8 (400 ppm), T_6 (300 ppm), T_9 (450 ppm) and T_{10} (500 ppm) in a descending manner when compared with control and rest of the treatments under study. Next to these treatments, treatments T_5 (250 ppm), T_4 (200 ppm), T_3 (150 ppm) and T_2 (100 ppm) also gave significantly more potassium content over control (T_1). The range of potassium content was 1.12, 0.95 and 0.97 per cent in control and 1.48, 1.45 and 1.33 per cent in foliar application of 350 ppm humic acid through CDW (T_7) at 35, 50 and 65 DAS respectively.

Potassium in leaf tissue was found higher at 35 DAS, it might be due to application of nutrients through CDW and it also might be because of relatively higher physiological activity, as the plant tissue were younger during this stage. At 50 and 65 DAS K content in leaves decreased, it might be because of translocation of leaf K and its utilization for development of food storage organ.

Protein content in seed :

Although quality of crop products such as oil content, protein content, sucrose content etc. is genetically controlled, the nutrition of plants can have considerable impact on the expression of quality. It is therefore, necessary to take care on the nutrient supply at grain formation stage also. Protein content of seed is one of the considerable factor for seed quality determination.

The maximum seed protein was recorded in 350 ppm humic acid through CDW (T_7) treatment followed by T_6 (300 ppm) when compared with control and rest of the treatments, treatments T_8 (400 ppm), T_9 (450 ppm), T_{10} (500 ppm), T_5 (250 ppm) and T_4 (200 ppm) in a descending manner also exhibited significantly more protein content over treatments T_1 (control), T_2 (100 ppm) and T_3 (150 ppm).

Nitrogen is key components in organic fertilizer and has more influence on plant growth, appearance and fruit production quality than any other elements. Foliar application of such nutrient through CDW increases the uptake and availability of nutrients and its further assimilation of biosynthesis of protein. This might be the reason for increase in protein content in seeds in the present study.

Santhi *et al*. (2003) reported that the protein content increased with the application of humic acid in rice, maize and sugarcane.

Venkatramna *et al*. (2010) reported that foliar application of cowdung wash at 25 and 35 days after pruning increased protein content in mulberry leaves.

Ashraf *et al*. (2005) reported that foliar application of humic acid derived from coal of lakhara (0.005%) significantly increased protein per cent up to 30.62 in soybean.

Yield contributing parameters :

Yield is complex character determined by several traits internal plant processes and environmental factors. In present study data on effect of humic acid sources i.e. CDW on yield and yield contributing parameters viz., number of pods plant^{-1}, 100 seed weight, seed yield plant^{-1} and plot^{-1} are presented in table 2.

Number of pods plant^{-1}

Significantly maximum number of pods were recorded by treatments T_7 (350 ppm), T_6 (300 ppm), T_5 (250 ppm), T_8 (400 ppm) and T_9 (450 ppm) over treatment T_1 (control) and rest of the treatments. Treatments T_{10} (500 ppm), T_4 (200 ppm) and T_3 (150 ppm) were found at par with each other but these treatments also found superior over treatments T_1 (control) and T_2 (100 ppm). Treatment T_2 (100 ppm) was also exhibited their significance over treatment T_1 (control) in number of pods plant^{-1}.

Kaya *et al*. (2005) also reported that foliar spray of humic acid with Zn increased yield and yield components of common bean.

Talavia *et al*. (2007) reported that increase in pod yield may be attributed to mineralization of nutrients, which leads to improve growth and better partitioning of assimilates to various metabolic sinks.

100 seed weight :

Data regarding 100 seed weight showed significant variation. It was observed that treatment with 350 ppm humic acid through CDW (T_7) had maximum weight of 100 seeds followed by T_6 (300 ppm), T_5 (250 ppm) and T_8 (400 ppm) when compared with control and rest of the treatments. Next to these treatments, treatments T_9 (450 ppm), T_4 (200 ppm), T_{10} (500 ppm), T_3 (150 ppm) and T_2 (100 ppm) in a descending manner also found significantly superior over control.

The yield contributing parameters mainly include number of pods plant^{-1} and 100 seed weight. Data showed that all these yield contributing parameters significantly increased in the treatments receiving foliar spray of humic acid through CDW over control.

The uptake of N, P and K during reproductive stage greatly influenced the pod formation and quality aspects of seeds. The photosynthetic rates at grain filling are also increased. Cheng *et al*. (1985) reported that spraying of humic acid increased thousand grain weight and retarded senescence in wheat.

Seed yield :

Seed yield is combination of yield attributing parameters and physiological efficiency of plant during present investigation.

Source sink relation is key of the seed yield. The phloem loading at source (leaf) and unloading at sink (seed and fruit) by which the economic part will be getting the assimilates synthesized by photosynthesis. Partitioning of the assimilates in the plant during reproductive development is important for flower, fruit and seed crops. Thus, crop yield can be increased either by increasing the total dry matter production or by increasing the proportion of economic yield (HI) or both (Gardner *et al*., 1998).

The maximum seed yield plant^{-1} and plot^{-1} was observed in treatment receiving 350 ppm humic acid through CDW (T_7) when compared with control and rest of the treatments under study.

The maximum seed yield plant^{-1} and plot^{-1} were recorded in 350 ppm humic acid CDW (T_7) i.e. 2.09 g and 0.209 kg and minimum in control (T_1) i.e. 1.51 g and 0.151 kg respectively.

Next to treatment T_7 (350 ppm) maximum seed yield was recorded in treatment T_6 (300 ppm) when compared with control and rest of the treatments under study. Next to these treatments, treatments T_5 (250 ppm), T_8 (400 ppm), T_4 (200 ppm), T_9 (450 ppm) and T_{10} (500 ppm) in a descending manner also gave significantly more seed yield over treatments T_1 (control), T_2 (100 ppm) and T_3 (150 ppm).

Hu and Wang (2001) reported that komix humic acid containing organic fertilizer significantly increased seed yield plant^{-1} of spring soybean.

Table 1. Effect of foliar application of humic acid through cowdung wash on chlorophyll content, leaf nitrogen, leaf phosphorus, leaf potassium and seed protein

Treatments	Leaf chlorophyll content (mg g^{-1})			Leaf nitrogen (%)			Leaf phosphorus (%)			Leaf potassium (%)			Seed protein (%)
	35 DAS	50 DAS	65 DAS	35 DAS	50DAS	65 DAS	35 DAS	50 DAS	65 DAS	35 DAS	50 DAS	65 DAS	
T1 - Control (Water spray)	1.505	0.991	0.966	2.66	1.76	1.23	0.247	0.148	0.107	1.12	0.95	0.97	20.82
T2 - 100 ppm HA through CDW	1.515	1.020	1.030	2.72	1.79	1.56	0.252	0.155	0.128	1.23	0.97	1.10	21.17
T3 - 150 ppm HA through CDW	1.519	1.097	1.037	2.83	1.90	1.68	0.253	0.158	0.148	1.27	1.02	1.12	21.52
T4 - 200 ppm HA through CDW	1.542	1.200	1.059	3.02	1.99	1.79	0.275	0.162	0.185	1.32	1.07	1.15	22.22
T5 - 250 ppm HA through CDW	1.623	1.406	1.082	3.11	2.01	1.99	0.283	0.255	0.192	1.37	1.13	1.18	22.73
T6 - 300 ppm HA through CDW	1.629	1.560	1.093	3.28	2.10	2.13	0.313	0.268	0.217	1.45	1.27	1.25	23.45
T7 - 350 ppm HA through CDW	1.652	1.592	1.095	3.42	2.32	2.21	0.373	0.273	0.230	1.48	1.45	1.33	24.67
T8 - 400 ppm HA through CDW	1.626	1.473	1.091	3.32	2.27	2.18	0.322	0.270	0.222	1.47	1.33	1.28	23.10
T9 - 450 ppm HA through CDW	1.559	1.423	1.076	3.13	2.07	1.99	0.303	0.261	0.210	1.42	1.25	1.23	22.92
T10 - 500 ppm HA through CDW	1.549	1.202	1.068	3.08	1.93	1.76	0.278	0.231	0.200	1.40	1.15	1.22	22.75
SE(m)±	0.026	0.052	0.024	0.093	0.087	0.083	0.015	0.014	0.012	0.040	0.048	0.038	0.460
CD at 5%	0.077	0.154	0.070	0.276	0.258	0.247	0.043	0.041	0.035	0.119	0.143	0.113	1.366

Table 2. Effect of foliar application of humic acid through cowdung wash on number of pods plant^{-1}, 100 seed weight, seed yield plant^{-1} and plot^{-1}

Treatments	No. of pods plant^{-1}	100 seed weight (g)	Seed yield	
			Plant^{-1} (g)	Plot $^{-1}$ (kg)
T1 - Control (Water spray)	15.25	2.73	1.51	0.151
T2 - 100 ppm HA through CDW	15.77	2.83	1.58	0.158
T3 - 150 ppm HA through CDW	17.33	2.87	1.64	0.164
T4 - 200 ppm HA through CDW	18.27	2.90	1.74	0.174
T5 - 250 ppm HA through CDW	18.87	2.97	1.86	0.186
T6 - 300 ppm HA through CDW	19.55	3.00	1.98	0.198
T7 - 350 ppm HA through CDW	20.02	3.07	2.09	0.209
T8 - 400 ppm HA through CDW	18.85	2.93	1.85	0.185
T9 - 450 ppm HA through CDW	18.80	2.91	1.73	0.173
T10 - 500 ppm HA through CDW	18.30	2.88	1.72	0.172
SE(m)±	0.512	0.046	0.069	0.007
CD at 5%	1.520	0.135	0.205	0.021

Santhi *et al*. (2003) reported that grain yield of rice increased over control due to application of HA.

Zekeriya Akman (2004) reported that humic acid added foliar fertilizers significantly increased grains ear^{-1} and yield of sweet corn.

Boote *et al*. (1978) also reported that the foliar application of N, P, K enhances carbon balance and delay "self destructive mechanism" thus the plant resulting in increased yield of soybean. The increasing other yield attributing parameters viz., 100 seed weight and number of pods plant^{-1} might have helped in attaining better grain yield of green gram in the present investigation.

From the overall results, it can be stated that foliar nutrition through humic sources such as CDW with different concentrations significantly improved the chemical, biochemical parameters viz., chlorophyll content, leaf nitrogen, leaf phosphorus, leaf potassium, seed protein and yield contributing parameters viz.,100 seed weight and number of pods plant^{-1} etc. also might have helped in attaining better seed yield in the present investigation.

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SENSORY EVALUATION AND ECONOMICS OF GULABJAMUNS PREPARED FROM DIFFERENT READY MIXES

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ABSTRACT

Sensory evaluation of any consumable product is the best method of judging the acceptability of the product by the consumers .In traditional method, gulabjamuns were prepared from the mixture of khoa, wheat flour (Maida) and baking powder. A few readymade gulabjamuns mix powders are sold in the market to make gulabjamuns at home. The present experiment was conducted to evaluate the sensory attributes viz., colour and appearance, body and texture, flavour, overall acceptability and cost of production kg^{-1} gulabjamuns prepared from pure khoa (control) and different ready mixes RM-1, RM-2, RM-3 and RM-4. The study was undertaken at Animal Husbandry and Dairying Section, College of Agriculture, Nagpur during 2009-10. The sensory evaluation, carried out by the panel of 10 judges, showed that gulabjamuns prepared from pure khoa secured the highest score for colour and appearance(7.34), body and texture(7.05) and flavour(7.07) as compared to other ready mix treatments. Overall acceptability of gulabjamuns prepared from pure khoa on Nine Point Hedonic Scale was7.15 which was found to be the highest as compared to other ready mix treatments. However, the score obtained by the gulabjamuns prepared from different ready mixes for all the sensory attributes was nearly the same. The cost of production kg^{-1} gulabjamuns, prepared from pure khoa was Rs. 176.94 which was found less as compared to gulabjamuns from ready mix gulabjamuns powders. Hence, it can be opined that the good quality gulabjamuns can be prepared from khoa which has less kg^{-1} cost of production, provided genuine pure khoa is used.

(Key words: Sensory evaluation, khoa, gulabjamuns, ready mix gulabjamuns, economics)

INTRODUCTION

Gulabjamuns, a khoa based sweet is one of the popular indigenous sweet in the country (Prajapati et al. 1994). Among the Indian sweet, gulabjamuns is the most important milk product throughout northern, western and central parts of India (Mathur 1991). Traditionally gulabjamuns is prepared from mixture of pure khoa, maida (wheat flour) and baking powder.

The increased interest in the mechanization of gulabjamuns manufacture along modern processing lines has ascribed not only to its growing demands within the country but also to its potential for export to Europe and North America, where there is sizeable Indian ethic population. In this context, product quality becomes particularly important (Rao *et al*., 2002).

Gulabjamuns mix powder is one such product, made from skimmed milk powder (SMP), has been commercialized for many years under quite a few brand names. It is designed to allow house wives to make gulabjamuns at home, however, the consumer may find some variation in sensory qualities and cost in between these products due to product diversification. Hence, it is necessary to evaluate the sensory characteristics of these readymade formulations and to assess the kg^{-1} production cost of gulabjamuns prepared from different ready mixes and hence, the experiment was conducted with an objective to assess the sensory attributes like colour and appearance, body and texture, flavour, overall acceptability alongwith cost of production of gulabjamuns.

MATERIALS AND METHODS

The experiment was conducted at Animal Husbandry and Dairying Section, College of Agriculture, Nagpur during 2009-10 to evaluate the sensory characteristics of gulabjamuns prepared from four ready mixes and one from fresh khoa. Thus, there were five treatments each with four replications. The gulabjamuns were prepared by using four different ready mixes collected from local market of Nagpur and each of them was allotted a code name viz., RM-1, RM-2, RM-3 and RM-4 so as to avoid their identity and one control treatment i.e. gulabjamuns prepared from pure khoa. During the entire study fresh, clean, whole cow milk was obtained from Animal Husbandry and Dairying Section, College of Agriculture, Nagpur, for preparing traditional fresh pure khoa. Ingredients like ready mixes, sugar,

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maida, vegetable oil and baking powder were purchased from local market of Nagpur.

Fresh standardized cow milk (4.0 % fat) was used for khoa preparation. Khoa was prepared by standard procedure given by Rangi *et al*. (1985). The sugar syrup was prepared by dissolving cane sugar in 1:1 proportion and kept boiling for 10 to 15 minutes. The syrup was ready when it attains the first signs of stickiness. A few millilitres of milk was added to remove the scum in the sugar syrup. The syrup was then filtered through a clean muslin cloth and used from dipping the fried gulabjamuns from different ready mixes and fresh khoa. Traditional gulabjamuns were prepared as per standard procedure suggested by Prajapati *et al.* (1991).

Sensory evaluation of gulabjamuns :

The sensory evaluation of gulabjamuns was carried out for the following attributes viz., colour and appearance, body and texture and flavour. Overall acceptability of the product was evaluated by using 'Nine Point Hedonic Scale' (Lawless and Haymann, 1998), by the panel of 10 judges from the faculty and staff members of Animal Husbandry and Dairying Section, College of Agriculture, Nagpur.

Cost of production :

The cost of production of kg^{-1} gulabjamuns was worked out by taking into consideration the prevailing retail rates in market for readymade mix and other ingredients used. The estimation of cost was on the lines of the standard economic procedure.

The data were subjected to analysis of variance as per Snedecor and Cochran (1994).

RESULTS AND DISCUSSION

The product was provided with 'Nine Point Hedonic Scale' to the panel of judges. Each sample was bearing a code number so as to avoid its identity and have impartial results.

Colour and appearance :

The average score for colour and appearance for the gulabjamuns prepared from pure khoa, RM-1, RM-2, RM-3 and RM-4 was 7.34, 6.92, 6.46, 6.71 and 6.96 respectively. Colour and appearance showed significant difference ($P < 0.05$) with highest score (7.34) for gulabjamuns prepared from pure khoa over the rest of ready mix treatments. This might be due to pure khoa acquiring brown colour crust and uniform texture while frying. Good quality gulabjamuns has characteristic light brown colour and spherical to oval shape (Ghosh *et al*., 1986). Further Sharma (2006) stated that gulabjamuns is characterized by brown colour and smooth and spherical shape. The presence of protein and sugar in the mix enables the fried gulabjamuns Maillard browning colour (Namiki, 1988).

