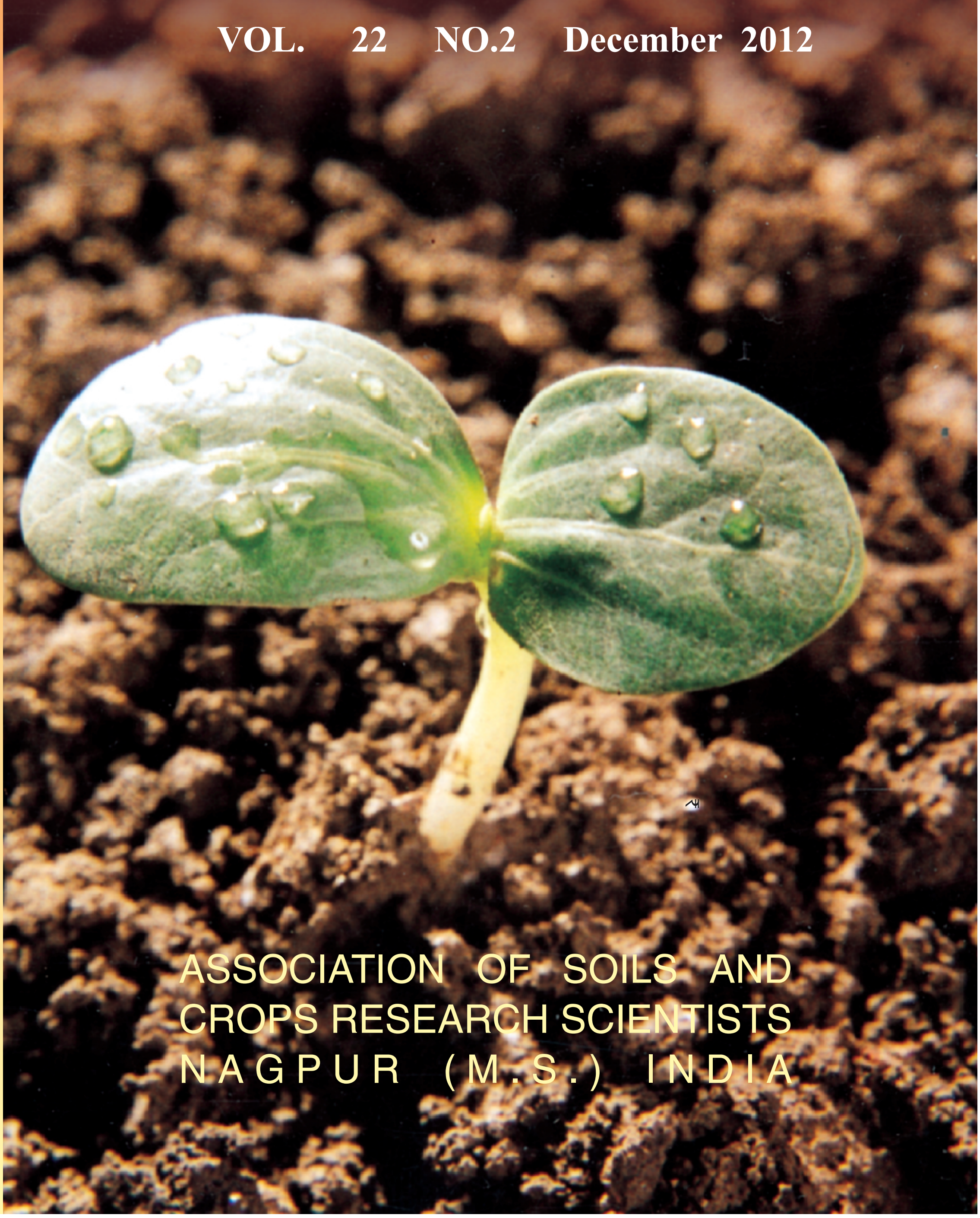
ISSN 0971-2836

JOURNAL OF SOILS & CROPS

VOL. 22 NO.2 December 2012



ASSOCIATION OF SOILS AND CROPS RESEARCH SCIENTISTS
NAGPUR (M.S.) INDIA

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JOURNAL OF SOILS AND CROPS

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(Six Monthly Research Journal Registered with the Registrar of Newspapers of India
No. 042515 / 30 / AU / TC / 91)

Published By : **Association of Soils and Crops Research Scientists**
21 Anand Nagar, Atrey Lay-out, Near Datta Meghe College, Ranapratap Nagar Post Office Nagpur,440022 (M.S.) India. Tel : 0712-2235023

Composed by : Tuljai Graphics, C-5 Neelkamal Aprt. Bajaj Nagar Nagpur -10.
Printed at : Sukhkarta Printers, 62, Bajaj Nagar, Nagpur.

Journal of Soils and Crops

Volume 22 Number 2 December 2012

C O N T E N T S

J. Soils and Crops 22 (2) 216-225, Dec., 2012 ISSN 0971-2836

CHARACTERIZATION AND CLASSIFICATION OF THE SOILS OF MALWA PLATEAU IN BANSWARA DISTRICT OF RAJASTHAN

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ABSTRACT

Typical pedons representing major landforms of Malwa plateau transect of Banswara district viz., hill top, side slope, foot slope, undulating pediment, moderately sloping pediment, gently sloping pediment and very gently sloping alluvial plain, developed from basalt and occurring at different elevations under varying land use were studied during 2005 for their morphological, physical and chemical characteristics and then classified. Soils were shallow to deep, slightly acidic to neutral (pH 6.4-7.3), rich in organic carbon, high CEC and base saturation. Soils were classified as lithic ustorthents, vertic haplustepts, lithic haplustepts and typic haplusterts. All soils were low in available nitrogen while soils of lithic ustorthents and typic haplusterts were low in available phosphorus whereas soils of vertic haplustepts and lithic haplustepts were medium in available phosphorus and all soils were medium to high in available potassium except typic haplusterts which was high in available potassium. All the soils were rich in DTPA- extractable iron and manganese and the status of copper and zinc were above the critical limits. Based on the rationale of critical limits of different workers, the soils were categorized as deficient in Fe (<4.5 mg kg^{-1}), Mn (<1.0 mg kg^{-1}), Cu (<0.2 mg kg^{-1}) and Zn (<0.6 mg kg^{-1}). All the soils were observed to be sufficient in available Fe, Mn, Cu and Zn.

(Key words*:* Malwa plateau, morphological, physical and chemical characteristics, soil classification)

INTRODUCTION

Soil is the most precious natural resources. Maintaining soils in a condition of high productivity on sustainable basis is important for meeting the basic needs of the people. Therefore, knowledge of soils with respect to their extent, distribution, characteristics and potential use is important for optimizing land use. It is still more important for hilly district like Banswara, which is highly prone to the tremendous loss of soil and plant nutrients due to undulating sloping landscape and exploitation of natural resources like soils and forests. Banswara district is the south most district of Rajasthan, covering 6.7 per cent of the geographical area of the state (34.28 m ha). Primarily people are resources poor and depend on agriculture for their day to day life. The district comprise of hill range, denuded hills, piedmont plain, valley, undulating plain and escarpments dissected hill. The soils on these land forms range from very shallow to deep, gravelly sandy loam to clayey, excessive to moderately well drained. These soils were affected with various kind of degradation e.g. deterioration in vertic properties, lack of argillions in argillic horizon particularly in paddy growing area of the district. Keeping these factors in mind, the study was undertaken to characterize and classify the soils under different land forms in the Banswara district of Rajasthan.

MATERIALS AND METHODS

The study area lies between 23°10' 26" to 23°31' 5" N latitudes and 74° 20' 34" to 74° 39' 20" E longitudes encompassing Malwa plateau area in southern part of Rajasthan with attitude ranging from 140 to 425 m above mean sea level (amsl). The average annual rainfall is 972 mm and the climate of the area is semi- arid characterized by extremes of temperature and low wind velocity. The mean annual temperature varied from 10.3°C to 42°C. The temperature regime of the area is hyperthermic. The area comprises hills, undulating pediments, undulating plain, alluvial plain with basalt as an igneous parent rock. The soil moisture regime is "Ustic".

Ten typical pedons representing major landforms of the area viz., hill top, side slope, foot slope, undulating pediment, moderately sloping pediment, gently sloping pediment and very gently sloping alluvial plain were studied in detail. The site characteristics of the pedons are presented in table 1. The pedons were exposed during January 2005 and studied morphomatric properties of the soils as per the procedure outlined in the Survey Mannual

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(Anonymous, 1995). Horizon wise samples were collected for detailed characterization. The physical and chemical characteristics of the soils including pH (Richards, 1954), organic carbon (Jackson, 1987), CEC (Richards, 1954), organic carbon (Jackson, 1987), CEC (Richards, 1954), base saturation and available nutrients were carried out by following standard methods. The available nitrogen was estimated through alkaline permanganate method as suggested by Subbiah and Asija (1956). Available phosphorus was determined by Olsen method (Olsen *et al.,* 1954) and available potassium was estimated by flame photometer after extraction with neutral normal ammonium acetate solution (pH 7.0). The available iron, manganese, zinc and copper were extracted using DTPA (Lindsay and Norvell, 1978) and their concentrations were determined using atomic absorption spectrophotometer. The soils were classified according to Key to Soil Taxonomy (Anonymous, 1998).

RESULTS AND DISCUSSION

Morphological characteristics :

The colour (Table 2) of the surface horizon was dark brown (Pedon 1, 2, 3), very dark brown (Pedon 7 and 8), raddish brown (Pedon 4), dark raddish brown (Pedon 10), dark yellowish brown (Pedon 6), black (Pedon 9) and dark grey (Pedon 5). The dark colour of pedons was mainly due to the complexation of humus with mineral matter. The grey colour (10 YR 3/1) of pedon 5 indicated poor drainage condition. The depth of pedon (Table 2) varied from very shallow to very deep. The soils of hill top (P1) and undulating pediment(P4) were very shallow and soils of side slope (P2), foot slope(P3) and very gently sloping alluvial plain(P9 and P10) were shallow while soils of gently sloping pediment(P6, P7 and P8) were moderately deep to very deep. Gentle to moderate slope, rapid runoff and severe erosion account for very shallow to shallow soils on the elevated segment of transect. The soil texture of the pedons varied from clay loam to clayey. Structure of the soils mainly remained sub angular blocky, except in the lower layer of the foot slope and moderately sloping pediment soils (Pedon 3 and 5) where it was massive. Except pedons 3, 4, 7 and 8, the rest showed fine and coarse gravels and stones in the lower layers which usually increased with depth.

Physical characteristics:

The sand content ranged from 12.49 to 41.28 per cent (Table 3) and was the highest in the soils of hill top (41.28%). The clay content ranged from 35.12 to 62.17 per cent and the highest was in the soils of gently sloping pediment (P6, P7 and P8). Clay content, in general, increased with depth in all pedons except soils of foot slope (P3) where it has decreased. The higher clay content in the soil down the slope was also reported by Sarkar *et al.* (2001). These soils were developed over basalt and hence produced higher amount of clay (Bhattacharyya *et al.,* 1993 and Eswaran *et al.,* 1988) under prevailing pedo-environment. Sankar *et al.* (2010) also reported similar trend of distribution of clay in soils of Kutturavupatti village of Sivagangai district of Tamil Nadu.

Water holding capacity and moisture storage at 0.03 MPa and 1.5 MPa were higher in surface layer as compared to subsoil. They were higher in the soils of gently sloping pediment (P8) as compared to other soils. The variations in moisture retention were mainly due to the variations in organic matter and clay contents of these soils. The available water storage capacity was also high in the soils of gently sloping pediment as compared to other soils. These differences were due to the variation in the depth, clay and organic matter content of the pedons. Available water content (AWC) was found to be positively and significantly correlated with clay ($r = 0.733^{**}$) and organic matter ($r = 0.502$).

Chemical characteristics:

The pH of the soils ranged from 6.4 to 7.3 and generally increased with depth and slope (Table 4). The relatively higher pH in soils of gently sloping pediment (P8) and very gently sloping alluvial plain (P9 and P10) might be due to basalt as the parent material. The pH also increased down the slope (Datta *et al.,* 1990 and Deshmukh and Bapat, 1993). Similar results were also observed by Sarkar *et al.* (2002) who observed gradual increase in pH with depth in soils of Loktak catchment area of Manipur. The organic carbon content varied from 0.52 to 1.36 per cent through depth being higher in surface layer than in subsurface horizon. These findings are in conformity with the finding of Likhar and Prasad (2011) who noticed that the soils of Nagpur district showed the higher organic carbon in surface layers than underlying horizons. Patil and Prasad (2004) also reported that relatively higher pH in soils of P1 might be due to basalt as parent material and higher organic carbon content in surface layer as compared subsurface layer in soils of Dindori district of Madhya Pradesh. The CEC of the soils varied from 20.50 to 38.10 Cmol(p+) kg^{-1}. The higher CEC observed in soils of gently sloping pediment (P8) followed by soils of foot slope (P3). The relatively low CEC in soils of hilltop (P1) and undulating pediment (P4) was the reflection of parent material and higher degree of weathering leading to depletion of bases. However, CEC was found to be positively and significantly correlated with clay (r = 0.972**) and organic carbon (r = 0.425**) content. The base saturation of soils ranged from 89.45 to 99.33 per cent.

Soil Classification:

Based on morphology and soil properties, soils have been classified according to Soil Taxonomy (Anonymous, 1998) into the order Entisols (pedon 1, 2, 3, 4, 6, 9 and 10) with no diagnostic horizon and Inceptisols (pedon 5 and 7) having diagnostic cambic horizon and Vertisols (pedon 8) having slickenside, was the important feature. The soils of pedon 1, 2, 3, 4, 6, 9 and 10 could not qualify for psamments and fluents suborder, consequently placed in Orthents. Based on the soil moisure regime, the soils of pedon 5, 7 and 8 were classified as a member of Ustepts and Usterts suborder, respectively. The ustic moisture regime was considered for bringing down the soil of orthants to the ustorthents at great group level. Since ustepts and usterts do not qualify for any other great group within suborder, consequently, these have been placed in Haplustepts and Hapluserts great group of their respective suborder.The presence of rock within 50 cm of the soil profile was the criteria to separate the soils of pedon 1, 2, 3, 4, 6, 9 and 10 from other ustorthents to lithic ustorthents at the sub group level. The soils of pedon 8 belonging to the Haplusterts great group also represent the central concept, consequently qualify for Typic Haplusterts, sub group of vertisols soil order. The remaining pedons 5 and 7 belonging to the Haplustepts great group, the pedon 5 represent Vertic Haplustepts while pedon 7 belongs to Lithic Haplustepts subgroup of Inceptisols soil order.

Based on the particle size class, hyper thermic soil temperature regime, mixed mineralogy class, soils were further taken down to the lowest texa of soil taxonomy, soil family. According these features, soils of pedon 1, 2, 3, 4, 6, 9 and 10 have been classified as a member of clayey skeletal mixed hyperthermic soil family of Entisols soil order. The pedon 5 and 7 were classified as a member of fine smectite hyperthermic and clayey smectite hyperthermic soil family, respectively of Inceptisols soil order. The pedon 8 was classified as a fine smectite hyperthermic family of Typic Haplustersts subgroup of Vertisols soil order.

Nutrient status and Soil fertility:

Macronutrients: Soil fertility exhibits the status of different soils with regard to the amount and availability of elements essential for plant growth. The available nitrogen content of the soils of Lithic ustorthents varied from 103.48 to 232.06 kg ha^{-1} with mean value 183.62 kg ha^{-1} and Typic haplustert varied from 144.25 to 175.61 kg ha^{-1} with mean value 159.30 kg ha^{-1} whereas soils of Vertic haplustept varied from 109.76 to 166.2 61 kg ha^{-1} with mean value 144.76 kg ha^{-1} and Lithic haplustepts varied from 103.48 to 116.03 kg ha^{-1} with mean value 110.80 kg ha^{-1}. All soils were low in available nitrogen due to its use for cultivation and plantation purpose. Relatively higher content of available nitrogen was found in soils of Lithic ustorthents and Typic haplustert as compared to soils of Vertic haplustept and Lithic haplustepts. This might be due to presence of vegetation which in turn resulted in a higher organic carbon content of these soils and a higher status of available nitrogen. This could be attributed to organic carbon which has a high correlation with available nitrogen. While Vertic haplustept and Lithic haplustepts, the soils were subjected to intensive cultivation, encouraging the oxidation of organic carbon. These findings are corroborated with the finding of Sarkar e*t al*. (2002) who observed that the higher content of nitrogen in soils of Loktak Catchment area of Manipur which might be due to high organic matter content.

Available phosphorus content in soils of Lithic ustorthents varied from 14.25 to 19.95 kg ha^{-1} with mean value of 17.33 kg ha^{-1} and Typic haplustert varied from 17.65 to 20.50 kg ha^{-1} with mean value of 19.16 kg ha^{-1} whereas soils of Vertic haplustept and Lithic haplustepts varied from 19.10 to 21.15 kg ha^{-1} (20.0 kg ha^{-1}) and from 18.74 to 21.24 kg ha^{-1} (20.26 kg ha^{-1}), respectively. The soils were low in available phosphorus which might be due to its fixation by free oxide and exchangeable aluminum. Higher amount of phosphate in the soils of Vertic haplustept and Lithic haplustepts might be due to the presence of free iron oxide and exchangeable aluminium in smaller amount. These obsevations are in accordance with the findings of Sarkar *et al.* (2002) who reported that higher amount of phosphate in the plain land soil of Loktak Catchment area of Manipur. The soils of Vertic haplustept and Lithic haplustepts were positioned on lower topographic position. Variation in available phosphorus content may be attributed to the erosion in pedon positioned at higher elevation and deposition of alluvial materials from the surrounding in the pedons located in the valley or plains. Sharma (1994) had also reported an increase in available phosphorus content with the descending slope in soils of southern Rajasthan.

Available potassium content in soils of Lithic ustorthents and Typic haplustert, varied from 190.40 to 728.0 kg ha^{-1} with mean value of 405.68 kg ha^{-1} and from 347.20 to 436.80 kg ha^{-1} with mean value of 385.0 kg ha^{-1}, respectively. The soils of Vertic haplustept and Lithic haplustepts, the content of available potassium were low (mean value 250.13 and 306.13 kg ha^{-1}) as compared to soils of Lithic ustorthents and Typic haplustert. The surface soils of all most all pedons were generally rich in potassium content which might be because of management practices followed in cultivated soils and addition of crop residues. These findings are in conformity with the finding of Khan *et al.* (1997) who noticed that the higher concentration of available potassium was found in upper horizon of the pedons in some Benchmark soils of Bangladesh. Sarkar *et al.* (2002) also reported that higher content of available potassium in hill soils and it was decreased with depth in soils of Loktak Catchment Area of Manipur.

Micronutrients: The DTPA- extractable Fe content ranged from 6.34 to 54.71 mg kg^{-1} (Table 5) and it was high in the soils of Lithic ustorthents (39.76 mg kg^{-1}) followed by Vertic haplustept (23.52 mg kg^{-1}), Lithic haplustepts (18.50 mg kg^{-1}), and Typic haplustert (17.84 mg kg^{-1}). The available Mn content varied from 2.42 to 57.64 mg kg^{-1} (Table 5). It was the highest in Lithic ustorthents (40.05 mg kg^{-1}) followed by Vertic haplustept (35.10 mg kg^{-1}), Lithic haplustepts (33.79 mg kg^{-1}), and Typic haplustert (25.48 mg kg^{-1}). There was no definite pattern with respect to its distribution with depth as well as slope. These findings are corroborated with the finding of Nayak *et al.* (2000) who was noticed that no regular distribution pattern of manganese in Alluvial soils of Arunachal Pradesh. The high Fe and Mn contents in soils might be due to ferro-magnesium minerals present in parent material.

The DTPA- extractable Cu ranged from 1.20 to 7.19 mg kg^{-1} (Table 5). The all soils were sufficient in available copper. It was the highest in Typic haplustert (5.07 mg kg^{-1}) followed by Vertic haplustept (4.65 mg kg^{-1}), Lithic haplustepts (3.97 mg kg^{-1}) and Lithic ustorthents (3.80 mg kg^{-1}). Available Zn content was sufficient and ranged from 1.01 to 5.10 mg kg^{-1} (Table 5). In all the surface layers, the available Zn was higher than critical limit (0.6 ppm). It was highest in Lithic ustorthents (2.42 mg kg^{-1}) followed by Lithic haplustepts (2.34 mg kg^{-1}), Vertic haplustept (2.21 mg kg^{-1}) and Typic haplustert (1.55 mg kg^{-1}). In general, higher contents of DTPA-extractable cations were observed in surface than in the sub-surface layers. Ghosh *et al.* (2010) also reported similar trend of distribution in some soils of hot dry sub humid agro-ecological zone of West Bengal.

Based on the rationale of critical limits of different workers, the soils were categarised as deficient in Fe (<4.5 mg kg^{-1}), Mn (<1.0 mg kg^{-1}), Cu (<0.2 mg kg^{-1}) and Zn (<0.6 mg kg^{-1}). All the soils were observed to be sufficient in available Fe, Mn, Cu and Zn.

Table 1. Site characteristics of the soils

Pedons	Location	Elevation (m) above msl	Parent Material	Slope (%)	Erosion	Drainage	Land use
			Hilltop				
P_1	23°10'26" N 74°20' 34" E	350	Basalt	30-50	Very severe	Somewhat excessive	Degraded uncultivable
			Side slope				
P_2	23°10' 26"N 74°20' 34" E	325	Basalt	30-50	Very severe	Somewhat excessive	Degraded uncultivable
			Foot slope				
P_3	23°10'26" N 74°20' 34" E	275	Basalt	30-50	Very severe	Somewhat excessive	Degraded uncultivable
			Undulating pediment				
P_4	23°30'43" N 74°35' 26" E	375	Basalt	3-8	Severe	Somewhat excessive	Barren
			Moderately sloping pediment				
P_5	23°21' 18"N 74°27' 25" E	390	Basalt	3-8	Moderate	well	Cultivated single crop
			Gently sloping pediment				
P_6	23°16' 39"N 74°29' 52" E	410	Basalt	3-8	Moderate	Somewhat excessive	Degraded pasture/grazing
P_7	23°27' 29"N 74°31' 8" E	310	Basalt	3-8	Moderate	well	Cultivated single crop
P_8	23°31' 5" N 74°39' 20" E	375	Basalt	3-8	Moderate	well	Cultivated double crop
			Very gently sloping alluvial plain				
P_9	23°10' 47"N 74°22' 31" E	325	Basalt	1-3	Moderate	well	Cultivated double crop
P_{10}	23°17' 18"N 74°25' 1" E	190	Basalt	1-3	Moderate	Somewhat excessive	Cultivated double crop

Table 2. Morphological characteristics

Horizon	Depth (cm)	Boundary	Colour (moist)	Texture	Gravel volume (%)	Structure	Consistence			Roots
							D	M	W	
Pedon-1:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents										
All	0-30	cs	10YR 2/2	gcl	50-60	$m_1$sbk	h	fr	sp	mc
Pedon-2:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents										
All	0-22	ds	10YR2/1	gc	40-50	$m_2$sbk	h	fr	sp	mm
C1	22-45	cs	10YR 2/1	gc	70-80	massive	h	fr	sp	cc
Pedon-3:Clayey- skeletal, mixed hyperthermic VerticUstorthents										
AP	0-17	ds	10YR 2/1	gc	-	$m_2$sbk	h	fr	sp	mm
C12	17-45	ds	10YR 2/1	gc	-	massive	h	fr	sp	cc
Pedon-4:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents										
All	0-25	cs	5YR 3/3	gcl	-	$f_2$sbk	h	fr	sp	ff
Pedon-5:Fine, smectite, hyperthermic Vertic Haplustepts										
AP	0-21	ds	10YR 3/1	c	10-15	$m_3$abk	h	fi	sp	ff
B21	21-40	cs	10YR 3/1	c	10-15	$m_3$abk	h	fi	sp	ff
B31	40-60	cs	10YR 3/4	c	30-40	massive	h	fi	sp	cc
Pedon-6:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents										
Al	0-20	cs	5YR 2.5/2	gcl	40-50	$m_2$sbk	h	fr	sp	mc
Pedon-7:Clayey, smectite, hyperthermic Lithic Ustorthents										
AP	0-15	ds	10YR 2/1	c	-	$m_2$sbk	h	fr	sp	ff
B21	15-30	cs	10YR2/1	c	-	$m_2$sbk	h	fr	sp	ff
BC	30-50	cs	10YR3/3	gc	-	massive	h	fr	sp	ff
Pedon-8:Fine, smectite, hyperthermic Typic Haplusterts										
AP	0-23	ds	10YR 2/1	c	-	$m_2$sbk	h	fr	sp	mc
A12	23-45	cs	10YR 2/1	c	-	$m_2$sbk	h	fr	sp	mc
A13	45-68	ds	10YR 2/1	c	-	$m_2$sbk	h	fr	sp	mc
A14	68-100	cs	10YR 2/1	c	-	$m_2$sbk	h	fr	sp	mc
A15	100-130	ds	10YR 2/1	c	-	$m_2$sbk	h	fr	sp	mc
Pedon-9:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents										
AP	0-30	cs	10YR 2/1	gc	40-50	$m_2$sbk	h	fr	sp	fc
Pedon-10:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents										
AP	0-20	cs	5YR 3/3	gcl	30-40	$m_2$sbk	h	fr	sp	mm

Boundary: c- clear, d- diffuse, s- smooth
Texture: c- clay, l- loam, g- gravelly
Structure: m- medium, f- fine, 2- moderate, sbk- subangular blocky
Consistence: h- hard, fr- friable, fi- firm, s- sticky, p- plastic
Roots: mc- medium common, ff- fine few, cc- coarse common, fc- fine common

Table 3. Physical characteristics of the soils

Horizon	Depth (cm)	Coarse fragments	Particle size distribution (%)			Bulk density (Mgm^{-3})	Moisture retention (m^3/m^3) on suction	
			Sand	Silt	Clay		0.03 MPa	1.5 MPa
Pedon-1:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents								
All	0-30	50-60	41.28	22.19	36.53	1.24	0.19	0.07
Pedon-2:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents								
All	0-22	40-50	35.93	23.09	40.98	1.20	0.24	0.08
C1	22-45	70-80	34.95	21.76	43.29	ND	0.28	0.11
Pedon-3:Clayey- skeletal, mixed hyperthermic Vertic Ustorthents								
AP	0-17	-	30.21	22.55	47.24	1.22	0.32	0.12
C12	17-45	-	29.12	26.86	44.02	ND	0.29	0.08
Pedon-4:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents								
All	0-25	-	37.27	27.62	35.12	1.49	0.35	0.15
Pedon-5:Fine, smectite, hyperthermic Vertic Haplustepts								
AP	0-21	10-15	19.80	30.35	49.85	1.30	0.37	0.12
B21	21-40	10-15	22.14	26.76	51.10	1.38	0.44	0.13
B31	40-60	30-40	22.73	27.31	49.96	1.33	0.42	0.15
Pedon-6:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents								
Al	0-20	40-50	36.34	25.39	38.27	1.26	0.37	0.13
Pedon-7:Clayey, smectite, hyperthermic Lithic Ustorthents								
AP	0-15	-	22.80	27.93	49.27	1.45	0.38	0.12
B21	15-30	-	20.18	27.32	52.50	1.47	0.45	0.15
BC	30-50	-	24.42	22.47	54.10	1.78	0.49	0.17
Pedon-8:Fine, smectite, hyperthermic Typic Haplusterts								
AP	0-23	-	16.41	29.13	54.46	1.28	0.53	0.20
A12	23-45	-	12.49	35.31	52.20	1.37	0.54	0.20
A13	45-68	-	14.28	29.98	55.74	1.54	0.61	0.22
A14	68-100	-	14.68	23.15	62.17	1.58	0.72	0.25
A15	100-130	-	19.23	23.57	57.20	1.55	0.68	0.22
Pedon-9:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents								
AP	0-30	40-50	23.89	21.77	54.34	1.18	0.48	0.16
Pedon-10:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents								
AP	0-20	30-40	32.72	27.06	39.82	1.61	0.33	0.15