Body and Texture :

The average score for body and texture was found 7.05, 6.28, 6.36, 6.88 and 6.82 per cent for the gulabjamuns prepared from pure khoa, RM-1, RM-2, RM-3 and RM-4 ready mixes respectively. Gulabjamuns prepared from pure khoa has ($P < 0.05$) scored significantly the highest (7.05) among all the treatments. The desired body of gulabjamuns should be soft and slightly spongy while the texture should be uniform and slightly granular (Ghosh *et al*., 1986). Use of maida in gulabjamuns mix provides product with firmness (Manay and Shadaksharaswami, 2008).

Flavour :

The average values of score for flavour for gulabjamuns prepared from pure khoa, RM-1, RM-2, RM-3 and RM-4 were 7.07, 6.57, 6.82, 6.47 and 6.53 respectively. Gulabjamuns prepared from pure khoa was found superior than the rest treatments with significant difference ($P < 0.05$). Prajapati *et al.* (1994) observed that addition of trisodium citrate improves the flavour of gulabjamuns.

Overall acceptability :

The average overall acceptability score of gulabjamuns prepared from pure khoa, RM-1, RM-2, RM-3 and RM-4 was 7.15, 6.59, 6.54, 6.68 and 6.75 respectively. Overall acceptability score was significantly ($P < 0.05$) the highest for pure khoa gulabjamuns as compared to other ready mix gulabjamuns. The sensory attributes like colour and appearance, body and texture, flavour and overall acceptability of gulabjamuns prepared from khoa was higher as compared to rest of the ready mix treatments. However, the gulabjamuns prepared by using different ready mixes viz., RM-1, RM-2, RM-3 and RM-4 was good, but the gulabjamuns prepared from khoa was better than the gulabjamuns prepared from these different ready mixes in respect of sensory attributes and overall acceptability. Khoa preparation

Table 1. The mean score for sensory parameters and overall acceptability of gulabjamuns prepared from different ready mix (out of 9)

Treatments	Sensory Characteristics			
	Colour and appearance	Body and texture	Flavour	Overall acceptability
Khoa (control	7.37	7.05	7.07	7.15
RM - 1	6.92	6.28	6.57	6.59
RM - 2	6.46	6.36	6.82	6.54
RM - 3	6.71	6.88	6.47	6.68
RM - 4	6.46	6.82	6.53	6.72
S.E. (m) ±	0.150	0.232	0.159	0.141
C.D.	0.451	0.698	0.479	0.159

Table 2. Cost of production kg^{-1} gulabjamuns for different treatments

Ingredients	Rate (Rs. kg^{-1})	Treatments									
		Khoa (control)		RM-1		RM-2		RM-3		RM-4	
		Qty (g)	Cost (Rs.)	Qty (g)	Cost (Rs.)	Qty (g)	Cost (Rs.)	Qty (g)	Cost (Rs.)	Qty (g)	Cost (Rs.)
Khoa (Rs. kg^{-1})	160	200.00	32.00	-	-	-	-	-	-	-	-
RM-1 (Rs. kg^{-1})	245	-	-	200	49	-	-	-	-	-	-
RM-2 (Rs. kg^{-1})	250	-	-	-	-	200	50	-	-	-	-
RM-3 (Rs.kg^{-1})	195	-	-	-	-	-	-	200	39	-	-
RM-4 (Rs.kg^{-1})	240	-	-	-	-	-	-	-	-	200	48
Maida (Rs/kg^{-1})	20	50.00	1.00	-	-	-	-	-	-	-	-
Baking powder (Rs.kg^{-1})	300	0.10	0.33	-	-	-	-	-	-	-	-
Oil (Rs.kg^{-1})	76	100.0	7.60	100.0	7.60	100.0	7.60	100.0	7.60	100.0	7.60
Sugar (Rs.kg^{-1})	35	600.0	21	600.0	21	600.0	21	600.0	21	600.0	21
Cost of ingredients	--	--	61.93	--	77.6	--	78.6	--	67.6	--	76.6
Total quantity prepared (kg)	-	0.350	-	0.370	-	0.380	-	0.368	-	0.365	
Total cost of gulabjamuns (kg)	--	--	**176.9**	--	**209.7**	--	**206.8**	--	**183.6**	--	**209.8**

at home is not possible for everyone and hence they have to depend on marketed khoa whose purity is doubtful and hence unless pure khoa is available for preparation of gulabjamuns, the superior quality of gulabjamuns over ready mix gulabjamuns is a problem. Hence, use of ready mixes of gulabjamuns is more convenient.

Cost structure :

All the ingredients required for preparation of gulabjamuns whether, it is from khoa or different ready mix formulations were rated as per the market prices during year 2010. It is revealed from the table 2 that cost of production kg^{-1} gulabjamuns prepared from pure khoa was less (Rs. 176.94) and the highest cost kg^{-1} gulabjamuns was observed in ready mix treatment RM-4 (Rs. 209.86).

The increase in the cost of production in treatments other than control (standard) was due to the market influence and variation in the price of the ready mix depending upon the type of ingredients used. Hence, it can be opined that, the good quality gulabjamuns can be prepared from pure khoa with less cost of production kg^{-1}, provided genuine pure khoa is available. Yawale and Rao (2012) stated the use of khoa powder and maida in ratio of 70:30 with 0.5 parts of baking powder which gave best body and texture, flavor and highest overall acceptability of gulabjamuns.

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CHARACTERIZATION OF CARBOXYLESTERASE IN *Plutella xylostella* (L.) AGAINST FLUBENDIAMIDE RESISTANCE

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ABSTRACT

With a view to studying the, development of resistance in *Plutella xylostella* against flubendiamide insecticide, protein estimation level in susceptible and resistance enzyme source and characterization of carboxylesterase (CarE) in *plutella xylostella* (L.) against flubendiamide resistance was carried out. For this purpose larvae of *Plutella xylostella* were collected from cauliflower field of different localities of Akola district and their mass rearing was done in Entomology Department, Dr. PDKV, Akola. These studies were conducted at Entomology Department and Biotechnology Centre, Dr. PDKV, Akola during the session 2010-11. In this study, for development of insecticide resistance, estimation level of protein in susceptible and resistance enzyme source was obtained and level of Carboxylesterase associated with flubendiamide was determined. The results revealed that resistance ratio increased to 16.62 in F_{10} generation when compared to the resistance in F_5 generation. For F_5 to F_{10} generation, LC_{50} and LC_{90} of flubendiamide was 0.38 ppm and 2.86 ppm at F_5 generation which was increased to 6.35 ppm and 23.89 ppm at F_{10} generation respectively. For optimum pH and optimum temperature of CarE assay was performed by using sodium phosphate buffers having wide range of pH (5-9) and different range of temperature during incubation. The study revealed that having optimum pH 8 and the optimum temperature 60°C appears to be stable.

(Key words: Flubendiamide, *Plutella xylostella,* Carboxylestarase, Characterization)

INTRODUCTION

Diamond back moth is cosmopolitan in distribution (Annonymous, 1967), particulary dominant in South East Asia (Robert and Wright, 1996). It is one of the most widely distributed insects in the world being reported from more than eight countries (Mohan and Gujar, 2003). The larva of this insect feed on the foliage of cruciferous plant from the seedling stage to harvest and greatly reduce both yield and quality of the produce (Talekar, 1992). In India, Diamond back moth was first reported in 1914 on cruciferous vegetables (Fletcher, 1914). *Plutella xylostella* is one of the difficult insects in the world to control. It shows resistivity to every class of insecticide used against it (Sarfraz and Keddie, 2005).

Flubendiamide represents a novel class of broad spectrum insecticides with extremely high activity against lepidopterious pests. Flubendiamide belongs to class of chemical pthalic acid diamides which are new to crop protection developed by Nihon Nohyaku Co. Ltd., (Tokyo, Japan). It acts on rynodine receptors (RyRs) and release Ca^{2+} from rynodine channel. Ryanodine receptors, which carried out muscle contraction process releasing Ca^{2+} intracellular channels from intracellular stores, which is an essential step in the muscle contraction process. In contrast to most other commercially successful insecticides which act on the nervous system, flubendiamide disrupts proper muscle function in insects and therefore it showed a unique and novel mode of action (Settele *et al*., 2008).

Insect induced detoxifying enzymes are responsible for detoxification of xenobiotics and chemical insecticides (Ugale, 2009). The detoxifying enzymes of insect include mostly Glutathion-S-Transferase (GSTs) and Carboxylesterase (CarE). Carboxylesterase is highly efficient catalyst for the hydrolysis of a wide variety of aliphatic and aromatic esterase as well as amides and thioesterase, and are important in many different processes including chemotaxis and metabolism of drug and pesticides (Sreerama and Veerabhadrappa 1991). There is no adequate information available regarding mechanism of resistance to flubendiamide molecule in *P. xylostella*. The primary objectives of present investigation was to develope insecticide resistance, estimation level of protein in susceptible and resistance enzyme source and to determine level of Carboxylesterase associated with flubendiamide against *P. xylostella*.

MATERIALS AND METHODS

The larvae of *Plutella xylostella* were collected from cauliflower fields of different localities of Akola district from Cruciferous fields and mass rearing was done in Entomology Department, Dr. PDKV, Akola. Further studies were done at Biotechnology Centre, Dr. PDKV, Akola during the session 2010-11.

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The rearing procedure described by Lu and Sun (1984) was followed to maintain the test culture of *P. xylostella*. For rearing required controlled conditions of temperature 25°C ± 2°C, relative humidity 75 ± 5 per cent and photoperiod of 13 hrs light : 11 hrs dark were maintained. Rearing was done for upto F_4 generations on the same diet for establishing homogeneous laboratory population. Mustard seedlings were used as common diet for rearing purpose. The pupae were kept in oviposition chamber, keeping mustard seedling so that adults emerged can utilize the seedling as oviposition substrate. After hatching, the neonate larvae were provided with tender mustard seedlings. Subsequently, the larvae were transferred to fresh seedlings. The mustard seedlings were kept inside the rearing chamber and were replaced by new seedling on alternate days. The adults were provided with adult diet. Composition of adult diet listed in table 1 mixed in of five hundred ml distilled water in a conical flask one by one. The mixture was kept on a magnetic stirrer for thorough mixing. After complete dissolution of all ingredients, liquid adult diet was filled in amber coloured bottle and stored in refrigerator and used as and when required for adult feeding.

The insecticide solutions required for the bioassays were prepared using the commercial formulation which was diluted with distilled water. Fresh solutions were prepared as and when required. Preparation of different concentrations of insecticide solution was made using following formula.

$$V = \frac{C \times A}{ai}$$

Where,
V = Volume of water to be added
C = Required concentration of insecticide
A = Required quantity of solution
ai = Active ingredient in insecticide formulation

Leaf dip method of bioassay as described by Tabashnik *et al*. (1987) was adopted in the present study using cabbage leaves for assessing the resistance levels. About 5 cm diameter cabbage leaf discs were cut and then washed with distilled water and wiped out to remove excess water. Then these fresh discs were dipped in a test solution for 10 seconds. Then leaf disc was placed over a blotting paper in a tray the for about 2 minutes to drain excess solution. Ten third instar larvae of *Plutella xylostella* were released on each disc in an individual petriplate wherein blotting paper was placed at the bottom. Three replications were used for each concentration. The bioassay were conducted at room temperature. Similarly ten larvae were released on cabbage leaf disc dipped in water only, which was treated as control. This study was conducted from F_5 to F_{10} generation for all aspects of the study.

The median lethal concentration (LC_{50} value) determined by using log dose probit (ldp) assay. The resistance intensity of a population or a strain of insects to a particular insecticide was named as the resistance ratio (RR), which was calculated by the formula (Regupthy and Dhamu, 1990).

$$RR\ LC_{50} = \frac{LC_{50} \text{ of resistant strain (RS)}}{LC_{50} \text{ of susceptible strain (SS)}}$$

Preparation of ppm dose of insecticide, Flubendiamide (480 SC) :

Preparation of flubendiamide (480 SC) total 20 concentrations were prepared as 0.01 ml, 0.02 ml, 0.03 ml, 0.05 ml, 0.06 ml, 0.09 ml, 0.1 ml, 0.3 ml, 0.5 ml, 0.6 ml, 0.8 ml, 0.9 ml, 1 ml, 2 ml, 3 ml, 5 ml, 7 ml, 8 ml, 9 ml, 10 ml and final volume was made to 10 ml.

The treated larvae weighing 3.0 - 4.0 mg approximately were separated and starved for 7-8 hours to remove all digested food particles. Insects were chilled in refrigerator before homogenization. Whole larvae were homogenized using mortar and pestle in sodium phosphate buffer (SPB) (100 mM, pH 6.5), containing 0.1 mM of EDTA (Ethidium Diamine TetraAcetic Acid), PTU (Phenylthiourea) and PMSF (Phenyl Methyl Sulphonyl Fluoride) each, The homogenate, thus obtained, was centrifuged at 10,000 rpm for 15 minutes at 4°C in high speed refrigerated centrifuge and then solid debris and cellular material was discarded. The resultant post mitochondrial supernatant substrate obtained was stored at -20°C and used as enzyme source. The protein was estimated by Bradford (1976) method. It is a simple and accurate procedure for determination of concentration of solubilized protein. It involves the addition of an acidic dye to protein solution, and subsequent measurement of OD at 595 ηm with a spectrophotometer. Comparison to a standard curve provides a relative measurement of protein concentration.

Characterization of Carboxylestase assay for optimum pH :

In this study characterization of Carboxylesterase was carried out. Methodology was adopted with modification in the protocols given by Xu and Bull (1995). Substrate solution was freshly prepared with α-napthyl acetate (30 mM) dissolved in 1 ml acetone and volume was made to 10 ml with SPB (0.04 M, different pH 5.0, 6.0, 7.0, 8.0, 9.0). Staining solution freshly was prepared freshly with 2 parts of 1% Fast Brilliant Blue BB salt in SBP (0.04 M, 6.8 pH) and 5 parts of 5% SDS in DDH2O. 20 µl enzyme was added to well of microplate with three replicates followed by 30 µl SPB (0.04 M, 6.8 pH). 100 µl substrate solution was added to each well. Plate was incubated at room temperature for 30 min. After incubation 100 µl of staining solution was added to it in dark and plate was kept in dark for 30 min. Blank was also taken along with samples. After incubation absorbance was taken on the microplate reader. Calculations were done by substracting blank from sample reading and resultant values were plotted on standard curve to get carboxylesterase concentration of samples.

Characterization of carboxylestase assay for optimum temperature :

Substrate solution was freshly prepared with α-napthyl acetate (30 mM) dissolved in 1 ml acetone and volume was made to 10 ml with SPB (0.04 M, 6.8 pH). Staining solution was freshly prepared with 2 parts of 1% Fast Brilliant Blue BB salt in SBP (0.04 M, 6.8 pH) and 5 parts of 5% SDS in DDH2O. 20 µl enzymes were added to well of microplate with three replicates followed by 30 µl SPB (0.04 M, 6.8 pH). 100 µl substrate solution was added to each well. Plate was incubated at different temperatures viz., 10, 20, 30, 40, 50, 60 and 70^{0}C in water bath for 30 min. After incubation, 100 µl of staining solution was added in each well in dark and plate was kept in dark for 30 min. Blank was also taken along with samples. After incubation absorbance was taken on the microplate reader. Calculations were done by substracting blank from sample reading and resultant values were plotted on standard curve to get carboxylesterase concentration of samples.

RESULTS AND DISCUSSION

Toxicity of flubendiamide against field collected population of *Plutella xylostella* :

The data obtained was subjected to standard procedure of log dose probit analysis and then $LC_{50,}$ LC_{90} and resistance ratio were determined. Generation wise studies against flubendiamide revealed that the resistance increased with the increase in the number of selection regimes under insecticide pressure. The LC_{50} and LC_{90} values of F_5 population were 0.38 ppm and 2.86 ppm. In F_8 generation the LC_{50} and LC_{90} values were 1.68 ppm and 6.79 ppm. Resistance increased generation after generation. The LC_{50} and LC_{90} values of F_{10} selected population were found to be 6.35 ppm and 23.89 ppm. It was found that resistance ratio F_{10} was 16.62 as compared to F_5 population of *P. Xylostella* (Table 2). Nirmal and Singh (2001) reported the development of resistance in DBM to the extent of 198-615 fold resistance to cypermethrin and 590 - 4576 fold resistance to fenvalerate and also Patil (2009) studied the toxicity of emamectin benzoate in *Plutella xylostella*, who was found that continuous selection pressure upto seven generations increased the LC_{50} of resistant strain by 44.54 folds to that of susceptible strain.