Table 4. Chemical characteristics of the soils

Horizon	Depth (cm)	pH (1:2)	Organic carbon (g kg^{-1})	Exchangeable cations				Sum of cations	CEC	BS (%)
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}			
				(C mol (p^{+}) kg^{-1})						
Pedon-1:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents										
All	0-30	6.4	12.3	13.10	6.43	0.48	0.75	20.76	22.40	92.67
Pedon-2:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents										
All	0-22	6.4	11.5	16.54	8.77	0.63	0.90	26.84	27.90	96.20
C1	22-45	6.5	9.2	17.68	8.45	0.51	0.84	27.48	28.20	97.44
Pedon-3:Clayey- skeletal, mixed hyperthermic Vertic Ustorthents										
AP	0-17	6.5	10.2	21.14	9.67	0.76	0.73	32.30	33.60	96.13
C12	17-45	6.6	9.1	20.75	8.32	0.68	0.79	30.54	32.30	94.55
Pedon-4:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents										
All	0-25	6.7	5.5	12.18	6.12	0.22	0.73	19.25	20.50	93.90
Pedon-5:Fine, smectite, hyperthermic Vertic Haplustepts										
AP	0-21	6.4	8.2	16.09	12.93	0.87	1.16	31.05	31.70	97.94
B21	21-40	6.6	7.5	18.98	13.26	0.64	1.04	33.92	34.50	98.31
B31	40-60	6.9	5.2	16.24	10.97	0.95	0.90	29.06	30.90	94.04
Pedon-6:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents										
Al	0-20	6.5	13.6	15.40	6.10	0.87	0.71	23.08	24.10	95.76
Pedon-7:Clayey, smectite, hyperthermic Lithic Ustorthents										
AP	0-15	6.9	6.1	16.79	12.54	0.66	1.20	31.19	31.40	99.33
B21	15-30	6.9	5.8	18.30	13.18	0.98	1.03	33.49	35.10	95.41
BC	30-50	7.2	5.2	14.62	10.45	0.57	0.84	26.48	29.60	89.45
Pedon-8:Fine, smectite, hyperthermic Typic Haplusterts										
AP	0-23	6.7	9.4	20.82	10.95	0.79	1.30	33.86	34.50	98.14
A12	23-45	6.6	8.4	19.65	8.16	0.94	1.10	29.85	31.10	95.98
A13	45-68	6.9	7.6	22.12	9.48	1.10	1.35	34.05	35.30	96.45
A14	68-100	7.1	7.9	25.31	10.54	0.98	1.21	38.04	38.10	99.31
A15	100-130	7.3	7.8	21.02	8.33	0.74	1.05	31.14	33.70	92.40
Pedon-9:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents										
AP	0-30	7.1	9.9	21.36	9.28	0.74	1.02	32.40	33.90	95.57
Pedon-10:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents										
AP	0-20	6.9	8.5	12.48	8.10	0.60	0.98	22.16	24.10	91.95

Table 5. Soil fertility status

Horizon	Depth (cm)	Available Macronutients (kg ha^{-1})			Available Micronutrients (mg kg^{-1})			
		N	P	K	Fe	Mn	Zn	Cu
Pedon-1:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents								
All	0-30	197.56	16.84	280.00	38.56	19.40	2.36	1.20
Pedon-2:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents								
All	0-22	203.84	14.25	313.60	41.66	30.36	2.38	1.97
C1	22-45	175.61	17.50	302.40	32.22	37.72	2.80	1.67
Pedon-3:Clayey- skeletal, mixed hyperthermic Vertic Uustorthents								
AP	0-17	206.97	17.88	380.80	38.17	29.98	2.10	2.22
C12	17-45	181.88	18.14	291.20	47.70	54.40	1.44	4.47
Pedon-4:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents								
All	0-25	103.48	16.55	190.40	27.02	54.96	1.73	4.64
Pedon-5:Fine, smectite, hyperthermic Vertic Haplustepts								
AP	0-21	166.20	19.74	280.00	34.14	54.04	3.43	6.56
B21	21-40	156.80	21.15	235.20	30.08	49.76	1.58	5.74
B31	40-60	109.76	19.10	235.20	6.34	2.42	1.64	1.65
Pedon-6:Clayey- skeletal, mixed hyperthermic Lithic Uustorthents								
Al	0-20	232.06	19.95	660.80	42.50	57.64	2.42	7.19
Pedon-7:Clayey, smectite, hyperthermic Lithic Uustorthents								
AP	0-15	112.89	20.80	336.00	25.38	44.00	3.21	4.60
B21	15-30	116.03	21.24	324.80	20.63	35.56	2.10	4.56
BC	30-50	103.48	18.74	257.60	9.51	21.82	1.73	2.77
Pedon-8:Fine, smectite, hyperthermic Typic Haplusterts								
AP	0-23	175.61	20.50	392.00	20.68	24.48	1.65	4.74
A12	23-45	166.20	18.78	358.40	19.85	46.38	2.17	6.37
A13	45-68	150.52	19.70	347.20	17.16	10.48	1.05	4.26
A14	68-100	159.93	19.20	436.80	14.92	20.58	1.01	5.03
A15	100-130	144.25	17.65	392.00	16.60	25.48	1.90	4.99
Pedon-9:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents								
AP	0-30	188.16	16.70	728.00	35.34	20.80	1.48	4.79
Pedon-10:Clayey- skeletal, mixed hyperthermic Lithic Ustorthents								
AP	0-20	163.07	18.20	504.00	54.71	55.23	5.10	6.10

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Rec. on 27.09.2011 & Acc. on 15.12.2011

J. Soils and Crops 22 (2) 226-232, Dec., 2012 ISSN 0971-2836

DIFFERENT FRACTIONS OF ZINC IN SOIL AS INFLUENCED BY MANURES AND FERTILIZERS IN LONG TERM RICE-WHEAT CROPPING SYSTEM IN NORTHWEST INDIA

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ABSTRACT

The present study was conducted during 2008-09 in a long term experiment under rice-wheat cropping system initiated during 1981-82 to know the effect of NPK fertilizers alone and in combination with farm yard manure (FYM), *Sesbania aculeata* green manure (GM) and wheat cut straw (WCS) on different fractions of zinc (Zn) and their interactions with each other. In the experiment 50% N was substituted through FYM, WCS and GM after their analysis in the laboratory. The results of the investigation revealed that after 27 years of rice-wheat cropping system, the application of FYM, WCS and GM resulted in significantly higher content of the water soluble and exchangeable Zn (WSEX-Zn) in the soil with Gm (3.40 mg kg^{-1}) followed by FYM (2.93-3.25 mg kg^{-1}) and WCS (1.96 mg kg^{-1}) which may be ascribed to the higher supply of Zn by these sources. The Zn fractions in specifically adsorbed (SPAD) and manganese-oxide bound (MnOX) fractions increased with manures and fertilizers application. Very high contents of MnOX, amorphous Fe-Oxides bound Zn (AFeOX) and crystalline Fe-Oxides bound Zn (CFeOX) fractions were reported and these fractions were continuously exchanging to WSEX-Zn fraction in the soil solution as their content is replenished. Zinc fractions held by SPAD and MnOX sites reported their increase with the application of manure. Among these manures, 50% NPK (Fert.) + 50% NPK (GM) treatment reported higher concentrations of WSEX, SPAD, MnOX, AFeOX, CFeOX and organically bound Zn fraction (OM) bound fractions of Zn followed by the treatment of 100% NPK (Fert.) + 50% NPK (FYM) whereas, higher concentrations of Zn for total micronutrient (TM) were reported by 50% NPK (Fert.) + 50% NPK (WCS) treatment. The increase in the WSEX, AFeOX, CFeOX and OM bound fractions of Zn were indicative of the enhanced availability of Zn with the application of GM, FYM and WCS.

(Key words: Zinc fractions, green manure, farm yard manure, wheat cut straw, NPK fertilizers)

INTRODUCTION

The integrated plant nutrient supply (IPNS) system, by which we can apply the nutrients in balanced form, is emerging as the most logical concept for managing and sustaining long term soil fertility and productivity. The integrated use of green manure (GM) and farmyard manure (FYM) with chemical fertilizer resulted in build up of available nutrients in soil more effectively (Dhaliwal and Walia, 2008). It ought to be desirable to encourage IPNS system by reverting to the use of FYM, crop residues incorporation (CRI) and GM in conjunction with the chemical fertilizers with the hope that such technology could bring sustainability to agriculture by maintaining the soil health with reference to available macro and micronutrients. Long term experiments on different soil types have shown that CRI increased organic carbon and available N,P,K, Zn and Cu contents in soil (Walia *et al.,* 2008). The study of various fractions of Zn present in soil and conditions under which these become available to plants is pre-requisite in assessing their availability to plants. It is important to know the relationship between chemical fractions of micronutrients in the soil and their uptake by the crop. The distribution of Zn among various fractions is sensitive to cultivation and management practices (Sangwan and Singh, 1993). The alternate flooding (reduced stage) in rice and upland (Sangwan and Singh, 1993). The alternate flooding (reduced stage) in rice and upland (oxidized stage) conditions in wheat affect transformation of Zn from one chemical form to another (Manchanda *et al.,* 2006). They further reported higher level of crystalline and oxide bound cations in calcareous soils which were transformed from reducible oxides forms into exchangeable and carbonate fractions whereas, Rupa *et al.* (2002) reported transformation of DTPA-Zn fraction in two alfisols with addition of FYM. Manure applied to rice-wheat system decreased WSEX-Zn specifically adsorbed on the inorganic sites (Dhaliwal, 2008). Saha and Mandal (2000) reported that more than 85% of applied Zn was distributed in water soluble plus exchangeably (WSEX), organic matter bound (OM), and amorphous iron oxide bound (AFeOX) fractions and it was due to application of organic matter in soil which mobilized applied Zn from OM to amorphous manganese oxide bound (AMnOX) fraction and reduced net transformation into residual fraction.

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Herencia *et al.* (2008) showed the percentage of Zn in the specific fractions with respect to the total content are as follows : WSEX-Zn >reducible-Zn>Oxidizable-Zn and also showed that addition of OM caused Zn to move from less soluble forms to more plant available forms, WSEX and reducible for Zn. The higher concentration of OM-Zn in the soil solution indicated that the Zn associated with OM may play a beneficial role in the release of Zn in the soil solution and its uptake in rice and wheat crops (Dhaliwal and Manchanda, 2008).

In a long term expeeriment Behra and Singh (2009) reported increase in the uptake of micronutrients in maize-wheat cropping system. Sekhon *et al.* (2006) reported that OM-bound concentration of Zn increased with the application of FYM, which increased the yield in rice-wheat system. Herencia *et al.* (2008) reported that with addition of organic and mineral fertilization, OM-bound fractions of micronutrients increased their availability and uptake in the soil. Rupa *et al.* (2002) reported similar uptake of Zn with addition of FYM and Zn fertilization. In an inceptisol, Behera *et al.* (2008) reported that total-Zn fraction contributed more towards its availability and plant uptake under long-term maize-wheat cropping.

With these observations, the present study was aimed at an experiment on the long term basis with graded levels of NPK in combination with farm yard manure (FYM), green manyre (GM) and wheat cut straw (WCS) in rice-wheat system on various fraction of Zn in soil. So, the cherished objectives of the study were to investigate the changes in Zn fractions as a result of continuous fertilization and manures and to work out relationships between various fractions of Zn in rice-wheat cropping sequence.

MATERIALS AND METHODS

Location of the experimental site :

Laboratory studies were conducted during 2008-09 on the soil samples collected from an on-going long-term experiment on rice-wheat sequence which is in progress since 1983 in the research farm area of Department of Agronomy, Punjab Agricultural University, Ludhiana under "All India Co-ordinated Research Project on Cropping Systems". The treatments are reported in table 1.

The Soil of the experimental field was classifed as Tolewal loamy and sand with EC 0.32 dS m^{-1}, pH 8.15, low in organic carbon, available N,P and K (Table 2). During the year 2002-03 the mean value of DTPA-extractable Zn level before rice cropping was 1.92 mg kg^{-1} soil whereas, during 2008-09 these values were elevated to 2.10 mg kg^{-1} soil respectively in 0-15 cm depth.

Six diffreent treatment combinations were selected for the present investigation in the ongoing long term experiment and these six treatment combinations consist of addition of NPK fertilizers alone and in conjunction with FYM, wheat cut straw (WCS) and GM as mentioned in table 1. Recommended nutrients viz., N,P and K for rice and wheat were added @ 120 kg, 30 kg and 30 kg ha^{-1} and 120 kg, 60 kg and 30 kg ha^{-1}, respectively. N recommended for rice and wheat were applied through urea whereas, P and K were applied only on soil test basis. Dhaincha (*Sesbania aculeata*) as GM crop was raised during summer by applying phosphorus dose of succeeding rice crop. *Insitu Sesbania aculeata* was grown during the last week of April after harvest of wheat crop. After two months, the GM was incorporated in the filed, followed by puddling with disc plow. The quantities of FYM, GM and WCS were added on laboratory test basis to substitute 50 per cent N through these manures.

Collection and analysis of soil samples :

The surface (0-15) cm soil samples from each treatment were taken using a 5 cm diameter auger, after harvest of rice crop these soil samples were mixed throughly, air dired in shade and crushed to pass through 2 mm sieve and stored in sealed plastic jars for analysis. For determining DTPA-extractable Zn content, soil samples were taken at harvesting of wheat and Zn was determined from 1:2 soil-extractant ratio using DTPA-TEA buffer (0.005 M DTPA + 0.001 M CaCl2 + 0.1 M TEA, pH 7.3) and concentration of Zn was measured on an atomic absorption spectrophotometer (Lindsay and Norvell, 1978). The experiment was designed in a randomized block design.

Sequential extraction of soil samples for different fractions:

The processed soil samples were used to fractionate Zn into following chemical fractions as per sequential procedure described below.

Water soluble plus exchangeable Zn fraction (WSEX)

Five grams of soil was shaken with 20 ml of 0.005 M Pb $(NO_3)_2$ in 100 ml centrifuge tubes for fifteen minutes at 25^0 C orbital shaker and mixture was centrifuged for ten minutes at 6000 rpm. The supernatant was filtered, separated and stored for analysis (Manchanda *et al.,* 2006). The sequential extraction continued in the residue of the soil sample.

Specifically adsorbed Zn (SPAD) :

The soil residue from water soluble plus exchangeable fraction was shaken with 20 ml of 0.05 M Pb $(NO_3)_2$ for 2 hours at 25^0C in orbital shaker and the sample was, thereafter, centrifuged for ten minutes at 6000 rpm and the supernatant was filtered. The sequential extraction continued in the remaining soil sample.

Mn-Oxide bound Zn fraction (MnOX) :

To the soil sample residue of SPAD 20.0 ml of 0.1 mol L^{-1} $NH_2OH.HCI$ (hydroxylamine hydrochloride), at pH 2.0 was added and the mixture was shaken for 30 minutes, centrifuged and filtered. The separated supernatant was stored for analysis (Chao,1972).

Amorphous Fe-Oxides bound Zn (AFeOX) :

To the MnOX bound fraction free soil sample 20.0 ml of $NH_2OH.HCI$ (hydroxylamine hydrochloride) 0.1 mol L^{-1} plus HCI 0.25 mol L^{-1}, at pH 1.3 were added, and the mixture was shaken for 30 minutes at 25^0C in orbital shaker, centrifuged, filtered and the separated supernatant was stored for analysis (Chao and Zhou, 1983).

Crystalline Fe-Oxides bound Zn (CFeOX) :

To the AFeOX free soil sample 20.0 ml of 0.25 M $NH_2OH.HCI$ + 0.25 M HCL + ascorbic acid 0.01 mol L^{-1}, at pH 1.21 were added, the mixture was heated with boiling water (100^0C) in a beaker placed on hot plate for 30 minutes, shaking from time to time; thereafter centrifuged and filtered and the separated supernatant was stored for analysis (Manchanda *et al.,* 2006).

Organically bound Zn fraction (OM) :

To the CFeOX free soil sample was shaken with 20 ml of 1% $Na_4P_2O_7$ for one hour at 25^0C in orbital shaker and mixture was centrifuged for ten minutes at 6000 rpm, the supernatant filtered, separated and stored for analysis (Raja and Ieyngar, 1986).

Total Zn content :

For total analysis of Zn, a 0.5 g sample of soil was digested with 5 ml of hydrofluoric acid (HF), 1.0 ml of perchloric acid ($HCIO_4$) and 5-6 drops of nitric acid (HNO_3) in a 30 ml capacity platinum crucibles (Page *et al.,* 1982). When the soil became completely dry in the crucible the residue in the crucible was completely dissolved in 5 ml of 6N HCI. The contents of the crucible were transferred to 100 ml volumetric flask with double distilled water. The digests were analyzed for total Zn after apropriate dilutions. The results of the elemental analysis were reported on an oven dry weight basis.

Statistical analysis :

Different fractions of Zn were subjected to randomized complete block design analysis of variance. The statistical analysis was done with the help of method described by Panse and Sukhatme (1985). Least significant difference was used to compare the treatments effects at $P<0.05$.

RESULTS AND DISCUSSION

Water soluble and exchangeable (WSEX-Zn) fraction:

The WSEX-Zn fraction in different treatments tended to increase with the combined application of fertilizer and manures over control (Table 3). The highest value of WSEX-Zn (3.40 mg kg^{-1} soil) was reported in the treatment where 50% NPK was added through GM. Further, it is interesting to note that with 50% additional NPK dose through FYM along with 100 per cent recommended N dose through fertilizer, an increase in the WSEX-Zn (3.25 mg kg^{-1} soil) was observed in comparison to 100 per cent NPK fertilizers dose (1.86 mg kg^{-1}). This may be attributed to the creation of submerged conditions at the time of rice crop growth. After 27 years the WSEX-Zn decreased in control (1.32 mg kg^{-1} soil) over its initial content. However, FYM, WCS and GM resulted in significantly higher Zn content of the soil amended with GM (3.40 mg kg^{-1}) followed by FYM (2.93-3.25 mg kg^{-1}) and WCS (1.96 mg kg^{-1}).

Dhaliwal and Walia (2008) and Walia *et al.* (2008) reported similar increase in WSEX- fratctions under rice-wheat rotation. Behera and Singh (2009) reported the data regarding WSEX-Zn in soil before sowing of maize and after harvest of wheat during 32nd cropping cycle of maize-wheat system.

Specifically adsorbed (SPAD) Zn fraction :

The SPAD-Zn didn't show any significant increase in all the treatments over control. The treatment receiving 50% NPK (Ferti.) + 50% NPK through GM doubled its magnitude over control (Table 3). In general, the addition of GM, FYM and WCS substituting 50% NPK through fertilizer proved beneficial in enhancing the SPAD-Zn reported its higher level in all the treatments over control (1.63 mg kg^{-1}). Interestingly, the highest level of SPAD-Zn was reported in100% NPK (Fert.) + 50% NPK (FYM) treatment where 50 per cent N was substituted through FYM. These results are also in agreement with the results obtained by Chatterjee *et al.* (1992) who reported increase in SPAD-Zn with addition of GM.

Mn-Oxide (MnOX) bound Zn fraction :

MnOx-Zn fraction did not increase in with the application of fertilizer, FYM WCS and GM over control (Table 3). The lowest level of MnOx-Zn was reported in control (1.87 mg kg^{-1}) whereas, the highest level of MnOx-Zn (3.13 mg kg^{-1}) was reported in treatment with 50% NPK (Fert.) + 50% NPK (FYM) followed by 50% NPK (Fert.) + 50% NPK (GM) treatment (2.86 mg kg^{-1}). The highest MnOx-Zn (5.70 mg kg^{-1}) was reported in GM treatment 50% NPK (Fert.) + 50% NPK (GM) as compared to 100% NPK (Fert.) + 50% NPK (FYM) (4.7 mg kg^{-1}) followed by 50% NPK (Fert.) + 50% NPK (WCS) (3.80 mg kg^{-1}). Hellal (2007) reported that addition of composted mixtures increased MnOX-Zn in soil. On the other hand, Herencia *et al.* (2008) showed the percentage of Zn in the specific fractions with respect to the total content are Zn with addition of OM caused Zn to move from less soluble forms to more plant available fraction which was always favored by organic amendment.

Amorphous Fe-Oxides (AFeOX) bound Zn fraction:

The data presented in table 3 reported that AFeOX-Zn increased significantly in all the treatments containing FYM, GM and WCS. The minimum level of this fraction was reported in T_1 (no fertilizer, no manure) where no fertilizer or manure was applied. The highest concentration of this fraction was reported in T_5 where 50 per cent N was substituted through GM. Among FYM, GM and WCS, low concentration of AFeOX-Zn fraction was reported by WCS (50% NPK Fert.) + 50% NPK (WCS) followed by the treatment of 50% NPK (Fert.) + 50% NPK (FYM). Sekhon *et al*. (2006) reported that addition of GM to rice increased AFeOX form of Zn under rice-wheat rotation. Hellal (2007) reported that addition of composed mixtures increased amorphous Fe oxide but occluded fractions did not differ significantly due to application of composted mixture.

Crystallinie Fe-Oxides (CFeOX) bound Zn fraction:

The data presented in table 4 reported that the CFeOX-Zn fraction increased significantly in all the treatments over control (No fertilizer, No manure). The highest CFeOX-Zn (4.54 mg kg^{-1}) was reported in 50% NPK (Fert.) + 50% NPK (WCS), where 50 per cent N was substituted by GM and this was further followed by 100% NPK (Fert.) + 50% NPK (FYM) treatment. Among three manures, WCS in 50% NPK (Fert.) + 50% NPK (WCS) reported least CFeOX-Zn (3.38 mg kg^{-1}) fraction in the solution. Like other fractions, GM played major role in releasing more CFeOX-Zn fraction in the soil. Singh *et al.* (1988) in a study on11 soils reported that 17 per cent of total Zn was associated with CFeOX fraction.

Organically (OM-Zn) bound Zn fraction :

The concentrations of OM bound fraction in the soil after 23rd rotation under rice-wheat system varied from 17.78 - 25.39 mg kg^{-1} (Table 4). The highest OM-Zn fraction was reported in 50% NPK (Fert.) + 50% NPK (GM) treatment where GM was added. All other treatments contributed equally towards this fraction. OM-Zn showed similar trend of this fraction in the soil. OM bound Zn fraction was supposed to be helpful in fulfilling the crop requirement under sub-merged conditions. The treatments receiving 100% NPK (Fert.) and 50%NPK (Fert.) + 50% NPK (WCS) contribute alomst equally towards this fraction. The higher concentration of

OM-Zn in the soil solution indicated that the micronutrients associated with OM bound fraction may play a beneficial role in the uptake of these nutrients by the plants. Sekhon *et al.* (2006) reported that OM bound fraction of Zn and Cu increased with application of FYM in rice-wheat system.

Total (T-Zn) Zn fraction :

The T-Zn fraction in all the treatments varied from 170 to 590 mg kg^{-1} soil (Table 4). Interestingly, TM-Zn did not show any regular trend among different treatments. Among different manures, the highest TM-Zn was reported in treatment with 50% NPK (Fert.) + 50% NPK (FYM) followed by 50% NPK (Fert.) + 50% NPK (WCS) treatment. The treatments of 100% NPK (Fert.) and 50% NPK (Fert.) + 50% NPK (GM) were able to contribute equally towards this fraction. Agbenin and Henningsen (2004) reported distribution of TM fractions and their contribution towards availability and plant uptake of Zn under long-term maize-wheat cropping sequence indicated residual micronutrients as the dominant portion of total Zn. Similar results were reported by Behera *et al.* (2008) who reported the distribution of T-Zn fractions and their contribution towards availability and plant uptake of Zn under long-term maize-wheat cropping in an inceptisol.

Relationship between micronutrients fractions :

The correlation coefficients between various micronutrients fractions were worked out and the results are presented in table 5. All the fractions of Zn were positively and significantly correlated with each other except total Zn where these fractions were significantly but negatively correlated with other fractions. WSEX-Zn showed its strong correlation with SPAD-Zn (0.951), AFeOX-Zn (0.901) and CFeOX-Zn (0.982). Both the AFeOX-Zn and CFeOX-Zn fractions reported the storng correlation (0.938). Behera *et al.* (2009) reported WSEX fraction of Zn contributing towards its availability and its uptake under long term maize (*Zea mays* L.)- Wheat (*Triticm astivum* L.) cropping in an inceptisol. Similar to Zn fractions different Cu fractions were also significantly but negatively correlated (Table 5). Dhaliwal (2008) reported that with addition of GM in rice-wheat system. WSEX, SPAD and SPAD-Zn fractions increased whereas, MnOX and AMFeOX-Zn decreased.

Table 1. Different treatment combinations of manures and fertilizers

Treatments	Rice	Wheat
T_1	No fertilizer, No manure	No fertilizer, No manure
T_2	100% NPK (Fert.)	100% NPK (Fert.)
T_3	50% NPK (Fert.) + 50% NPK (FYM)	100% NPK (Fert.)
T_4	50% NPK (Fert.) + 50% NPK (WCS)	100% NPK (Fert.)
T_5	50% NPK (Fert.) + 50% NPK (GM)	100% NPK (Fert.)
T_6	100% NPK (Fert.) + 50% NPK (FYM)	100% NPK (Fert.)

Table 2. Changes in properties of the experimental soil (1983-2008) before sowing of rice

Soil Properties	Year of Sampling		
	1983	2002-03	2008-09
Texture	Is	Is	Is
pH (1:2 :: soil : water)	8.15	7.36	7.32
EC (dSm^{-1})	0.32	0.28	0.27
Organic Carbon (%)	0.39	0.40	0.43
Available N (kg ha^{-1})	43.30	139.8	142.80
Available P (kg ha^{-1})	11.20	15.90	16.70
Available K (kg ha^{-1})	101.0	100.70	104.80
Available Zn (mg kg^{-1} soil)	NA	1.92	2.10

Table 3. Effect of different manures and fertilizers combinations on WSEX, SPAD, MnOX and AFeOX fractions of Zn (mg kg^{-1}) after harvest of rice crop

Rice	Wheat	WSEX	SPAD	MnOX	AFeOX
No fert., No Manure	No fert., No Manure	1.32	1.63	1.87	16.0
100% NPK (Fert.)	100% NPK (Fert.)	1.86	1.99	2.08	20.70
50% NPK (Fert.) + 50% NPK (FYM)	100% NPK (Fert.)	2.93	2.52	3.13	21.60
50% NPK (Fert.) + 50% NPK (WCS)	100% NPK (Fert.)	1.96	2.09	2.28	20.90
50% NPK (Fert.) + 50% NPK (GM)	100% NPK (Fert.)	3.40	3.51	2.86	25.50
100% NPK (Fert.) + 50% NPK (FYM)	100% NPK (Fert.)	3.25	2.64	2.66	22.00
SE m ±		0.05	0.06	0.07	0.79
CD (0.05)		0.15	0.18	0.22	2.38

Table 4. Effect of different manures and fertilizers combinations on crystalline Fe-oxides bound (CFeOX), OM bound and total fractions of Zn (mg kg^{-1}) after harvest of rice crop

Rice	Wheat	CFeOX	OM	Total Zn
No fertilizer, No manure	No fertilizer, No manure	2.60	17.78	590
100% NPK (Fert.)	100% NPK (Fert.)	3.08	17.93	440
50% NPK (Fert.) + 50% NPK (FYM)	100% NPK (Fert.)	3.45	17.81	320
50% NPK (Fert.) + 50% NPK (WCS)	100% NPK (Fert.)	3.38	17.91	170
50% NPK (Fert.) + 50% NPK (GM)	100% NPK (Fert.)	4.54	25.39	180
100% NPK (Fert.) + 50% NPK (FYM)	100% NPK (Fert.)	3.98	18.00	173
SE m±		0.10	0.31	5.75
CD (0.05)		0.32	1.05	17.25

Table 5. Coefficient of correlation of Zn with different chemical fractions

Fractions	WSEX-Zn	SPAD-Zn	MnOX-Zn	AFeOX-Zn	CFeOX-Zn	OM-Zn
SPAD-Zn	0.951	--	--	--	--	--
MnOX-Zn	0.699	0.779	--	--	--	--
AFeOX-Zn	0.901	0.927	0.736	--	--	--
CFeOX-Zn	0.982	0.968	0.723	0.938	--	--
OM-Zn	0.721	0.837	0.387	0.718	0.758	--
Total Zn	-0.759	-0.704	-0.625	-0.804	-0.832	-0.389

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Rec. on 21.12.2011 & Acc. on 29.03.2012

J. Soils and Crops 22 (2) 233-239, Dec., 2012 ISSN 0971-2836

EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH, YIELD AND QUALITY OF CABBAGE (*Brassica oleracea* var. Capitata)

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ABSTRACT

The field experiment was conducted during 2009-2010 at Experimental Farm of School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema Campus to study the effect of integrated nutrient management on growth, yield and quality of cabbage under foothill conditions of Nagaland. The treatments consisted of: T_1 - Control, T_2 - FYM 30 t ha^{-1}, T_3 - Pig manure 20 t ha^{-1}, T_4 - Vermicompost 10 t ha^{-1}, T_5 - Poultry manure 15 t ha^{-1}, T_6 – 100 % NPK (120:60:60 kg ha^{-1}), T_7 – 50 % NPK + 50 % FYM, T_8 – 50 % NPK + 50 % Pig manure, T_9 – 50 % NPK + 50 % Vermicompost, T_{10} – 50 % NPK + 50 % Poultry manure, T_{11} – 50 % NPK + 50 % FYM + Biofertilizers, T_{12} - 50 % NPK + 50% Pig manure + Biofertilizers, T_{13} – 50 % NPK + 50 % Vermicompost + Biofertilizers and T_{14} – 50 % NPK + 50 % Poultry manure + Biofertilizers. Results revealed that application of different levels of fertilizers, organic manures and biofertilizers either alone or in combination significantly increased the growth, yield and quality of cabbage as compared to control. The maximum head yield (56.37 t ha^{-1}) was recorded with 50 % NPK + 50 % FYM + biofertilizers which was significantly superior over other treatments except 100 % NPK, 50 % NPK + 50% Pig manure + Biofertilizers and 50 % NPK + 50 % Vermicompost + Biofertilizers where value of head yield was 49.38 t ha^{-1}, 50.56 t ha^{-1} and 53.64 t ha^{-1}, respectivey. The treatment 50 % NPK + 50 % FYM + biofertilizers also produced the highest net return of Rs 1, 69,698 with cost-benefit ratio of 1:3.0. It was followed by 50 % NPK + 50% Pig manure + Biofertilizers and 100 % NPK for achieving more returns than other treatments. These results suggested that the optimum production of cabbage can be obtained with integrated application of 50 % NPK + 50 % FYM + Biofertilizers or 50 % NPK + 50% Pig manure + Biofertilizers.