Characterization of carboxylestarase for optimum pH :

For determining the optimum pH of detoxifying enzyme assay was performed by using sodium phosphate buffers (SPB) having wide range of pH (5-9) and specific activity of detoxifying enzyme was determined. As shown in table 3 (Fig.1), the highest carboxylestarase specific activity was observed at pH 8. CarE activity in both susceptible and resistance strain was highly stable in alkaline pH. It implicated the probability of histidine, serine being present and prolin, tryptophan being absent at active site and these amino acids were essential for catalytic activity (Sreerama, and Veerabhadrappa1991). Arai *et al*. (2000) reported the highest enzyme activity of Carboxylestarase at pH 7 in Silkworm, *Bombyx mori.* Murthy Patnagese (1996) found highest activity of Carboxylestarase at pH 8.5 in midgut of Silkworm, *Bombyx mori.*

Table 1.Adult diet components

Sr. No.	Ingredients	Quantity
1)	Sucrose	50 g
2)	Honey	50 ml
3)	*Vitamin mixture	20 ml
4)	Methyl p-hydroxyl benzoate	2 g
5)	Streptomycin	1 g
6)	Formaldehyde	2 ml
7)	Distilled water	500 ml

* It consist of D-Biotin-616 mg. Nicotinic acid - 3056 mg, calcium pentothenate - 3056 mg, Pyridoxin HCL B6 - 764 mg, Riboflavin B-1528 mg

Table 2. Toxicity of *Plutella xylostella* to flubendiamide over generations

Sr. No.	Selected generation	Probit analysis parameters		
		LC_{50} (ppm)	LC_{90} (ppm)	Resistance ratio
1)	F_5	0.38	2.86	-
2)	F_6	0.24	1.82	0.64
3)	F_7	0.79	5.11	2.07
4)	F_8	1.68	6.79	4.41
5)	F_9	5.12	24.72	13.38
6)	F_{10}	6.35	23.89	16.62

Table 3. Optimum pH for CarE

pH range	Enzyme activity for susceptible strain (µM mg protein^{-1} min^{-1})	Enzyme activity for resistance strain(µM mg protein^{-1} min^{-1})
5	0.712	0.604
6	0.897	0.749
7	0.971	0.942
8	1.201	1.658
9	0.942	1.237

Table 4. Characterization of Carboxylestarase for temperature

Temperature (^{0}C)	Enzyme activity for susceptible strain(µM mg protein^{-1} min^{-1})	Enzyme activity for resistance strain(µM mg protein^{-1} min^{-1})
30	0.336	0.261
40	0.370	0.437
50	0.734	0.549
60	0.996	0.872

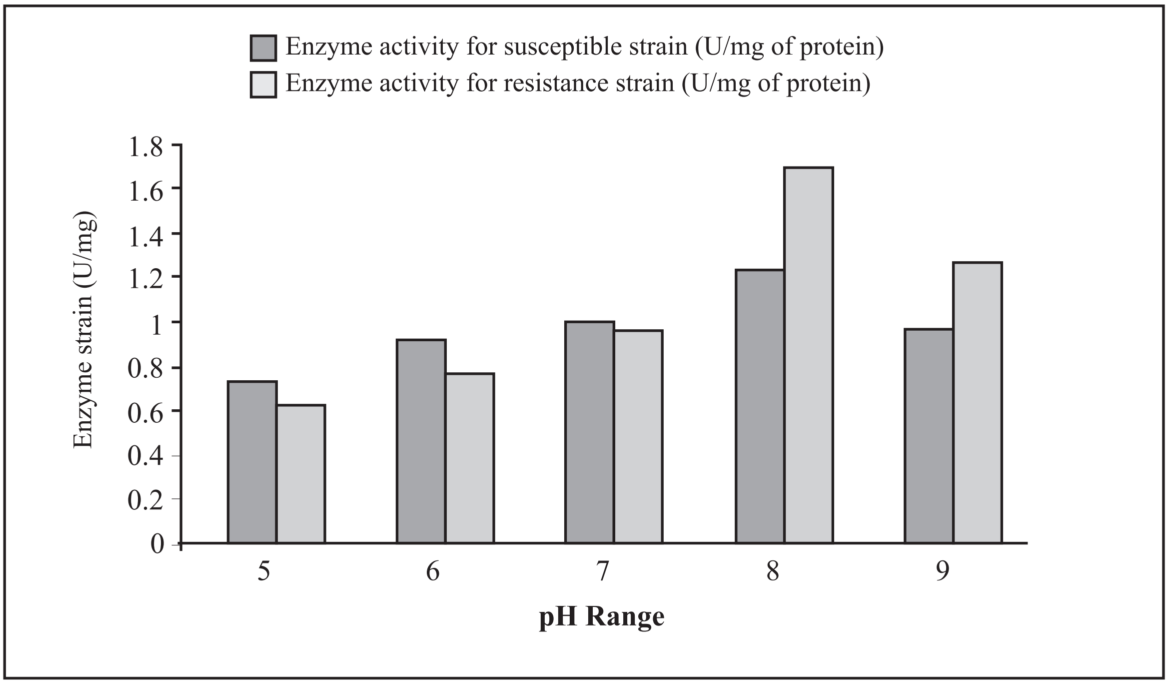

Fig. 1. Optimum pH for CarE

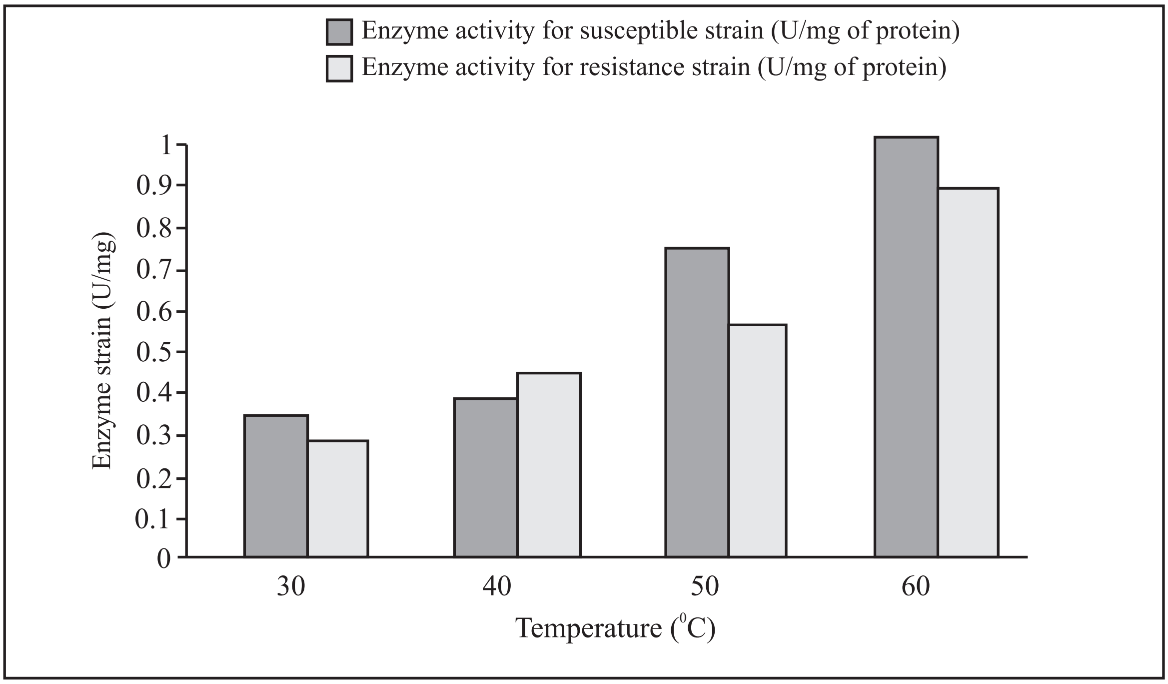

Fig 2. Characterization of carboxylestarase for temperature

Characterization of carboxylestarase for temperature :

In order to calculate the optimum temperature for detoxifying enzyme, carboxylestarase assay was performed by using different levels of temperature during incubation. The highest carboxylestarase specific activity was observed at temperature 60^0 C (Table 4, Fig 2). According to Murthy and Patnagese (1996) in susceptible and resistance strain CarE activity increased at 60^0 C. It can be opined that native isozymes present were more heat tolerant. After comparing the present finding, it could be stated that the temperature range of CarE varied with insecticide and insects. Murthy and Patnagese (1996) found optimum activity of Carboxylestarase at temperature 60^0 C in midgut of Silkworm, *Bombyx mori.* Arai *et al.* (2000) found optimum activity of Carboxylestarase at Temperature 40^0 C in Silkworm, *Bombyx mori* (L).

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GROWTH, YIELD ATTRIBUTES, YIELD, OIL AND ECONOMICS OF INDIAN MUSTARD (*Brassica juncea*) AS INFLUENCED BY THE DIFFERENT HERBICIDES

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ABSTRACT

A field experiment was carried out at Shankar Nagar Farm, College of Agriculture, Nagpur during 2011-2012 in *rabi* season. The ten treatments of weed management practices viz., application of (1) Pendimethalin @ 1.0 kg a.i. ha^{-1} PE, (2) Oxadiargyl @ 0.09 kg a.i. ha^{-1} PE, (3)Trifluralin @ 0.75 kg a.i. ha^{-1} PPI, (4)Oxyflurofen @ 0.15 kg a.i. ha^{-1} PE, (5) Quizalofop @ 0.06 kg a.i. ha^{-1} POE, (6) Clodinafop @ 0.06 kg a.i. ha^{-1} POE, (7) Isoproturon @ 1.0 kg a.i. ha^{-1} PE, (8) Isoproturon @ 1.0 kg a.i. ha^{-1} POE, (9) Weedy Check and (10) Weed-free check, were tried in RBD with three replications. Weed-free practice was the most effective weed control method throughout the crop growth period of mustard and oxadiargyl PE, oxyflurofen PE, isoproturon PE and clodinafop POE were at par and recorded seed yield in decreasing order. Compared to unweeded check, except trifluralin PPI and isoproturon POE, all other treatments recorded significantly higher seed yield. Among the herbicide treatments oxadiargyl PE recorded the highest seed yield followed by isoproturon PE, oxyflurofen PE and clodinafop. Similar trend of weed index in increasing order was noticed. The various growth attributes and yield attributes studied also showed similar results. On the basis of NMR, weedfree check (2 hand weedings at 20 DAS and 40 DAS) was superior followed by oxadiargyl PE, clodinafop POE and oxyflurofen PE.

(Key words : Economy, herbicide, weed control, yield)

INTRODUCTION

Weeds which emerge before crop offer severe competition, results in low yield, if not controlled. So, it is very important to keep the crop weed free in early stage. Traditionally the weeds are controlled by manual weeding. There is scarcity of labour for weeding and also the expenditure on manual weeding is increasing beyond limit. Thus, the cost of cultivation is increasing and the manual weeding is time consuming. With the herbicidal control, there is possibility of saving in time and saving in money with effective weed control. There are few herbicides that can be used as pre-emergence or post emergence. Rana (2006) at New Delhi found that pre-emergence application of pendimethalin @ 1 kg ha^{-1} effectively controlled the weeds and demonstrated a significant increase in seed yield and net returns over weedy check. However, there is less information of these herbicides and their doses against weeds in mustard. Herbicidal control is one of the potent means of controlling the weeds. Fluchloralin, pendimethalin and isoproturon are the most common herbicides used in oilseeds and recently some new herbicides have also been found effective. Considering these aspects the present study was planned with objective to study the effect of herbicides on mustard crop growth, yield attributes, yield oil and economics of mustard crop.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* season of 2011-2012 in randomized block design with ten treatments and three replications. The soil of experimental field was clayey, moderately high in organic carbon (0.63%), low in available nitrogen (261.25 kg ha^{-1}) and phosphorus (22.43kg ha^{-1}) and high in available potassium (359 kg ha^{-1}) with pH 7.17. The ten treatments of weed management practices like application of Pendimethalin @ 1.0 kg a.i. ha^{-1} PE (T_1), Oxadiargyl @ 0.09 kg a.i. ha^{-1} PE (T_2), Trifluralin @ 0.75 kg a.i. ha^{-1} PPI (T_3), Oxyflurofen @ 0.15 kg a.i. ha^{-1} PE (T_4), Quizalofop @ 0.06 kg a.i. ha^{-1} POE (T_5), Clodinafop @ 0.06 kg a.i. ha^{-1} POE (T_6), Isoproturon @ 1.0 kg a.i. ha^{-1} PE (T_7), Isoproturon @ 1.0 kg a.i. ha^{-1} POE (T_8), Weedy Check (T_9)and Weed-free (T_{10}) were tried in RBD with three replications. Spacing was 30 cm x 10 cm with fertilizer dose of 50:40:00 NPK kg ha^{-1}. The mustard crop with Pusa bold variety was sown on 28th Oct, 2011 and harvested on 22nd Feb., 2012. During the crop growth period, the mean weekly maximum temperature was ranged in between 26.5^{0}C to 35.0^{0}C(as against normal of 28.0^{0}C to 37.5^{0}C) and minimum 9.6^{0}C to 18.2^{0}C (as against the normal 11.6^{0}C to 20.4^{0}C) respectively.

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Thus, showing the deviation of nearly 2^{0}C below of normal temperature of Nagpur. The season was quite favourable for the mustard. Slight infestation of aphid was noticed. The herbicide treatment application not showed any adverse effect on crop except isoproturon PE treated plot which initially shown some chloratic patches on border of leaves of mustard plant. The plant height and number of branches plant^{-1} were recorded at harvest on five observational plants and average was worked out. For dry matter two plants from each net plot were taken and after oven drying the dry matter was recorded and average plant^{-1} was worked out. Similarly at harvest number of seeds siliquae^{-1}, number of siliquae plant^{-1}, seed and stover yield plant^{-1} were worked out based on five observational plants from each net plot. Seed yield and stover yield obtained from the net plot were converted in quintal hectare^{-1}. The oil content was estimated by the nuclear magnetic resonance method and oil yield was estimated from the oil content and seed yield. The GMR, NMR and B:C ratio were worked out from the cost of cultivation and cost of seed produced. The rate of seed was Rs 3000 quintal^{-1}.

RESULTS AND DISCUSSION

The data on growth and yield attributes, yield, oil content and economics are given in table 1.

Effect on growth attributes :

The plant height and number of branches plant^{-1} at harvest were not significantly influenced by the weed control treatments. But the dry matter accumulation plant^{-1} was significantly higher in weed-free check (23.3 g) and Pendimethalin PE(23.3 g) and other herbicidal treatments viz., Oxadiargyl PE (22.1 g), Isoproturon PE (21.4 g), Oxyflurofen PE (17.6 g) and Isoproturon POE (16.1 g) recorded at par values of plant dry matter. Thus, dry matter accumulation might be due to cumulative effect of more number of branches, height and lower weed count and weed dry matter with better growth condition of crop. Similar results were also reported by Bazaya *et al.* (2004) at Jammu who also found the highest values for branches plant^{-1} due to weed-free treatment.

Yield attributes :

Number of siliquae plant^{-1} was maximum and significantly superior due to weed-free check (160) among all the treatments. This was followed by application of oxadiargyl PE (148), clodinafop POE (137), oxyflurofen PE (133) and isoproturon PE (133) and these were at par with each other. Similar results were also reported by Bazaya *et al.* (2004) at Jammu where they also found the highest values for siliquae plant^{-1} due to weed-free treatment. Among the herbicidal treatments oxadiargyl PE recorded maximum and significantly higher number of siliquae plant^{-1}. This might be due to better crop condition due to lower weed population.

The number of seeds siliquae^{-1} was not significantly influenced. This might be due to fact that the number of seeds siliquae^{-1} is the inherited varietal character which is generally not influenced by the agronomic practices. Numerically the highest test weight was observed under the treatment oxadiargyl PE and oxyflurofen PE followed by clodinafop POE and trifluralin PE.

Weed-free check showed significantly higher seed yield plant^{-1} (3.3 g) as compared to all other treatments. However, oxadiargyl PE, isoproturon PE and POE, pendimethalin PE and oxyflurofen PE were at par with weed-free check. This might be due to more test weight and higher number of siliquae plant^{-1} which further might have enhanced due to better crop growth and effective weed control.

Oxadiargyl PE recorded maximum and significantly higher stover yield plant^{-1} over un-weeded control and quizalofop POE and all other treatments were at par. This might be due to the cumulative effect of dry matter accumulation and final plant population at harvest with effective weed control leading to better vegetative growth.