(Key words : Cabbage, Integrated Nutrient Management, chemical fertilizers, organic manures, biofertilizers, growth, yield, quality and economics)

INTRODUCTION

Cabbage is an important cole crop belonging to family Cruciferae. It is used as boiled vegetable, salad, in curries and processed too. Cabbage is rich in vitamin A, B_1, C and minerals. Cabbage has medicinal properties and used against gout, diarrhoea, constipation, gastric ulcers and bowel cancer. Among various factors responsible for low production of cabbage, nutrition is of prime importance. In order to maintain the productivity and profitability, chemical fertilizers are used heavily, thus creating environmental and ecological problems and adversely affecting the sustainability of agricultural system. Use of chemical fertilizer alone increased the crop yield in the initial year but adversely affected the sustainability subsequently. The cost of chemical fertilizers is also increasing day by day. On the other hand, organic manures like FYM, poultry manure and pig manure are cheap and easily available in local condition and can be efficiently utilized for cabbage production. The role of biofertilizers is perceived as growth regulators besides biological nitrogen fixation collectively leading to much higher response on various growth and yield attributing characters of cabbage. However, high yield of cabbage can not be realized only with use of organic manures and biofertilizers. Therefore, a judicious combination strategy of using chemical fertilizer, organic manures and biofertilizers would be helpful in increasing cabbage productivity (Zango *et al*., 2009). No information is available about the nutrient requirement of cabbage in north eastern region including acidic soils of Nagaland in particular. In view of the above, the present investigation was conducted to study the effect of integrated nutrient management on the growth, yield and quality of cabbage.

MATERIALS AND METHODS

A field experiment was conducted during September 2009 to January 2010 at the Experimental Farm of SASRD, Medziphema campus, Nagaland University, Nagaland. The field is located at the altitude of 304.8 m above mean sea level with geographical location at 20º 45' 43" N latitude and

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93 º 53' 04" E longitudes. The soil of the experimental site is sandy loam having pH 4.6, organic carbon 1.65%, available N 240.56 kg ha^{-1}, P_2O_5 17.83 kg ha^{-1} and K_2O 220.40 kg ha^{-1}. The experiment was laid out in a randomized block design with three replications. Plot size measured 1.8 m x 1.8 m and spacing was maintained at 60 cm x 45 cm. The hybrid Rare Ball of cabbage was used in the experiment. The treatments consisted of: T_1 - Control, T_2 -FYM 30 t ha^{-1}, T_3 - Pig manure 20 t ha^{-1}, T_4 - Vermicompost 10 t ha^{-1}, T_5 - Poultry manure 15 t ha^{-1}, T_6 – 100 % NPK (120:60:60 kg ha^{-1}), T_7 – 50 % NPK + 50 % FYM, T_8 – 50 % NPK + 50 % Pig manure, T_9 – 50 % NPK + 50 % Vermicompost, T_{10} – 50 % NPK + 50 % Poultry manure, T_{11} – 50 % NPK + 50 % FYM + Biofertilizers, T_{12}- 50 % NPK + 50% Pig manure + Biofertilizers, T_{13} – 50 % NPK + 50 % Vermicompost + Biofertilizers and T_{14} – 50 % NPK + 50 % Poultry manure + Biofertilizers. The quantity of organic manures was calculated on nitrogen equivalent basis, which were incorporated in each plot 15 days before planting. N, P and K were given through urea, SSP and MOP respectively. Full dose of SSP, MOP and half dose of urea were applied during final field preparation for transplanting of cabbage seedlings and remaining dose of urea was applied in two split doses, 30 and 60 days after transplanting. Biofertilizers (*Azospirillum and Phosphotica*) were inoculated before transplanting as seedling dip method @ 2 kg ha^{-1} each.

Observations were recorded at harvesting on plant height, plant spread, stalk length, head diameter, head size, head compactness, net head weight, net head yield and vitamin C content. Vitamin C content was determined by 2, 6-dichlorophenol indophenol visual titration method as prescribed by A.O.A.C. (Anonymous, 1984) and expressed in mg 100^{-1}g. Soil samples were collected before and after harvest of crop from different locations of the experimental plot to a depth of 15 cm with the help of screw type auger. The collected soil samples were mixed and reduced into 500 g and then dried under shade, ground and sieved through 2 mm sieve size. Soil samples were analysed for pH, organic carbon, available nitrogen, phosphorus and potassium. pH was determined by Digital pH meter (Jackson, 1973). Organic carbon was determined by Walkley and Black Rapid titration method (Jackson, 1973). Available nitrogen was determined by alkaline potassium permanganate method (Subhiah and Asija, 1956). Available phosphorus was determined by Olsen's method (Bray and Kurtz, 1945). Available potassium was determined by flame photometer method (Jackson, 1973). The statistical analysis was carried out as per procedure given by Panse and Sukhatme (1989). Economics of the treatments were also calculated as per prevailing market price of input and output. Treatment wise economics was carried out by calculating the cost of cultivation based on prevailing rate of input and outputs. Gross income was calculated by yield multiplied with whole sale rate of cabbage at Rs 4000 t^{-1}. Net income was estimated by deducting the total cost of cultivation (fixed cost + treatment cost) from gross income of the particular treatment. Cost-benefit ratio was worked out by dividing net return from total cost of cultivation.

RESULTS AND DISCUSSION

Growth characters:

Improvement in growth characters is considered to be pre-requisite to increased yield. NPK fertilizers with different organic manures along with biofertilizers alone or in combination was found to have significant positive effect on growth characters as compared to control (Table 1). All the treatments were found effective in increasing the plant growth over control. Application of 50 % NPK + 50 % FYM + biofertilzers recorded maximum plant height (29.65 cm), plant spread (45.59 cm) and stalk length (10.86 cm), while lowest values of growth parameters were recorded in control treatment. However, treatment difference between 50 % NPK + 50 % FYM + Biofertilizers, 50 % NPK + 50 % Vermicompost, 50 % NPK + 50 % Vermicompost + Biofertilizers and FYM 30 t ha^{-1} were found to be at par with each other for different growth parameters. The increase in growth attributes may be due to addition of organic manure and biofertilizers which improved the physical, chemical and biological properties of soil, increasing nutrient availability for improving the plant growth. This improvement might also be attributed to certain growth promoting substances secreted by the biofertilizers which in turn might have led to better root development, better transportation of water, uptake and deposition of nutrients. These results are in conformity with the finding of Kalalbandi *et al*. (2007) and Zango *et al*. (2009). They reported maximum vegetative growth of cabbage with the treatment of 50% recommended dose of NPK and 50% FYM.

Yield and quality characters:

Integrated application of chemical fertilizers, organic manures and biofertilizers alone or in combination significantly increased yield and quality of cabbage compared to control (Table 1). Application of 50 % NPK + 50 % FYM + biofertilizers recorded maximum values of all yield attributing characters such as head diameter (13.36 cm), head size (169.63 cm^2), head compactness (96.91) and net head weight (1141.87 g). However, treatment differences between 50 % NPK + 50 % FYM + Biofertilizers, 100 % NPK (120 : 60 : 60 kg ha^{-1}) , 50 % NPK + 50 % FYM, 50 % NPK + 50 % Pig manure, 50 % NPK + 50 % Vermicompost, 50 % NPK + 50 % Poultry manure, 50 % NPK + 50% Pig manure + Biofertilizers, 50 % NPK + 50 % Vermicompost + Biofertilizers were found to be at par with each other for head diameter of cabbage. The treatment 50 % NPK + 50 % FYM + Biofertilizers was found significantly superior over all the treatments for head size, head compactness and net head weight of cabbage. This result indicates positive effects of integrating NPK with manures as well as biofertilizers. This might be due to favourable effect of organic manures in INM in supplying essential nutrients in balanced ratio and improving physical, chemical and biological properties of soil which helps in better nutrient absorption and utilization by plant and results in achieving higher value of yield attributing characters. Besides increasing the nitrogen fixing abilities, biofertilizers might have played a vital role in increasing the yield related attributes. The highest head yield (56.37 t ha^{-1}) was recorded in treatment 50 % NPK + 50 % FYM + biofertilizers followed by 50 % NPK + 50 % Vermicompost + Biofertilizers, 50% NPK + 50% Pig manure + Biofertilizers and 100 % NPK which were found to be at par with each other. This might be due to corresponding response to increased yield attributing characters attained previously under this treatment. Singh *et al.* (2006) proved that bio-inoculants (*Azotobacter* and PSM) along with organic manures and inorganic fertilizers had significant and positive effect on yield parameters of cabbage. The present results are also in agreement with these results. The results were also in conformity with the findings of Sentiyangla *et al.* (2010) in radish and Vimera *et al*. (2010) in King chilli. They recorded maximum yield and quality characters with 50% NPK + 50% FYM + biofertilizers.

It is evident from table 1 that maximum values of vitamin C (116.97 mg 100^{-1} g) was recorded with treatment 50 % NPK + 50 % FYM + Biofertilizers which was found to be significantly superior over all the other treatments except 50 % NPK + 50 % FYM, 50% NPK + 50% Vermicompost + Biofertilizers, 50 % NPK + 50 % Poultry manure + Biofertilizers and 50 % NPK + 50 % Pig manure + Biofertilizers. Zango *et al*. (2009) reported that addition of organic manure in soil increases the availability of micronutrients, which might have great influence in increasing the ascorbic acid content of cabbage. Kalalbandi *et al*. (2007) also reported maximum ascorbic acid of cabbage with the treatment of 50% recommended NPK and 50% FYM. Thus, present results also proved the utility of organic manures as reported above.

Fertility status of the soil after harvest:

Sustainability of a cropping system is being evaluated on the basis of crop yield as well as nutrient status of the soil after harvest of the crop. Availability of NPK in soil after harvest was significantly influenced by application of NPK fertilizers, organic manures and biofertilizers alone or in combination over control. However, Soil pH and organic carbon was found non-significant (Table 2). Maximum available nitrogen (310.17 kg ha^{-1}) and available potassium (262.39 kg ha^{-1}) was recorded in the treatment 50% NPK + 50% Poultry manure + Biofertilizers. Poultry manure might have improved the CEC of the soil and thus increased the retention of K in exchangeable form by a mass action effect. On the other hand, maximum available phosphorus (20.15 kg ha^{-1}) was recorded in the treatment 50 % NPK + 50 % FYM + Biofertilizers. Similar beneficial effects of integrated use of inorganic fertilizers, organic manures and biofertilizers on nutrient status of soil after harvest were reported earlier by Kumar and Sharma (2004) and Chaudhary *et al.* (2005).

Economics of treatments:

It is evident from table 3 that the integration of 50 % NPK + 50 % FYM + biofertilizers was found

Table 1. Effect of integrated nutrient management on growth, yield and quality of cabbage

Treatments	Plant height (cm)	Plant spread (cm)	Stalk length (cm)	Head diameter (cm)	Head size (cm^2)	Head compact-ness	Net head weight (g)	Net head yield (t ha^{-1})	Vitamin C ($mg100^{-1}g$)
T_1 – Control	23.62	33.86	5.58	9.54	95.05	45.91	473.00	23.36	75.22
T_2 – FYM (30 t ha^{-1})	27.10	43.61	9.79	12.12	135.60	57.38	900.33	44.47	106.17
T_3 – Pig manure (20 t ha^{-1})	26.79	41.35	7.93	11.85	131.40	57.13	842.28	41.61	100.80
T_4 – Vermicompost (10 t ha^{-1})	26.89	41.81	8.90	11.96	135.45	58.29	879.86	43.46	94.73
T_5 – Poultry manure (15 t ha^{-1})	25.90	39.64	7.31	11.28	128.75	54.45	816.04	40.29	76.37
T_6 – 100% NPK (120:60:60 kg ha^{-1})	26.97	41.98	8.61	13.23	150.40	73.60	1000.25	49.38	109.23
T_7 – 50% NPK + 50% FYM	27.53	41.72	9.00	12.81	141.58	71.33	993.81	49.07	115.00
T_8 – 50% NPK + 50% Pig manure	27.19	42.89	8.39	13.02	147.75	63.69	975.09	48.14	105.37
T_9 – 50% NPK + 50% Vermicompost	27.68	44.55	9.41	12.45	139.23	69.59	983.47	48.58	105.50
T_{10} – 50% NPK + 50% Poultry manure	26.58	40.63	8.19	12.63	140.20	60.53	912.10	45.03	99.50
T_{11} – 50% NPK + 50% FYM + Biofertilizers	29.65	45.59	10.86	13.36	169.63	96.91	1141.87	56.37	116.97
T_{12} – 50% NPK + 50% Pig manure + Biofertilizers	26.50	42.15	8.74	12.43	137.96	69.51	1023.92	50.56	101.40
T_{13} – 50% NPK + 50% Vermicompost + Biofertilizers	28.45	43.21	9.50	13.07	152.62	74.35	1045.97	53.64	114.80
T_{14} – 50% NPK + 50% Poultry manure + Biofertilizers	27.15	42.47	8.24	12.30	136.35	62.18	960.35	47.42	107.60
SE $\pm$	0.67	1.24	0.55	0.35	5.12	7.14	30.18	2.36	4.96
CD at 5%	2.03	3.74	1.65	1.05	15.37	21.43	90.56	7.08	14.88

Table 2.: Effect of integrated nutrient management on nutrient status of soil after harvest of cabbage

Treatments	Available Nitrogen (kg ha $^{-1}$)	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})	Organic carbon (%)	Soil pH
T_1– Control	217.42	14.28	181.62	1.88	4.55
T_2 – FYM (30 t ha^{-1})	280.92	18.96	235.10	2.44	4.74
T_3 – Pig manure (20 t ha^{-1})	279.24	18.82	228.11	2.28	4.68
T_4 – Vermicompost (10 t ha^{-1})	273.32	19.07	230.81	2.30	4.69
T_5 – Poultry manure (15 t ha^{-1})	282.20	18.54	238.48	2.20	4.70
T_6 – 100% NPK (120:60:60 kg ha^{-1})	296.19	20.05	246.19	2.16	4.62
T_7 – 50% NPK + 50% FYM	287.32	19.91	243.27	2.21	4.73
T_8 – 50% NPK + 50% Pig manure	290.67	19.44	239.86	2.09	4.73
T_9 – 50% NPK + 50% Vermicompost	282.63	19.65	240.62	2.16	4.71
T_{10} – 50% NPK + 50% Poultry manure	294.02	19.60	243.04	2.23	4.74
T_{11} – 50% NPK + 50% FYM + Biofertilizers	304.62	20.15	259.17	2.31	4.79
T_{12} – 50% NPK + 50% Pig manure + Biofertilizers	298.52	19.76	248.56	2.40	4.75
T_{13} – 50% NPK + 50% Vermicompost + Biofertilizers	296.40	19.94	257.35	2.24	4.76
T_{14} – 50% NPK + 50% Poultry manure + Biofertilizers	310.17	19.81	262.35	2.31	4.78
SE $\pm$	5.36	0.92	3.60	-	-
CD at 5%	16.08	2.76	10.81	-	-

Table 3 . Effect of integrated nutrient management on economics of the treatments

Treatments	Cost of cultivation (Rs ha^{-1})			Yield (t ha^{-1})	Gross income (Rs ha^{-1})	Net income (Rs ha^{-1})	Cost : benefit ratio
	Fixed cost	Treatment cost	Total cost				
T_1– Control	45000	-	45000	23.36	93456	48456	1:1.0
T_2 – FYM (30 t ha^{-1})	45000	15000	60000	44.47	177900	117900	1:1.9
T_3 – Pig manure (20 t ha^{-1})	45000	14000	59000	41.61	166460	107460	1:1.8
T_4 – Vermicompost (10 t ha^{-1})	45000	100000	145000	43.46	173868	28868	1:0.9
T_5 – Poultry manure (15 t ha^{-1}))	45000	15000	60000	40.29	161192	101192	1:1.6
T_6 – 100% NPK (120:60:60 kg ha^{-1})	45000	6536	51536	49.38	197532	145996	1:2.8
T_7 – 50% NPK + 50% FYM	45000	10768	55768	49.07	196296	140528	1:2.5
T_8 – 50% NPK + 50% Pig manure	45000	10268	55268	48.14	192592	137324	1:2.4
T_9 – 50% NPK + 50% Vermicompost	45000	53268	98268	48.58	194320	96052	1:0.9
T_{10} – 50% NPK + 50% Poultry manure	45000	10768	55768	45.03	180124	124356	1:2.2
T_{11} – 50% NPK + 50% FYM + Biofertilizers	45000	10818	55818	56.37	225516	169698	1:3.0
T_{12} – 50% NPK + 50% Pig manure + Biofertilizers	45000	10318	55318	50.56	202264	146946	1:2.6
T_{13} – 50% NPK + 50% Vermicompost + Biofertilizers	45000	53318	98318	53.64	214568	116250	1:1.1
T_{14}– 50% NPK + 50% Poultry manure + Biofertilizers	45000	10818	55818	47.42	189712	133894	1:2.3

to be the most profitable treatment in cabbage exhibiting highest net return of Rs. 1,69,698 with cost-benefit ratio of 1:3.0 followed by the treatment 50 % NPK + 50% Pig manure + Biofertilizers (net return of Rs. 1,46,946 with cost:benefit ratio of 1:2.6) and 100 % NPK (net return of Rs. 1,45,996 with cost:benefit ratio of 1:2.8). This might be due to lower cost of input and higher yield. These findings are in accordance with Devi and Roy (2008) in cabbage, Vimera *et al.* (2010) in King chilli and Sentiyangla *et al.* (2010) in radish. They recorded the highest net return in the treatment 50% NPK + 50% FYM + biofertilizers.

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Rec. on 11.11.2011 & Acc. on 13.03.2012

J. Soils and Crops 22 (2) 240-245, Dec., 2012 ISSN 0971-2836

IDENTIFICATION OF RESTORERS AND MAINTAINERS IN NEW PLANT TYPE LINES OF RICE FOR DEVELOPING SUPER RICE HYBRID

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ABSTRACT

Three cytoplasmic male sterile (CMS) lines of rice having wild abortive (WA) cytoplasmic male sterility source were crossed with 9 entries to assess their maintainer/restorer behaviour at Research Farm, Department of Genetics and Plant Breeding, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh during *rabi* season 2009-2010 and *kharif* 2010. Among the crosses genotype NPTR-2 was identified as potential restorer for IR79156A and IR58025A. Similarly new plant type genotypes ET-1-10, ET 1-12 and ET 1-1 showed potential restorer for CMS line APMS 6A, SR-6-SW-8 for IR79156A. Genotypes TOX 981-11-2-3, SR-6-SW-8, IR64-SR-6 and IRFAN-115 recorded as partial restorer for CMS line APMS 6A, while ET 1-12 for IR79156A and IR58025A.Genotype ET 1-13 found as partial maintainer for APMS 6A and IR58025A, while IRFAN-115 for IR79156A. The result stated based on the pollen fertility and spikelet fertility percentage 3 partial maintainer, 6 partial restorers and 6 potential restorers were identified and frequency of potential restorers was much higher and no effective maintainer could be identified in the material under study.

(Key words: New plant type, hybrid rice, CMS, restorer, maintainer)

INTRODUCTION

Basic step in hybrid development programme is identification of restorers and maintainers through test cross evaluation. Breeding CMS lines adapted to the tropics began in 1980, using the CMS source (WA) from China. A commercially usable CMS line needs to have complete and stable male sterility, adaptability to tropical rice-growing conditions, and good out-crossing potential to effect an economically viable hybrid seed production. From the first set of CMS lines developed from 1983 to 1987, IR58025A has been used more extensively to develop public and private commercial rice hybrids in national agricultural research and extension systems (NARES) (Virmani, 2003). The CMS lines developed outside the country are not so good to use as such in developing hybrid rice in India as well as in state. Identification of locally adapted restorer shows consistently high degree of restoration of CMS lines which would be of great value in commercial, hybrid programme, if restoring ability is combined with high combining ability. Exotic CMS line IR-79156A has been widely used CMS line in three line breeding system therefore incorporation of some new indigenous CMS lines viz., APMS 6A and CRMS 31A would have an immense effect (Mishra *et al*., 2003). Hybrid rice technology can thus make an important contribution to increased food security, production efficiency, and environmental protection (Virmani *et al*., 2003).

The practical use of cytoplasmic male sterility in developing hybrid varieties in grain crops is possible only when effective restorer lines are identified or developed in practical and commercial scale. The CMS and restorer lines should possess high combining ability and morphological and floral characters suitable for high out crossing in seed production plots. The maintainers which may be converted into a CMS line in future should have desirable characters like medium plant height, more number of panicles and spikelets, longer stigma and style, and higher stigma angle. Similarly, a restorer should have medium-tall plant height, more number of panicles and spikelets, bigger anther and longer filament length (Virmani and Edwards, 1983). The frequency of usable CMS lines is very low since such lines should have good combining ability, higher out crossing potential, good grain quality and resistance to major pests and diseases besides being stable in male sterility. Therefore, the present piece of research work reports the results on Identification of maintainers and restorer lines for various CMS lines under study. In present study it represents an attempt to put the improved New Plant Types lines to test cross with CMS line of WA type cytoplasm and to identify its strength and its short comings.

MATERIALS AND METHODS

The present investigation was conducted at Research Farm , Department of Genetics and Plant

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Breeding, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, during *rabi* 2009-2010 and *kharif* 2010. The experimental material comprised of 27 hybrids obtained from the lines involving three CMS lines (APMS 6A, IR 79156A, IR58025A) and nine testers (ET-1-10, TOX 981-11-2-3, SR-6-SW-8, IR64-SR-6, NPTR-2, ET 1-1,ET 1-12,ET 1-13, IRFAN-115).The set of hybrids were generated in line x tester pattern for the purpose and evaluated along with parents in Randomized Complete Block Design with two replications. Twenty one days old seedlings of 27 hybrids and 9 parents were transplanted in the field. Single seeding hill^{-1} was transplanted. Recommended package of practices were followed and recorded on five randomly selected plants in both the replications. Observations were recorded on five randomly selected plants in both the replications for following traits *viz*., days to 50% flowering, flag leaf length, flag leaf width, flag leaf area, plant height, productive tillers plant^{-1}, pollen fertility (%), sterile spikelets panicle^{-1}, fertile spikelets panicle^{-1}, number of spikelets panicle^{-1}, spikelet fertility (%), panicle length, thousand seed weight, grain yield plant^{-1} and head rice recovery (%). Pollen studies were carried out for their fertility/ sterility of testcross F_1 plants. For this purpose, 15-20 spikelets from the just emerged panicles of three randomly selected plants were collected in a vial containing 70% ethanol. All the anthers from at least six spikelets were taken out with a forceps and placed on a glass slide with a drop of 1 per cent iodine potassium iodide (IKI) stain. The anthers were gently crushed by using a needle to release the pollen grains. After removing the debris, a cover slip was placed and the slide was observed under the microscope. For spikelet fertility/sterility, five panicles of each testcross were covered with butter paper bags to avoid foreign pollen contamination and were harvested at maturity.

Estimation of pollen fertility.

$$\text{Pollen fertility(\%)} = \frac{\text{Number of darkly stained pollen grains under a macroscopic field}}{\text{Total number of pollen grains}} \times 100$$

The following criteria for classifying the parental lines as maintainers and restorers were used as proposed by Virmani *et al*. (1997).

Pollen fertility (%)	Category	Spikelet fertility (%)
0-1	Maintainers	0
1.1-50	Partial maintainers	0.1-50
50.1-80	Partial restorers	50.1-75
>80	Restorers	>75

RESULTS AND DISCUSSION

The maintainers and restorers identified in the present investigation are presented in the table1. In the present study, the frequency of restorers appears to be quite higher as compared to maintainers for cytoplasmic sterile lines APMS 6A, IR 79156A and IR 58025A. Identification of maintainers and restorers could be possible by way of recording pollen and spikelet fertility percentages. The studies on pollen and spikelet fertility percentages indicated that none of the hybrids possessed complete pollen and spikelet sterility. So, none of the hybrids could be identified as maintainer, of course partial maintainers were identified based on the pollen and spikelet fertility percentage.

From the F1 test hybrid evaluated 3 partial maintainers, 6 partial restorers and 6 potential restorers were categorized on the basis of pollen fertility and spikelet fertility studies. The maximum pollen fertility was observed in the cross ET-1-10 with APMS6A (94%). 3 genotypes were found as partial maintainer in which ET 1-13 for APMS 6A and IR58025A and IRFAN-115 for IR79156A. Hence, the investigated results can be utilized for the development of new CMS line for this area as well as *per the per se* performance of the maintainers under recurrent backcrossing and revaluation program. The partial maintainers so identified could be multiplied and used developing in CMS line through repeated back crossing programme, following work plans reported by Durai and Nadarajan (2007). Jayashudha and Sharma (2010) also reported partial maintainer using CMS lines CRMS31A, CRMS32A and IR58025A in which greater frequency of partial maintainer is for CMS line CRMS31A.

The new plant type parents ET-1-10, ET 1-12 and ET 1-1 can be considered potential restorers for CMS line APMS 6A as their respective hybrids had more than 80% pollen fertility and 75% spikelet fertility percentage. Parents SR-6-SW-8 and NPTR-2 were identified as potential restorers for both CMS lines IR79156A and IR58025A. The findings are also in agreement with the reports of Rosamma and Vijayakumar (2005) and Pradhan *et al.* (2006). Sabar *et al*. (2007) reported that the traditional basmati lines Basmati 370,Super Basmati and Shaheen Basmati acted as restorers for certain WA CMS lines.