Yield study :

The weed-free check recorded maximum and significantly higher seed yield (782.9 kg ha^{-1}) over other treatments and oxadiargyl PE (666.7 kg ha^{-1}), oxyflurofen PE (616.7 kg ha^{-1}), isoproturon PE (622.5 kg ha^{-1}) and clodinafop POE (615 kg ha^{-1}) were at par and recorded seed yield in decreasing order. Compared to un-weeded check except trifluralin PPI and isoproturon POE, all other treatments recorded significantly higher seed yield. Among the herbicide treatments, oxadiargyl PE recorded the highest seed yield (666.7 kg ha^{-1}) followed by isoproturon PE

(622.5 kg ha^{-1}), oxyflurofen PE (616.7 kg ha^{-1}) and clodinafop POE (615 kg ha^{-1}). The increased seed yield ha^{-1} in these treatments might be because of the cumulative effect of more number of siliquae plant^{-1}, more test weight and more seed yield (g) plant^{-1}. Yadav (2004) also found the highest seed yield with weed-free treatment and trifluralin PPI. Similarly Chauhan *et al.* (2005) found higher seed yield with 2 hand weedings and oxyflurofen PE, Singh and Sinsinwar (2002) also found increase in seed yield with weed-free treatment and isoproturon PE. Thus, the findings of present investigation are in line with these findings. The Directorate of Rapeseed Mustard Research, Bharatpur also reported better yield due to weed free treatment followed by isoproturon PE in their annual report of 2010-11 (Anonymous, 2011).

Herbicide oxadiargyl PE recorded significantly higher stover yield (41.7 q ha^{-1}) and except quizalofop PE and un-weeded check, all other treatments recorded statistically at par stover yield indicating no adverse effect due to herbicides on vegetative growth of crop. Least stover yield (19.4 kg ha^{-1}) was recorded in un-weeded control. Thus, it indicates the suppression of crop growth due to weeds in unweeded control. Increase in stover yield of mustard might be due to luxurious crop growth and less crop weed competition. These results are also supported by those found by Sharma and Jain (2002) at Bikaner who reported that the pre-emergence application of 0.75 kg isoproturon ha^{-1} was most effective in increasing yield.

The highest harvest index was recorded by quizalofop PE (17.1%) followed by weed-free check. Lower harvest index was shown by pendimethalin PE (13.1%).

The pre-emergence application of oxadiargyl showed least weed index (14.9 %) compared to weed free check followed by pre-emergence application of isoproturon (20.5%), pre-emergence application of oxyflurofen (21.2%), post-emergence application of clodinafop (21.5%) and pre-emergence application of pendimethalin (22.6%). All the herbicidal treatments showed lower and better weed index than the un-weeded control. Thus, all the herbicides were effective in controlling weed with different intensity.

Oil content and oil yield :

The highest oil content (40%) was noticed in weed-free treatment and the lowest in clodinafop POE (38.3%). The oil content did not vary more due to weed control treatments. Weed-free check recorded maximum and significantly higher oil yield and pendimethalin PE, oxadiargyl PE, oxyflurofen PE, clodinafop POE and isoproturon PE also recorded at par values for oil yield. This might be due to variation in seed yield hectare^{-1}.

Economic study :

The weed-free control recorded maximum and significantly higher gross monetary return (Rs 23488 ha^{-1}) over other treatments and oxadiargyl PE (Rs 20000 ha^{-1}), isoproturon PE (Rs 18675 ha^{-1}), oxyflurofen PE (Rs 18500 ha^{-1}) and clodinafop (Rs 18450 ha^{-1}) recorded at par values of GMR. Among the herbicide oxadiargyl was leading in GMR. The higher GMR might be due to more yields in these treatments.

The net monetary return (NMR) also showed trend similar to gross monetary return where the weed-free check recorded maximum NMR and was significantly higher (Rs 14308 ha^{-1}) over other treatments except oxadiargyl PE (Rs 11844 ha^{-1}) and clodinafop POE (Rs 10150 ha^{-1}) which recorded statistically similar NMR. This might be due to more yields and comparatively less herbicide cost. The lowest NMR (Rs 10758 ha^{-1}) was recorded due to un-weeded control. Yadav (2004) also reported lowest NMR (Rs 9312 ha^{-1}) due to un-weeded check at Morena.

The data on benefit : cost ratio showed that weed-free check recorded highest B : C ratio (2.56) and this was followed by oxadiargyl PE (2.45) and clodinafop POE (2.22). Similar trend was also observed in NMR, thus indicating the most economical and beneficial weed control method. This might be due to comparative higher yield coupled with lower herbicide cost. Bazaya *et al.* (2004) also found highest B : C ratio with weed-free treatment.

Table 1. Growth and yield parameters, yield, oil content and economics as influenced by different weed control treatments

Treatments	Growth attributes at harvest			Yield attributes					Yield			Oil yield and content		Economics				Weed index %
	Plant height (cm)	No. of branches plant^{-1}	Dry matter plant^{-1} (g)	No. of siliqua plant^{-1}	No. of seeds siliqua^{-1}	TW (g)	Seed yield plant^{-1} (g)	Stover yield plant^{-1} (g)	Seed yield (kg ha^{-1})	Stover yield (q ha^{-1})	HI (%)	Oil yield (kg ha^{-1})	Oil content (%)	CoC (Rs ha^{-1})	GMR (Rs ha^{-1})	NMR (Rs ha^{-1})	B:C ratio	
1 Pendimethalin @ 1.0 kg a.i. ha^{-1} PE	145	3.9	23.3	130	12.2	4.6	2.5	18.8	606	40.3	13.1	236	38.9	9100	18192	9092	2.0	22.6
2 Oxadiargyl @ 0.09 kg a.i. ha^{-1} PE	149	4.7	22.1	148	13.5	4.8	2.9	19.2	667	41.7	13.8	261	39.1	8156	20000	11844	2.45	14.9
3 Trifluralin @ 0.75 kg a.i. ha^{-1} PPI	160	5.0	14.6	117	12.5	4.2	2.1	12.5	514	29.2	15.0	198	38.6	7984	15413	7429	1.93	34.4
4 Oxyflurofen @ 0.15 kg a.i. ha^{-1} PE	145	4.5	17.6	133	12.4	4.8	2.5	15.1	617	31.9	16.2	242	39.2	9095	18500	9405	2.03	21.2
5 Quizalofop @ 0.06 kg a.i. ha^{-1} POE	150	5.1	12.6	111	12.5	4.3	1.9	10.7	487	23.6	17.1	194	39.8	9460	14604	5144	1.54	37.8
6 Clodinafop @ 0.06 kg a.i. ha^{-1} POE	148	4.9	15.2	137	12.6	4.7	2.3	12.9	615	30.6	16.7	236	38.3	8300	18450	10150	2.22	21.5
7 Isoproturon @ 1.0 kg a.i. ha^{-1} PE	150	4.7	21.4	133	13.4	4.6	2.6	18.8	623	40.3	13.4	240	38.6	9633	18675	9042	1.94	20.5
8 Isoproturon @ 1.0 kg a.i. ha^{-1} POE	144	4.5	16.1	125	12.1	4.3	2.2	13.9	476	27.8	14.6	185	38.9	9633	14267	4634	1.48	39.3
9 Weedy check (No Weeding)	151	4.4	10.5	108	13.0	4.2	1.6	8.9	359	19.4	15.6	139	38.8	7260	10758	3498	1.48	54.2
10 Weed free(2 W at 20 & 40DAS)	153	4.3	23.3	160	13.2	4.6	3.3	20.0	783	38.9	16.8	313	40.0	9180	23488	14308	2.56	-
SE(m)±	3.7	0.29	2.6	9.3	0.46	-	0.29	2.8	57	5.7	-	27	-	-	1714	1714	-	-
CD(=0.05)	-	-	7.5	27.7	-	-	0.85	7.96	170	16.8	-	78	-	-	5091	5091	-	-

Mustard rate :Rs 3000 q^{-1}

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COMPARATIVE BEHAVIOUR OF INDIAN MUSTARD VARIETIES IN RESPECT OF GROWTH, YIELD ATTRIBUTES AND YIELD UNDER IRRIGATED CONDITION

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ABSTRACT

A field experiment was conducted at College of Agriculture, Nagpur during *rabi* season of 2011-12 in factorial randomized block design with twelve treatment combinations of six varieties as one factor and two weed management practices as a another factor replicated thrice on clayey soils, low in nitrogen, medium in available phosphorus and high in potassium content with pH 7.3.

The plant height was significantly more in variety GM-3 at 65 and 85 DAS, and at harvest while weed management and interaction did not influence the height significantly. The leaf area was significantly influenced at 65 DAS only where variety GM-3 recorded maximum and significantly more leaf area. While the weed management significantly influenced the leaf area at 45 and 65 DAS where weedfree practice recorded maximum. The plant biomass and dry matter at 65 and 85 DAS, and at harvest were significantly influenced by the variety GM-3 and weed free management practices.

Mustard variety GM-3 recorded significantly higher grain yield (810 kg ha^{-1}), number of seed siliquae^{-1}, number of siliquae plant^{-1}, stover yield (q ha^{-1}), GMR (Rs 24294 ha^{-1}) and NMR (Rs 15553 ha^{-1}) over varieties Kranti and GM-2. Varieties ACN-9, BIO-902 and Pusa bold were at par with variety GM-3 in respect of above parameters. The B:C ratio was also higher in GM-3 (2.77). The weed free practice recorded significantly higher grain yield ha^{-1} (787 kg ha^{-1}), GMR (Rs 13914 ha^{-1}) and higher B:C ratio (2.43). The interaction effects in respect of all the parameters were found not significant.

(Key words: Indian mustard, varieties, growth and yield attributes economics)

INTRODUCTION

There is an urgent need to increase the yield of oilseeds in our country with growing demand. There are many reasons for low production of mustard viz., unavailability of irrigation, cultivation of mixed cropping system, poor adoption of plant protection measures and adoption of traditional package of practices. Apart from many reasons, the major reason for low yield is non-availability of high yielding and weed suppressing variety for this region. It has been observed that the farmers often prefer to grow their old and traditional varieties without looking into the merits of new varieties. This is one of the major constraints influencing the production of mustard in the country. Large number of improved varieties evolved in Northern India. These are to be tested in this region for their suitability. In Vidarbha ACN-9 and Pusa bold are cultivated. Apart from these, the varieties GM-2, GM-3, Kranti and BIO-902 are also found promising in mustard growing area of Vidarbha. The study on varietal behavior to weeds is meagre and hence the varietal behavior against the weeds needs to be tested. Different varieties behave differently with weed. Thus along-with non availability of suitable cultivar for a particular agro climatic region, the management of weed is also a major problem. It was therefore considered necessary to study the comparative behaviour of Indian mustard varieties along with weed management for their growth and yield attributes under irrigated condition.

MATERIALS AND METHODS

A field experiment was conducted at College of Agriculture, Nagpur, during *rabi* season of 2011-12. The experiment was laid out in factorial randomized block design with six varieties (viz., Kranti, GM-2, GM-3, BIO-902, ACN-9 and Pusa Bold) as one factor and two weed management practices (Weedy check i.e.Unweeded control and Weed free-two hand weeding at 20 and 40 DAS) as another factor. The soil of the experimental site was clayey in texture, low in available N (263.65 kg ha^{-1}), medium in available phosphorus (20.32 kg ha^{-1}) and very high in available potassium (414.42 kg ha^{-1}). Organic carbon content was medium (0.52 %) and soil reaction (7.9) was neutral. The crop was sown at spacing of 30 cm x 10 cm with recommended fertilizer dose 50:40:00 kg NPK ha^{-1} (through urea

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and single super phosphate). The gross plot of 30.24 m^2 was used for the experimentation and three irrigations were given after germination. The plant height was recorded at 65 and 85 DAS, and at harvest on five observational plants and average was worked out. For plant biomass, dry matter and leaf area two plants from each net plot were taken and after estimating leaf area by leaf area meter in dm^2, the same plant weight was recorded for biomass and after oven drying the dry matter was recorded and average $plant^{-1}$ was worked out. Similarly at harvest number of seeds $siliquae^{-1}$, number of siliquae $plant^{-1}$, seed and stover yield $plant^{-1}$ were worked based on five observational plants from each net plot. Seed yield and stover yield were estimated from the net plot and converted in quintal $hectare^{-1}$. The oil content was estimated by the nuclear magnetic resonance machine and oil yield was estimated from the oil content and seed yield. The GMR, NMR and B:C ratio was worked out from the cost of cultivation and cost of seed produced. The rate was Rs. 3000 $quintal^{-1}$.

RESULTS AND DISCUSSION

Growth attributes :

The data regarding various growth attributes are presented in table 1.

Effect of varieties :

The data on plant height showed that the height of the variety GM-3 was significantly more at 65 and 85 DAS, and at harvest than rest of the varieties except GM-2. But numerically GM-2 at 65 and 85 DAS recorded more height than rest of the varieties. At 65 DAS, GM-2 variety recorded maximum and significantly higher leaf area (5.1 dm^2) $plant^{-1}$ and GM-3, BIO-902 recorded at par leaf area. The data in respect of the plant biomass and plant dry matter accumulation at 65 and 85 DAS, and at harvest showed that, GM-3 recorded the highest plant biomass and dry matter accumulation and variety BIO-902, ACN -9 and Pusa bold were at par at all these stages. The GM-2 recorded the least plant biomass and dry matter accumulation.

Effect of weed management practice :

The weedfree check recorded numerically higher plant height at 65 and 85 DAS, and at harvest but the effect was non-significant at all these stages. Yadav (2004) also showed that the weedfree check recorded higher plant height than unweeded plot. The weedfree treatment recorded significantly more leaf area $plant^{-1}$ over unweeded control at 45 DAS and 65 DAS. The weedfree check recorded higher dry matter and biomass accumulation but the results were significant only at 65 and 85 DAS, and at harvest. This might be the cumulative effect of more plant height, leaf area leading more dry matter accumulation due to weed free condition.

Interaction effect :

The interaction effects of varieties and weed management practices on plant height, leaf area $plant^{-1}$, mean plant dry matter and plant fresh weight (g) $plant^{-1}$ were found to be non-significant.

Yield attributes :

Effect of varieties :

The data shown in table 1 indicated that the number of siliquae $plant^{-1}$ and seed yield $plant^{-1}$ were significantly influenced by the varieties. GM-3 recorded maximum and significantly higher number of siliquae $plant^{-1}$ (72.36) and seed yield $plant^{-1}$ (2.95 g). BIO-902, ACN -9 and Pusa bold recorded at par values of number of siliquae $plant^{-1}$ and seed yield $plant^{-1}$, while number of seeds $siliquae^{-1}$ was non-significant which may be attributed to varietal character. Maximum test weight of 4.40 g was reported in BIO-902 and Pusa bold and least was in ACN-9. Gurjar and Chauhan (1997) recorded more siliquae $plant^{-1}$ and seeds $siliquae^{-1}$ in Pusa bold than Kranti. Present findings are in line with these results.

Effect of weed management practices :

The number of siliquae $plant^{-1}$ and seed yield $plant^{-1}$ were significantly more in weed free check. Similar trend was also noticed regarding number of seeds $siliquae^{-1}$ but treatment differences were non-significant. The higher test weight was also reported in weedfree check. Yadav (2004) also reported significant increase in number of siliquae $plant^{-1}$ with weed free compared to weedy check.

Interaction effect :

The interaction effect in respect of number of siliquae $plant^{-1}$, grain yield $plant^{-1}$ and number of seeds $siliquae^{-1}$ was not significant.

Table 1. Comparative behavior of mustard varieties against weeds

Treatments	Growth attributes at											Yield attributes						Seed and oil Yield				Economics		
	Plant height (cm)			Plant biomass (g plant^{-1})			Plant dry matter (g plant^{-1})			Leaf area (dm^2 plant^{-1})		No. of seeds Siliquae^{-1}	No. of siliquae plant^{-1}	Seed yield plant^{-1} (g)	Stover yield plant^{-1} (g)	Test weight (g)	Seed yield (q ha^{-1})	Stover yield (q ha^{-1})	HI (%)	Oil content (%)	Oil yield (q ha^{-1})	GMR (Rs ha^{-1})	NMR (Rs ha^{-1})	B:C ratio
	65 DAS	85 DAS	Harvest	65 DAS	85 DAS	Harvest	65 DAS	85 DAS	Harvest	45 DAS	65 DAS													
Variety																								
Kranti	101	114	116	26.6	35.6	28.1	5.1	7.9	9.0	2.4	3.2	8.2	55.4	2.4	14.2	4.10	6.20	43.55	12.46	39.42	2.45	18600	9859	2.13
GM-2	124	133	136	31.3	38.3	30.0	6.0	8.5	9.6	3.9	5.1	10.0	57.3	2.4	11.6	4.10	6.41	35.73	15.22	39.29	2.52	19238	10497	2.21
GM-3	120	129	130	47.9	54.5	41.2	9.2	12.1	13.2	3.4	3.8	11.2	72.4	3.0	15.6	4.10	8.10	47.62	14.50	39.50	3.20	24294	15553	2.77
BIO-902	104	112	114	41.2	47.7	36.5	7.9	10.6	11.7	3.2	3.8	10.7	65.0	2.7	14.2	4.40	7.27	44.17	14.12	39.80	2.89	21804	13063	2.50
ACN-9	97	103	106	39.6	39.2	30.6	7.6	8.7	9.8	1.7	2.3	10.0	62.2	2.6	12.1	3.45	6.96	37.73	15.50	37.80	2.63	20894	12153	2.37
Pusa Bold	115	125	123	32.3	47.7	35.3	6.2	10.6	11.3	2.3	2.4	10.7	65.8	2.7	12.9	4.40	7.36	40.33	15.40	39.70	2.92	22073	13332	2.53
SEm±	8.8	7.5	7.1	5.4	5.2	3.8	1.0	1.2	1.2	0.5	0.5	1.2	3.6	0.1	0.9	-	0.40	2.32	-	-	0.16	1197	1197	-
CD(P=0.05)	2.7	-	-	15.7	15.3	11.2	3.0	3.4	3.6	-	1.4	-	10.5	0.4	2.7	-	1.17	6.81	-	-	0.46	3510	3510	-
Weed management																								
Weedy check	105	118	119	30.2	38.7	30.0	5.8	8.6	9.6	2.3	2.8	9.4	55.7	2.4	12.9	3.92	6.23	38.70	13.93	39.15	2.44	18686	10905	2.40
Weedfree	115	121	122	42.7	48.6	37.4	8.2	10.8	12.0	3.4	4.1	10.3	70.3	2.9	14.0	4.27	7.87	44.34	15.14	39.35	3.10	23615	13914	2.43
SEm±	3.6	4.3	4.1	3.5	3.2	2.2	0.7	0.7	0.7	0.3	0.3	0.4	2.1	0.1	0.3	-	0.23	1.34	-	-	0.09	691	691	-
CD(P=0.05)	-	-	-	10.4	9.2	6.5	2.0	2.1	2.1	0.9	0.8	-	6.0	0.2	0.9	-	0.68	3.93	-	-	0.27	2027	2027	-
Interactions																								
SEm±	8.8	10.6	5.8	8.7	7.7	7.7	1.7	1.7	1.7	0.4	0.7	0.5	2.9	0.1	0.8	-	0.33	1.90	-	-	0.13	977	977	-
CD(P=0.05)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Seed yield, stover yield, harvest index, oil content and oil yield :

Effect of varieties :

The data presented in table 1 indicated that, GM-3 variety recorded maximum (8.10 q ha^{-1}) and significantly higher seed yield but was at par with BIO-902, ACN-9 and Pusa bold. The significant yield increase in these variety might be due to the cumulative effect of higher number of siliquae $plant^{-1}$, higher seed yield $plant^{-1}$, number of seed $siliquae^{-1}$ and test weight which is more in respective variety. The Directorate of Rapeseed Mustard Research, Bharatpur also reported GM-3 and BIO-902 better competitive against weeds in proceedings of research workers meeting (Anonymous, 2012) and in their annual report of 2010-12 (Anonymous, 2011).

In respect of stover yield (q ha^{-1}) GM-3 recorded maximum and significantly higher stover yield (47.65 q ha^{-1}) and it was at par with Bio-902 and Kranti. This might be due to more dry matter accumulation, fast and better growth leading to higher stover yield. Maximum harvest index (15.50%) was reported in ACN-9 followed by Pusa bold and least in Kranti (12.46%).

The data in the table 1 showed that the highest oil content was observed in BIO-902 (39.80 %) followed by GM-3 but the variety GM-3 had the highest oil yield. However, the variety BIO-902 and Pusa bold were at par with the variety GM-3 in oil yield.

Effect of weed management practices :

The weedfree check recorded significantly higher seed yield (7.87 q ha^{-1}) over weedy check (6.23 q ha^{-1}). Thus, the weeds caused 15.5 %(1.64 q ha^{-1}) loss in yield. The Directorate of Rapeseed Mustard Research, Bharatpur also reported 16.8 to 33.3 % reduction in yield due to weedy plots over weedfree at different locations in country in mustard (Anonymous, 2012).

The weedfree check recorded significantly higher (44.34 q ha^{-1}) stover yield over weedy check. Same treatment also reported higher harvest index. The weed free practices gave the higher oil content as well as oil yield compared to weedy check condition. This might be attributed to better growth condition in weed free due to weeding.

Interaction effect :

Interaction effect of varieties and weed management practices were non significant in respect of seed yield, stover yield and oil yield.

Economic study :

Effect of varieties :

The GM-3 variety recorded maximum gross monetary return (Rs 24,294 ha^{-1}) and maximum net monetary return (Rs 15553 ha^{-1}). This GM-3 was significantly superior over other varieties except BIO-902, ACN-9 and Pusa bold which recorded at par values of GMR and NMR with GM-3. This might be due to more seed yield ha^{-1} and constant cost of cultivation. The B:C was higher in GM-3 (2.77) followed by BIO-902 (2.50), Pusa bold (2.53) and ACN -9 (2.37). The higher B:C ratio again may be attributed to higher yield (Table 1).

Effect of weed management practices :

Weedfree check recorded significantly more GMR (Rs 23615 ha^{-1}) and NMR (Rs 13914 ha^{-1}). But B:C ratio was narrowed down in weedfree compared to weedy check which might be due to higher weeding cost and comparatively lower yield increase. Yadav (2004) also reported better NMR in weedfree over weedycheck which support present findings.

Interaction effect :

GMR and NMR were not significantly influenced by the interactions.

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NUTRIENT MANAGEMENT IN LINSEED THROUGH BIOFERTILIZERS

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ABSTRACT

A field experiment was conducted at College of Agriculture, Nagpur during *rabi* season of 2011-2012 in randomized block design with nine treatments, replicated thrice on clayey soil, medium in organic carbon, low in available nitrogen, medium in available phosphorus and very high in available potassium having 7.65 pH. Linseed variety NL-97 was grown. Various growth characters (viz., height of plant, number of branches plant^{-1} and dry matter accumulation plant^{-1}), yield contributing characters (*viz.,* number of capsules plant^{-1} and grain weight plant^{-1}), seed yield (q ha^{-1}), gross and net monetary return were significantly increased and were the highest in treatment receiving 100% RDF+ *Azotobactor* +PSB, but remained at par with treatments 100% RDF + *Azotobactor*, 100% RDF and 75% RDF + *Azotobactor* +PSB. The B:C ratio was the highest with 100% RDF + *Azotobactor* +PSB. However, test weight and oil content remained unaffected. Oil yield was significantly influenced and application of 100% RDF + *Azotobactor* +PSB recorded significantly maximum oil yield which was at par with treatment 100% RDF + *Azotobactor*. Treatment 100% RDF + *Azotobacter* +PSB was found to be significantly higher in residual available nitrogen, phosphorus and potassium and it was at par with treatments 100% RDF + *Azotobactor*, 100% RDF, 75% RDF + *Azotobactor* +PSB and 50% RDF+*Azotobactor*+ PSB.

(Keywords: Linseed, growth, seed yield, oil yield, economy, soil status)

INTRODUCTION

Linseed (*Linum usitatissimum* L.) is one of the oldest important *rabi* oilseed crop of central India. To ensure high crop productivity, adoption of improved agronomic techniques is essential viz., use of organic fertilizers and their optimum doses, use of bio-fertilizers in appropriate doses etc. Nutrient supply is a key factor in increasing productivity of linseed but escalation in the prices of fertilizers and in spite of heavy inputs the crop yields are declining, leads to give a greater emphasis on supplementing the chemical fertilizers with low price sources of nutrient such as bio-fertilizers which sustain the soil health for longer period (Gawai and Pawar, 2006). Bio-fertilizers play an important role in improving soil fertility and productivity. To reduce the expenditure on cost of fertilizer and increase the productivity, judicious and balanced use of bio-fertilizer like PSB and *Azotobacter* may be good alternative. It also reduces the demand of chemical fertilizers and improves fertilizer use efficiency by decreasing the deterioration of soil. This will help to maintain the soil health, sustain the productivity, check environmental pollution and thus could help in increasing the net profit of the farmer. In view of the importance of nutrient management in linseed cultivation, the study was undertaken with the objectives of studying the effect of integrated nutrient management treatments on growth and yield of linseed, effect on soil fertility and their economics.

MATERIALS AND METHODS

The field experiment on nutrient management in linseed through biofertilizer was laid out at Agronomy Farm, College of Agriculture, Nagpur during *rabi* 2011-2012 in randomized block design with three replications and nine treatments viz., T_1 -100% RDF (25:25:00 kg NPK ha^{-1}), T_2 -75% RDF, T_3-50% RDF, T_4-100% RDF + *Azotobacter,* T_5-100% RDF + *Azotobacter* + PSB, T_6-75% RDF + *Azotobacter,* T_7-75% RDF + *Azotobacter* + PSB, T_8-50% RDF + *Azotobacter,* T_9-50% RDF + *Azotobacter* + PSB on clayey soil, medium in organic carbon (0.59%), low in available nitrogen (243 kg ha^{-1}), medium in available phosphorus (20.5 kg ha^{-1}) and very high in available potassium (382.4 kg ha^{-1}) having 7.65 pH. Linseed variety NL-97 was grown with spacing of 30 cm x 5 cm. During the growth season of crop the maximum temperature varied from 26.5 ^{0}C to 39.8^{0}C and minimum temperature varied from 9.6 ^{0} C to 18.4 ^{0} C. The relative humidity at morning varied from 21 to 86 per cent where as it was 10 to 55 per cent in evening during the period of crop season. The fertilizers were applied through urea and single superphosphate as per the treatments with recommended fertilizer dose of 25: 25:00 kg NPK ha^{-1}. The bio-fertilizers *Azotobacter* and phosphate solubilising bacterial (PSB) were applied at the time of sowing as seed treatment at the rate of 25 g kg^{-1} of

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seed. Observations on growth parameters viz., plant height and number of branches plant^{-1} and all the yield parameters were recorded on the selected five plant and average was worked out. The dry matter was recorded on two plant sampled from each net plot and weight was recorded after oven drying. The oil content was estimated by Soxhlet method (Anonymous, 1997) and oil yield was calculated on net plot yield and expressed in kg hectare^{-1}. The phosphate and potash was estimated by Walkley and Black method (Jackson, 1967) and nitrogen was estimated by the Alkaline permanganate method (Subbaiah and Asija, 1956).

RESULTS AND DISCUSSION

Growth attributes :

The data regarding the growth attributes are presented in table 1. At 30 DAS plant height, number of branches plant^{-1} and dry matter accumulation plant^{-1} (g) were not influenced significantly. This might be due to initially less requirement of nutrient which was equally fulfilled by all the treatments. At 60 and 90 DAS and at harvest, the treatment 100% RDF + *Azotobacter* + PSB was found to be significantly superior in respect of plant height, number of branches plant^{-1} and dry matter accumulation plant^{-1} over all other treatments except the treatments 100% RDF + *Azotobacter*, 100% RDF and 75% RDF + *Azotobacter* +PSB as these treatments were at par with it . This might be due to immediate and easy availability of nutrients through inorganic fertilizer assisted by the bio fertilizer and probable replacement of 25% reduction of RDF by the bio-fertilizer. The enhanced availability of phosphorus might have favoured nitrogen fixation and subsequently the increase in height and other growth parameters. Kanse *et al.* (2006) also observed increased growth parameters viz., plant height, number of branches plant^{-1}, dry matter plant^{-1}, leaf area plant^{-1} and leaf area index of soybean due to application of 75 per cent N through fertilizer + 25 per cent N through weed biomass + PSB and *Rhizobium* inoculation, however it was at par with other promising treatment viz., applications of RDF (30:75:00 NPK kg ha^{-1}) + inoculation with *Rhizobium* and PSB. These findings are supported by Dash *et al.* (2005) who also reported maximum plant height, higher number of branches, LAI and dry matter accumulation with the application of 100 per cent RDF (20:60:40 kg NPK ha^{-1}) to soybean crop.

Yield attributes :

Data regarding **i**mportant yield contributing characters viz., number of capsules plant^{-1}, number of seeds capsule^{-1}, seed yield plant^{-1} and test weight recorded are given in table 2.

Number of capsules plant^{-1} :

Treatment 100% RDF+*Azotobacter*+PSB recorded significantly higher number of capsules plant^{-1}, seed yield plant^{-1} and number of seeds capsule^{-1} over all other treatments except the treatments 100% RDF+ *Azotobacter* and 100% RDF which were at par. Treatment 50% RDF + *Azotobacter* + PSB and 75% RDF + *Azotobacter* +PSB were also par in respect of number of seeds capsule^{-1}. This might be due to increased effect of various growth parameters. Higher doses of nutrient increased the availability of nutrients to the plant through inorganic fertilizers. The enhanced availability of phosphorus due to PSB might have favoured nitrogen fixation, uptake by the plant and thereby better plant growth. Samie *et al*. (2002) also reported higher yield attributes with 100% mineral nitrogen alone or two third mineral nitrogen + biofertilizer in linseed. Application of various integrated nutrient management treatments as well as sole fertilizer treatments did not show any significant influence on test weight of linseed.

Seed and straw yield of linseed (q ha^{-1}) :

The treatment 100% RDF+*Azotobacter* +PSB registered maximum seed yield (9.91q ha^{-1}) and straw yield and were significantly higher over all other treatments except the treatments 100% RDF + *Azotobacter*, 100% RDF and 75% RDF+ *Azotobacter* +PSB. The treatment 75% RDF + *Azotobacter* was also at par with it in respect of seed yield ha^{-1}. Full dose of nutrient through inorganic source alone or reduced quantity of inorganic source coupled with bio-fertilizers might have facilitated efficient utilization of nutrients resulting in better vegetative and reproductive growth resulting in higher seed yield. All India Coordinated Research project on linseed at Nagpur reported higher yield of linseed with 100% RDF and 75%RDF+Azotobacter +PSB was at par with it, thus supports the present findings (Anonymous, 2013). The influence of integrated nutrient management in increasing straw yield could be attributed to the cumulative effect of plant height, number of branches and dry matter resulting in more vegetative growth.