Table 1. Maintainer and restorer for CMS lines (Based on pollen and spikelet fertility percentages)

CMS Lines	Partial Maintainer Pollen fertility (1.1-50) Spikelet fertility (0.1-50)	PF%	SF%	Partial Restorers Pollen fertility (50.1-80) Spikelet fertility (50.1-75)	PF %	SF %	Potential Restorers Pollen fertility (>80) Spikelet fertility (>75)	PF%	SF%
APMS 6A	1. ET 1-13	12.5	67.07	1.TOX 981-11-2-3	62.5	76.82	1. ET-1-10	94	83.07
				2. SR-6-SW-8	72.5	71.68	2. ET 1-12	91	74.62
				3. IR64-SR-6	74	76.37	3. ET 1-1	82	81.32
				4. IRFAN-115	59.5	61.18			
IR 79156A	2. IRFAN-115	43.5	67.67	5. ET 1-12	67.5	60.66	4. SR-6-SW-8	96.55	77.58
							5. NPTR-2	77.5	87.17
IR58025A	3. ET 1-13	36.5	38.44	6. ET 1-12	64	75.83	6. NPTR-2	77.5	77.62

PF = Pollen fertility %
SF = Spikelet fertility %

Table 2.1. Mean performance of parents for different characters

Parents	Characters 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Lines															
APMS 6A	78.50	31.00	1.80	41.78	95.00	11.50	0.14	41.12	159.50	181.02	79.46	23.81	20.24	27.20	53.26
IR 79156A	79.00	34.45	1.70	43.87	97.50	14.50	0.14	61.78	210.10	271.88	77.30	25.57	17.76	48.02	48.08
IR58025A	92.25	29.95	1.35	30.33	86.12	10.75	0.02	40.00	249.50	289.50	86.23	23.25	19.61	18.10	45.70
Average	83.25	31.80	1.62	38.66	92.87	12.25	0.10	47.63	206.37	247.47	81.00	24.21	19.20	31.11	49.01
E-T-1-10	84.00	40.50	2.35	71.36	106.90	8.00	82.50	38.00	223.38	261.38	85.44	22.85	25.58	23.38	43.57
TOX 981-11-2-3	81.00	44.50	2.05	68.40	136.95	8.50	96.50	53.50	153.50	207.00	74.16	26.75	21.56	34.12	32.73
SR-6-SW-8	107.00	43.94	2.05	67.56	104.75	11.00	99.00	40.00	131.00	171.00	76.59	20.75	17.85	17.96	49.79
IR64 - SR-6	87.50	43.50	1.65	53.81	145.50	8.50	97.00	75.31	70.50	145.81	48.36	28.00	25.08	16.74	45.63
NPTR-2	94.50	30.60	2.15	49.32	126.56	7.00	96.00	38.00	157.50	195.50	80.57	27.63	20.90	26.22	40.71
E-T-1-1	80.00	32.40	2.25	54.64	115.75	5.50	100.00	50.30	165.50	215.80	76.68	24.53	22.84	21.03	28.38
E-T-1-12	81.00	41.50	2.70	84.00	112.15	6.00	99.00	49.55	171.15	220.70	77.63	26.90	26.03	32.06	39.75
E-T-1-13	78.50	36.75	2.60	71.61	109.35	10.00	100.00	69.10	187.85	256.95	73.12	31.95	27.22	46.30	49.49
IRFAN-115	81.00	27.63	1.55	32.10	92.00	9.00	87.50	81.15	223.25	304.40	73.51	20.90	19.51	22.73	24.10
Average	86.06	37.92	2.15	61.42	116.66	8.17	95.28	54.99	164.85	219.84	74.01	25.58	22.95	26.72	39.35
Overall parental average	85.35	36.39	2.02	55.73	110.71	9.19	71.48	53.15	175.23	226.74	75.75	25.24	22.01	27.82	41.76
S E ±	1.12	0.51	0.06	1.47	1.13	0.70	1.74	7.83	18.70	24.85	1.16	0.70	0.40	1.14	0.49
CD at 5 %	3.22	1.47	0.18	4.20	3.23	2.00	4.99	22.4	53.54	71.17	3.33	2.00	1.15	3.26	1.40
CD at 1 %	4.31	1.98	0.23	5.62	4.33	2.67	6.68	30.03	71.71	95.32	4.47	2.68	1.54	4.37	1.88
CV %	1.85	1.93	4.45	3.67	1.44	11.94	3.70	17.31	14.29	14.11	2.23	3.68	2.69	4.20	2.58

1. Days to 50% flowering, 2.Flag leaf length (cm), 3.Flag leaf width (cm), 4.Flag leaf area (cm^2), 5.Plant height (cm), 6. Productive tillers $plant^{-1}$,7.Pollen fertility (%), 8.Sterile spikelets $panicle^{-1}$, 9.Fertile spikelets $panicle^{-1}$, 10.Spikelets no. $panicle^{-1}$, 11.Spikelets fertility (%), 12.Panicle length (cm), 13.1000Seed weight (g), 14.Grain yield $plant^{-1}$, 15.Head rice recovery (%).

Table 2.2. Mean performance of hybrids for different charaters

Hybrids	Characters 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
APMS 6A/															
ET-1-10	79.00	51.28	2.38	91.52	118.85	6.70	94.00	81.50	405.50	487.00	83.07	28.95	24.78	14.85	41.39
TOX 981-11-2-3	86.25	38.50	1.55	44.74	86.60	8.00	62.50	29.50	96.50	126.00	76.82	26.74	20.88	25.39	34.49
SR-6-SW-8	83.50	46.30	2.05	71.20	107.80	9.63	72.50	72.38	182.55	254.93	71.68	26.80	19.75	16.28	49.62
IR64 - SR-6	74.50	41.25	1.66	51.35	134.95	10.20	74.00	61.88	200.00	261.88	76.37	29.55	27.83	23.08	40.42
NPTR-2	84.00	46.01	2.45	84.52	119.50	6.85	0.15	60.13	266.88	327.00	81.64	28.98	21.92	36.33	44.81
ET-1-1	83.00	41.10	2.34	72.15	115.60	6.75	82.00	37.75	164.25	202.00	81.32	28.45	22.86	20.06	34.59
ET-1-12	78.50	40.50	2.08	63.08	111.63	5.10	91.00	85.00	250.00	335.00	74.62	29.99	19.81	42.20	24.42
ET-1-13	85.50	38.88	1.65	48.08	116.51	6.20	12.50	36.00	74.25	110.25	67.07	25.90	20.08	29.07	35.59
IRFAN-115	80.00	33.50	1.66	41.69	108.31	9.05	59.50	26.49	41.75	68.24	61.18	26.90	26.58	24.68	26.64
Average	81.58	41.92	1.98	63.15	113.30	7.61	60.91	54.51	186.85	241.37	74.86	28.03	22.72	25.77	36.88
IR 79156A/															
ET-1-10	88.00	40.06	1.65	49.57	90.75	4.63	69.00	82.00	418.00	500.00	83.49	24.20	17.98	43.76	46.93
TOX 981-11-2-3	87.50	37.80	1.85	52.44	121.05	9.80	84.00	91.50	208.50	300.00	69.50	24.84	21.41	30.80	54.13
SR-6-SW-8	81.50	36.10	1.96	53.08	120.60	8.10	96.55	39.00	135.00	174.00	77.58	27.99	20.93	21.63	36.75
IR64 - SR-6	94.00	23.95	1.47	26.34	131.75	12.30	53.50	28.35	231.30	259.65	89.20	29.17	16.90	5.91	30.88
NPTR-2	99.50	30.05	2.30	51.83	118.85	8.10	77.50	37.75	256.75	294.50	87.17	25.70	19.00	14.72	32.67
ET-1-1	90.00	42.50	2.50	79.65	115.60	8.30	82.00	109.13	103.38	212.50	48.64	28.67	26.94	33.86	51.57
ET-1-12	81.00	42.50	2.31	73.43	109.20	6.90	67.50	107.00	165.00	272.00	60.66	28.85	21.00	47.17	29.28
ET-1-13	91.50	41.00	2.18	66.89	122.75	7.00	62.50	28.88	194.88	223.75	87.23	30.96	21.05	51.60	25.70
IRFAN-115	78.50	38.20	2.05	58.72	97.90	10.75	43.50	115.50	238.00	353.50	67.67	25.20	23.78	38.22	21.00
Average	87.94	36.91	2.03	56.88	114.27	8.43	70.67	71.01	216.76	287.77	74.57	27.29	21.00	31.96	36.5
IR58025A/															
E-T-1-10	80.50	41.10	2.45	75.52	106.35	8.00	67.50	54.50	204.00	258.50	78.92	29.90	18.32	10.62	41.58
TOX 981-11-2-3	95.00	35.75	1.50	40.20	113.70	8.70	0.25	52.00	130.50	182.50	71.53	29.00	18.19	18.18	53.37
SR-6-SW-8	76.50	38.45	1.61	46.43	107.90	10.80	82.50	62.88	115.00	177.88	64.64	27.56	9.75	27.19	22.38
IR64 - SR-6	85.50	40.10	2.25	67.66	96.16	6.75	47.50	103.00	257.00	360.00	71.39	23.80	5.43	8.04	35.89
NPTR-2	99.50	36.05	1.82	49.08	113.10	5.30	77.50	60.25	208.63	268.88	[illegible]	26.55	27.99	29.33	39.39
ET-1-1	102.50	35.50	2.05	54.60	100.50	3.50	99.00	106.75	232.50	339.25	68.51	28.93	18.99	12.93	44.80
ET-1-12	76.50	32.50	1.90	46.28	100.47	5.90	64.00	39.60	124.25	163.85	75.83	25.81	21.55	5.59	48.48
ET-1-13	96.00	35.80	1.45	[illegible]	95.83	12.30	36.50	212.00	132.15	344.15	38.44	27.00	19.46	48.09	20.47
IRFAN-115	77.50	32.84	1.56	38.43	98.75	8.20	77.50	35.99	83.10	119.09	69.80	27.66	27.13	36.52	25.49
Average	87.72	36.45	1.84	50.79	103.64	7.72	61.36	80.77	165.24	246.01	68.52	27.36	8.53	21.83	36.87
Overall average	85.63	37.80	1.97	56.57	110.50	8.31	66.52	63.96	185.19	248.65	73.61	26.84	21.14	26.92	38.30
SE	1.12	0.51	0.06	1.47	1.13	0.70	1.74	7.83	18.70	24.85	1.16	0.70	0.40	1.14	0.49
CD at 5 %	3.22	1.47	0.18	4.20	3.23	2.00	4.99	22.4	53.54	71.17	3.33	2.00	1.15	3.26	1.40
CD at 1 %	4.31	1.98	0.23	5.62	4.33	2.67	6.68	30.03	71.71	95.32	4.47	2.68	1.54	4.37	1.88
CV (%)	1.85	1.93	4.45	3.67	1.44	11.94	3.70	17.31	14.29	14.11	2.23	3.68	2.69	4.20	2.58
Range lowest	74.5	23.95	1.35	26.34	86.11	3.5	0.01	26.50	41.75	68.24	38.43	20.75	5.42	20.47	5.59
Range highest	107.00	51.27	2.70	91.52	145.50	14.50	100.00	212.00	418.00	500.00	89.20	31.95	28.00	54.13	51.60

1. Days to 50% flowering, 2.Flag leaf length (cm), 3.Flag leaf width (cm), 4.Flag leaf area (cm^2), 5.Plant height (cm), 6. Productive tillers $plant^{-1}$,7.Pollen fertility (%), 8.Sterile spikelets $panicle^{-1}$, 9.Fertile spikelets $panicle^{-1}$, 10.Spikelets no. $panicle^{-1}$, 11.Spikelets fertility (%), 12.Panicle length (cm), 13.1000Seed weight (g), 14.Grain yield $plant^{-1}$, 15.Head rice recovery (%).

Jaiswal and Parveen (2009) also reported effective restorers Pusa 25-17-251, Taraori Basmati, and Mahisugandha for CMS line IR68890A. The genotypes TOX 981-11-2-3, SR-6-SW-8, IR64-SR-6 and IRFAN-115 were identified as partial restoter for CMS line APMS 6A and ET 1-12 for both CMS line IR79156A and IR58025A. The findings are also in agreement with the reports of Pradeep Kumar and Reddy (2011) in which Indica tropical japonica parent (M7, M11, M16, M21) crossed with APMS 6A and IR58025A resulted partial restorers.

In some cases, the genotypes behaved as a restorer for one CMS line but partial restorer for other CMS source and as a maintainer for the other line. IRFAN-115 behaved as partial maintainer for IR79156A but identified as partial restorer for APMS 6A. Similarly SR-6-SW-8 with APMS 6A behaved as partial restorer but with IR79156A behaved as potential restorers and ET 1-12 with IR79156A (partial restorer) and with APMS 6A (potential restorers). This type of rice genotypes with different CMS lines of the same cytoplasmic sources has been reported by Jaiswal and Parveen (2009) in which Super Basmati behaved as an effective maintainer for CMS line DRR 2A but was an effective restorer for CMS lines PMS 2A and UPRI 95-17A. Kasturi was an effective maintainer for CMS lines IR68890A and DRR 2A while it was an effective restorer for CMS line PMS 2A. The findings are also in agreement with the reports of Jayashudha and Sharma (2010) in which R 1241-1856-1-1 behaved as partial restorer for CRMS 31A and IR 58025A and as partial maintainer for CRMS 31A and CRMS 32A.In the variation in behavior of fertility restoration indicates that either the fertility-restoring genes are different or that their expression varied with the genotypes of the parents or the modifiers of female background.This might be also due to the influence of female genetic background on the restoration ability of the genotypes tested (Wilson, 1968). Further, it was interpreted that phenomenon as the results of variation in sterility gene number or in the presence of fertility genes that act in a complementary or additive fashion with restorer genes. Virmani *et al.* (1986) indicated that the excessive sterility genes could act as inhibiters of pollen fertility restoration in the F_1 generation.

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Rec. on 10.06.2011 & Acc. on 23.09.2011

J. Soils and Crops 22 (2) 246-252, Dec., 2012 ISSN 0971-2836

EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH, YIELD AND QUALITY OF TOMATO UNDER POLY-HOUSE CONDITION

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ABSTRACT

A pot experiment was conducted during 2009-2010 at the Experimental Farm of School of Agricultural Sciences and Rural Development, Medziphema campus, Nagaland University, Nagaland to study the effect of integrated nutrient management on growth, yield and quality of tomato under poly-house condition. The experiment was laid out in a completely randomized design with three replications. The treatments consisted of T_1-Control, T_2- 100 % NPK (120:60:60 kg ha^{-1}), T_3- FYM 20 t ha^{-1}, T_4- Pig manure 15 t ha^{-1}, T_5-Poultry manure 8 t ha^{-1}, T_6- Vermicompost 10 t ha^{-1}, T_7- 50 % NPK + 50 % FYM, T_8-50 % NPK + 50 % Pig manure, T_9- 50 % NPK + 50 % Poultry manure, T_{10}- 50 % NPK + 50 % Vermicompost, T_{11}- 50 % NPK + 50 % FYM + Biofertilizers, T_{12}- 50 % NPK + 50 % Pig manure + Biofertilizers, T_{13}- 50% NPK + 50 % Poultry manure + Biofertilizers, T_{14}- 50 % NPK + 50 % Vermicompost + Biofertilizers. Results revealed that integrated application of 50 % NPK + 50% Poultry manure + Biofertilizers recorded significantly higher plant height (164.33 cm), number of branches plant^{-1} (12.26), number of leaves plant^{-1} (58.19), fruit length (6.55 cm), fruit diameter (4.48 cm), number of fruits plant^{-1} (33.27), fresh weight of fruit (63.02 g), yield (77.54 t ha^{-1}), TSS (6.67^{o} Brix) and vitamin C content (79.70 mg 100^{-1} g) over other treatments. However, 100 % NPK recorded 56.45 t ha^{-1} fruit yield of tomato. The treatment 50 % NPK + 50% Poultry manure + Biofertilizers treatment also gave the highest net return Rs 3,49,887. These results suggested that the optimum production of tomato under poly-house can be obtained with integrated application of 50 % NPK + 50 % Poultry manure + Biofertilizers. The next best treatment was 50 % NPK + 50 % Vermicompost + Biofertilizers for improving the values of above aspects. Both these treatments were significantly more superior to 100 % NPK.

((Key words: Tomato, polyhouse, Integrated Nutrient Management, chemical fertilizers, organic manures, biofertlizers, growth, yield, quality and economics)

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important vegetable grown under open as well as protected condition throughout the world for supplying in the fresh market as well as for processing. Tomato is thermo-sensitive crop and fruit set is adversely affected when night temperature falls below 13^{o}C or day temperature exceeds 30^{o}C. The optimum temperature required for its cultivation is 15^{o}C-27^{o}C. Prevailing low temperature and frost injury during winter are limiting factors in north India and hills. To make their cultivation successful in winter and spring summer season, poly house is a vital solution. Green houses have tremendous potential in increasing productivity of tomato (Chandra *et al*., 2000). Tomato being a heavy feeder and exhaustive crop responds very well to nutrients application. Among various factors responsible for low production of tomato, nutrition is of prime importance. Use of chemical fertilizer alone increased the crop yield in the initial year but adversely affected the sustainability subsequently. The cost of chemical fertilizers is also increasing day by day. Therefore, to reduce dependence on chemical fertilizers along with sustainable production are vital issues in modern agriculture which can be achieved possible through integrated plant nutrient supply system (IPNS). On the other hand, organic manures like FYM, poultry manure and pig manure are cheap and easily available in local condition and can be efficiently utilized for tomato production. Integrated nutrient sources increase the nutrient use efficiently and soil fertility thus enhance the productivity of tomato. However, the information about cultivation of tomato crop under poly house cultivation in align with integrated nutrient management is very limited in North East Region. In view of the above, the present investigation was conducted to study the effect of integrated nutrient management on growth, yield and quality of tomato under poly-house condition.

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MATERIALS AND METHODS

A pot experiment was conducted in a poly-house located at the Experimental Farm of SASRD, Medziphema campus, Nagaland University, Nagaland during September 2009 to February 2010. The field is located at the altitude of 304.8 m above mean sea level with geographical location at 20º 45' 43" N latitude and 93 º 53' 04" E longitudes. The temperature inside the poly-house was set at 15-27°C throughout the experimenting period and Relative Humidity was set 70 % throughout the experimental period. The experimental soil was strongly acidic with a pH of 4.8, organic carbon 2.27 %, available N 309.42 kg ha^{-1}, P_2O_5 9.2 kg ha^{-1}, K_2O 208.32 kg ha^{-1}. The experiment was laid out in Completely Randomized Design with three replications. Treatments comprised of T_1- Control, T_2-100 % NPK (120:60:60 kg ha^{-1}), T_3- FYM 20 t ha^{-1}, T_4- Pig manure 15 t ha^{-1}, T_5- Poultry manure 8 t ha^{-1}, T_6-Vermicompost 10 t ha^{-1}, T_7- 50 % NPK + 50 % FYM, T_8-50 % NPK + 50 % Pig manure, T_9- 50 % NPK + 50 % Poultry manure, T_{10}- 50 % NPK + 50 % Vermicompost, T_{11}- 50 % NPK + 50 % FYM + Biofertilizers, T_{12}- 50 % NPK + 50 % Pig manure + Biofertilizers, T_{13}- 50% NPK + 50 % Poultry manure + Biofertilizers, T_{14}- 50 % NPK + 50 % Vermicompost + Biofertilizers. Full dose of organic manures were applied during final preparation of potting mixture. NPK was supplied through Urea, SSP and MOP. Full dose of P, K and half dose of N was applied at the time of transplanting and remaining half of N was applied 30 days after transplanting. Biofertilizers (*Azospirillum* and *Phosphotika*) were inoculated before transplanting as seedling root dip for 30 minutes @ 2 kg ha^{-1} each. Observations were recorded for plant height, number of branches plant^{-1}, number of leaves plant^{-1}, fruit length, fruit diameter, number of fruits plant^{-1}, fresh weight of fruit, yield plant^{-1} and hectare^{-1}, total soluble solid and vitamin C content. Total soluble solid was determined using hand refractometer and results expressed in ºbrix. Vitamin C content was determined by 2, 6-dichlorophenol indophenols visual titration method and expressed in mg 100^{-1} g as prescribed by A.O.A.C. (Anonymous, 1984).

Soil samples were collected before and after harvest of crop from different pots. The collected soil samples were mixed and reduced into 500 g and then dried under shade, ground and sieved through 2 mm sieve size. Soil samples were analysed for pH, organic carbon, available nitrogen, phosphorus and potassium. pH was determined by Digital pH meter (Jackson, 1973). Organic carbon was determined by Walkley and Black Rapid titration method (Jackson, 1973). Available nitrogen was determined by alkaline potassium permanganate method (Subhiah and Asija, 1956). Available phosphorus was determined by Olsen's method (Bray and Kurtz, 1945). Available potassium was determined by flame photometer method (Jackson, 1973). The statistical analysis was carried out as per procedure given by Panse and Sukhatme (1978).

Economics of the treatments were also calculated as per prevailing market price of input and output. Treatment wise economics was carried out by calculating the cost of cultivation based on prevailing rate of input and outputs. Gross income was calculated by yield multiplied with whole sale rate of tomato (Rs. 600 quintal^{-1}). Net income was estimated by deducting the total cost of cultivation (fixed cost + treatment cost) from gross income of the particular treatment. Cost:benefit ratio was worked out by dividing net return from total cost of cultivation.

RESULTS AND DISCUSSION

Growth characters:

Improvement in growth characters is considered to be pre-requisite to increased yield of any crop. NPK fertilizers with different organic manures along with biofertilizers alone or in combination were found to have significant positive effect on growth characters as compared to control (Table 1). Application of 50 % NPK + 50 % Poultry manure+Biofertilizers recorded maximum plant height (164.33 cm), number of leaves plant^{-1} (58.19) and number of branches plant^{-1} (12.26) followed by 50 % NPK + 50 % vermicompost + biofertilizers. The lowest values of growth characters were recorded with control. This clearly indicates the importance of adding organic manures and biofertilizers to the soil in conjunction with inorganic fertilizer, which increases the availability of nutrients considerably resulting in positive effect on growth parameters. Poultry manure which was readily available to the plant, more C : N ratio, abundant supply of available nutrients to the soil with comparatively lesser retention in roots and more translocation to the aerial parts for protoplasmic proteins and synthesis of other compounds. The added organic manures in term of poultry manure would have improved the soil physical conditions and increased nutrient availability resulting in better plant growth. The increased growth characters might be due to higher availability of nitrogen which improved the plant growth due to the fact that nitrogen after being taken up by the plant is converted into amino-acids which are the building blocks of protein which might have led to increase in the rate of meristematic activity resulting in better growth characters. This might be attributed to certain growth promoting substances secreted by the biofertilizers which in turn might have led to better root development, better transportation of water, uptake and deposition of nutrients. These results are in conformity with the finding of Deepika *et al*. (2010) in *Capsicum*, Vimera *et al.* (2010) in King Chilli and Sentiyangla *et al.* (2010) in radish. They recorded maximum growth characters with 50% NPK + 50% FYM + biofertilizers.

Yield and yield attributing characters:

Integrated application of chemical fertilizers, organic manures and biofertilizers alone or in combination significantly increased yield and yield attributing characters of tomato compared to control (Table 1). Application of 50 % NPK + 50 % Poultry manure + Biofertilizers recorded maximum values of all yield attributing characters such as fruit length (6.55 cm), fruit diameter (4.48 cm), number of fruits plant^{-1} (33.27) and fresh weight of fruit (63.02g) respectively followed by 50 % NPK + 50 % vermicompost + biofertilizers. This result indicates positive effects of integrating NPK with manures as well as biofertilizers. The efficacy of inorganic fertilizer is much pronounced when they are combined with organic manure. Higher vegetative growth might have helped in synthesis of greater amount of food material which were later translocated into developing fruits resulting in increased fruit length and fruit diameter. Besides increasing the nitrogen fixing abilities, biofertilizers might have played a vital role in increasing the yield related attributes. The highest fruit yield plant^{-1} (2095.78 g) and fruit yield hectare^{-1} (77.54 t) was recorded in treatment of 50 % NPK + 50 % Poultry manure + Biofertilizers followed by 50 % NPK + 50 % vermicompost + biofertilizers. This might be due to corresponding response to increased yield attributing characters attained previously under this treatment. This finding has close conformity with Harikrishna *et al.* (2002) who reported the highest fruit yield of tomato (54.32 t ha^{-1}) with treatment of FYM 25 t ha^{-1} + 75% recommended dose of NPK + *Azosprillum.* Rane *et al.* (2007) also recorded highest fruit yield of tomato (35.56 t ha^{-1}) under the treatment of FYM 10 t ha^{-1} + 50% recommended dose of NPK + biofertilizers. Similar findings were also reported by Vimera *et al.* (2010) in King Chilli, Deepika *et al*. (2010) in *Capsicum* and Sentiyangla *et al.* (2010) in radish. They recorded maximum yield characters with 50% NPK + 50% FYM + biofertilizers.

Quality characters:

Quality of tomato is usually evaluated by vitamin C and TSS which are found to variate according to nutrition. It is evident from table 1 that application of 50 % NPK + 50 % Poultry manure + Biofertilizers has resulted in significantly higher TSS (6.67^{o} Brix) and ascorbic acid (79.70 mg 100^{-1}g) over other treatments followed by 50 % NPK + 50 % vermicompost + biofertilizers.. The higher level of vitamin C content in tomato fruit may be due to action of specific soil nutrients which may be made more readily available into soil for plant absorption as a result of mineral fertilizer + organic manure 'or' with biofertilizers integration effect which in term may activate specific enzymes for the synthesis of these compounds. It is therefore certain that specific nutrients in soil play pivotal role in determining the quality parameters. Rofi *et al.* (2002) and Rodge and Yadlod (2009) reported that application of 50 % recommended dose of FYM @ 12.5 t ha^{-1} along with 50% recommended dose of fertilizer of 100:50:50 NPK kg ha^{-1} resulted high TSS and ascorbic acid. Similar findings were also reported by Vimera *et al*. (2010) in King chilli, Deepika *et al*. (2010) in *Capsicum* and Sentiyangla *et al.* (2010) in radish. They recorded maximum TSS and ascorbic acid with 50% NPK + 50% FYM + biofertilizers.

Fertility status of the soil after harvest:

Sustainability of a cropping system is being evaluated on the basis of crop yield as well as nutrient status of the soil after harvest of the crop. Available NPK and organic carbon in soil after harvest were significantly influenced by application of NPK fertilizers, organic manures and biofertilizers alone or in combination over control (Table 2).

Table 1. Effect of integrated nutrient management on growth, yield and quality of tomato

Treatments	Plant height (cm)	No. of branches $plant^{-1}$	No. of leaves $plant^{-1}$	Fruit length (cm)	Fruit diameter (cm)	Number of fruits $plant^{-1}$	Fresh weight of fruit (g)	Yield $plant^{-1}$ (g)	Yield ha^{-1} (t)	TSS (°Brix)	Vitamin C (mg 100 g^{-1})
T_1 - Control	112.04	6.46	40.37	4.90	3.08	20.03	38.03	761.75	28.18	4.67	48.30
T_2 – 100 % NPK(120:60:60 kg ha^{-1})	137.13	8.06	52.05	5.87	4.14	27.62	55.16	1525.76	56.45	5.07	59.83
T_3 - FYM 20 t ha^{-1}	125.48	9.42	49.72	5.30	3.91	24.86	45.04	1119.00	41.40	5.43	61.67
T_4- Pig manure 15 t ha^{-1}	124.91	7.69	43.28	5.67	3.69	25.80	46.31	1193.84	44.17	5.41	62.22
T_5 - Poultry manure 8 t ha^{-1}	121.07	9.49	51.19	6.14	4.08	26.70	49.42	1326.24	49.07	5.67	63.96
T_6 - Vermicompost 10 t ha^{-1}	143.47	9.32	43.59	6.06	4.07	26.12	46.12	1203.25	44.52	5.48	62.58
T_7 -50 % NPK + 50 % FYM	157.84	9.43	48.82	6.02	3.74	27.65	48.20	1327.40	49.11	5.95	67.37
T_8 - 50 % NPK + 50 % Pig manure	149.22	9.32	50.84	5.64	3.96	26.96	48.44	1306.94	48.35	5.90	67.27
T_9 -50 % NPK + 50 % Poultry manure	160.05	11.24	52.16	6.08	4.09	30.53	54.26	1656.58	61.29	6.19	70.72
T_{10}- 50% NPK + 50%Vermicompost	159.31	10.81	46.21	5.67	3.82	29.88	53.05	1585.63	58.66	5.87	67.78
T_{11}- 50 % NPK + 50 % FYM + Biofertilizers	140.51	11.18	48.12	5.88	4.09	30.47	47.89	1448.83	53.60	6.37	75.73
T_{12}- 50% NPK + 50% Pig manure + Biofertilizers	143.74	10.10	46.49	5.91	3.73	28.72	48.30	1387.73	51.27	6.33	71.83
T_{13}- 50 % NPK + 50 % Poultry manure + Biofertilizers	164.33	12.26	58.19	6.55	4.48	33.27	63.02	2095.78	77.54	6.67	79.70
T_{14}- 50 % NPK + 50 % Vermicompost + Biofertilizers	163.11	11.42	56.79	6.33	4.15	32.01	56.07	1795.30	66.42	6.60	78.89
SE $\pm$	4.13	0.56	2.27	0.16	0.14	1.13	1.76	65.76	2.43	0.32	3.01
CD (0.05)	12.41	1.70	6.83	0.50	0.42	3.39	5.30	197.29	73.12	0.97	9.05

Table 2. Effect of integrated nutrient management on fertility status of soil after harvest

Treatments	Available Nitrogen (kg ha $^{-1}$)	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})	Organic carbon (%)	Soil pH
T_1 - Control	262.23	6.82	201.60	2.15	4.78
T_2 – 100 %NPK (120:60:60 kg ha^{-1})	**375.77**	10.50	247.70	2.28	4.85
T_2 - FYM 20 t ha^{-1}	313.60	8.25	219.64	2.35	4.90
T_4 - Pig manure 15 t ha	321.96	8.07	224.05	2.58	4.90
T_5 - Poultry manure 8 t ha^{-1}	338.69	8.16	226.05	2.33	4.91
T_6 - Vermicompost 10 t ha^{-1}	326.14	7.65	215.21	2.30	4.80
T_7 -50 % NPK + 50 % FYM	331.98	8.29	239.24	2.57	4.86
T_8 - 50 % NPK + 50 % Pig manure	345.25	9.27	242.50	2.66	4.86
T_9 - 50 % NPK + 50 % Poultry manure	351.23	9.36	245.64	2.60	4.90
T_{10}- 50 % NPK + 50 %Vermicompost	357.59	8.63	236.42	2.45	4.86
T_{11} -50 % NPK + 50 % FYM + Biofertilizers	347.05	12.20	246.32	2.94	4.90
T_{12}- 50 % NPK + 50 % Pig manure + Biofertilizers	338.69	10.51	248.03	2.80	4.86
T_{13}- 50 % NPK + 50 % Poultry manure + Biofertilizers	364.68	11.24	250.25	2.92	4.93
T_{14}- 50 % NPK + 50 % Vermicompost + Biofertilizers	337.14	9.70	241.25	2.75	4.83
SE $\pm$	0.83	0.26	0.84	0.03	-
CD (0.05)	2.50	0.80	2.52	0.10	NS

Table 3. Effect of integrated nutrient management on economics of the treatments (Rs ha^{-1})

Treatments	Cost of cultivation (Rs ha^{-1})			Yield (q ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	Cost: benefit ratio
	Fixed cost	Treatment cost	Total cost				
T_1 - Control	1,08,002	-	1,08,002.00	281.84	1,69,104	61,102.00	1:0.56
T_2 – 100 %NPK (120:60:60 kg ha^{-1})	1,08,002	6,536.40	1,14,538.96	564.55	3,38,730	2,24,191.04	1:1.95
T_2 - FYM 20 t ha^{-1}	1,08,002	10,000.00	1,18,002.00	414.02	2,48,412	1,30,410.00	1:1.10
T_4 - Pig manure 15 t ha	1,08,002	9,000.00	1,17,002.00	441.72	2,65,032	1,48,030.00	1:1.26
T_5 - Poultry manure 8 t ha^{-1}	1,08,002	8,000.00	1,16,002.00	490.70	2,94,420	1,78,418.00	1:1.53
T_6 - Vermicompost 10 t ha^{-1}	1,08,002	1,00,000.00	2,08,002.00	445.20	2,67,120	59,118.00	1:0.28
T_7 -50 % NPK + 50 % FYM	1,08,002	8,268.48	1,16,270.48	491.13	2,94,678	1,78,407.52	1:1.53
T_8 - 50 % NPK + 50 % Pig manure	1,08,002	7,768.48	1,15,770.48	483.56	2,90,136	1,74,865.52	1:1.51
T_9 - 50 % NPK + 50 % Poultry manure	1,08,002	7,268.48	1,15,270.48	612.93	3,67,758	2,52,487.52	1:2.19
T_{10}- 50 % NPK + 50 %Vermicompost	1,08,002	53,268.48	1,61,270.48	586.68	3,52,008	1,90,737.52	1:1.18
T_{11} -50 % NPK + 50 % FYM + Biofertilizers	1,08,002	8,368.48	1,16,370.48	536.06	3,21,636	2,05,265.52	1:1.76
T_{12}- 50 % NPK + 50 % Pig manure + Biofertilizers	1,08,002	7,868.48	1,15,870.48	512.79	3,07,674	1,91,803.52	1:1.65
T_{13}- 50 % NPK + 50 % Poultry manure + Biofertilizers	1,08,002	7,368.48	1,15,370.48	775.43	4,65,258	3,49,887.52	1:3.03
T_{14}- 50 % NPK + 50 % Vermicompost + Biofertilizers	1,08,002	53,368.48	1,61,370.48	664.26	3,98,556	2,37,185.52	1:1.46

However, pH was found non significant. Application of 100 % NPK gave maximum available N (375.77 kg ha^{-1}) after harvest which was followed by (364.68 kg ha^{-1}) in 50% NPK + 50% poultry manure + Biofertilizers. The probable cause of high available nitrogen after harvest in 100 % NPK may be due to poor soil physical structure, lack of organic manures and microbial activities thus resulting in poor utilization of N to plants at its growth stages. As such the applied N could bring about higher residual nitrogen in soil after harvest. On the other hand, application of 50% NPK + 50% FYM + Biofertilizers obtained maximum available P_2O_5 (12.20 kg ha^{-1}) and maximum organic carbon (2.94 %). Maximum K_2O (250.25 kg ha^{-1}) was recorded with the application of 50 % NPK + 50 % Poultry manure + Biofertilizers. Poultry manure might have improved the CEC of the soil and thus increased the retention of K in exchangeable form by a mass action effect. The effect of integrated nutrient management on the general nutrient availability in the soil after harvest is better than those treatments without integration with exception to application of 100% NPK which gave the highest available N after harvest. Similar results were reported by Choudhary *et al*. (2005) who reported that the incorporation of Az, PSB, and FYM with inorganic fertilizers significantly improved the organic carbon content and available N, P_2O_5 and K_2O status of the soil in tomato.