Table 1. Growth and yield attributes as influenced by different treatments

Treatments	Plant height (cm) at				Number of branches plant^{-1} at				Dry matter plant^{-1} (g) at			
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest
T_1 –100% RDF	18.3	44.6	45.1	46.0	1.30	2.91	3.89	4.41	0.28	1.03	1.90	2.89
T_2 –75% RDF	17.1	43.2	43.1	43.9	1.28	2.32	3.34	3.62	0.26	0.83	1.50	2.32
T_3 –50% RDF	17.6	41.2	42.8	43.8	1.27	2.12	3.21	3.44	0.25	0.71	1.43	2.11
T_4 –100% RDF + Azot.	18.4	44.7	45.3	46.3	1.31	2.96	3.92	4.45	0.29	1.07	2.00	2.96
T_5 –100%RDF+ Azot.+PSB	19.7	45.2	46.1	47.1	1.32	3.00	4.11	4.60	0.29	1.15	2.12	3.21
T_6 – 75% RDF+ Azot.	19.0	42.1	44.5	44.5	1.29	2.63	3.32	3.49	0.26	0.92	1.61	2.70
T_7 – 75% RDF + Azot.+PSB	19.1	44.4	44.9	45.9	1.30	2.79	3.79	4.31	0.28	1.00	1.77	2.84
T_8 – 50% RDF + Azot.	17.7	42.4	43.1	44.1	1.29	2.44	3.42	3.76	0.26	0.78	1.65	2.39
T_9 – 50% RDF + Azot.+PSB	18.1	43.1	43.3	44.6	1.31	2.46	3.51	3.89	0.27	0.81	1.71	2.49
S E m$\pm$	0.92	0.29	0.48	0.41	0.07	0.12	0.14	0.18	0.01	0.06	0.12	0.16
CD(P=0.05)	-	0.89	1.43	1.21	-	0.36	0.44	0.54	-	0.18	0.37	0.47

Table 2. Yield, economics and residual available nutrients in soil as influenced by different treatments

Treatments	Yield attributes				Yield ($q\ ha^{-1}$)		Oil content and yield		Economics				Available residual status of soil ($kg\ ha^{-1}$)		
	No. of capsules $plant^{-1}$	Number of seeds $capsule^{-1}$	Yield $plant^{-1}$ (g)	Test weight (g)	Seed	Straw	Content (%)	Yield ($q ha^{-1}$)	C0C (Rs ha^{-1})	GMR (Rs ha^{-1})	NMR (Rs ha^{-1})	B:C ratio	N	P_2O_5	K_2O
T_1 – 100% RDF	30.11	7.39	1.31	7.61	8.96	14.56	42.65	3.82	14616	34048	19432	2.32	262.0	32.0	466.7
T_2 – 75% RDF	28.34	6.71	0.98	7.18	7.56	11.56	42.43	3.22	14165	28728	14563	2.02	241.2	23.1	437.3
T_3 – 50% RDF	27.15	6.43	0.83	7.11	7.11	11.23	42.08	2.99	13715	27018	13303	1.98	230.1	20.0	430.1
T_4 – 100% RDF + *Azot.*	30.23	7.41	1.37	7.65	9.11	15.11	42.80	3.90	15397	34618	19221	2.24	280.2	32.1	474.0
T_5 – 100% RDF + *Azot.*+PSB	31.82	7.55	1.46	7.86	9.91	15.56	43.05	4.27	15936	37658	21722	2.36	291.3	32.4	481.5
T_6 – 75% RDF + *Azot.*	28.67	6.93	1.12	7.38	8.23	12.23	42.48	3.51	14945	31274	16329	2.09	246.0	24.4	443.2
T_7 – 75% RDF + *Azot.* +PSB	28.91	7.31	1.20	7.56	8.59	14.22	42.57	3.67	15365	32642	17277	2.12	257.3	30.1	457.8
T_8 – 50% RDF + *Azot.*	28.06	6.81	1.06	7.21	7.69	11.87	42.20	3.25	14374	29222	14848	2.03	248.4	24.2	450.5
T_9 – 50% RDF + *Azot.* +PSB	28.11	6.87	1.08	7.34	7.89	12.00	42.35	3.34	14794	29982	15188	2.02	251.3	25.3	455.6
SEm$\pm$	0.81	0.23	0.07	0.21	0.65	0.83	0.57	0.11	-	-	-	-	8.6	1.8	5.3
CD(P=0.05)	2.41	0.68	0.21	-	1.94	2.49	-	0.34	-	-	-	-	25.4	5.4	15.8
Initial fertility status													243.0	20.5	382.4

PSB: Phsphate solubalizing bacteria, *Azot.* : *Azotobacter*, COC: Cost of cultivation, GMR: gross moneatary return, NMR: Net monetary return

Oil content (%) and oil yield :

Application of 100 % RDF+*Azotobacter* +PSB recorded numerically maximum oil content in linseed but results were not significant. Oil yield (q ha^{-1}) in treatment 100% RDF + *Azotobactor* +PSB was found to be significantly higher over all other remaining treatments. Higher seed yield and oil content might have increased the oil yield further.

Economics :

Data in respect of economic parameters viz., gross monetary returns, net monetary returns and benefit : cost ratio are presented in table 2.

Application of 100 % RDF + *Azotobacter* +PSB recorded maximum and significantly more gross monetary returns (Rs 37658 ha^{-1}) and net monetary return (Rs 21722 ha^{-1}) over rest of the treatments, but 100% RDF + *Azotobactor* and 100% RDF treatments were found at par. The maximum B: C ratio of 2.36 was registered due to treatment 100% RDF + *Azotobactor* +PSB followed by treatment 100% RDF(2.32) and 100% RDF + *Azotobactor* (2.24). Application of higher fertilizer levels and biofertilizers in combination as INM treatment increased the gross monetary returns, net monetary returns and B: C ratio of linseed. This might be due to higher application of fertilizer and biofertilizers, particularly INM treatments resulting in production of higher grain and straw yield.

Soil studies (NPK status of soil before and after harvest of crop):

The data regarding the initial and final status of soil given in table 2 indicated that the soil status was improved after the crop harvest over the initial status.

It was revealed from the data that highest residual available nitrogen in soil was present due to application of 100 % RDF + *Azotobacter* +PSB which was found at par with treatments 100% RDF + *Azotobacter*. Significantly higher residual available phosphorus in soil was observed due to application of 100 % RDF + *Azotobacter* +PSB which was at par with treatments 100% RDF + *Azotobacter* , 100% RDF and 75% RDF + *Azotobacter* +PSB. Increase in available soil phosphorus status might be due to biofertilizers application as phosphate solubilising bacteria (PSB) solubilises the phosphorus fixed in the soil. It was further revealed from the data that significantly higher available potassium in soil was present in treatment 100% RDF + *Azotobacter* +PSB which was at par with treatments 100% RDF + *Azotobacter* and 100% RDF .

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CHARACTERIZATION, CLASSIFICATION AND EVALUATION OF SOILS AND IRRIGATION WATER IN OSMANABAD TAHSIL, MAHARASHTRA

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ABSTRACT

Nine representative pedons and eighteen ground water samples of adjoining area of the soil profiles from different physiographic unit of Osmanabad tahsil were characterized and classified during year 2009-2010. The morphological, chemical and physical properties of soil were differing in relation to microtopographic position of the soil profile. The soils were very shallow to very deep in depth, black (10YR2.5/1) to yellowish brown (10YR 5/6) in colour, calcareous in nature (0.7- 19.37%), granular to angular blocky in structure, sandy clay loam to clayey in texture. The AWC of soils varied from 7.5 to 20.8 per cent. These soils were slightly acidic to moderately alkaline(6.8 to 8.3) in nature. The cation exchange capacity varies from 23.19 to 44.8 cmol (p+) kg^{-1}, and low to moderately high(0.2 to 1.8) in organic carbon. The electrical conductivity of soil was less than 1 dSm^{-1}. The calcium was the dominant cation followed by magnesium, sodium and potassium. The base saturation per cent was greater than 90 per cent. Taxonomically, these soils were classified as Lithic Ustorthents, Typic Haplustepts and Typic Haplusterts. The irrigation water samples were from medium salinity low sodicity (C2S1) to high salinity to low sodicity (C3S1). The residual sodium carbonate in well and bore water samples were less than 1.25 mmolel^{-1}. This suggested that the quality of water is suitable for irrigation under moderate leaching .The soil-site suitability indicated that the Lithic Ustorthents soils were suitable for shallow rooted crop like soybean whereas Typic Haplustepts and Typic Haplusterts soils were suitable for both shallow and deep rooted crops soybean and pigeon pea .

(Key words: Soil classification, morphological, physical and chemical characteristic of soil, soil site suitability and quality of irrigation water)

INTRODUCTION

Most of the soils of Osmanabad tahsil are shallow and generally underlined by murrum layer. The murrum (saprolite) layer has been defined by Tamhane *et al.*(1976) as stony and gravelly layer below the solum. The transformation of saprolite to soil occurs through a transitional horizon where saprolite loses its characteristic and develops structural characteristic of soil. The productivity of soil depends upon the quality of soil in which it sustained. The important crops grown in the study area, Osmanabad thasil were soybean and pigeon pea. The present yield of these crops is much below the experimental yields. Deep soils with high clay content pose management problem due to water logging and require greater draft in cultivation. The shallow soils underlined by murrum layer are used for climatically adopted crop. Since these are grouped as marginal/ degraded lands, farmers paid least attention for their conservation and management when cultivated. The selection of crop is not site specific. For the proper land resource management in this area, investigation on the land properties and their constraints is a prerequisite. A documentation of soil properties in systematic manner is one of the vital components in formulating effective land use planning programme (Deshmukh and Bapat, 1993). Therefore, the present investigation on soils and ground water resources of Osmanabad tahsil have been evaluated for land use planning by characterizing various aspects of soils and irrigation water .

MATERIALS AND METHODS

The studies were carried during the year 2009-10 at Department of Soil Science and Agricultural Chemistry, College of Agriculture, Osmanabad (Marathawada). Osmanabad tahsil is located exactly in between 18^{0} 01' 35” to 18^{0} 25' 49” North latitude and 75^{0} 55' 36” to 76^{0} 19' 10” East longitude at an altitude of 640 to 660 m above MSL. The total geographical area is 1358.86 sq. km. (1,35, 886 ha). In the area mean annual rainfall received is 870 mm and mean annual temperature is 26.03 ^{0}C and mean maximum and mean minimum temperatures were 33.55 and 18.62^{0}C respectively. The area has Ustic soil moisture regime, Hyperthermic temperature regime and length of growing period is 151 days. Nine representative pedons from nine villages namely viz., Kini(P1), Dhoki (P2), Ter (P3), Alni (P4), Keshegawan (P5), Wadgawan (P6), Sarola (P7), Chikhli (P8) and Shumbha (P9) were selected by using SOI toposheet (1:50,000 scale) and satellite data IRS-1D from different physiographic positions.

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Eighteen irrigation water samples either from bore or conventional well as detailed in table 4 were collected from adjoining area of the soil profiles from these nine villages. Both soil and irrigation water samples were collected in the month of May, 2009. Morphological study of the soil was undertaken as per soil survey manual (Anonymous , 2002). The soil samples were collected horizon wise as given village wise in table 1. These samples were air dried, ground and sieved using 2 mm sieve. Particle size analysis of the sample was carried out by international pipette method (Jackson,1979). Water retention characteristics were determined by pressure plate apparatus and PAWC determined by expression suggested by Gardner *et al.* (1984). Bulk density of the soil was determined by clod coating technique (Black, 1965). EC. pH, organic carbon, $CaCO_3$, exchangeable cations and cation exchange capacity (CEC) were determined by standard procedure described by Jackson (1973). The soils were classified as per Soil Taxonomy (Anonymous, 1994b). The quality of irrigation water and other determinations as detailed in table 4 were made according to method of Richards (1954). Soil site suitability were made as per the criteria suggested by Sys *et al.* (1991) and modified by NBSS & LUP (Anonymous ,1994a). In addition, suitability classes were also derived based on the actual yield as suggested by FAO (Anonymous, 1983).

RESULTS AND DISCUSSION

Morphological characteristics:

The data regarding morphological characteristics of soils are given in table 1. The depth of the soil ranged from very shallow (<10 cm) to very deep (>150cm) and it gradually decreased with the increasing elevation of the soil profile. The shallow soil were found in elevated area whereas deep soils were found in low lying area. The soils were developed on moderate to gently sloping over weathered basalt. The soil colour varied from black (10 YR 2.5/2) to yellowish brown (10 YR 5/6) in colour. The soil structure of the pedons located on elevated area (Kini -P1, Alni- P4 and Shumbha- P9) were granular in structure whereas pedons located on gently sloping (Dhoki-P2, Keshegawan - P5 and chikhli- P8) and low lying area (Ter-P3, Wadgawan-P6 and Sarola-P7) were sub angular blocky to angular blocky in structure.

Physical properties:

Data regarding physical properties of soils are presented in table 2. The soil situated in elevated area (P1, P4 and P9) were sandy loam to silt loam in texture and high amount of coarse fragments varied from 6.9 to 96 per cent. The soils developed on sloping land (P2, P5 and P8) were sandy loam to clayey in texture whereas pedons located on low lying area (P3,P6 and P7) were clayey in texture. Topography and slope were found to affect particle size distribution. Bulk density of soil above murrum layer ranged from 1.23 to 1.69 Mgm^{-3} and murrum layer ranged from 2.02 to 2.15 $Mgm^{-3.}$ The available water content (AWC) of the soil ranged from 7.5 to 20.8 per cent followed the trend of clay distribution. The maximum available water content was recorded in soils of Typic Haplusterts (P3,P6 and P7) followed by Typic Haplustepts (P2,P5 and P8) and Lithic Ustorthent (P1, P4 and P9) .The capacity of soil to store moisture for plant use is largely a function of their clay content, depth of soil and mineralogy of soil. Therefore, a significant positive linear correlation of soil depth with PAWC ($r = 0.908$) and clay content with PAWC ($r = 0.901$) were obtained. This suggests that the soil depth, texture and PAWC are interrelated to each other and in turn influence the crop yield. The saturated hydraulic conductivity of soil varied from 0.27 to 29.50 cm hr^{-1} . This variation may be attributed to textural variation. The hydraulic conductivity of the surface soil was found less than subsurface soil in pedon P6 and P7 (Typic Haplusterts). This variation may be attributed to application of irrigation water.

Chemical properties of soil:

The pH data are presented in table 2. The soils were slightly acidic to alkaline in nature. The pH ranged from 6.8 to 8.3. The pH of the soil decreased with increasing altitude. The surface soil layers were slightly acidic in nature. This might be due to leaching of appreciable amount of exchangeable bases. The $CaCO_3$ content in soils ranged from 0.7 to 19.37 per cent indicating that soils were calcareous in nature. The calcium carbonate content of soil at high altitude was very low and varied from 0.7 to 1.8 per cent as compared to low altitude (2.8 to 19.3 %). It may be attributed to the leaching of bicarbonate which gets precipitate down to the slope as well as at lower horizon. High $CaCO_3$ affects the physical and chemical properties of soil and has a great influenced on crop production under rainfed condition. These soils were low to moderate in organic carbon which varied from 0.2 to 0.8 per cent and decreased with depth. The cation exchange capacity (CEC) ranged from 23.19 to 44.08 cmol(p+) kg^{-1}. The maximum cation exchange capacity was noticed in Typic Haplusterts. The high CEC of black soil is attributed to the high amount of clay and semectitic clay mineralogy (Pal and Deshpande, 1987). The relationship of cation exchange capacity (CEC) with crop yield suggested that the yield of crop was influenced by the CEC of soil and it had positive correlation between CEC of soil and yield of soybean (r = 0.751) and pigeonpea (r = 0.759). The exchangeable Ca^{++}, Mg^{++}, Na^{+} and K^{+} ranged between 12.8 to 30.8, 8.1 to 15.4, 0.02 to 2.0 and 0.16 to 0.31 cmol(p+) kg^{-1} respectively. The exchangeable sodium per cent were < 5 indicating that there was no sodicity.

Soil classification:

The pedon located on elevated topography (P1, P4 and P9) does not have any diagnostic horizon and thus, these soils are qualified as order Entisols and due to the presence of Ustic moisture regime soils were grouped into Ustorthents. Further in a view of Lithic contact within 50 cm of soil depth, these soils belonging to the subgroup Lithic Ustorthants. The pedon located on sloping topography (P2, P5 and P8) having Ocric epipedon underlined by cambic horizon have been classified as Ustepts within the order Inceptisols and this area belonging to Ustic moisture regime, these soils qualify for the great group Haplustepts at subgroup level and thus these soils are classified as Typic Haplustepts . The pedons located on lower topographic position (P3, P6 & P7) were deep to very deep black colour, clayey (>50%) and characterized by deep , wide cracks and well developed slickenside and pressure faces. Therefore, these soils were classified under the order Vertisols and due to presence of Ustic moisture regime, these soils were grouped into Haplusterts and subgroup Typic Haplusterts.

Quality of irrigation water:

The data pertaining to chemical analysis of irrigation water are presented in table 4. The ionic concentration and proportion of monovalent to divalent cation govern the behavior of water (0.4 to 1.63) which indicated less sodiumnisation of water in all samples. The EC of the irrigation water varied from 0.2 to 1.13 dSm^{-1} and SAR ranged between 1.5 to 4.5 $mmoll^{-1}$. RSC was less than 1.25 $mmoll^{-1}$. This indicated that the water is safe for irrigation purpose. As per US salinity laboratory (Richards, 1954) the quality of irrigation water was classified into class C2S1 (medium salinity low sodicity) to C3S1 (high salinity low sodicity).The irrigation water from both bore and well from Wadgawan and Sumbha had high salinity and low sodicity (C3S1) whereas irrigation water from rest of the locations had medium salinity and low sodicity (C2S1) except irrigation water of one of the bores of Ter (P3) which had high salinity and low sodicity.