Economics of treatments:

It is evident from table 3 that the most profitable way for cultivating tomato could be achieved by application of 50 % NPK + 50 % poultry manure + Biofertilizers which gave highest net return of Rs 3,49,887.52 with the cost : benefit ratio of 1: 3.03 followed by 50 % NPK + 50 % Poultry manure. Vermicompost 10 t ha^{-1} recorded minimum net return of Rs 59,118.00 with least cost : benefit ratio (1: 0.28). These findings are in accordance with Vimera *et al.* (2010) in King Chilli, Deepika *et al*. (2010) in *Capsicum* and Sentiyangla *et al.* (2010) in radish. They recorded the highest net return in the treatment 50% NPK + 50% FYM + Biofertilizers.

The investigation established that the integrated application on 50 % NPK + 50 % poultry manure + Biofertilizers (*Azospirillum* + *Phosphotika*) in tomato is the best treatment in terms of plant growth, yield, quality and net return (profit). The treatment 50 % NPK + 50 % vermicompost + biofertilizers was found second best treatment in terms of plant growth, yield, quality and net return (profit). Integrated use of chemical fertilizers with organic manure and biofertilizers is therefore recommended over their lone application for optimum plant growth, yield, productivity, quality and profitability in tomato cultivation which is also in aligned with sustainable use of soil.

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Rec. on 11.11.2011 & Acc. on 13.03.2012

J. Soils and Crops 22 (2) 253-257, Dec., 2012 ISSN 0971-2836

EFFECT OF VERMICOMPOST AND FYM IN COMBINATION WITH INORGANIC FERTILIZER ON GROWTH, YIELD AND FLOWER QUALITY OF GLADIOLUS (*Gladiolus hybridus*)

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ABSTRACT

An experiment on gladiolus variety 'Candyman' was conducted at Horticulture Farm, Department of Horticulture, IGKV Raipur (C.G.) during the *rabi* season of 2010-11 to study the effect of FYM and Vermicompost in combination with various doses of inorganic fertilizer. The experiment was laid out in Randomized Block Design (RBD) with four replications. There were ten treatment combinations under the study namely, T_1: Control, T_2: 50% RDF, T_3: 75% RDF, T_4: 100% RDF, T_5: FYM 10 t ha^{-1}, T_6: 50% RDF + FYM 10 t ha^{-1}, T_7: 75% RDF + FYM 10 t ha^{-1}, T_8: Vermicompost Only 3 t ha^{-1}, T_9: 50% RDF + Vermicompost 3 t ha^{-1}, T_{10}:75% RDF + Vermicompost 3 t ha^{-1}.

Under the combinations of various levels of vermicompost, FYM and organic fertilizer, the treatment receiving 75% RDF + FYM 10 t ha^{-1} recorded better in days to sprouting, number of sprouts, number of leaves $plant^{-1}$, girth of plant base, width of leaf, height of the plant, days to spike emergence, diameter of corm, weight $corm^{-1}$, total corm weights $plot^{-1}$ and number of corms $plant^{-1}$. However, length of the spike, number of florets $spikes^{-1}$, vase life of cut spikes were found maximum with the application of 75% RDF+Vermicompost 3 t ha^{-1}.Whereas, treatments with FYM 10 t $ha^{-1}$and Vermicompost only 3.0 t ha^{-1} showed significantly minimum leaves $plant^{-1}$, diameter of corm, weight $corm^{-1}$, total corms weight $plot^{-1}$ and number of corms $plant^{-1}$.

(Key words: Gladiolus, vermicompost, inorganic fertilizer, growth, yield, flower quality)

INTRODUCTION

Gladiolus is known as 'Queen' of the bulbous flowers. It is excellent for cut flower as it lasts longer in flower vase and has magnificent inflorescence with variety of colors. It is mainly cultivated for cut flower, which fetches good price in the cities of India, besides having an export market as well. Gladiolus is one of the important flowers which occupy 5^{th} position in terms of global floriculture trade (Balaram *et al.*, 2009). The major gladiolus growing area in India are Kalimpong (West Bengal), New Delhi, Srinagar (Jammu Kashmir), Pune, Ludhiana, Benagluru and Nainital (Uttarakhand). In Chhattisgarh, area under floriculture crops is about 77130.40 hectares, out of which gladiolus crop occupied area around 1346.63 hectares during 2010-2011 (Anonymous, 2011).

MATERIALS AND METHODS

The present investigation was conducted at Horticulture Farm, Department of Horticulture. IGKV Raipur (C.G.) during the *rabi* 2010-2011 adopting RBD with four replications. There were ten treatment combinations under the study namely, T_1: Control, T_2: 50% RDF, T_3: 75% RDF, T_4: 100% RDF, T_5: FYM 10 t ha^{-1}, T_6: 50% RDF + FYM 10 t ha^{-1}, T_7: 75% RDF + FYM 10 t ha^{-1}, T_8: Vermicompost 3 t ha^{-1}, T_9: 50% RDF + Vermicompost 3 t ha^{-1}, T_{10}:75% RDF + Vermicompost 3 t ha^{-1}. Date of planting of corm was 5 Nov., 2010. However, the date of final harvesting was 15 April, 2011. The experimental field having clay loam soil which containing 25.68% sand, 32.44% silt and 45.39% clay particles and the available nutrient levels were: Organic carbon percentage 0.50 (i.e. Medium), Available N 260.42 kg ha^{-1} (i.e. Low), Available P 40.23 kg ha^{-1} (i.e. Medium) and Exchangeable K 325 kg ha^{-1} (i.e. High).

The Recommended dose of fertilizer was 120:80:60 kg of N_2, P_2O_5 and K_2O ha^{-1} respectively. Each treatment was assigned to a plot size of 2.0 m x 1.5 m and five plants at random were selected for the recording of the observations in each plot. Parameters for which observations were recorded included days to sprouting of corms, numbers of sprouts $mother^{-1}$ corm, number of leaves $plant^{-1}$, girth of plant base, width of leaf, height of the plant upto tip of leaf, days to spike emergence, length of the spike, number of florets $spike^{-1}$, vase life of cut spikes, diameter of corm, weight $corm^{-1}$, total corm weights $plot^{-1}$ and number of corms $plant^{-1}$. The observations on

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number of leaves plant^{-1}, plant height, girth of plant base, width of leaves were recorded at 20,40,60 and 80 days after planting. The length of spike was recorded from the nodal base of spike to the top most floret at the time of complete opening of all the flowers.

RESULTS AND DISCUSSION

The results of the present investigation are elaborated in following subheadings.

Growth characters :

Data regarding number of days required for 50 per cent sprouting revealed that minimum number of days (5.25) was recorded in the treatment 75% RDF + FYM 10 t ha^{-1} which was statistically superior over the rest of the treatments. The maximum number of sprouts mother^{-1} corm (1.55) was also found in the same treatment i.e. 75% RDF+FYM 10 t ha^{-1} followed by 75% RDF +Vermicompost 3.0 t ha^{-1} which were significantly superior over remaining treatments except with the treatment 50% RDF + FYM 10 t ha^{-1} and 50% RDF + Vermicompost 3.0 t ha^{-1}. The superiority of the treatments 75% RDF + FYM 10 t ha^{-1} and 75% RDF +Vermicompost 3.0 t ha^{-1} over the rest of the treatments might be due to availability of optimum amount of nutrient from inorganic fertilizer in combination with FYM and vermicompost. This result is in close conformity with the findings of Gupta *et al.* (2008). Who studied that different levels of Vermicompost, NPK and FYM on performance of gladiolus and found that the among three treatments of gladiolus i.e. Vermicompost (1.25 t ha^{-1}), NPK (0.75 t ha^{-1}) and FYM (25 t ha^{-1}). Treatment FYM (25 t ha^{-1}) recorded the best result of plant growth, flowering and corm yield.

As far as number of leaves plant^{-1} was concerned, the treatment 75% RDF + FYM 10 t ha^{-1} in 80 DAP was significantly superior over all the treatments except the treatment 75% RDF +Vermicompost 3.0 t ha^{-1}.Whereas minimum number of leaves plant^{-1} (5.45) was counted in control in 80 DAP. It may be due to availability of essential nutrients to the crop by the application of inorganic fertilizer in combination with organics FYM and vermicompost, which is the finding of Sonawane *et al.* (2009). They studied the individual effect of nitrogen and FYM on China aster (*Callistephus chinensis* L.) and found that the maximum plant height (66.89 cm), plant spread (25.03 cm) and number of branches (12.73) was achieved with the application of 10 t ha^{-1} of FYM.

Information procured on width of leaf also exhibited significant superiority of the treatment 75% RDF + FYM 10 t ha^{-1} over the other treatments by producing 3.9 cm, while the another treatment 75% RDF + Vermicompost 3.0 t ha^{-1} was at par with this treatment. Minimum leaf width 3.02 cm was observed in control. The present results are in line with those results reported by Alla *et al. (*2003). They found that the treatment with chicken manure resulted in the highest leaf number with highest fresh and dry weight of leaves and spikes.

Data regarding plant height indicated that the treatment 75% RDF + FYM 10 t ha^{-1} recorded maximum plant height (86.38 cm) which was significantly greater than the treatments FYM 10 t ha^{-1} and only Vermicompost @3.0 t ha^{-1}. Minimum height of the plant (66.15 cm) was found in control (T_1). Similar trends were earlier reported by Godse *et al.* (2006),who found that the plants receiving vermicompost 8 t ha^{-1}+*Azotobacter* and PSB @ 25 kg ha^{-1} each+80% RDF significantly increased growth, yield and quality attributes of gladiolus *viz*., plant height, number of leaves, number of spikes plant^{-1}, number of corms plant^{-1} and weight of corms ha^{-1}.

Economic characters :

Results obtained on number of days required for spike emergence depicted that the treatment 75% RDF +Vermicompost 3.0 t ha^{-1} took minimum number of days (63.25 days) for spike emergence by decreasing growing period and maintenance cost. Whereas, control took maximum days (72.5) for spike emergence. It was observed that the application of FYM in combination with inorganic fertilizer might be due to optimum availability of nutrients to the plant due to which plant completed their vegetative growth soon and resulting in early spike emergence. These results are in close conformity with the findings of John *et al.* (2007). Who studied the response of organic manure and inorganic fertilizer on tulip and reported that longest plant height, stem thickness, wrapper leaf area, bulb number and their weight were recorded with highest level of 60 t ha^{-1} organic manure.

Table 1. Effect of various combinations of inorganic fertilizer, FYM and Vermicompost on growth attributes of gladiolus Cv. 'Candyman'

Treatments	Days to sprouting of corm	No. of sprout mother corm^{-1}	No. of leaves plant^{-1} at 80 DAP	Girth of plant base at 80 DAP (cm)	Width of leaves at 80 DAP (cm)	Height of plant at 80 DAP (cm)
T_1: Control	9.00	1.18	5.45	1.32	3.02	66.15
T_2: 50% RDF	7.70	1.37	5.95	1.60	3.41	77.05
T_3: 75% RDF	7.50	1.37	6.50	1.62	3.46	77.80
T_4: 100% RDF	6.70	1.46	6.55	1.67	3.50	79.10
T_5: FYM 10 t ha^{-1}	8.00	1.32	5.77	1.57	3.36	76.50
T_6: 50% RDF + FYM 10 t ha^{-1}	6.70	1.47	6.60	1.70	3.55	79.73
T_7: 75% RDF + FYM 10 t ha^{-1}	5.20	1.55	7.35	1.92	3.90	86.38
T_8: Vermicompost Only 3.0 t ha^{-1}	8.00	1.37	5.65	1.57	3.37	76.15
T_9: 50% RDF +Vermicompost 3.0 t ha^{-1}	6.70	1.47	6.57	1.70	3.53	79.45
T_{10}: 75% RDF +Vermicompost 3.0 t ha^{-1}	6.50	1.55	7.10	1.90	3.70	82.20
S Em±	**0.411**	**0.030**	**0.207**	**0.098**	**0.113**	**3.347**
CD (p=0.05)	**1.193**	**0.090**	**0.601**	**0.285**	**0.329**	**9.713**

Table 2. Effect of various combinations of inorganic fertilizer, FYM and Vermicompost on economical attributes of gladiolus Cv. 'Candyman'

Treatments	Days to spike emergence	Length of spike (cm)	Number of florets spike^{-1}	Vase life of cut spike (days)	Diameter of corm (cm)	Weight corm^{-1} (g)	Total corm weight plot^{-1} (kg)	Total no. of corms plant^{-1}	Total no. of cormels plant^{-1}
T_1: Control	72.50	80.65	10.37	3.17	2.92	30.10	1.08	1.00	60.25
T_2: 50% RDF	68.50	90.85	12.37	4.25	4.20	43.27	1.40	1.10	53.25
T_3: 75% RDF	68.00	96.65	12.52	4.55	4.25	47.57	1.55	1.11	50.25
T_4: 100% RDF	67.50	99.12	12.77	4.72	4.35	51.35	1.60	1.12	46.25
T_5: FYM 10 t ha^{-1}	69.00	86.97	11.42	3.80	3.95	39.80	1.36	1.07	54.75
T_6: 50% RDF + FYM 10 t ha^{-1}	65.50	100.18	13.12	5.00	4.65	56.95	1.75	1.16	45.25
T_7: 75% RDF + FYM 10 t ha^{-1}	63.50	101.80	13.87	5.92	5.82	65.07	2.16	1.25	42.25
T_8: Vermicompost Only 3.0 t ha^{-1}	69.20	87.15	11.57	3.72	3.62	39.50	1.32	1.10	55.25
T_9: 50% RDF +Vermicompost 3.0 t ha^{-1}	66.00	100.20	13.55	5.32	4.57	53.37	1.72	1.15	44.25
T_{10}: 75% RDF +Vermicompost 3.0 t ha^{-1}	63.25	101.88	14.47	6.40	5.75	60.02	1.90	1.22	40.75
S Em±	**1.665**	**3.970**	**0.824**	**0.172**	**0.393**	**2.952**	**0.125**	**1.856**	**3.258**
CD (p=0.05)	**4.833**	**11.521**	**2.391**	**0.500**	**1.142**	**8.568**	**0.364**	**5.387**	**9.456**

As far as length of spike was concerned, the treatment 75% RDF +Vermicompost 3.0 t ha^{-1} got maximum length of spike (101.8 cm) and the minimum length of the spike (80.65 cm) was obtained in Control. Results obtained on number of florets $spike^{-1}$ depicted that treatment (75% RDF + Vermicompost 3.0 t ha^{-1}) proved the best treatment. Number of florets produced by 75% RDF +Vermicompost 3.0 t $ha^{-1}$was 14.47, whereas control produced minimum florets $spike^{-1}$ (10.37). These findings are in line with the finding of Ahmed *et al.* (2004). They reported that the treatment which was comprised of 200 kg urea ha^{-1}+ 400 kg DAP ha^{-1} +40 t FYM ha^{-1} gave the highest number of flowers in Dahlia.

Results obtained on Vase life of cut spikes revealed that the longest vase life (6.4 days) was recorded in the treatment 75% RDF +Vermicompost 3.0 t ha^{-1} which was significantly greater than the all treatments except with the treatment 75% RDF + FYM 10 t ha^{-1} ,whereas the minimum vase life (3.17 days) was obtained in control. As far as corm diameter is concerned, application of 75% RDF + FYM 10 t ha^{-1} and 75% RDF +Vermicompost 3.0 t ha^{-1} resulted in large corms with more diameter (5.82 and 5.75 cm) respectively than the result of rest of the treatments . Control produced corms of minimum diameter (2.92 cm). The data regarding weight of corm under different treatments are presented in table 2. The maximum weight $corm^{-1}$ (65.07 g) was received in the treatment 75% RDF + FYM 10 t ha^{-1} which was significantly superior to rest of the treatments except with the treatments 75% RDF + Vermicompost 3.0 t ha^{-1} and 50% RDF + FYM 10 t ha^{-1}. The minimum weight $corm^{-1}$ (30.1g) was found in control.

The maximum number of corms $plant^{-1}$ (1.25) was observed in the treatment 75% RDF + FYM 10 t ha^{-1} and it was significantly superior over the rest of the treatments except with the treatment 75% RDF +Vermicompost 3.0 t ha^{-1} and 50% RDF + FYM 10 t ha^{-1}. The minimum number of corms $plant^{-1}$ (1.0) was found in control. This result is in close agreement with the findings of Gupta *et al.* (2008). They found that the among three treatments of gladiolus i.e. Vermicompost (1.25 t ha^{-1}), NPK (0.75 t ha^{-1}) and FYM (25 t ha^{-1}), the treatment FYM (25 t ha^{-1}) recorded best results of plant growth, flowering and corm yield.

The data recorded with regard to total number of cormels $plant^{-1}$ are presented in the table 2. It reveals that the maximum number of cormels $plant^{-1}$ (60.25) was observed in control followed by treatment 50% RDF. It might be due to non availability of nitrogen in the later stage of growth which prevented the cormels from developing into corms. The present findings are in conformity with the findings of Godse *et al.* (2006),who reported that the plants receiving vermicompost 8 t ha^{-1} + Azotobacter and PSB @ 25 kg ha^{-1} each + 80% RDF significantly increased growth, yield and quality attributes of gladiolus *viz*., plant height, number of leaves, number of spikes $plant^{-1}$, number of corms $plant^{-1}$ and weight of corms ha^{-1}.

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Rec. on 02.09.2011 & Acc. on 29.12.2011

J. Soils and Crops 22 (2) 258-263, Dec., 2012 ISSN 0971-2836

EFFECT OF SULPHUR LEVELS ON GROWTH, YIELD AND QUALITY OF INDIAN MUSTARD GENOTYPES AND THEIR ECONOMICS

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ABSTRACT

A field experiment was conducted during winter season of 2008-09 and 2009-10 on sandy loam soil at Agricultural Research Farm of Raja Balwant Singh College, Bichpuri, Agra to find out the effect of sulphur levels on growth, yield and quality of Indian mustard [*Brassica juncea* (L.), Czernj and Cosson genotypes. The treatments consisted of four genotypes (Pusa Bold, Rohni, Varuna and Kranti) of mustard and four levels of sulphur (0, 30, 60 and 90 kg ha^{-1}) applied through elemental sulphur in factorial randomize block design replicated thrice. Pusa Bold genotype recorded the highest seed yield of 2.05 and 2.09 t ha^{-1} during 2008-09 and 2009-10 respectively followed by Varuna, Rohini and Kranti genotype. Mean seed yield of mustard recorded under 90 kg S ha^{-1}were higher by 30.67, 21.18 and 3.76 per cent over 0, 30 and 60 kg S ha^{-1}respectively. The seed yield of mustard significantly increased with the level of 60 kg S ha^{-1}, however the stover yield of mustard increased significantly up to 90 kg S ha^{-1}. Oil content and nutrient uptake were also highest under this treatment. The oil content recorded less than 90 kg S ha^{-1}were higher by 11.31, 7.44 and 1.52 per cent over 0, 30 and 60 kg S ha^{-1}, respectively. The interaction between genotypes and sulphur levels was found not significant for seed and stover yield and other parameters of mustard. The highest net return of Rs. 42,018 was recorded with the application of 90 kg S ha^{-1}. However, C: B ratio of 4.34 was higher at 60 kg S ha^{-1}.

(Key words: Growth and yield components, Indian mustard, sulphur, quality, nutrient uptake)

INTRODUCTION

Rapeseed- mustard is an important group of oilseed crops in the world. In mustard cultivation India ranks 2nd in acreage and 3rd in production with contribution of 21.7% and 10.7% to the estimated global area (30.74 million hectares) and production (59.93 million tones), respectively during 2009-10 (Anonymous, 2011). Mustard [*Brassica juncea* (L.) Czernj and Cosson] is one of the important oilseed crops grown in India. Due to poor yield, oil seed production in the country does not meet the requirement of growing population. To bridge the gap between demand and supply, the country is forced to import edible oils and spends lot of foreign exchange every year. The productivity of mustard can be increased by proper fertilizer management and putting more area under irrigation. Knowledge of the concentration of plant nutrients in a crop and the amount of nutrients removed by a particular crop from the soil may be a helpful guide for the formulation of a sound fertilizer management programme.

There are reports of reduction in yield even due to constant use of NPK fertilizers. The reduction in the yield is generally traced due to the deficiency of secondary and micronutrients, particularly in oil seed crops. Sulphur application not only improves the grain yield but also improves the quality of crops. This is mainly due to its associations with S-containing amino acids like cysteine, cystine and methionine. It is regarded as the nutrient, which is responsible in improving the quality of crop. It is also an important constituent of many enzymes and is involved in the oxidation and synthesis of fatty acids. Photosynthesis and nitrogen fixation are attributed to the type of sulphur linkage present. Sulphur occurs in volatile compounds responsible for the characteristic taste and smell of plants in the mustard and onion families. Sulphur enhances oil formation in mustard.

Sulphur deficiency has been found to occur in soils, which are coarse textured, and low in organic matter. Sulphur requirements of crop plants are quite high and high yielding varieties require higher amounts of sulphur as compared to low yielding varieties of the crops. About 42.3%, Indian soils and 32.0% U.P. soils are deficient in sulphur, whereas higher for Agra soils are 37.0%. It is well accepted that sulphur deficiency in Indian soils is wide spread and major constraint in the way of increasing crop productivity, produce quality and farm incomes (Tandon 2010).In light of these, the present investigation was therefore, undertaken to study the effect of sulphur levels on mustard genotypes.

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MATERIALS AND METHODS

The field experiment was conducted during winter season of 2008-09 and 2009-10 at Agricultural Research Farm of Raja Balwant Singh College, Bichpuri, Agra, Uttar Pradesh. The soil was sandy loam with pH 7.88 and 7.87 containing organic carbon 0.34 and 0.35%, available nitrogen 212.0 and 204.5 kg ha^{-1}, P_2O_5 17.88 and 17.17 kg ha^{-1}, K_2O 258.24 and 262.08 kg ha^{-1} and sulphur 8.1 and 8.8 kg ha^{-1} during the first and second year, respectively. There were 16 treatment combinations comprising of four genotypes (Pusa Bold, Rohini, Varuna and Kranti) and 4 levels of S (0, 30, 60 and 90 kg ha^{-1}) replicated thrice in factorial randomized block design. A half dose of 80 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1} and 30 kg K_2O ha^{-1} was applied at the time of sowing through Urea, DAP, Muriate of potash respectively. The remaining half dose of N was top dressed after the first irrigation. Different doses of sulphur were applied through elemental sulphur at sowing as basal dressing. The crop was sown on 20th October 2008 and 26th October 2009 with seed rate of 5 kg $ha^{-1}$and harvested on 16th March 2009 and 21th March 2010. The seed was sown in rows apart 30 cm distance at depth of 5 cm as per treatments. Growth parameter was recorded at 30,60,90 DAS and at harvest stage and yield parameters were recorded at harvest stage by taking five random plant samples from each treatment. Dry weight of plant was recorded at different stages of crop growth. Plant samples were dried in sun and subsequently into the oven at 70^{0}C until constant weight were obtained and total dry matter accumulation of whole plant was recorded. Crop was harvested at physiological maturity, threshed and plot-wise yields were recorded. Grain and stover samples were taken for analysis of N, P, K and S by standard procedure. Nitrogen content was determined by micro-kjeldahls method (Chopra and Kanwar, 1980), phosphorus content was determined in digested material colorimetrically by vanadomolybdate procedure laid down by Champan and Pratt (1961), potassium was determined in diacid by flame photometric method as described by Jackson (1973) and Sulphur content was determined by turbidimetric procedure (Chesnin and Yien, 1951). Oil was determined by extracting 2 g seed material by petroleum ether (B.P. 60-80^{o}C) in a Soxhlet oil extractor glass apparatus for 8 hours at 60^{o}C as per procedure described in Anonymous (1960).

RESULTS AND DISCUSSION

Performance of genotypes :

Among the genotypes, the plants of cv Varuna were significantly taller than Kranti, Pusabold and Rohini at all the growth stages except 30 DAS. Significantly maximum dry weight of plant accumulation was exhibited in Pusabold which was 47.0, 9.8, 19.3 and 9.0 % higher than Rohini at 30, 60, 90 DAS and harvest stage respectively. However, the cultivar Pusabold and Varuna were statistically on a par for dry weight at same stages. Significantly highest number of pods $plant^{-1}$, seeds pod^{-1} and 1000 seed weight were recorded in Pusabold followed by Varuna, Rohini and Kranti. The maximum seed yield of 2.05 and 2.09 t ha^{-1} was produced by cv Pusabold during 2008-09 and 2009-10 respectively which was significantly superior over Rohini, Varuna and Kranti. This was due to the fact that Pusabold produced better yield attributes *viz.,* plant height, dry weight, number of pods $plant^{-1}$, number of seeds pod^{-1} and 1000 seed weight than other genotypes (Table 1). The lowest seed yield in Kranti in both the years was due to less number of pods $plant^{-1}$, number of seeds pod^{-1} and 1000 seed weight. In case of stover yield, it is evident from the table 2 that the cv Varuna produced maximum stover yield of 6.00 and 6.08 t ha^{-1} during 2008-09 and 2009-10 respectively, which was significantly higher over rest of the genotypes. Pusabold produced significantly higher oil content than Rohini and Kranti, however, the difference of oil content between Pusabold and Varuna was at par. Pusabold showed 0.44 and 0.65 % higher oil content than Varuna during the first and second year respectively. Abdin *et al.* (2003) also reported higher oil content in Pusa Bold as compared to other genotypes of mustard. The increase in oil content was mainly due to increase in glucoside formation (allyisothiocynate) and sulphur as a constituent of multi enzyme complex. After harvesting of the crop maximum total uptake of N, P, K and S were recorded from Varuna (115.5, 28.3, 78.4 and 22.4 kg ha^{-1}) which was closely followed by Pusabold (115.2, 28.2, 75.3 and 21.1 kg $ha^{-1)}$. However, both the genotypes were significantly superior over Kranti and Rohini genotypes. The minimum total uptake was noted by Kranti variety (100.4, 24.0, 65.4 and 16.5 kg ha^{-1}).