Soil site suitability evaluation:

Data regarding soil site suitability evalution are presented in table 5 and it was carried out by using criteria suggested by Sys *et al.* (1991) and modified by NBSS and LUP (Anonymous, 1994a). The soils of Lithic Ustorthents (P1, P4 and P9) were unsuitable (N_2) to currently not suitable (N_1) for soybean and unsuitable (N2) for pigeonpea. Whereas Typic Haplustepts (P2, P5 and P8) and Typic Haplusterts (P3, P6 & P7) were moderately (S_2) to marginally (S3) suitable for soybean and pigeonpea. In addition, suitability classes were also derived based on the actual yield as suggested by FAO (Anonymous, 1983). The soils of Lithic Ustorthents were moderately (S2) to marginally suitable (S3) for soybean and pigeonpea, whereas Typic Haplustepts were moderately suitable (S2) for soybean and pigeonpea . The soils of Typic Haplusterts were highly suitable (S1) for Soybean and moderately (S2) to highly suitable (S1) for pigeonpea. This suggested that Lithic Ustorthents soils were suitable for shallow rooted crop like soybean whereas Typic Haplustepts and Typic Haplusterts soils were suitable for both shallow and deep rooted crop soybean and pigeonpea for sustaining the productivity of soils in the study area.

This investigation clearly indicated that the productivity of very shallow soil (Typic Ustorthents) was very less than Typic Haplustepts and Typic Haplusterts. This may be attributed to limitation of the soil depth, clay content, PAWC and cation exchange capacity. This limitation may be improved by application of tank silt as suggested earlier by Vaidya and Dhawan (2011).

Table 1. Morphological characteristics of soils of Osmanabad tahsil

Horizones	Depth (cm)	Boundary	Matrix Colour	Texture	Structure	Consistency	Pores	Roots	Effervescence
Pedon 1 Kini (*Lithic Ustorthents*)									
Ap	0-18	cs	10YR4/4	scl	m2gr	shfrnsnp	fm	fm	e
Ac	18-45	gs	10YR5/6	scl	m3gr	lfrnsnp	fm	cm	e
M	45-52				----murrum (Weather basalt) ----				
Pedon 2 Dhoki (*Typic Haplustepts)*									
Ap	0-19	cs	10YR3/2	c	m2sbs	shfrssps	vfm	fc	es
Bw	19-43	cs	10YR3/2	c	m3abk	vhfrssps	ff	fc	es
Bc	43-86	-	10YR5/6	sl	c2gr	sfrnsnp	cc	ff	e
M	86-95				----murrum (Weather basalt) ----				
Pedon 3 Ter (*Typic Haplusterts)*									
Ap	0.-17	cs	10YR4/2	c	m2sbk	hfisssp	fm	vfm	es
Bw	17.36	cs	10YR3/2	c	m3abk	hfisssp	fm	vff	es
BSS1	36-60	cs	10YR3/2	c	m3abk	hvfivsvp	ff	vff	ev
BSS2	60-92	cs	10YR4/2	c	m3abk	vhfivsvp	ff	vff	ev
BSS3	92-130	cs	10YR4/4	c	m3abk	vhfivsvp	-	--	ev
Bc	130-150	-	10YR4/3	c	c3abk	vfivsvp	-	-	ev
Pedon 4 Alni (*Lithic Ustorthents)*									
Ap	0-15	cs	10YR 5/4	scl	f1gr	sfrnsnp	fm	fm	e
Ac	15-26	aw	10YR5/6	sl	f1gr	sfrnsnp	fm	vfm	e
M	26-35				----murrum (Weather basalt) ----				
Pedon 5 Keshgawan (*Typic Haplus tepts)*									
Ap	0-16	cs	10YR 3/2	c	m2sbk	hfrsssp	vfm	vfm	e
B1	16-42	gi	10 YR3/1	c	m2sbk	hfrsssp	vff	vff	e
B2	42-60	gw	10 YR 3/1	cl	m2sbk	hfrsssp	vfm	vfc	e
Bc	60-90	-	10 YR 4/3	l	m2gr	svfrsssp	-	-	e
M				Murrum (Weathered Basalt)					
Pedon 6 - Wadgawan (*Typic Haplusterts)*									
Ap	0-20	cs	10YR 3/2	c	m1abk	shfivsvp	vfm	vfc	e
Bw1	20-42	gw	10YR3/1	c	m3abk	vhvfivsvp	vfm	vff	es
Bw2	42-59	gw	10YR2.5/1	c	m3sbk	vhvfivsvp	vfm	vff	es
BSS1	59-86	gi	10YR 2.5/1	c	m3sbk	vhvfivsvp	vfm	ff	es
BC	86-140	-	10YR 5/6	gr	m3gr	sfrvsvp	-	-	ev
Pedon 7 - Sarola (*Typic Haplusterts*)									
Ap	0-15	cs	10YR 4/2D	c	m3sbk	hfisssp	vfm	vfm	e
Bw1	15-38	cs	10 YR 3/1	c	m3 sbk	hfimsmp	fm	vfm	e
Bw2	38-57	gi	10 YR 4/3	c	m3 sbk	vfivsvp	fm	fm	e
BSS1	57-80	gi	10 YR 4/3	c	m3 abk	hfrvfivsvp	ff	ff	ev
BSS2	80-106	gw	10 YR 4/4	c	m 3abk	vfivsvp	-	cm	ev
Bc	106-150	-	10 YR 5/6	c	m3 abk	vfivsvp	-	cc	ev
Pedon 8 - Chikhli (*Typic Haplustepts)*									
Ap	0-16	cs	10 YR 4/3	cl	m1sbk	shsfrsssp	fm	fm	e
Bw1	16-27	gi	10 YR 4/4	cl	m1sbk	shsfsssp	ff	fm	e
Bc	27-40	-	10 YR 5/6	sl	gr	Shsfrnsnp	ff	ff	e
M	40-52				----murrum (Weather basalt) ----				
Pedon 9 Sumbha (*Lithic Ustorthents)*									
Ap	0-15	cs	10 YR 4/3	cl	m2gr	sfrnsnp	fm	vfm	-
Ac	15-28	gi	10 YR 4/3	cl	figr	Sfrnsnp	fm	fm	-
M	28-39	-	10 YR 5/6	s	figr		cm	cf	-

Table 2. Physical properties of soils of Osmanabad tahsil

Horizones	Depth (cm)	Coarse fragment (%)	BD (Mg m^3)	HC (cmhr^{-1})	Partial size analysis (%)			Moisture retention (%)		AW C (%)	PAW C (mm)
					Sand	Silt	Clay	33kPa	1500 kPa		
Pedon 1 Kini (*Lithic Ustorthents*)											
Ap	0-18	34.06	1.23	28.42	56.19	25.76	18.05	19.3	7.8	11.5	90.1
Ac	18- 46	82.43	1.44	29.50	60.69	23.51	15.80	19.4	7.3	12.1	
M	45-52	96.00	2.15			----murrum (Weather basalt) ----					
Pedon 2 Dhoki(*Typic Haplustepts)*											
Ap	0-19	8.03	1.34	10.88	11.44	29.64	58.92	26.3	12.1	14.2	156.2
Bw	19-43	11.63	1.48	10.28	17.13	22.05	60.82	31.7	17.2	14.5	
Bc	43-86	46.09	1.38	17.42	37.57	26.10	36.33	19.4	7.3	12.1	
M	86-95				----murrum (Weather basalt) ----						
Pedon 3 Ter (*Typic Haplusterts)*											
Ap	0.-17	10.42	1.51	1.32	7.79	34.59	57.62	37.6	21.3	16.3	256.6
Bw	17.36	12.90	1.51	1.24	7.38	35.26	69.36	37.7	21.8	15.9	
BSS1	36-60	14.46	1.59	1.28	7.46	26.56	65.98	39.3	23.6	15.7	
BSS2	60-92	15.00	1.69	0.27	7.28	22.94	59.78	46.3	27.2	19.1	
BSS3	92-130	18.66	1.68	6.78	9.75	33.82	56.43	47.9	27.1	20.8	
Bc	130-150	20.05	1.55	0.34	6.28	42.70	51.02	46.2	27.8	18.4	
Pedon 4 Alni (*Lithic Ustorthents)*											
Ap	0-15	16.90	1.31	3.24	56.01	22.52	21.47	23.0	10.8	12.2	51.5
Ac	15-26	28.65	1.43	16.78	68.87	14.95	16.18	15.9	7.2	8.7	
M	26-35	90.00	2.15			----murrum (Weather basalt) ----					
Pedon 5 Keshgawan (*Typic Haplustepts)*											
Ap	0-16	8.56	1.38	7.35	21.71	37.58	40.71	30.0	16.2	13.8	167.1
B1	16-42	12.5	1.39	8.42	17.35	41.98	40.67	31.7	16.9	14.8	
B2	42-60	12.71	1.38	8.80	30.18	35.58	34.24	28.2	14.7	13.5	
Bc	60-90	71.02	1.47	18.35	47.00	34.64	18.36	20.4	9.5	10.9	
M				----murrum (Weather basalt) ----							
Pedon 6 - Wadgawan (*Typic Haplusterts)*											
Ap	0-20	8.51	1.32	0.84	3.17	28.45	68.38	45.9	27.4	18.5	197.6
Bw1	20-42	10.87	1.33	3.23	5.38	29.34	65.28	41.3	28.3	13.0	
Bw2	42-59	12.31	1.35	3.44	2.81	25.44	71.75	41.9	28.9	13.0	
BSS1	59-86	15.64	1.48	3.49	2.08	30.43	67.49	42.4	30.4	12.0	
BC	86-140	18.64	1.35	4.68	36.78	40.34	22.88	42.3	31.7	10.6	
Pedon 7 - Sarola (*Typic Haplusterts)*											
Ap	0-15	6.90	1.35	5.12	9.62	33.63	56.72	37.9	20.9	17.0	240.8
Bw1	15-38	10.56	1.40	9.49	8.02	29.62	62.36	38.3	21.3	17.0	
Bw2	38-57	13.29	1.66	9.19	8.52	26.46	65.02	38.1	24.1	14.0	
BSS1	57-80	15.62	1.64	9.36	7.40	26.23	66.37	39.4	28.2	11.2	
BSS2	80-106	19.90	1.68	9.99	7.68	23.86	68.46	46.3	27.1	11.2	
Bc	106-150	70.24	1.63	2.39	4.27	26.07	69.66	46.8	27.9	18.9	
Pedon 8 - Chikhli (*Typic Haplustepts)*											
Ap	0-16	9.37	1.31	11.50	33.99	32.90	33.11	22.9	11.1	11.8	80.5
Bw1	16.27	15.00	1.43	17.28	34.28	38.25	27.47	26.8	14.8	12.0	
Bc	27.40	66.82	1.48	18.22	30.85	39.81	28.34	27.7	18.6	19.1	
M	40-52	86.35	2.02			----murrum (Weather basalt) ----					
Pedon 9 - Sumbha (*Lithic Ustorthents)*											
Ap	0-15	17.58	1.37	11.19	24.31	50.47	25.22	20.9	8.2	12.7	69.2
Ac	15-28	17.53	1.42	15.97	16.12	51.74	22.14	18.4	8.1	10.3	
M	28-39	63.35	1.54	18.35	34.60	45.34	20.06	15.4	7.9	7.5	

Table 3. Chemical properties of soils of Osmanabad tahsil

Horizones	Depth (cm)	pH	EC (dSm^{-1})	OC (%)	$CaCO_3$ (%)	CEC (cmol (p+) kg^{-1})	Cations (cmol (p+) kg^{-1})					Base Saturation (%)	ESP
							Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Sum of Cations		
Pedon 1 Kini (*Lithic Ustorthents*)													
Ap	0-18	6.8	0.07	0.7	1.5	26.67	12.8	10.4	0.02	0.24	23.46	87	0.08
Ac	18-46	6.9	0.08	0.4	0.7	25.02	12.8	10.2	0.03	0.23	22.49	89	0.13
M	45-52	----murrum (Weather basalt) ----											
Pedon 2 Dhoki (*Typic Haplustepts)*													
Ap	0-19	7.6	0.2	0.5	4.5	28.09	16.2	10.2	0.37	0.20	26.97	96	1.3
Bw	19-43	7.7	0.1	0.5	4.1	30.81	18.6	11.0	0.44	0.16	30.20	98	1.4
Bc	43-86	7.8	0.1	0.3	9.1	32.97	18.9	11.0	0.20	0.24	30.34	92	0.6
M	86-95	----murrum (Weather basalt) ----											
Pedon 3 Ter (*Typic Haplusterts)*													
Ap	0.-17	7.9	0.2	0.6	10.3	44.08	30.6	11.0	0.85	0.31	42.76	97	1.92
Bw	17.36	8.0	0.2	0.6	11.2	41.75	28.6	10.8	1.22	0.30	40.92	98	2.92
BSS1	36-60	8.2	0.2	0.5	11.6	41.94	28.0	11.0	1.82	0.29	41.11	98	4.33
BSS2	60-92	8.3	0.3	0.4	10.1	40.01	26.4	11.0	1.53	0.28	39.21	98	3.82
BSS3	92-130	7.7	0.6	0.3	11.2	39.24	26.0	10.2	2.00	0.26	38.46	98	5.09
Bc	130-150	7.8	0.9	0.2	12.8	37.83	25.4	09.4	2.07	0.26	37.08	98	5.47
Pedon 4 Alni (*Lithic Ustorthent)*													
Ap	0-15	7.1	0.08	0.4	1.8	23.19	13.8	08.8	0.05	0.20	22.13	93	0.20
Ac	15-26	7.2	0.08	0.3	1.0	26.93	14.4	10.0	0.15	0.77	25.32	94	0.55
M	26-35	----murrum (Weather basalt) ----											
Pedon 5 Keshgawan (*Typic Haplustepts)*													
Ap	0-16	7.6	0.19	0.7	14.0	29.23	17.6	10.2	0.11	0.21	28.12	93	0.36
B1	16-42	7.5	0.18	0.6	14.3	27.88	16.2	10.0	0.32	0.25	26.77	96	1.14
B2	42-60	7.9	0.15	0.4	17.1	26.31	14.6	10.2	0.24	0.22	25.26	96	0.91
Bc	60-90	7.9	0.13	0.2	19.3	24.61	13.4	10.0	0.03	0.20	23.63	96	0.12
M		----murrum (Weather basalt) ----											
Pedon 6 - Wadgawan (*Typic Haplusterts)*													
Ap	0-20	7.3	0.14	0.6	2.87	38.31	27.8	8.8	0.15	0.29	36.77	96	0.39
Bw1	20-42	7.0	0.10	0.5	6.37	36.87	26.6	8.8	0.09	0.28	35.77	97	0.24
Bw2	42-59	7.1	0.10	0.5	5.12	34.86	26.0	7.8	0.13	0.24	34.17	98	0.37
BSS1	59-86	7.2	0.14	0.5	4.12	33.45	24.6	7.8	0.13	0.26	32.79	98	0.38
BC	86-140	7.7	0.12	0.4	14.6	34.39	24.2	7.8	0.09	0.24	32.33	94	0.26
Pedon 7 - Sarola (*Typic Haplusterts)*													
Ap	0-15	7.5	0.16	0.8	7.5	34.55	24.2	8.4	0.36	0.21	33.17	96	1.04
Bw1	15-38	7.6	0.16	0.7	8.3	40.76	23.8	15.2	0.27	0.27	39.54	97	0.66
Bw2	38-57	7.7	0.22	0.5	8.5	39.75	22.8	15.4	0.49	0.27	38.96	98	1.23
BSS1	57-80	7.9	0.24	0.4	9.0	38.36	22.0	15.0	0.38	0.22	37.60	98	0.99
BSS2	80-106	8.0	0.34	0.4	11.8	38.38	24.6	11.4	1.36	0.26	37.62	98	3.54
Bc	106-150	8.2	0.50	0.3	14.8	37.61	24.2	11.2	1.26	0.20	36.86	98	3.35
Pedon 8 - Chikhli (*Typic Haplustepts)*													
Ap	0-16	7.5	0.10	0.3	1.75	30.26	18.8	9.4	0.03	0.22	28.45	94	0.09
Bw1	16.27	7.4	0.09	0.3	12.5	28.67	17.6	8.8	0.07	0.20	26.67	93	0.24
Bc	27.40	7.7	0.82	0.1	14.8	26.93	16.2	9.0	0.04	0.08	25.32	94	0.14
M	40-52	----murrum (Weather basalt) ----											
Pedon 9 Sumbha (*Lithic Ustorthents)*													
Ap	0-15	7.2	0.11	0.5	1.03	27.41	13.8	10.6	1.35	0.29	26.04	95	4.92
Ac	15-28	7.2	0.08	0.3	0.75	27.08	14.8	10.8	0.18	0.22	26.00	96	0.66
M	28-39	7.3	0.13	0.3	0.62	25.62	13.2	11.0	0.12	0.28	24.60	96	0.46

Table 4. Quality of irrigation water of Osmanabad tahsil

Adjoining area of pedon	Location	Source	Depth (ft)	pH	Ec (dSm^{-1})	SAR	RSC ($mmolel^{-1}$)	Water quality class	Kelley's ratio
Pedon-1	Kini	Bore	150	8.3	0.28	1.7	0.5	C2S1	0.50
	Kini	Bore	150	7.9	0.34	1.7	0.8	C2S1	0.49
Pedon-2	Dhoki	Bore	400	8.2	0.60	2.6	0.7	C2S1	0.73
	Dhoki	Well	35	7.5	0.61	2.7	0.9	C2S1	0.76
Pedon-3	Ter	Bore	350	7.8	0.73	5.8	0.9	C3S1	1.63
	Ter	Bore	250	7.6	0.63	2.7	1.1	C2S1	0.78
Pedon-4	Alni	Bore	300	7.5	0.42	1.8	1.0	C2S1	0.53
	Alni	Well	38	7.9	0.48	2.0	1.2	C2S1	0.62
Pedon-5	Keshegawan	Bore	250	7.1	0.57	1.7	0.6	C2S1	0.51
	Keshegawan	Well	40	7.2	0.55	2.6	0.2	C2S1	0.75
Pedon-6	Wadgawan	Bore	250	7.2	0.97	1.5	0.4	C3S1	0.42
	Wadgawan	Well	40	7.6	0.97	2.6	1.1	C3S1	0.77
Pedon-7	Sarola	Bore	250	7.5	0.53	2.3	0.7	C2S1	0.67
	Sarola	Well	30	7.5	0.56	2.3	1.2	C2S1	0.66
Pedon-6	Chikhali	Bore	300	7.1	0.43	1.9	0.7	C2S1	0.55
	Chikhali	Bore	250	7.4	0.48	1.8	1.1	C2S1	0.55
Pedon-9	Sumbha	Bore	250	7.1	0.83	4.1	1.1	C3S1	1.29
	Sumbha	Well	45	7.1	1.13	3.9	0.8	C3S1	1.19

Table 5. Soil site suitability classes and yield of soybean and pigeonpea in Osmanabad tahsil.