Effect of sulphur :

Various levels of sulphur significantly influenced the growth and yield attributes viz., plant height, dry weight of plant, number of pods pant^{-1}, number of seeds pod^{-1} and 1000 seed weight in both the years. The plant height increased significantly with each increment in the dose of sulphur upto 60 kg ha^{-1}. However, the difference in plant height due to further increase in the dose of sulphur was not significant. The rate of increase in plant height was more at 60 kg S ha^{-1}, beyond which it declined, perhaps due to better nutritional environment for plant growth at active vegetative stages as a result of improvement in root growth, cell multiplication, elongation and cell expression in the plant body (Steffenson, 1954). Application of 60 kg S ha^{-1} produced more dry weight of plant at 90 DAS compared with control and 30 kg S ha^{-1}. Better nutrition to plant resulted in more height and number of branches and other growth parameter, which resulted in higher dry weight of plant. These results are in conformity with those reported by Kumar and Yadav (2007) in mustard.

The number of pods plant^{-1} significantly increased up to 60 kg S ha^{-1}. However, the highest number of pods of 374.7 plant^{-1} was recorded with 90 kg S ha^{-1}. The difference between 60 and 90 kg S ha^{-1} was non significant. The highest number of seeds pod^{-1} was recorded at 90 kg S ha^{-1}, which was at par with that of 60 kg S ha^{-1}, and significantly superior to the control and 30 kg S ha^{-1}. The maximum seed weight of 5.25 g 1000^{-1} seeds was recorded with 90 kg S ha^{-1} and minimum in the control (4.61 g 1000^{-1} seeds). This may be due to large amount of sulphur found in the seed and siliqua, which is considered essential for seed formation and boldness of seeds.

Different levels of sulphur significantly influenced the seed and stover yields and oil content (Table 2). The highest seed yield of 2.17 and 2.26 t ha^{-1} was recorded at 90 kg S ha^{-1} during 2008-09, 2009-10 respectively which was at par with those at 60 kg S ha^{-1}, and this was significantly superior to the control and 30 kg S ha^{-1} during both the years. Choudhary *et al*. (2003), who observed that the seed yield of mustard significantly, increased 25.0 q ha^{-1} with application of 60 kg S ha^{-1}. Sarangthem *et al*. (2008) also confirmed that the seed yield of mustard significantly increased from 0.95 to 1.09 t ha^{-1} with the increase in level of sulphur from 0 to 40 kg ha^{-1}. Sharma *et al.* (2009), also observed that mustard seed yield increased significantly by 33% to 141% over control with the application of sulphur. Kumar and Yadav (2007) also reported that a significant response of 30 kg S ha^{-1} in seed and stover yields of mustard.This may be attributed to the increasing levels of S, which resulted in greater accumulation of carbohydrates, protein and their translocation to the productive organs, which in turn improved all the growth and yields attributing characters, resulting more seed yield. However, maximum Stover yield was also recorded at 90 kg S ha^{-1}, which was significantly superior to all the other sources of sulphur treatments. The increase in oil content due to application of 30, 60 and 90 kg S ha^{-1} over control was 4.5, 9.6 and 11.3% during 2008-09 and 5.7, 9.9 and 10.6% during 2009-10 respectively. Singh *et al*. (2005), also observed that the oil content in mustard seed significantly increased 6.3% with 60 kg S ha^{-1} over no sulphur application. The increasing levels of sulphur significantly increased the uptake of N, P, K and S. The maximum uptake of 131.0 N, 31.1 P, 87.9 K and 27.4 S kg ha^{-1} was recorded with the application of 90 kg S ha^{-1}, which was significantly superior to all other sulphur treatments. However, the minimum uptake of N, P, K and S was recorded under control treatment (83.8, 19.8, 53.9 and 11.2 kg ha^{-1}). The increase in nutrient uptake was mainly due to better nutrition, which resulted in better growth and yield and ultimately in higher uptake of nutrients. Enhanced uptake of N, P, K and S with 60 kg ha^{-1} sulphur application has also been reported by Choudhary *et al*. (2003) in mustard and Singh and Singh (2007) in linseed.

The interaction between genotypes and sulphur levels were found not significantly affected all yield attributing characteristics.

Economics :

Pusabold was more remunerative than all the other varieties of mustard. The maximum C:B ratio of 4.35 was obtained with Pusabold followed by Varuna (4.30), Rohini (4.08) and Kranti (3.98) respectively. Application of 60 kg S ha^{-1} gave the maximum C:B ratio of 4.34 where as 90 kg S ha^{-1} gave 4.25 followed by 30 kg S ha^{-1} (4.06) and control plot (4.04).

Table 1. Effect of genotypes and sulphur levels on growth and yield component of Indian mustard (pooled mean of two years)

	Plant height (cm)				Dry weight of plant (g)				No. of pods plant^{-1}	No. of seeds pod^{-1}	1000 seed weight (g)
Genotype	**30DAS**	**60 DAS**	**90 DAS**	**At Harvest**	**30DAS**	**60 DAS**	**90 DAS**	**At Harvest**			
Pusa Bold	15.85	132.16	165.40	165.74	2.74	11.33	38.81	84.35	356.01	13.66	5.12
Rohini	15.34	127.24	163.42	164.09	1.86	10.31	32.53	77.32	325.46	13.11	4.87
Varuna	16.27	138.60	170.05	171.97	2.54	10.80	36.90	83.74	351.25	13.66	5.07
Kranti	16.09	141.36	166.94	168.57	2.06	11.86	35.41	78.85	317.98	12.48	4.66
SEm±	**0.32**	**1.29**	**1.46**	**1.56**	**0.12**	**0.39**	**1.15**	**1.59**	**7.11**	**0.22**	**0.055**
CD(5%)	**NS**	**3.73**	**4.20**	**4.49**	**0.35**	**1.13**	**3.31**	**4.58**	**20.48**	**0.64**	**0.16**
S-Level (kg ha^{-1})											
0	14.36	127.00	162.20	162.65	1.67	9.96	26.68	75.32	288.25	10.93	4.61
30	15.69	134.06	165.02	165.56	2.11	10.89	34.75	80.73	324.04	11.84	4.82
60	16.65	138.44	169.25	170.86	2.62	11.40	40.64	84.44	363.62	14.90	5.06
90	16.84	139.86	169.34	171.29	2.79	12.05	41.57	83.78	374.79	15.24	5.25
SEm±	**0.32**	**1.29**	**1.46**	**1.56**	**0.12**	**0.39**	**1.15**	**1.59**	**7.11**	**0.22**	**0.055**
CD (5%)	**0.92**	**3.73**	**4.20**	4.49	**0.35**	**1.13**	**3.31**	**4.58**	**20.48**	**0.64**	**0.16**

Table 2. Effect of genotypes and sulphur levels on yields , oil content , total uptake and economics of Indian mustard (pooled mean of two years)

Genotype	Seed yield (t ha^{-1})		Stover yield (t ha^{-1})		Oil content (%)		Total uptake (kg ha^{-1})				Economics (Rs, ha^{-1})			
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	N	P	K	S	Gross return	Net return	Net return invested^{-1}	C:B ratio
Pusa Bold	2.05	2.09	5.17	5.95	40.83	41.22	115.2	28.2	75.3	21.1	51459	39575	3.33	4.35
Rohini	1.88	1.93	5.20	5.40	39.28	40.10	104.0	25.5	68.3	18.0	46529	35125	3.08	4.08
Varuna	2.02	2.07	6.00	6.08	40.65	40.95	115.5	28.3	78.4	22.4	50975	39148	3.31	4.30
Kranti	1.80	1.89	5.01	5.25	39.07	39.84	100.4	24.0	65.4	16.5	44701	33470	2.98	3.98
SEm±	**0.034**	**0.033**	**0.063**	**0.058**	**0.16**	**0.20**	**1.39**	**0.38**	**0.65**	**0.31**				-
CD(5%)	**0.098**	**0.095**	**0.183**	**0.167**	**0.47**	**0.51**	**4.03**	**1.09**	**1.87**	**0.91**	-	--	--	-
S-Level (kg ha^{-1})														
0	1.68	1.70	4.28	4.40	37.56	38.08	83.86	19.8	53.91	11.20	40841	30732	3.04	4.04
30	1.81	1.85	5.01	5.22	39.28	40.26	98.22	23.8	64.61	15.42	44449	33501	3.06	4.06
60	2.11	2.18	6.06	6.29	41.18	41.88	122.2	30.7	81.19	24.06	53261	41076	3.35	4.34
90	2.17	2.26	6.57	6.77	41.81	42.12	131.0	31.1	87.92	27.47	54928	42018	3.25	4.25
SEm±	**0.034**	**0.033**	**0.063**	**0.058**	**0.16**	**0.20**	**1.39**	**0.38**	**0.65**	**0.31**	-			-
CD (5%)	**0.098**	**0.095**	**0.183**	**0.167**	**0.47**	**0.51**	**4.03**	**1.09**	**1.87**	**0.91**	-	-	-	-

It was concluded that Indian mustard variety 'Pusabold' fertilized with 60 kg S ha^{-1} is beneficial and effective for growth, yield attributes, yield and oil content.

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Rec. on 14.09.2011 & Acc. on 27.12.2011

J. Soils and Crops 22 (2) 264-269, Dec., 2012 ISSN 0971-2836

INTEGRATED MANAGEMENT OF ALTERNARIA BLIGHT OF YELLOW SARSON (*Brassica campestris* L. var. Yellow Sarson Prain) CAUSED BY *Alternaria* sp.

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ABSTRACT

A field experiment was conducted during *rabi* seasons of 2006-07 and 2007-08 to study the integrated management of Alternaria blight of yellow sarson caused by *Alternaria brassicae* (Berk) Sacc. and *Alternaria brassicicola* (Sehwein) Wiltshire. Three management practices viz., two dates of sowing, two varieties and five fungicidal sprays were tested. First date of sowing i.e. 20 October showed lower Alternaria leaf blight intensity of 41.59%, pod blight of 24.58% and higher seed yield of 1371.05 kg ha^{-1} as compared to 30th October sown crop, while in case of varieties, 'YST 151' expressed less Alternaria leaf blight intensity of 43.00%, pod blight of 24.67% and more yield of 1377.47 kg ha^{-1} as compared to 'NDYS 2'. All the fungicidal sprays reduced the Alternaria blight intensity and increased the seed yield over control (unsprayed check). 'YST151' sown on 20th October and sprayed with iprobenfos @ 0.075% showed least disease intensity (27.51%) and gave the highest seed yield (1624.75 kg ha^{-1}). It also gave the highest net return (Rs. 5773.50 ha^{-1}) and maximum benefit : cost ratio of 3.27. The highest avoidable yield loss of 30.42% was noted in 30th October sown 'NDYS2' under iprobenfos @ 0.075% spraying followed by 20th October sown 'YST151' sprayed with same fungicide.

(Key words: Alternaria blight, integrated management, fungicides, B:C ratio)

INTRODUCTION

Amongst the oilseed crops, specially rapeseed-mustard plays an important role in agricultural economy of the world. These two crops are affected by a number of diseases limiting productivity of the crop over a wide area. Among the various diseases, Alternaria blight caused by *Alternaria brassicae* (Berk.) Sacc. and *Alternaria brassicicola* (Sehwein) Wiltshire is one of the most important diseases attacking yellow sarson. The disease causes an average yield loss of 10-70% (Gupta *et al*., 2003). In addition to direct loss of yield, it also affects the quality of seed, seed colour and oil content. Due to unavailability of resistant varieties, the management of this disease by injudicious use of chemicals is causing health hazards. The present studies were undertaken to investigate the effects of integrated management like date of sowing, varieties and different fungicidal sprays on the severity of Alternaria blight of yellow sarson (*Brassica campestris* L. var. Yellow sarson Prain).

MATERIALS AND METHODS

The field experiment was conducted at the Student's Instructional Farm of Narendra Deva University of Agriculture and Technology Kumarganj, Faizabad, Uttar Pradesh (26°47' N, 82°12'E and 113m above mean sea level) following recommended cultural practices. Design followed was split plot with 35 m x 8.5 m main plot, 17.5 m x 8.5 m sub plot and 4 m x 3 m sub-sub plot replicated thrice. Dates of sowings viz., 20 October and 30 October served as main plot treatments, varieties 'YST151' and 'NDYS2' as sub-plot treatments and spraying offungicides viz., F_1- mancozeb @ 0.2%, F_2- companion @ 0.15%, F_3- propiconazole @ 0.075%, F_4 - iprobenfos @ 0.075% and F_0 - unsprayed control as sub-sub plot treatments. A 0-5 disease rating scale (Sangeetha and Siddaramaiah, 2007) based on blighted leaf and pod area was followed. Per cent disease intensity (PDI) was calculated using the following formula:

$$PDI= (\frac{\text{A total numerical rating}}{\text{Total No. of observations}} \times \text{maximum disease score}) \times 100$$

Avoidable yield loss (AYL) due to Alternaria blight using 1000 seed weight and yield data from management trial was calculated as:

$$AYL = \frac{Yp - Yu}{Yp} \times 100$$

Where, YP, yield under protection, Yu, yield under unprotected condition.

The seed yield data were recorded after harvest and economics i.e. net return and benefit : cost ratio were also determined.

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RESULTS AND DISCUSSION

Effect of date of sowing :

First date of sowing i.e. 20 October showed lowerAlternaria leaf blight intensity of 41.59%, pod blight of 24.58% and higher seed yield of 1371.05 kg ha^{-1}(Table 1). It proved significantly superior to second date of sowing (30 October) in respect of disease intensity, while seed yield was at par. These results support the findings of Gupta e*t al*. (2003) who reported that the crop sown on 21st October showed significantly lower disease intensity, which was enhanced in subsequent sowing dates. Kumar and Kumar (2006) noted the minimum Alternaria blight intensity in 1st October sown crop and it was increased with delayed sowing. Singh and Singh (2006) also reported the lower Alternaria blight severity in 15th October sown crop which enhanced with delayed sowing.

Effect of varieties :

'YST151' yellow sarson showed lower Alternaria leaf blight intensity of 43.00% and pod blight of 24.67%. It gave higher seed yield of 1377.47 kg ha^{-1}(Table 1). It proved significantly superior to 'NDYS2' that showed a leaf blight intensity of 44.62%, pod blight of 26.26% and seed yield of 1259.87 kg ha^{-1}. These results are in conformity with the results of Sharma *et al*.(2002) who evaluated 38 species of 9 genera including cultivated and wild and reported 8 spp.namely*Brassica desnottesii*, *Camelina sativa*, *Coincya pseuderucastrum*, *Diplotaxis berthautii, Diplotaxis catholica, Diplotaxis cretacea, Diplotaxis eurocoides* and *Erucastrum gallicum*as completely resistant, 12 spp. as moderately resistant, 11 spp. as susceptible and 7 spp. as highly susceptible, Patni *et al*. (2005) also screened the ten Indian mustard genotypes and reported 4 (EC-399301, PHR-1, EC-399313 and PHR-2) as tolerant, 4 (EC-399294, PAB-9511, PAB-9534 and Divya) as moderately tolerant and 2 (Varuna and Kranti) as susceptible.

Fungicidal effect :

The foliar spray of iprobenfos @ 0.075% resulted in expression of lowest Alternaria leaf blight intensity of 31.38%, pod blight of 14.14% and the highest seed yield of 1477.74 kg ha^{-1}(Table 1)followed by sprays using propiconazole @ 0.075% that resulted in Alternaria leaf blight intensity of 37.05%, pod blight of 19.24% and seed yield of 1413.43 kg ha^{-1}.The effectiveness of iprobenfos was earlier reported against inhibiting the *Alternaria brassicae* spore germination by Kumar *et al.* (2004).Raja and Reddy (2008) earlier reported that the effectiveness of propiconazole @ 0.0125% in controlling the Alternaria blight of senna and Barnwal *et al*. (2011) also resulted the effectiveness of propiconazole @ 0.1%in reducing the Alternaria blight of linseed.The former treatment proved significantly superior to the control. All these fungicidal sprays i.e.mancozeb @ 0.2%,companion @ 0.15%,propiconazole@ 0.075% and iprobenfos @ 0.075% expressed least disease intensity and highest seed yield for 'YST151' as compared to 'NDYS 2'. Thus, the foliar sprays of iprobenfos @ 0.075% on 'YST151' resulted in Alternaria leaf blight intensity of 30.36%, pod blight of 13.20% and seed yield of 1551.95 kg ha^{-1}. It proved significantly superior to 'NDYS2' which under similar protection expressed an Alternaria leaf blight intensity of 32.41%, pod blight of 15.08% and seed yield of 1403.54 kg ha^{-1} (Table 1). Furthermore, all the sprays fungicides expressed the highest seed yield under first date of sowing i.e. 20 October. Thus, spraying of iprobenfos @ 0.075% had lowest Alternaria leaf blight intensity of 28.95%, pod blight of 13.15% and the highest seed yield of 1529.66 kg ha^{-1} under 20 October sowing. Unsprayed (control) sown on 30 October had the highest Alternaria leaf blight intensity of 71.47%, pod blight of 45.52% and lowest seed yield of 1010.20 kg ha^{-1} (Table 1). Concurrent with present findings Kumar *et al*. (2009) reported highest Alternaria blight reduction in case of mustard with three sprays of iprobenfos @ 0.1% followed by propiconazole. Singh *et al*. (2009) also reported the maximum reduction of Alternaria blight intensity in case of linseed by companion @ 0.125%.

Interactions :

'YST151' yellow sarson sown on 20 October showed the lowest Alternaria leaf blight intensity of 40.41%, pod blight of 23.72% and highest seed yield of 1434.20 kg ha^{-1} followed by 'NDYS 2' sown on same date, whereas 'NDYS2' sown on 30 October showed the highest Alternaria leaf blight intensity of 46.46%, pod blight of 27.08% and lowest seed yield of 1211.83 kg ha^{-1}(Table 1).

Overall, combination of 'YST151' yellow sarson sown on 20 October and sprayed

Table 1. Effect of yellow sarson varieties and date of sowing under different fungicidal sprays on the intensity of Alternaria blight and seed yield (mean of two years data)

Factors	Alternaria blight intensity (%)			Pod blight (%)			Seed yield (kg ha^{-1})		
	'YST151'	'NDYS2'	Mean	'YST151'	'NDYS2'	Mean	'YST151'	'NDYS2'	Mean
Date of sowing (F_1)× Variety (F_2)									
D_1	40.41	42.78	41.59	23.72	25.45	24.58	1434.20	1307.91	1371.05
	(39.47)	(40.86)	(40.16)	(29.47)	(30.40)	(29.73)			
D_2	45.60	46.46	46.03	25.62	27.08	26.35	1320.75	1211.83	1266.29
	(42.48)	(42.99)	(42.71)	(30.40)	(31.37)	(30.20)			
Mean	43.00	44.62		24.67	26.26		1377.47	1259.87	
	(40.48)	(41.90)		(29.93)	(30.85)				

Variety (F_2) x fungicide (F_3)

Factors	AB F1	AB F2	AB F3	AB F4	AB F0	AB Mean	PB F1	PB F2	PB F3	PB F4	PB F0	PB Mean	SY F1	SY F2	SY F3	SY F4	SY F0	SY Mean
V_1	40.71	38.58	36.62	30.36	68.74	43.00	25.86	22.30	18.25	13.20	43.73	24.67	1333.95	1406.87	1480.62	1551.95	1113.95	1377.47
	(39.64)	(38.41)	(37.23)	(33.46)	(55.98)	(40.48)	(30.59)	(28.18)	(25.33)	(21.30)	(41.38)	(29.93)						
V_2	43.73	39.52	37.49	32.41	69.95	44.62	27.21	24.02	20.23	15.08	44.78	26.26	1229.79	1291.66	1346.25	1403.54	1028.12	1259.87
	(41.38)	(38.94)	(37.76)	(34.70)	(56.79)	(41.90)	(31.44)	(29.33)	(26.71)	(22.87)	(42.02)	(30.85)						
Mean	42.22	39.05	37.05	31.38	69.34		26.53	23.16	19.24	14.14	44.25		1281.87	1349.27	1413.43	1477.74	1071.03	
	(40.51)	(38.70)	(37.47)	(34.08)	(56.35)		(30.98)	(28.79)	(25.99)	(22.06)	(41.73)							

Date of sowing (F_1) x fungicide (F_3)

Factors	AB F1	AB F2	AB F3	AB F4	AB F0	AB Mean	PB F1	PB F2	PB F3	PB F4	PB F0	PB Mean	SY F1	SY F2	SY F3	SY F4	SY F0	SY Mean
D_1	40.50	36.80	34.49	28.95	67.22	41.59	25.80	22.44	18.54	13.15	42.98	24.58	1340.41	1396.45	1456.87	1529.66	1131.87	1371.05
	(34.52)	(37.35)	(35.97)	(32.58)	(55.06)	(40.16)	(30.53)	(28.25)	(25.48)	(21.30)	(40.98)	(29.73)						
D_2	43.94	41.31	39.61	33.82	71.47	46.03	27.27	23.88	19.93	15.13	45.52	26.35	1223.33	1302.08	1370.00	1425.83	1010.20	1266.29
	(41.50)	(39.99)	(39.00)	(35.55)	(51.73)	(42.71)	(31.50)	(29.27)	(26.49)	(22.87)	(42.42)	(30.20)						
Mean	42.22	39.05	37.05	31.38	69.34		26.53	23.16	19.24	14.14	44.25		1281.87	1349.27	1413.43	1477.74	1071.03	
	(40.51)	(38.70)	(37.52)	(34.08)	(56.35)		(30.98)	(28.79)	(25.99)	(22.06)	(41.73)							

	Alternaria blight SEM±	Alternaria blight CD (P=0.05)	Pod blight SEM±	Pod blight CD (P=0.05)	Seed yield SEM±	Seed yield CD (P=0.05)
Factor 1	0.19	0.54	0.17	0.49	26.24	75.91
Factor 2	0.19	0.54	0.17	0.49	26.24	75.91
Factor 3	0.20	0.67	0.31	1.02	39.58	124.31
F1 x F2	0.73	1.86	1.15	2.54	24.99	79.99
F1 x F3	0.20	0.59	0.32	0.92	58.33	169.16
F2 x F3	0.20	0.59	0.32	0.92	58.33	169.16

Continued (Table 1)

Date of sowing (F_1) × Variety (F_2) × Fungicides (F_3)	F1	F2	F3	F4	F0	Mean	F1	F2	F3	F4	F0	Mean	F1	F2	F3	F4	F0	Mean
D_1V_1	38.39	35.77	33.60	27.51	66.77	40.41	25.10	21.80	17.30	11.65	42.73	23.72	1398.75	1457.08	1527.92	1624.75	1162.50	1434.20
	(38.59)	(36.75)	(35.43)	(31.63)	(54.82)	(39.64)	(30.07)	(27.83)	(24.58)	(20.10)	(40.80)	(29.13)						
D_1V_2	42.61	37.83	35.39	30.40	67.67	42.78	26.50	23.08	19.79	14.65	43.24	25.45	1282.08	1335.83	1385.83	1434.58	1101.25	1307.91
	(40.74)	(37.94)	(36.51)	(33.46)	(55.37)	(40.86)	(30.98)	(28.73)	(26.42)	(22.55)	(41.09)	(30.33)						
D_2V_1	43.04	41.40	39.64	33.22	70.71	45.60	26.62	22.81	19.20	14.76	44.73	25.62	1269.16	1356.67	1433.33	1479.17	1065.41	1320.75
	(40.98)	(40.05)	(39.00)	(35.18)	(57.23)	(42.48)	(31.11)	(28.52)	(25.99)	(22.63)	(41.96)	(30.40)						
D_2V_2	44.85	41.22	39.59	34.43	72.23	46.46	27.92	24.96	20.67	15.51	46.32	27.08	1177.50	1247.50	1306.67	1372.50	955.00	1211.83
	(42.07)	(39.93)	(39.00)	(35.91)	(58.18)	(42.99)	(31.85)	(30.00)	(27.06)	(23.19)	(42.88)	(31.37)						
Mean	42.22	39.05	37.05	31.39	69.34		26.53	23.16	19.24	14.14	44.25		1281.87	1349.27	1413.44	1477.75	1071.04	
	(40.63)	(38.70)	(37.52)	(34.08)	(56.35)		(31.05)	(28.79)	(25.99)	(22.06)	(41.73)							
		SEM±			CD (P=0.05)			SEM±			CD (P=0.05)			SEM±			CD (P=0.05)	
F1 x F2 x F3		0.29			0.85			0.45			1.30			83.33			239.99	

D_1, 20 Oct. 2006 & 2007; D_2, 30 Oct. 2006 & 2007; V_1, 'YST151'; V_2, 'NDYS2'

Table 2. Avoidable yield loss, net return and benefit : cost ratio of different fungicides variety under different date of sowings (mean data 2006-07 and 2007-08)

Factors	Yield	Additional yield over control	Avoidable yield loss (%)	Additional income (Rs. ha^{-1})	Cost of protection	Net return (Rs. ha^{-1})	Benefit:cost ratio
$D_1V_1F_1$	1398.75	236.25	16.89	4252.50	1947.00	2305.50	2.18
$D_1V_1F_2$	1457.08	294.58	20.22	5302.44	3177.00	2125.44	1.67
$D_1V_1F_3$	1527.92	365.42	23.92	6577.56	3087.00	3490.56	2.13
$D_1V_1F_4$	1624.75	462.25	28.45	8320.50	2547.00	5773.50	3.27
$D_1V_1F_0$	1162.50						
$D_1V_2F_1$	1282.08	180.83	14.10	3254.94	1947.00	1307.94	1.67
$D_1V_2F_2$	1335.83	234.58	17.56	4222.44	3177.00	1045.44	1.33
$D_1V_2F_3$	1385.83	284.08	20.53	5122.44	3087.00	2035.44	1.66
$D_1V_2F_4$	1434.58	333.33	23.23	5999.94	2547.00	3452.94	2.35
$D_1V_2F_0$	1101.25						
$D_2V_1F_1$	1269.16	203.75	16.05	3667.50	1947.00	1720.50	1.96
$D_2V_1F_2$	1356.67	291.26	21.47	5242.68	3177.00	2065.68	1.59
$D_2V_1F_3$	1433.33	367.92	25.67	6622.56	3087.00	3535.56	1.99
$D_2V_1F_4$	1479.17	413.76	27.97	7447.68	2547.00	4900.68	2.87
$D_2V_1F_0$	1065.41						
$D_2V_2F_1$	1177.50	222.50	18.89	4005.00	1947.00	2058.00	2.06
$D_2V_2F_2$	1247.50	292.50	23.45	5265.00	3177.00	2088.00	1.66
$D_2V_2F_3$	1306.67	351.67	26.91	6330.06	3087.00	3243.06	2.05
$D_2V_2F_4$	1372.50	417.50	30.42	7515.00	2547.00	4968.00	2.95
$D_2V_2F_0$	955.00						

D_1,20 Oct.2006&2007; D_2, 30 Oct.2006&2007; V_1, 'YST151'; V_2, 'NDYS2'; F_1, mancozeb @ 0.2%; F_2, companion @ 0.15%; F_3, propiconazole @ 0.075%; F_4, iprobenfos @ 0.075% and F_0, control with iprobenfos @ 0.075% had the lowest Alternaria leaf blight intensity of 27.51%, pod blight intensity of 11.65% and seed yield of 1624.75 kg $ha^{-1}$and this set of combination proved most effective in reducing the disease intensity and increasing the seed yield followed by 'NDYS2' sown on 20 October and 'YST151' sown on 30 October sprayed with the same fungicide in respect of disease intensity. Latter treatments were at par. The highest Alternaria leaf blight intensity of 72.23%, pod blight of 46.32% and the lowest seed yield of 955.00 kg ha^{-1} was recorded in the unsprayed control in 'NDYS2' sown on 30 October (Table 1).Present study was undertaken with the integrated approach on the use of these factors to reduce the disease intensity and maximize the seed yield.