Pedons	Soil site suitability class (with limitation) Sys et al. (1991) and NBSS & LUP (1994)		FAO (1983)					
	Soybean	Pigeonpea	Soybean			Pigeonpea		
			Yield (q/ha)	% yield of optimum yield (25 q ha^{-1})	Suitability class	Yield (q ha^{-1})	% yield of optimum yield (20q ha^{-1})	Suitability class
Pedon -1	N1 (dt)	N2 (dt)	7.9	30	S3	6.5	32	S3
Pedon- 2	S2 (c,t,h,w,k,p)	S2 (s,dt,e,w,k,p)	18.8	72	S2	12.5	63	S2
Pedon -3	S3 (t,h,k, p)	S2 (S,t,w,k,p)	20.8	83	S1	10.25	50	S2
Pedon- 4	N2 (dt)	N2 (dt)	10.2	40	S2	7.25	37	S3
Pedon- 5	S2 (s,t,k,p)	S2 (s.dt,e,k)	18.8	75	S2	11.25	57	S2
Pedon -6	S2 (c,dr,t,k)	S2 (s,e,t,dr,k)	21.5	86	S1	15.75	83	S1
Pedon -7	S2 (t,dr,p)	S2 (s,e,t,k,p)	23.5	94	S1	17.20	86	S1
Pedon -8	S3 (S,dt,c,w,k)	S3 (s,dt,k)	15.7	60	S2	10.00	50	S2
Pedon -9	N2 (dt)	N2 (dt)	11.5	46	S2	8.75	44	S2

Latter in parentheses show limitation as s- slope, dt- soil depth, c- coarse fragment, e- erosion , t- texture, dr-Drainage, w- plant available capacity, k- $CaCO_3$ and p- pH

Suitability class: S1 – Highly suitable, S2- moderately Suitable, S3- marginally suitable,N1- currently not suitable and N2- unsuitable.

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EFFICACY OF ENTOMOPATHOGENIC FUNGAL PESTICIDES UNDER LABORATORY CONDITION AGAINST *Spodoptera litura*

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ABSTRACT

An experiment was conducted to evaluate the efficacy of entomopathogenic fungi *viz.*, *Beauveria bassiana* and *Metarrhizium anisopliae* under laboratory condition against the larvae of *Spodoptera litura* at entomology Section, College of Agriculture, Nagpur during the year 2010 (*kharif*). Four concentrations of each of the entomopathogens were used along with the untreated control to determine the LC_{50} and LC_{90} as well as LT_{50} and LT_{90} for both the pathogen against $2^{nd}/3^{rd}$ instar larvae of *Spodoptera litura.*

The results revealed that the LC_{50} value of *Beauveria bassiana* was 5.0 x 10^4 spores ml^{-1} as against LC_{50} of *Metarrhizium anisopliae* was 6 x 10^4 spores ml^{-1}. The LT_{50} was also the least (4.05 days) at the same concentration for LC_{50} in case of *B.bassiana.* The LT_{50} of 4.60 days was the least in case of *M. anisopliae.* Thus, it is clear that, *M. anisopliae* was less effective than *B.bassiana*.

(Key Words: *Spodoptera litura*, Entomopathogenic Fungi, *Beauveria bassiana, Metarrhizium anisopliae,* $LC_{50,}$ $LC_{90,}$ $LT_{50,}$ LT_{90})

INTRODUCTION

Soybean (*Glycine max* L. Merrill) possesses a very high nutritional value. Soybean agro - system is being adopted rapidly by farmers of Vidarbha and it became second major *kharif* crop.

The luxuriant growth of soybean provide an unlimited source of food, space and shelter to insects (Jayappa *et al*., 2003). Farmers are facing severe problem of lepidopteran pests of soybean and *Spodoptera litura* is one of the insect pests causing great loss to soybean crop in Vidarbha now a days.

At present, synthetic insecticides have been used extensively to overcome the pest problems, but indiscriminate use of these chemicals resulted in numbers of problems *viz.,* the development of insect resistance to insecticides, induced resurgence of insect pest, environmental pollution and toxicity to non-target animals (Dodia *et al.,* 2008).

An attractive alternative method to chemical pesticides is the microbial biocontrol (MBCAs) agents. They are the natural enemies devastating the pest population with no hazardous effects on human health and the environment. Entomopathogenic fungi have an important position among all the biocontrol agents because of their route of pathogenicity, broad host range and ability to control both sap sucking as well as insect pest with chewing mouthparts (Khan *et al., 20*12).

The fungus, *M. anisopliae* has been found pathogenic causing mycosis and substantial mortality in tobacco leaf eating caterpillar, *Spodoptera litura* in groundnut field in Karnataka, India (Siddaramaiah *et al.,* 1986).

Utilization of bioagents can help in solving ecological problems resulting from toxic pesticides and manage the pest population efficiently. By considering the benefits and potential of microbials, an experiment was conducted to evaluate the efficacy of entomopathogenic fungi under laboratory condition on the larvae of *S.litura* .

MATERIALS AND METHODS

The present investigation on laboratory evaluation of entomopathogenic fungi against *Spodoptera litura* was undertaken in the Insectary Premises of Entomology Section, College of Agriculture, Nagpur during the *kharif* season of 2010.

On the basis of monitoring, $2^{nd}/3^{rd}$ instar healthy larvae of the *Spodoptera litura* were collected from untreated field of soybean in plastic containers when its peak larval population was observed. These field collected larvae were subjected to bioassay to determine the LC_{50} and LC_{90} as well as LT_{50} and $LT_{90.}$

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The field doses of the fungal suspension were decided as per the LC_{90} value, as 1 x 10^8 spores ml^{-1} reported earlier for *M. anisopliae* (Wadyalkar, 2001) and 1 x 10^7 spores ml^{-1} for *B. bassiana* (Easwaramoorthy and Santhalakshmi, 1993). Two higher doses than LC_{90} were considered for laboratory evaluation along with lower doses to have four concentrations of each bioagent alongwith one unprotected control.

The treatment details are as given below. These treatments were replicated thrice.

T_1 *M. anisopliae* (1 x 10^7 spores ml^{-1})
T_2 *M. anisopliae* (1 x 10^8 spores ml^{-1})
T_3 *M. anisopliae* (1 x 10^9 spores ml^{-1})
T_4 *M. anisopliae* (1 x 10^{10} spores ml^{-1})
T_5 *B.bassiana* (1 x 10^7 spores ml^{-1})
T_6 *B.bassiana* (1 x 10^8 spores ml^{-1})
T_7 *B. bassiana* (1 x 10^9 spores ml^{-1})
T_8 *B. bassiana* (1 x 10^{10} spores ml^{-1})
T_9 Control (Water spray)

Culture of entomopathogenic fungi were obtained from Pathology Section, College of agriculture, Nagpur.

For standardization of the fungal suspension, 20 g each inoculated medium with respective fungus was mixed in 70 ml sterilized distilled water in a separate flask. Thus, the mixture prepared was kept in rotary mixer for homogenization. The homogenate was screened through muslin cloth followed by Whatman No.1 filter paper. Final volume of 100 ml as a stock solution (1 x 10^{10} spores ml^{-1}) was made by adding sufficient quantity of sterilized distilled water.

The fungal suspension containing the spores of *M. anisopliae and B. bassiana* were obtained from stock solution, diluted separately upto 1:1000; with serial dilution method and were observed under phase contrast microscope for spore count with the help of Neaubaur's haemocytometer.

A set of 30 larvae of *S. litura* were kept separately in petriplate for each of the nine treatments. Then these larvae were topically treated with 2 ml fungal suspension of desired concentration with the help of Potter's tower. Distilled water was used for spraying the larvae in an untreated control. The sprayed petridish containing the insects were allowed to dry for 5 minutes. Then these treated larvae were transferred to plastic vials containing natural diet (soybean leaves) daily and incubated at 25 ± 1ºC temperature (Khan *et al.,* 1993). The larval body showed white mycelial growth i.e. disease symptom of white muscardine fungus within few days.

Observations on larval population reduction of *Spodoptera litura* :

The larval mortality was recorded on 3rd, 5th, 7th and 10th day from initiation of treatment, regarding development of disease. The moribund larvae, not giving any response were also considered as dead. From these observations, per cent larval mortality was calculated. Mortality was corrected by using Abbott's formula (Abbott, 1925 and Phokela *et al.,* 1997).

$$\text{Per cent larval Mortality} = \frac{\text{Pre- treatment population} - \text{post- treatment population}}{\text{Pre - treatment population}} \times 100$$

$$\text{Corrected mortality} = \frac{T - C \times 100}{100 - C}$$

Where,
T - % mortality in the treatment
C - % mortality in the control

The mortality data, thus, obtained was subjected to probit analysis (Finney, 1964) and the LC_{50}, LC_{90}, LT_{50} and LT_{90} values were worked out.

RESULTS AND DISCUSSION

LC_{50} and LC_{90} of entomopathogenic fungi:

The results obtained on LC_{50} and LC_{90} (Table 1) revealed that, the LC_{50} (5.0 x 10^4 spores ml^{-1}) as well as LC_{90} (5.8 x10^8 spores/ml) of *B. bassiana* against *S. litura* larvae was superior over LC_{50} (6.0 x 10^4 spores ml^{-1}) and LC_{90} (1.8 x 10^{10} spores ml^{-1}) of *M. anisopliae* against *S. litura*. The present results are comparable with the findings of following scientists.

Tambe *et al.* (2003) reported in the pathogenicity studies of *B. bassiana* that LC_{50} values were 4.14 x 10^4, 2.34 x 10^5 and 4.67 x 10^6 spores ml^{-1} for 2nd, 3rd and 4th instar larvae of *H. armigera,* respectively.

Nandanwar (2009) reported LC_{50} of *B. bassiana* as 2.188 x 10^3 spores ml^{-1} and LC_{90} as 8.11 x 10^8 spores ml^{-1}. While LC_{50} and LC_{90} of *M. anisopliae* were reported to be 4.786 x 10^3 spores ml^{-1} and 2.884 x 10^{14} spores ml^{-1} against *Plutella xylostella*.

Table 1. Probit analysis results on LC_{50} and LC_{90} values against *S. litura*

Treatments	LC_{50} spore ml^{-1}	Fiducial limit	LC_{90} spore ml^{-1}	Fiducial limit	Chi Square (Cal.)
M.anisopliae	6.0×10^{4}	1×10^{4} to 1.7×10^{6}	1.8×10^{10}	2.1×10^{9} to 3.2×10^{13}	0.033
B. bassiana	5.0×10^{4}	1×10^{4} to 1.0×10^{6}	5.8×10^{8}	1.5×10^{8} to 6.7×10^{9}	0.461

Table 2. Probit analysis result on LT_{50} and LT_{90} values against *S. litura*

Treatments	LT_{50} (days)	Fiducial limit	LT_{90} (days)	Fiducial limit	Chi square(cal.)
T_1 – *M.anisopliae*@10^{7} spores ml^{-1}	5.72	5.03 to 6.49	18.16	13.77 to 29.34	0.813
T_2 – *M.anisopliae*@10^{8} spores ml^{-1}	5.28	4.66 to 5.91	15.25	12.11 to 22.27	0.862
T_3 – *M.anisopliae*@10^{9} spores ml^{-1}	4.89	4.31 to 5.46	13.43	10.96 to 18.59	2.053
T_4–*M.anisopliae*@10^{10} spores ml^{-1}	4.60	4.06 to 5.11	11.79	9.89 to 15.46	4.071
T_5 – *B.bassiana*@10^{7} spores ml^{-1}	5.09	4.47 to 5.72	15.05	11.93 to 22.15	1.154
T_6 – *B.bassiana*@10^{8} spores ml^{-1}	4.90	4.24 to 5.52	15.24	11.94 to 23.07	0.946
T_7 – *B.bassiana*@10^{9} spores ml^{-1}	4.50	3.98 to 4.97	11.03	3.97 to 14.07	3.525
T_8 – *B.bassiana*@10^{10} spores ml^{-1}	4.05	3.57 to 4.47	9.16	8.01 to 11.13	5.807

LT_{50} and LT_{90} of entomopathogenic fungi:

The data regarding LT_{50} and LT_{90} are presented in table 2 against *S. litura.* Data revealed that, *B. bassiana* @ 1 x 10^{10} spores ml^{-1} had resulted into the lowest LT_{50} (4.05 days) and LT_{90} (9.16 days) and thus was most effective against *S. litura* which was followed by the treatment, *B. bassiana* @ 1 x 10^9 spores ml^{-1} with LT_{50} of 4.50 days and LT_{90} of 11.03 days, *M. anisopliae* @ 1 x 10^{10} spores ml^{-1} with LT_{50} of 4.60 days and LT_{90} of 11.79 days, *M. anisopliae* @ 1 x 10^9 spores ml^{-1} with LT_{50} of 4.89 days and LT_{90} of 13.43 days, *B. bassiana* @ 1 x 10^8 spores ml^{-1} with LT_{50} of 4.90 days and LT_{90} of 15.24 days, *B. bassiana* @ 1 x 10^7 spores ml^{-1} with LT_{50} of 5.09 days and LT_{90} of 15.05 days, *M. anisopliae* @ 1 x 10^8 spores ml^{-1} with LT_{50} of 5.28 days and LT_{90} of 15.25 days and *M. anisopliae* @ 1 x 10^7 spores ml^{-1} with LT_{50} of 5.72 days and LT_{90} of 18.16 days.

Zhang *et al.* (1997) reported that 2 strains (M_2 and M_4) of *Metarrhizium spp*. were pathogenic to fourth instar larvae of *Dendroliumus punctatus.* The LT_{50} was 6.19 to 12.20 days at the conc. of 1.0 x 10^{11} to 1.0 x 10^7 spores ml^{-1}.

Patil (2002) reported LT_{50} value of 79.43 to 123.02 hrs. at the conc. 2.26 x 10^{10} to 2.26 x 10^6 spores ml^{-1}. Similar trend of decrease in mortality in his investigation against different instars of *H. armigera* with fungal suspension of *M. anisopliae* was also observed.

Fungal concentration is directly proportional with mortality, as the concentration increases, the mortality increases and vice versa. On the other hand lethal time is inversely proportional with concentration i.e. when concentration increases lethal time decreases and vice versa.

From these results, it could be inferred that, *B. bassiana* was more effective than *M. anisopliae* against *S. litura* with the lower fungal concentration required to 50% larval mortality as compared to *M. anisopliae*.

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