Yield and avoidable yield loss :

'YST 151' yellow sarson sown on 20 October and sprayed with iprobenfos @ 0.075% gave the highest yield of 1624.75 kg ha^{-1} followed by same variety sown on same date and sprayed with propiconazole @ 0.075% and 'YST151' sown on 30 October and sprayed with iprobenfos @ 0.075%. However, the lowest yield of 955.00 kg ha^{-1} was obtained from control plot of 'NDYS 2' sown on 30 October (Table 2). 'NDYS 2' yellow sarson sown on 30 October and sprayed with iprobenfos @ 0.075% could avoid the highest yield loss of 30.42% followed by 'YST 151' sown on 20 October and sprayed with same fungicide. However, the minimum avoidable yield loss occurred in 'NDYS2' sown at 20 October (Table 2).

Economics :

The spray of iprobenfos @ 0.075% on 'YST151' under 20 October sown crop was found most economical (Rs.5773.50) with benefit:cost ratio of 3.27. It was followed by same fungicide sprayed on same variety under 30 October sown crop with the net return of Rs.4968.00 and benefit:cost ratio of 2.95. The minimum net return of Rs.1045.44 with lowest benefit : cost ratio of 1.33 was recorded by 'NDYS 2' sown on 20 October and sprayed by companion @ 0.15% (Table 2).

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Rec. on 29.11.2011 & Acc. on 13.02.2012

J. Soils and Crops 22 (2) 270-276, Dec., 2012 ISSN 0971-2836

EFFECT OF FARMYARD MANURE AND DIFFERENT SOURCES AND LEVELS OF SULPHUR ON GROWTH AND YIELD OF RAPESEED (*Brassica campestris*)

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ABSTRACT

A field experiment to evaluate the response of farmyard manure and different sources and levels of sulphur on growth and yield was conducted at the experimental farm of the Department of Agronomy, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema, Nagaland during *rabi* season of 2009-2010. Results from the experimental findings revealed that plant height and number of leaves recorded significantly higher at 5 t FYM ha^{-1}. Similarly number of primary and secondary branches also increased significantly at 5 t FYM ha^{-1}. Yield attributes such as number of siliquae plant^{-1}, number of seed siliquae^{-1}, 1000 seed weight and seed and stover yield also increased significantly due to application of 5 t FYM ha^{-1}. It also increased seed oil content (%).Among the two different sources of sulphur, elemental sulphur recorded higher plant height, number of leaves plant^{-1} and maximum number of primary and secondary branches plant^{-1}. Similarly, yield attributes viz., number of siliquae plant^{-1}, number of seeds siliquae^{-1} and test weight also increased significantly due to elemental sulphur. Different treatment combinations of FYM and S could record significant effect on seed oil content and harvest index. The highest uptake of N (57.62 kg ha^{-1}) was recorded at FYM 5 t ha^{-1}. As the sulphur doses increased, total uptake and available nutrient content also increased significantly. However, interaction effect of different growth and yield attributes were found not significant.

(Key words: FYM, Sulphur, growth attributes, yield attributes, nutrient uptakes)

INTRODUCTION

Rapeseed (*Brassica campestris* L. Sarson) is one of the most important oilseed crops of winter season, contributing 28.4 per cent of the total oil production in India. The consumption of edible oil in the country is 7.2 kg head^{-1} annum^{-1} compared to 11.0 kg of world average. One of the important ways for increasing productivity of mustard is improving crop nutrition through balanced fertilization. Fertilizer management is one of the most important agronomic factors that affect the yield of oilseed crops. In the fertilizer schedule of oilseeds, emphasis is generally laid on nitrogen, phosphorous and potassium, ignoring the secondary nutrients, particularly sulphur which plays a multiple role for better productivity of oilseeds (Singh and Sinsinwar, 2006). Among the sulphur supplying sources, gypsum and pyrite are being abundantly used in sulphur deficient soils. On the other hand, another factor which contributes in increasing crop yields is FYM. Use of organic manure in soil not only increases yield but also increases moisture holding capacity and also plays an important role in soil and water conservation by their binding and aggregation properties. Moreover, they also help in balancing the nutrient availability to growing plants and boost up the production and quality of crop. Judicious combination of FYM and inorganic fertilizers facilitate profitable and sustainable production (Singh and Sinsinwar, 2006). Farmyard manure (FYM) improves soil quality apart from supplying all essential nutrients. During the past few years S has received increasing attention. Global reports of sulphur deficiency and consequent crop responses are quite ostensible (Giri *et al*. 2005). Indian mustard responds to sulphur remarkably depending on soil type and source of its use (Arora and Sharma 2008). However, little is known about the relative sulphur requirement and its effect on yield and uptake of nutrients by mustard in Nagaland. Therefore, an attempt was made to study the effect of FYM and different sources and levels of sulphur on growth, yield and quality of Indian mustard.

MATERIALS AND METHODS

A field experiment was conducted at experimental farm of School of Agricultural Sciences and Rural Development (SASRD), Nagaland University, Medziphema, Nagaland during the *rabi* season of 2009-10. The soil of the experimental plot was sandy loam, having pH 4.5 with electrical conductivity 0.225 dSm^{-1}, organic carbon 1.34 per cent and available N, P_2O_5, K_2O and Sulphur 227.21, 35.02, 249.30 and 9.23 kg ha^{-1} respectively. The experiment comprised of sixteen treatments viz., two levels of FYM (0 t ha^{-1} and 5 t ha^{-1}), two sources of sulphur (elemental sulphur and gypsum) and four

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levels of sulphur (0, 20, 40 and 60 kg S ha^{-1}). The experiment with these treatments was laid out in factorial randomized block design with three replications. Sowing was done at the spacing of 30 cm row spacing with seed rate of 5 kg ha^{-1} at 4-5 cm depth and the variety used was T 38. Recommended dose of fertilizer (RDF) used for mustard was 50:40:30 kg NPK ha^{-1} in the form of Urea, Single Super Phosphate and Muriate of Potash which were applied in all the experimental plots. The two levels of farmyard manure (0 t ha^{-1} and 5 t ha^{-1}) and four levels (0, 20, 40 and 60 kg ha^{-1}) of different sources of Sulphur (Gypsum and Elemental sulphur) were applied in combination to plots along with the other fertilizers as per layout plan. The required amount of FYM containing 0.32 % N, 0.20% P, 0.40% K and 0.15% S as per the treatment was incorporated into the soil 15 days before sowing of crop. Full dose of phosphorus, potassium and sulphur and half dose of nitrogen (as per treatment) were applied at sowing. Remaining half dose of nitrogen was applied before flowering of the crop. The crop was sown on 29^{th} October,2009 and harvested on 2^{nd} February,2010. Need based plant protection measures were adopted to protect the crops from pests and diseases. It was observed that the crop was infested by aphids during flowering stage and was controlled by applying Rogor @ 1.5 ml $litre^{-1}$ of water. Observations on growth attributes viz., number of leaves $plant^{-1}$, plant height and number of branches $plant^{-1}$ at flowering stage and yield attributes viz., number of siliquae $plant^{-1}$, number of seeds $siliquae^{-1}$, test weight and yield were estimated at harvest and expressed as mean. Harvest index was calculated. Per cent oil content was estimated at Directorate of Rapeseed and Mustard Research, Bharatpur, Rajasthan. The seed and stover samples were separately collected after threshing from each plot and dried in oven. The oven-dried samples were ground to powder and analysed for N, P and K (%) and per cent sulphur content. Uptakes of nutrients were calculated multiplying total biomass (dry wt. kg ha^{-1} basis) with respective nutrient content in per cent. Soil samples were collected from each plot after harvest of the crop and prepared for Nitrogen was analysed as per alkaline potassium permanganate method (Subbiah and Asija, 1956), phosphorus by Brays no. 1 method (Bray and Kurtz, 1945), potassium by Flame photometer method and sulphur by turbidity method (Chesinin, 1951).

RESULTS AND DISCUSSION

Growth parameters :

It can be observed from the table 1, that application of 5 t FYM ha^{-1} significantly increased the plant height at harvest (82.50 cm). Application of gypsum as source of sulphur recorded higher plant height (81 cm) than elemental sulphur (73 cm). The highest plant height (79.74 cm) was recorded with the application of 60 kg S ha^{-1} though the lowest plant height was observed at control (0 kg S ha^{-1}). The highest number of leaves (21) was recorded due to the application of 5 t FYM ha^{-1} .The increase in number of leaves $plant^{-1}$ might be due to increase in plant height at every successive stages of growth (Srivastava *et al*, 2006). The highest number of leaves $plant^{-1}$ (19.50) was recorded due to application of elemental sulphur. Tripathi *et al.* (2010) also found increase in number of leaves $plant^{-1}$ in Indian mustard due to increased sulphur level. This might be due to the more synthesis of amino acids, increase in chlorophyll content in growing region and improving the photosynthetic activity, ultimately enhancing cell division and thereby resulting higher crop growth rate.

Application of 5 t FYM ha^{-1} gave maximum number of primary and secondary branches at maturity (7.08 and 10.21). Application of different sources of sulphur did not show significant influence on primary branches $plant^{-1}$; however it was observed that sources of sulphur showed significant effect on secondary branches $plant^{-1}$. Elemental sulphur gave higher primary and secondary branches $plant^{-1}$ (5.88 and 7.67) than gypsum. Increasing levels of sulphur increased both primary and secondary branches $plant^{-1}$ at maturity. The highest primary and secondary branches $plant^{-1}$ (6.92 and 31.50) was recorded at the application of 60 kg S ha^{-1} and the lowest (4.58 and 13.00) at control (0 kg S ha^{-1}). The increased number of branches by increased levels of sulphur might be due to role of sulphur in cell division, cell elongation and setting of cell structure as had been reported by Kumar and Yadav (2007). They also reported increase in number of branches with the increase in sulphur levels.

Yield attributes:

Data from table 2 indicated that the maximum number of siliqua $plant^{-1}$ (204.50), number of seeds $siliquae^{-1}$ (15.92) and 1000-seed weight (3.87g) was recorded with application of 5 t FYM ha^{-1}. Singh and Sinsinwar (2006) reported significant effect of FYM (5 t ha^{-1}) on yield component of mustard crop. Application of different sources of sulphur showed significant influence on number of siliquae plant^{-1} and number of seeds siliquae^{-1}, however, 1000-seed weight did not show significant influence. The highest number of siliquae plant^{-1} (174.75), number of seeds siliqua^{-1} (15.88) and 1000-seed weight (3.63 g) was recorded due to application of elemental sulphur than gypsum. The number of siliquae plant^{-1} significantly increased with the increased level of sulphur. The highest number of siliqua (213.92) plant^{-1} was obtained due to application of 60 kg S ha^{-1} through elemental sulphur and the lowest (173.67) was recorded at control (0 kg S ha^{-1}). These results are in close conformity with the findings of Prakash and Bhushan (2001) who reported that application of sulphur increased number of siliqua plant^{-1}. Piri and Sarmah (2008) also reported increase in number of siliquae plant^{-1} with the increase in levels of sulphur. Increased sulphur levels significantly increased the number of seeds siliquae^{-1} and 1000 seed weight. Application of 60 kg S ha^{-1} (elemental –S) recorded the highest number of seeds siliquae^{-1} (16.92) and the lowest (14.08) was recorded at control (0 kg S ha^{-1}). Krishna *et al.* (2005) reported increase in seed siliqua^{-1} with the increased levels of sulphur .Singh and Sinsinwar (2006) also reported significant increase in number of seeds siliquae^{-1} with successive increase in the level of S from 0 to 90 kg ha^{-1}. The findings of Kumar and Yadav (2007) revealed increase in number of seeds siliqua^{-1} with increase in the level of S from 0 to 45 kg ha^{-1}. Thus, present findings agree with these findings about the role of sulphur. The test weight (1000 seed weight) increased with the increased level of sulphur. The highest test weight (3.77g) was recorded at 60 kg S ha^{-1} and the lowest (3.31g) at 0 kg S ha^{-1}. This might be due to enhanced performance of reproductive parameters due to the role of sulphur in better absorption of nutrient and also due to high rate of assimilates partitioning towards the sink. Maximum seed yield (9.94 q ha^{-1}) and stover yield (21.98q ha^{-1}) was recorded with the application of 5 t FYM ha^{-1}. Significant improvement in seed yield might due to favorable effect of FYM on the growth and yield attributes in plants. Tripathi *et al.*(2010) reported significant effect of FYM on seed yield and stover yield. Different sources of sulphur showed significant influence on seed and stover yield. Higher seed and stover yield (9.23 q ha^{-1} and 18.89 q ha^{-1}) was recorded due to application of elemental sulphur than gypsum. The highest seed yield (14.34 q ha^{-1}) and stover yield (20.85 q ha^{-1}) was reported at 60 kg S ha^{-1} (elemental-S) and the lowest seed (6.50 q ha^{-1}) and stover yield (14.96 q ha^{-1}) was recorded at control (0 kg S ha^{-1}). Wani and Aga (2004) also reported significantly increase in seed and stover yield with the increasing levels of sulphur. Such an increase in the seed yield and stover yield were resulted from the corresponding improvement of yield attributing characters, such as increase in number of branches plant^{-1}, number of siliquae, number of filled siliquae, number of seeds siliqua^{-1}, and 1000 seed weight. Maximum seed oil content (40.98 per cent) was recorded with the application of 5 t FYM ha^{-1}. This was due to more uptake of sulphur (Giri *et al*. 2005) with FYM application, as they play an important role in oil synthesis. The seed oil content did not show significant effect with different sources of sulphur. Higher seed oil content (40.88 per cent) was recorded due to application of elemental sulphur than gypsum. The highest harvest index of 26.81 per cent was recorded with the application of 5 t FYM ha^{-1}. Different sources of sulphur did not show significant influence on harvest index. The interaction effect of most of the growth and yield attributes were found not significant.

Nutrient uptake:

Maximum uptake of NPK and S by rapeseed plant was recorded with the application of 5 t FYM ha^{-1} (Table 3). This might be due to synergistic effects of nutrients. Srivastava *et al.* (2006) reported maximum uptake of nutrients with the application of FYM. Different sources of sulphur showed no significant influence on total uptake of N, K and S. Application of elemental sulphur showed higher total uptake of N, P, K and S by plant than gypsum. Maximum N uptake (52.97 kg ha^{-1}) was recorded at 60 kg S ha^{-1}. The uptake of P increased with the increasing levels of sulphur. Application of 60 kg S ha^{-1} gave the maximum P uptake (7.3 kg ha^{-1}). This might be due to increase in yield and higher demand for plant growth. These findings agree with Singh *et al.* (2005) who also reported increased P uptake with increased sulphur level upto 60 kg S ha^{-1} (elemental-S). Maximum uptake of K (24.30 kg ha^{-1}) was recorded with the application of 60 kg S ha^{-1}. Increased

Table 1. Growth of mustard as influenced by different levels of FYM, sulphur and sources of sulphur at harvest

Treatments	Plant height (cm)	No. of functional leaves	No. of primary branches plant^{-1}	No. of secondary branches plant^{-1}
FYM (t ha^{-1})				
0 t ha^{-1}	66.52	16.96	4.25	4.58
5 t ha^{-1}	82.50	21.21	7.08	10.21
SEm±	6.20	0.76	0.22	0.33
CD at 5%	15.19	1.57	0.45	0.69
Sulphur sources				
Elemental –S	73.33	18.67	5.46	7.13
Gypsum	81.08	19.50	5.88	7.67
SEm±	6.20	0.76	0.72	0.33
CD at 5%	--	--	--	--
Sulphur (kg ha^{-1})				
No sulphur	74.78	14.50	4.58	13.00
20 kg S ha^{-1}	75.50	17.08	5.58	14.50
40 kg S ha^{-1}	78.82	20.92	5.68	29.75
60 kg S ha^{-1}	79.74	23.83	6.92	31.50
SEm±	1.92	1.08	0.31	0.47
CD at 5%	5.61	2.21	0.64	0.97
Interactions (FYM x S-sources x S-doses)				
SEm±	10.05	1.35	0.94	0.25
CD (P=0.05)	--	--	--	--

Table 2. Yield attributes, seed oil content and harvest index of mustard as influenced by different levels of FYM, sulphur and sources of sulphur

Treatments	No. of siliqua plant^{-1}	Seeds siliqua^{-1}	Test weight (g)	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Seed oil content (%)	Harvest index (%)
FYM doses							
0 t ha^{-1}	120.63	14.21	3.29	6.21	13.28	40.94	25.20
5 t ha^{-1}	204.00	15.92	3.87	9.94	21.98	48.94	26.81
SEm±	9.56	0.60	0.09	0.17	0.55	0.17	0.95
CD at 5%	19.54	1.60	0.24	0.41	1.35	--	--
Sulphur sources							
Elemental –S	150.38	14.75	3.53	8.86	17.03	40.86	25.69
Gypsum	174.75	15.88	3.63	9.23	18.09	40.88	26.32
SEm±	9.56	0.60	0.09	0.17	0.55	0.17	0.95
CD at 5%	19.54	--	--	0.41	1.35	--	--
Sulphur (kg ha^{-1})							
No sulphur	129.33	14.08	3.31	6.50	14.96	40.74	25.36
20 kg S ha^{-1}	147.42	14.75	3.57	10.34	16.69	40.87	25.72
40 kg S ha^{-1}	159.58	15.50	3.68	11.79	18.01	40.90	25.75
60 kg S ha^{-1}	213.92	16.92	3.77	14.34	20.85	40.97	27.20
SEm±	13.52	0.85	0.08	0.33	0.44	0.04	1.34
CD at 5%	27.63	1.74	0.17	0.48	0.92	--	--
Interactions (FYM x S-sources x S-doses)							
SEm±	27.05	0.93	0.12	0.33	0.63	0.06	2.69
CD (P=0.05)	--	--	--	--	--	--	--

Table 3. Nutrient uptake and available nutrient as influenced by different levels of FYM, sulphur and sources of sulphur at harvest

Treatments	Total uptake (kg ha^{-1}) by plants				Available nutrients (kg ha^{-1}) in soil			
	N	P	K	S	N	P	K	S
FYM doses								
0 t ha^{-1}	38.27	5.10	20.41	7.88	275.95	21.95	208.58	24.65
5 t ha^{-1}	57.62	6.67	23.19	8.86	328.46	27.52	272.62	25.71
SE m±	1.47	0.09	0.25	0.06	3.78	0.16	0.19	0.13
CD at 5%	3.65	0.22	0.62	0.15	9.25	0.41	0.48	--
Sulphur (kg ha^{-1}) source								
Elemental - S	42.27	5.63	21.38	7.47	294.73	23.14	223.35	25.00
Gypsum	48.62	6.13	22.54	9.18	309.68	26.33	257.85	25.37
SE m±	1.49	0.09	0.25	0.06	3.78	0.16	0.19	0.13
CD at 5%	--	--	0.62	0.15	59.25	0.41	0.48	0.32
Sulphur (kg ha^{-1})								
No sulphur	43.14	4.70	19.63	6.85	285.38	22.25	223.36	10.16
20 kg S ha^{-1}	46.68	4.86	21.03	7.72	295.52	24.19	235.07	17.01
40 kg S ha^{-1}	48.98	6.22	22.62	8.44	316.23	26.54	253.50	27.16
60 kg S ha^{-1}	52.97	7.30	24.30	9.91	321.68	26.87	255.45	31.40
SE m±	0.65	0.15	0.17	0.12	2.46	0.23	0.36	0.18
CD at 5%	1.35	0.32	0.38	0.24	5.09	0.48	2.06	0.39
Interactions (FYM x S-sources x S-doses)								
SE m±	0.91	0.18	0.17	0.12	2.46	0.23	0.25	0.18
CD (P=0.05)	--	--	--	--	--	--	--	--

Table 4. Interaction effect of farmyard manure and different sources and levels of sulphur on available N, K and total S and K uptake (kg ha^{-1})

Treatments	Available N (kg ha^{-1})	Available K (kg ha^{-1})	Available uptake (kg ha^{-1})	Total K uptake (kg ha^{-1})
$F_0S_1D_0$	235.57	174.39	5.69	18.44
$F_0S_1D_1$	246.65	187.98	6.70	19.74
$F_0S_1D_2$	284.89	201.35	7.36	21.02
$F_0S_1D_3$	304.00	207.21	7.96	22.55
$F_0S_2D_0$	271.51	212.60	6.95	18.86
$F_0S_2D_1$	278.56	222.28	7.42	19.85
$F_0S_2D_2$	281.23	228.19	8.08	21.51
$F_0S_2D_3$	305.14	234.66	9.22	23.11
$F_1S_1D_0$	306.50	233.12	7.51	19.40
$F_1S_1D_1$	319.68	246.31	8.83	21.13
$F_1S_1D_2$	328.04	262.31	9.95	23.59
$F_1S_1D_3$	332.48	273.56	10.72	25.38
$F_1S_2D_0$	327.91	273.35	7.70	21.84
$F_1S_2D_1$	337.21	283.21	9.39	23.30
$F_1S_2D_2$	330.78	302.17	11.86	24.63
$F_1S_2D_3$	345.10	306.36	13.22	26.40
SE m±	**2.46**	**0.25**	**0.12**	**0.17**
CD (P=0.05)	**7.20**	**0.74**	**0.35**	**0.52**

NB : F-FYM, S-Sources of sulphur, D-Doses of sulphur application of sulphur levels significantly increased sulphur uptake. The highest S uptake (9.91 kg ha^{-1}) was reported by the application of 60 kg S ha^{-1} (elemental-S) and the lowest (6.85 kg ha^{-1}) at control (0 kg S ha^{-1}).

Maximum available NPK and S were recorded with the application of 5 t FYM ha^{-1}. Piri and Sarmah (2008) reported increase in available nutrient (N, P, K and S) content in soil at harvest with the application of FYM. Sources of sulphur did not show significant effect on available S however, it showed significant influence on available nutrient N, P and K in soil at harvest. Available N, P and K content in soil at harvest increased significantly with the increase in levels of S applied. Maximum available N (321.68 kg ha^{-1}), P (26.87 kg ha^{-1}) and K (255.45 kg ha^{-1}) was recorded by the application of 60 kg S ha^{-1}(elemental-S). Available S content in soil significantly increased with the application of increased level of sulphur. Maximum available S (31.40 kg ha^{-1}) content in soil was recorded with the application of 60 kg S ha^{-1} and the lowest at control (0 kg S ha^{-1}).

The interaction effect of FYM and different sources and levels of sulphur on available N, K in soil and uptake of K and S by plants were found significant, however available S in soil was found not significant. Application of 5 t FYM and 60 kg elemental sulphur ha^{-1} recorded highest available N (345.10 kg ha^{-1}) and K (306.36 kg ha^{-1}) and highest uptake of sulphur (13.22 kgha $^{-1}$) and K (26.40 kg ha^{-1}).

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Rec. on 20.08.2011 & Acc. on 30.12.2011

J. Soils and Crops 22 (2) 277-279, Dec., 2012 ISSN 0971-2836

STUDIES OF VARIATION IN NODULATION AND NITROGEN UPTAKE IN CHICKPEA GENOTYPES SUITABLE FOR MADHYA PRADESH

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ABSTRACT

A field experiment on twenty chickpea genotypes to study nodulation and nitrogen uptake was carried out during *rabi* season of 2007-08 and 2008-09 in nitrogen deficient soil under rain fed condition. Wide variations in nodule number (7 to 26 plant^{-1}), dry weight of nodules (0.11 to 0.23 g plant^{-1}) and an uptake of N (34.10 to 109.40 mg plant^{-1}) were found among different genotypes. Genotypes with higher nodule number and nodule dry weight resulting in higher shoot dry matter. There was slight variation in nitrogen content (1.50 to 1.82%) in roots among genotypes, while 30% variability was resulted in N uptake by chickpea. Among the 20 genotypes studies JG-130 and JG-63 were found to be high N accumulating (109.40 mg plant^{-1}) genotypes.

(Key words: Chickpea genotypes, nodulation, root-shoot uptake of nitrogen)

INTRODUCTION

Chickpea remarkably predominates among other pulse crops in terms of both area and production. The year 2009-10 marked significant increase in area under chickpea (8.56 million ha) which is highest in last 10 years. Similarly, the chickpea production (7.35 million tonnes) also surpassed last 50 years record with highest productivity (858 kg ha^{-1}) ever recorded in the history of India (Anonymous, 2012). Besides grain production it improves soil fertility through symbiotic nitrogen fixation. However, nitrogen fixation in legumes mainly depends on the presence of efficient nodulating rhizobia and a suitable host variety. Genotypic variation in nodulation was reported in several legumes viz., Soybean (Sharma *et al.* 2004, Dhage and Kachhave, 2008) and Urd bean (Singh and Usha, 2002). However, limited information is available on genotypic variations in chickpea under rain fed condition. In a deficient condition characterization of 10 soil profiles representing different pulse growing region of India showed that all the profiles were low in available nitrogen (Shriniwas Rao *et al.,* 2002). The present study was therefore, under taken to examine the variation in nodulation and nitrogen uptake in 20 chickpea genotypes under rainfed condition.

MATERIALS AND METHODS

Field experiments were conducted at the Instructional Farm, College of Agriculture in KVK cafeteria, Rewa (MP) during *rabi* seasons of 2008 and 2009. Twenty genotypes JG-315,VIKASH, RADHE, VIJAY, DIGVIJAY, ICCV-2, KAK-2, JKG-1, JKG-2, JG-7, JG-130, JKG-3, JG-18, JG-63, PG-5, JG-11, JG-14, JG-6, JG-74 and JGG-1 were sown without inoculation on 28 October 2008 and 02 November 2009 in 6 m X 4 m plots. Soil of experimental field were low in organic carbon (0.42 g kg^{-1}), available N (165 kg ha^{-1}) and Zinc (0.32 mg kg^{-1}). The soil properties of experimental location are given in table 1 in which the main soil properties are mention. Various nutrients were applied as basal as recommended dose 20 kg N, 60 kg P_2O_5, 20 kg K_2O, 20 kg S and 25 kg $ZnSO_4$ ha^{-1}. At 60 days after sowing five plants of each genotypes were uprooted carefully and thoroughly washed with plain water and then with distilled water. For collecting root samples, deep pits (30 cm x 30 cm) were dug and soil + root blocks were excavated from each plot. Roots were soaked in a container filled with water and soil was gently washed from the roots. The water in the container was strained or filtered screen through a 0.5 mm sieve to avoid the loss of small roots/rootlets. After counting number of nodules, the same were separated carefully and fresh weights were recorded. Root, shoot and nodules were dried at 60^0 C and dry weights were recorded. Root and shoot samples were digested in Triacid and analysed for total N by Kjeldahl method (Jackson, 1973). In order to evaluate soil properties such as mechanical analysis by Bouyoucos hydrometer method (Piper, 1944), pH, EC organic carbon, available phosphorus and potassium (Jackson, 1967), available nitrogen (Subbiah and Asija, 1956),

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available sulphur was determined by turbidimetric method (Bardsley and Lancaster, 1960) and zinc was determined by (Lindsay and Norvell, 1978). Data, thus, generated were analysed statistically. Relationship of the nodulation with different plant parameters and N uptake were established by simple correlations (Panse and Sukhatme,1967).

RESULTS AND DISCUSSION

Plant growth parameters of chickpea genotypes :

Data regarding variation in dry matter, nodule number and nodule weight among 20 Chickpea genotypes are presented in table 2. Dry matter varied from 0.21 to 0.61 g plant^{-1} with a mean of 0.40 g plant^{-1} in root and 0.88 to 2.57 g plant^{-1} with mean of 1.85 g plant^{-1} in shoot among genotypes. Palta *et al.* (2010) reported that the roots of the kabuli cultivar Almaz had greater dry matter and length than desi cultivar of chickpea. Nodule number varied from 7 to 26 plant^{-1} with a mean of 14.1 among genotypes. Similar findings were reported by Dhage and Kachhave (2008), Amule (2010) in reference to nodule number on soybean crop. There were 42% variations in the nodule number. Among genotypes JG-63 had the highest root nodulation followed by JG-74, JGG-1 and JG1-30 showed higher number of nodules than other genotypes. Fresh weight of nodules varied from 0.32 to 1.20 g plant^{-1} with a mean of 0.68 g plant^{-1}. Dry weight of nodules varied from 0.11 to 0.23 g plant^{-1} with a mean of 0.16 g plant^{-1}. Genotypes Digvijay followed by JG-11 and JG-7 showed higher nodule dry weight among 20 genotypes.

Nitrogen content and uptake in root and shoot of chickpea genotypes :

Nitrogen content in root varied from 1.50 to 1.82 per cent with mean of 1.65 per cent and nitrogen content in shoot varied from 3.36 to 4.34 per cent with mean of 3.77 per cent. Nitrogen uptake in root ranged from 3.3 to 9.4 mg plant^{-1} with mean of 6.6 mg plant^{-1} and nitrogen uptake by shoot varied from 29.9 to 106.8 mg plant^{-1} with mean of 22.6 mg plant^{-1}. The total uptake including root and shoot were varied from 34.10 to 109.40 mg plant^{-1} with mean of 77.40 mg plant^{-1} (Table 2).

Co-relation co-efficient between nodulation, plant growth and N uptake :

Shoot dry weight showed significant positive relationship (r=0.70** table 3) with nodule number. The co-efficient of variation in total N uptake among 20 genotypes was 33%. The positive relation between root N uptake and nodule number (r = 0.42) was also recorded. Correlation among root N uptake and nodule dry weight (r=0.36) was not found significant. Among genotypes JG-63, JG-130, JG-11, JG-315 and JG-14 showed higher N uptake than other genotypes. Nodule number showed better co-relation with N uptake as compared to that of nodule dry weight. Based on these results it can be concluded that JG-130 and JG-63 were higher N fixers while JGK-3 and JG-18 were low N fixers.

Table 1. Soil properties of experimental field

Soil Properties	Mean values
pH	7.6
EC (dS^{-1})	0.38
Org. C (g kg^{-1})	0.42
Clay %	11.9
Silt %	22.4
Sand %	33.2
Available N(kg ha^{-1})	165.4
Available P(kg ha^{-1})	10.6
Available K(kg ha^{-1})	195
Available S(kg ha^{-1})	10.6
Available Zn (mg kg^{-1})	0.32

Table 2. Plant growth parameters and nodulation in twenty chickpea genotypes under rainfed condition (mean of two years)

Genotypes	Dry matter (g plant^{-1})		Nodule No.	Nodule wt. (g plant^{-1})		N content (%)		Uptake (mg plant^{-1})		
	Root	Shoot		Fresh	Dry	Root	Shoot	Root	Shoot	Total
JG-315	0.31	2.57	15	0.69	0.19	1.62	3.92	5.0	100.7	105.7
VIKASH	0.21	1.48	13	0.54	0.12	1.59	3.65	3.3	54.0	57.3
RADHE	0.56	1.61	10	0.98	0.19	1.68	3.78	9.4	60.9	70.3
VIJAY	0.61	2.29	18	1.20	0.20	1.52	3.36	9.3	76.9	86.2
DIGVIJAY	0.51	1.75	16	1.03	0.23	1.50	3.60	7.7	63.0	70.7
ICCV-2	0.22	1.48	13	0.76	0.19	1.66	3.52	3.7	52.1	55.7
KAK-2	0.42	1.80	11	0.59	0.12	1.51	3.84	6.3	69.1	75.5
JKG-1	0.37	1.25	7	0.44	0.13	1.71	3.57	6.3	44.6	51.0
JKG-2	0.36	1.38	7	0.49	0.13	1.64	3.60	5.9	49.7	55.6
JG-7	0.31	2.05	10	1.15	0.21	1.62	4.06	5.0	83.2	88.3
JG-130	0.51	2.46	21	0.69	0.19	1.67	4.10	8.5	100.9	109.4
JKG-3	0.37	1.04	9	0.46	0.11	1.62	3.76	6.0	39.1	45.1
JG-18	0.26	0.88	8	0.32	0.12	1.72	3.40	4.5	29.9	34.1
JG-63	0.34	2.52	26	0.89	0.18	1.65	4.12	5.6	103.8	109.4
PG-5	0.37	2.11	11	0.41	0.13	1.68	3.70	6.2	78.1	84.3
JG-11	0.48	2.24	17	0.85	0.22	1.82	4.34	8.7	97.2	105.9
JG-14	0.50	2.21	11	0.38	0.18	1.73	4.20	8.7	92.8	101.5
JG-6	0.21	1.53	10	0.50	0.14	1.68	3.36	3.5	51.4	54.9
JG-74	0.53	2.51	24	0.71	0.19	1.63	3.62	8.6	90.9	82.1
JGG-1	0.54	1.83	24	0.48	0.11	1.68	3.99	9.1	73.0	52.1
Mean	**0.40**	**1.85**	**14.1**	**0.68**	**0.16**	**1.65**	**3.77**	**6.6**	**70.6**	**77.4**
SD	**0.124**	**0.51**	**5.9**	**0.26**	**0.04**	**0.08**	**0.29**	**2.0**	**22.6**	**23.6**
CV (%)	**30**	**28**	**42**	**38**	**25**	**4.8**	**7.7**	**30**	**32**	**33**

Table 3. Co-relation co-efficient between nodulation, plant growth and N uptake parameters

Parameters	Co-relation co-efficient
Nodule number vs. Shoot dry matter	0.70**
Nodule dry weight vs. Shoot dry matter	0.60**
Nodule dry weight vs. Shoot N content	0.30 NS
Shoot N content vs. Shoot dry matter	0.54**
Nodule dry weight vs. Shoot N uptake	0.58**
Root N uptake	0.34 NS
Total N uptake	0.59**
Nodule number vs. Shoot N uptake	0.67**
Root N uptake	0.42 NS
Total N uptake	0.68**

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Rec. on 25.06.2011 & Acc. on 28.09.2011

J. Soils and Crops 22 (2) 280-286, Dec., 2012 ISSN 0971-2836

EFFECT OF CONTINUOUS USE OF ORGANICS AND INORGANICS ON NUTRIENT STATUS OF SOIL AND YIELD UNDER MAIZE-WHEAT INTENSIVE CROPPING SYSTEM IN AN INCEPTISOL

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ABSTRACT

A long term fertilizer experiment was initiated in *kharif* 1997 and laid on Typic Haplustept at Instructional farm, Rajasthan College of Agriculture, Udaipur under All India Co-ordinated Research Project in a randomized block design for growing maize-wheat in sequence involving varying doses of N, NP, NPK with FYM, Zn, S and *Azotobacter.* The data generated during 2004-05 and 2005-06 were used to report the results. 100% NPK (120, 60 and 30 kg NPK ha^{-1}) + FYM @ 10 t ha^{-1} gave the highest yield of both the crops. 150%NPK gave almost equal yield to that of 100% NPK + FYM @ 10 t ha^{-1}. Application of FYM @ 20 t ha^{-1} gave low yields of crops which were as low as the treatment receiving 100%N alone. Treatments where addition of Zn or S and seed inoculation with Azotobacter with 100%NPK was done, yield did not improve significantly. Available phosphorus and nitrogen increased significantly in the treatments receiving 150% NPK and 100% NPK + FYM @ 10 t ha^{-1} over 100% NPK and control treatment. Continuous application of N or NP had depressive effect on available K content of the soil. Moreover, a significant decrease in available sulphur and zinc was noticed in all the fertilizer treatments where these nutrients were not added directly except 100% NPK + Zn + S (100 kg elemental S ha^{-1}) and 100% NPK + Zn (5 kg ha^{-1}).

(Key words: Integrated nutrient management, maize-wheat cropping system, nutrient status of soil, yield of maize and wheat)

INTRODUCTION

India is endowed with diversity of climate, soils, flora and fauna offering both a blessing and challenge for sustainability of agriculture. Huge population and increasing population density is posing a danger to natural resources. Use of imbalanced fertilizers badly influences production potential and soil health. The problem is more severe in acid soils which are under continuous intensive cropping under chemical fertilizers (Prasad *et al.*, 2010). Integrated nutrient management will not only sustain the crop production but also be effective in improving soil health and enhancing nutrient use efficiency (Verma *et al.*, 2005). As maize has wide adaptability and compatibility under diverse soil and climatic conditions and among different maize based cropping systems, maize-wheat cropping system ranks first and most adaptable especially in rainfed ecologies (Dass *et al.*, 2008). Keeping this in view, a study was conducted in AICRP on long-term fertilizer experiments in maize-wheat cropping system to study the effect of continuous use of plant nutrients, in organic and inorganic forms on nutrient status of soil and crop yields.

MATERIALS AND METHODS

The present investigation was carried out in the on-going AICRP long-term fertilizer experiment initiated during *kharif* 1997 at the Instructional Farm, Rajasthan College of Agriculture, Udaipur. The field experiment was conducted on a pre-established long-term fertilizer experiment (1997 onwards) in the maize crop of the maize-wheat cropping system of the year (2004-05) and wheat crop of the maize-wheat cropping system of the year (2005-06) to study the effect of continuous use of plant nutrients, in organic and inorganic forms on nutrient status of soil and yield of the crop. The experiment consisted of 12 treatment combinations replicated four times in a randomized block design.

Treatments:

Maize	Wheat
T_1 = 100% NPK (120, 60, 30 kg NPK ha^{-1})	T_1 = 100% NPK (120, 60, 30 kg NPK ha^{-1})
T_2 = 100% NPK + Zn (5 kg ha^{-1})	T_2 = 100% NPK
T_3 = 100% NPK + Zn + S (100 kg elemental S ha^{-1})	T_3 = 100% NPK
T_4 = 100% NPK + S	T_4 = 100% NPK
T_5 = 100% NPK+ seed treatment with *Azotobacter*	T_5 = 100% NPK+ seed treatment with *Azotobacter*
T_6 = FYM @ 10 t ha^{-1} (only to maize) + (100% NPK–NPK content of FYM)	T_6 = 100% NPK
T_7 = 100% NPK + FYM @ 10 t ha^{-1}	T_7 = 100% NPK
T_8 = FYM @ 20 t ha^{-1}	T_8 = No FYM
T_9 = 150% NPK	T_9 = 150% NPK
T_{10} = 100% NP	T_{10} = 100% NP
T_{11} = 100% N	T_{11} = 100% N
T_{12} = Control (no manures and fertilizers)	T_{12} = Control (no manures and fertilizers)

Before the initiation of the experiment during 2004-05, soil was slightly alkaline in reaction (pH 8.2, EC 0.48 dSm^{-1}), sandy clay loam in texture, non-saline, and calcareous in nature having 35.3% Sand,

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39.1% Silt and 25.6% Clay. The soil is medium in organic carbon (8.5 g kg^{-1}), available nitrogen (427.75 kg ha^{-1}), available phosphorus (22.4 kg ha^{-1}) while high in available potassium (671 kg ha^{-1}) and is well supplied with available Sulphur (21 mg kg^{-1}). Sources of N, P and K were diammonium phosphate, urea and muriate of potash. FYM, $ZnSO_4$ (25 kg ha^{-1}), elemental sulphur (100 kg ha^{-1}) was applied only in *kharif* season. The bio fertilizers for seed inoculation were used @ 500 g ha^{-1} for both maize and wheat crops. Maize (cv. Ganga-2) and wheat (cv. Raj 3077) were raised as test crops in the cropping system. Maize crop was sown in the first week of July (7.7.2005) and harvested in first week of October (14.10.2005). Wheat crop was sown in the last week of November (21.11.2005) and harvested in the last week of March (29.3.2006). Crops were harvested at maturity and plot-wise yield data after harvest of each crop was recorded after threshing. Soil samples were collected from depth of 0-15 cm using core sampler. The soil was air dried, ground to pass through 2 mm sieve and then subjected to chemical characterization. Samples were analysed to assess the available nutrient status (N, P, K, S and DTPA Zn). The available N was determined by alkaline permanganate method (Subbiah and Asija, 1956), available P (Olsen *et al*., 1954), available K (Richards, 1968), available S (Chesnin and Yien, 1950) and DTPA Zn (Lindsay and Norvell, 1978).

RESULTS AND DISCUSSION

Effect of long term integrated nutrient management on crop productivity:

In maize crop, data indicates that the grain yield varied from 15.1 q ha^{-1} to 34.4 q ha^{-1} in control and 100% NPK + FYM @ 10 t ha^{-1}. Maximum yield (34.4 and 48.9 q ha^{-1} in grain and straw) was obtained when 100% NPK (120, 60 and 30 kg NPK ha^{-1}) + FYM @ 10 t ha^{-1}) was applied followed by 150% NPK (31.3 q ha^{-1}). When compared to 100% NPK, a significant increase in above two treatments was noticed. All the treatments showed significant increase in yield when compared to control (Table 1). Thakur *et al.* (2011b) also reported that in continuous cropping, application of FYM alongwith optimal dose of fertilizer i.e. 100% NPK+FYM@15t ha^{-1} was beneficial for enhanced crop productivity and soil fertility. Selvi *et al.* (2005) too stated that farm yard manure directly added an appreciable amount of major micronutrients to soil which could contribute to enhanced yield. The yield obtained under 100% N was 21.2 q ha^{-1} showing whereby significant reduction (27 per cent) in yield over 100% NPK emphasizing the need of balanced application of nutrients. Application of FYM @ 20 t ha^{-1} gave low yields of crop which were as low as the treatment receiving 100% N suggesting that organic manure alone can not sustain the yield. In wheat crop, both in grain and straw, maximum yield was obtained when 100 % NPK+ FYM was applied followed by 150% NPK. Humne *et al.* (2008) also reported higher yield of wheat (1837.5 kg ha^{-1}) in 150% NPK and (1540 kg ha^{-1}) in 100% NPK+ FYM @ 5 t ha^{-1} treated plots which might be due to higher nutrient uptake and improvement in soil environment. Application of 100% N (26.7q ha^{-1}) significantly increased the yield over control (18.0 q ha^{-1}) but was significantly less than integrated nutrient management and other NPK treatments. Further, supplementation with 100% NP increased the yields and on further addition of potassium in 100% NPK increased the yields by 16 and 11 per cent, respectively. Mishra *et al*. (2008) also reported that continuous organic manure application in combination with inorganic fertilizers significantly increased the grain yield over 100% NPK (recommended dose of fertilizer for maize and wheat was 110:90:70 kg ha^{-1} N:P_2O_5:K_2O) in a long term field experiment at Ranchi with maize and wheat cropping sequence in an alfisol.

Effect of long term integrated nutrient management on available nutrient status :

Available nitrogen:

In maize crop, data indicates that maximum available nitrogen content was 346 kg ha^{-1} and 345 kg ha^{-1} in the treatments receiving 150% NPK and 100% NPK + FYM @ 10 t ha^{-1}, which were statistically at par with each other. When compared with 100% NPK and control, a significant increase in available nitrogen content was observed over both the above treatments. Moreover, these treatments also recorded significantly higher available nitrogen content over rest of the treatments. Increase in available nitrogen content in the soil with the application of 150% NPK was 21 per cent higher than100% NPK treatment. Treatment 100% NPK + FYM @ 10 t ha^{-1} recorded an increase of 20 per cent in maize crop when compared with control. Walia *et al.* (2010) also reported that integrated use of organic manures in combination with chemical fertilizers i.e. 100% NPK (recommended dose) + 50% N through FYM improved nitrogen status in comparison to inorganic fertilizers alone. In treatments, 100 % NPK + Zn, 100 % NPK + S, 100 % NPK + *Azotobacter*, available nitrogen content observed was 294, 291 and 311 kg ha^{-1} but these treatments were statistically at par with each other (Table 2). In wheat crop, maximum available nitrogen content (339 kg ha^{-1}) was found in treatments receiving 150% NPK followed by 100% NPK + FYM @ 10 t ha^{-1} (329 kg ha^{-1}). These treatments were statistically at par with each other but significantly superior over 100% NPK and control. Jamwal (2005) also reported that most effective contribution of application of organics to nutrient status was observed when 40 kg N ha^{-1} was applied through inorganic source and 10 tonnes FYM through organic source. About 16 per cent increase in available nitrogen in 100% NPK + FYM @ 10 t ha^{-1} was recorded when compared to control and nearly 19 per cent higher available N content over 100% NPK treatment. A significant increase in available nutrient (NPK) content of the soil in plot receiving 100% NPK + FYM over the plot receiving 100% NPK is attributed to continuous addition of nutrients through FYM and their retention by the enhanced level of organic matter. Sharma *et al.* (2007) also reported that the available nutrients in the soil were lowest in the control plot and highest in super optimal plot. Moreover, a significant increase in available nutrient (NPK) content of the soil in the plot receiving 100% NPK +FYM over 100% NPK plot was also noticed.

Available phosphorus:

Data indicates that in maize crop, available phosphorus in treatment 100% NP was 22.0 kg ha^{-1}, whereas in 100% N it was 19.8 kg ha^{-1}. Use of 100% NP over 100% N significantly improved the available P status of the soil. A significant reduction in available P content of soil observed under N alone and unfertilized treatment occurred due to removal of P by the crop in the absence of external source of P. Singh *et al.* (2009) also stated that substantial build up of available P in plots receiving external P fertilizer application over the years is ascribed to poor utilization of added P. Further, addition of potassium i.e. (100 % NPK over 100% NP) had no significant influence on available P status. Similarly, non-significant difference in available phosphorus was recorded among the treatments 100 % NPK + Zn, 100 % NPK + Zn + S. Application of FYM @ 10 t ha^{-1} along with 100 % NPK significantly influenced available phosphorus over 100 % NPK and control. This increase in available phosphorus might be due to decomposition of organic matter accompanied by the release of appreciable quantities of carbon dioxide, organic acids, which might have solubilised the insoluble phosphate in the soil. Prasad *et al.* (2010) also reported a significant increase in the available P status in the plots receiving fertilizer P and those getting FYM due to mineralization of organic P due to microbial action and enhanced mobility of P. Similar to trend in maize, in wheat crop also, available P (27.5 and 27.0 kg ha^{-1}) was maximum in the treatments 150% NPK and 100% NPK + FYM @ 10 t ha^{-1}. Treatment 100% NP recorded available P 21.9 kg ha^{-1}, whereas it was 19.1 kg ha^{-1} in 100% N plot. The application of chemical fertilizers at higher levels (150 per cent NPK) also resulted in maximum available P (27.5) content over control. The increase in available P might be due to the addition of P at higher rates in 150% NPK and limited utilization of P by crops from the applied source, which resulted in build up of soil phosphorus status. Application of 150 %NPK increased the available P status of soil owing to higher rate of application was also reported by Verma *et al.* (2005).

Available potassium:

It is apparent from the data that exchangeable potassium in maize crop varied from 613 in control to 774 kg ha^{-1} in 100% NPK + FYM @ 10 t ha^{-1}. Maximum available potassium content was 801 kg ha^{-1} when 150 % NPK was applied (Table 2). The enhanced status of K could be attributed to the higher amount of potassium being added in super optimal dose of NPK i.e.150% NPK. Sharma *et al.* (2007) also reported significant increase in available nutrient (NPK) content of the soil in the plot receiving 100% NPK + FYM @ 10 t ha^{-1} over the plot receiving 100% NPK. A significant difference was found over control when 100 % NPK was applied. In wheat crop, available potassium content was 806 kg ha^{-1} when 150% NPK was applied followed by 775 kg ha^{-1} in 100% NPK + FYM @ 10 t ha^{-1}. When above treatments were compared to 100% NPK and control, a significant difference was recorded. The beneficial effect of organic manuring on K availability minimizes the loses from leaching by retaining K ions on exchange sites and solubilisation of soluble components through the action of organic acids released during decomposition. Higher values of K in 150% NPK, 100% NPK+FYM indicated greater release of K in soil solution. The exchangeable K status increased from initial value of 220 to 275 and 310 kg ha^{-1} in these plots (Yaduvanshi and Anand Swarup, 2006). Lower value of K was observed in N and NP treatments. In wheat crop, maximum decline (616 kg ha^{-1}) was observed in case of control followed by 636 kg ha^{-1} in 100% N alone. Continuous application of N or NP had depressive effect on available K content of the soil which may be due to nutrient imbalance in the soil. Potassium content in treatments 100% NPK + Zn + S, 100% NPK + S, 100% NPK + *Azotobacter* was statistically at par with each other. Increase in available K status of soil in FYM treated plots was observed when compared to 100% NPK and control. Thakur *et al.* (2011b) also reported that application of organic manure may have caused reduction in K fixation and consequently increased K content due to interaction of organic matter with clay besides the direct addition to the available K pools of soil.

Available sulphur:

In maize crop, maximum available sulphur content (24.8 and 23.1 mg kg^{-1}) was found in the treatments where elemental sulphur was added i.e. 100% NPK + Zn + S and 100 % NPK + S but these treatments were statistically at par with each other. All the treatments maintained significantly higher available sulphur over control except 100 % N (14.9 mg kg^{-1}) and 100% NPK (15.8 mg kg^{-1}). FYM @ 20t ha^{-1} alone and application of 100% NPK+ FYM @10 t ha^{-1} over control recorded significantly higher available sulphur content. The increase in available S content in FYM treated plots might be due to increase in the activity of heterotrophic sulphur oxidizing bacteria resulting from addition of FYM causing its mineralization. Kotangale *et al.* (2009) also reported that treatment of FYM application maintained adequate sulphur to guard its deficiency. Similarly, in wheat crop all the treatments maintained significantly higher available sulphur over control except 100% N, 100 %NP and 100 % NPK (Table 2). Maximum available sulphur content (24.5 and 22.6 mg kg^{-1}) was found in the treatments where elemental sulphur was added i.e. 100% NPK + Zn + S and 100% NPK + S and a significant difference was recorded when these treatments were compared to 100% NPK and control. Singh *et al.* (2011) also reported that application of NPK with FYM resulted in considerable increase in available S content.

DTPA Zinc :

Treatment 100% NPK + Zn recorded maximum Zn content (3.87 mg kg^{-1}) followed by 100% NPK + Zn + S (3.65 mg kg^{-1}) in maize crop and this increase was significant when compared to control. This might be due to direct application of Zn in the soil. Application of 100 % NPK + Zn increased the Zn content of soil by 4.94 per cent over 100 % NPK. Significantly higher Zn content in treatment receiving only FYM over 100% NPK was also observed. Thakur *et al.* (2011a) also stated that lowest contents of DTPA-Zn were recorded in control plot. Higher content of DTPA-Zn over control was observed in treatments 100% NP, 100% NPK, 100% NPK + *Azotobacter*, 100% NPK + S which were at par with each other (Table 2). Verma *et al.* (2005) also reported that application of Zn alone or in combination with S alongwith 100% NPK significantly increased Zn content of the soil over rest of the treatments. Application of FYM alone or in combination with fertilizers also increased the DTPA-Zn content of soil over rest of the treatments which might be due to formation of organic chelates of higher stability and decreasing their susceptibility to adsorption, fixation and precipitation. In wheat crop, maximum Zn content (3.85 mg kg^{-1}) was recorded in 100 % NPK + Zn followed by 100 % NPK + Zn + S (3.62 mg kg^{-1}). DTPA–Zn level in 100% NPK + Zn and 100% NPK + Zn + S treatments was significantly higher over control and 100% NPK. Application of FYM alone or in combination with fertilizers also increased the DTPA-Zn content of soil. The reason for enhancement of available Zn due to FYM is the release of organically bound Zn during decomposition. Prasad *et al.* (2010) also stated that due to FYM decomposition, there is formation of organic chelates thereby decrease zinc susceptibility to adsorption, fixation and precipitation and result in micronutrients enhanced availability in soil.

Table 1. Effect of integrated nutrient management on crop productivity after harvest of maize and wheat crop

Treatments	Maize (q ha^{-1})		Wheat (q ha^{-1})	
	Grain yield	Stover yield	Grain yield	Straw yield
T_1 - 100 % NPK	29.0	41.6	35.9	52.4
T_2 - 100 % NPK + Zn	30.6	43.3	37.8	52.7
T_3 - 100 % NPK + Zn + S	31.1	44.5	38.9	56.8
T_4 - 100 % NPK + S	29.6	41.8	37.3	53.8
T_5 - 100 % NPK + *Azotobacter*	30.0	42.4	38.2	55.9
T_6 - FYM @ 10 t ha^{-1} + (100 % NPK – NPK content of FYM)	29.4	41.9	37.8	54.2
T_7 - 100 % NPK + FYM @ 10 t ha^{-1}	34.4	48.9	42.6	61.4
T_8 - FYM @ 20 t ha^{-1}	21.1	31.3	24.3	65.1
T_9 - 150 % NPK	31.3	44.9	41.2	60.2
T_{10} - 100 % NP	25.8	36.7	31.8	46.3
T_{11} - 100 % N	21.2	31.8	26.7	39.0
T_{12} - Control	15.1	21.7	18.0	26.3
SEm ±	0.99	0.16	0.12	0.20
CD at 5 %	2.85	0.46	0.36	0.58

Table 2. Effect of integrated nutrient management on available nitrogen, phosphorus, potassium, sulphur and DTPA Zinc after harvest of maize and wheat crop

Treatments	Nitrogen ($kg\ ha^{-1}$)		Phosphorus ($kg\ ha^{-1}$)		Potassium ($kg\ ha^{-1}$)		Sulphur ($mg\ kg^{-1}$)		Available zinc ($mg\ kg^{-1}$)	
	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat
T_1 - 100 % NPK	287	22.7	22.7	22.3	668	683	15.8	15.9	2.59	2.53
T_2 - 100 % NPK + Zn	294	22.1	22.1	22.2	647	672	16.2	16.3	3.87	3.85
T_3 - 100 % NPK + Zn + S	289	23.1	23.1	21.5	688	682	24.8	24.5	3.65	3.62
T_4 - 100 % NPK + S	291	23.8	23.8	21.5	692	686	23.1	22.6	2.58	2.53
T_5 - 100 % NPK + *Azotobacter*	311	24.3	24.3	21.8	702	701	17.6	17.3	2.76	2.65
T_6 - FYM @ 10 t ha^{-1} + (100 % NPK – NPK content of FYM)	319	25.0	25.0	23.4	741	712	18.2	17.9	3.08	3.24
T_7 - 100 % NPK + FYM @ 10 t ha^{-1}	345	26.4	26.4	27.0	774	797	18.2	18.5	3.31	3.31
T_8 - FYM @ 20 t ha^{-1}	285	23.2	23.2	22.7	767	775	19.2	18.9	3.53	3.52
T_9 - 150 % NPK	346	28.6	28.6	27.5	801	806	17.5	17.1	2.49	2.45
T_{10} - 100 % NP	255	22.0	22.0	21.9	661	683	16.9	16.4	2.51	2.47
T_{11} - 100 % N	259	19.8	19.8	19.1	630	636	15.0	14.9	2.48	2.44
T_{12} - Control	243	18.2	18.2	18.1	613	616	14.9	14.4	2.46	2.42
SEm ±	7.7	0.6	0.6	0.5	11.1	10.1	0.4	0.4	0.063	0.060
CD at 5 %	22.2	1.6	1.6	1.4	31.9	28.9	1.2	1.1	0.182	0.173

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Rec. on 08.09.2011 & Acc. on 13.11.2011

J. Soils and Crops 22 (2) 287-291, Dec., 2012 ISSN 0971-2836

EFFECT OF MICRONUTRIENTS AND BIO-FERTILIZERS ON GROWTH, YIELD ATTRIBUTING CHARACTERS, YIELD AND ECONOMICS OF CHICKPEA (*Cicer arietinum* L.)

S.C.Gupta[1], Suchi Gangwar[2] and Megha Dubey[3]

ABSTRACT

A field experiment was conducted to study the response of chickpea to micronutrients as soil and seed application with bio-fertilizer inoculation during the *rabi* season of 2008-2009 at the research farm of R.A.K. College of Agriculture, Sehore under the Microbiology discipline of All India Co-Ordinated Research Project on Chickpea. The experiment was laid out for the first time in a randomized block design with three replications and ten treatments viz., T_1-RDF (20:50:20:20 kg NPKS ha^{-1}), T_2- RDF + *Rhizobium* (*Rh*) + PSB, T_3- RDF + 0.5 kg Ammo.molybdate ha^{-1} as soil application +*Rh* +PSB ,T_4- RDF +1.0 kg Ammo.molybdate ha^{-1} as soil application +*Rh* +PSB , T_5- RDF +0.5 g Ammo.molybdate kg^{-1} as seed treatment with *Rh* +PSB, T_6- RDF+ 1.0 g Ammo.molybdate kg^{-1} as seed treatment with *Rh*+PSB , T_7- RDF+2.0 g Ammo.molybdate kg^{-1} as seed treatment with *Rh*+PSB , T_8- RDF+0.5 g Ammo.molybdate+1.0 g Ferrous sulphate kg^{-1} seed treatment with *Rh*+PSB , T_9- RDF+1.0 g Ammo.molybdate+1.0 g Ferrous sulphate kg^{-1} seed treatment with *Rh* + PSB, T_{10} -RDF+2.0 g Ammo.molybdate+1.0 g Ferrous sulphate kg^{-1} seed treatment with *Rh*+PSB .

The highest plant height , branches plant^{-1} and plant dry weight were recorded in the treatment which consist of RDF along with 1.0 kg ammonium molybdate as soil application with *Rhizobium* and PSB. Significantly highest number of pods plant^{-1} (30.12), seed yield (5.52 g plant^{-1}), 100 seed weight (25.92 g), straw yield (1255 kg ha^{-1}) and harvest index (52.99 %) were also recorded in the same treatment. The net return (Rs.17258 ha $^{-1}$) with B: C ratio (2.86) was obtained in the treatment consisting of RDF+2.0 g Ammonium molybdate kg^{-1}seed treatment + *Rh* +PSB. As this treatment gave the better seed yield of chickpea with lower cost of cultivation, this treatment can be considered best one on B: C ratio basis. The next superior treatment can be considered as RDF+1 kg Ammo. molybdate ha^{-1} as soil application + *Rh* + PSB, because it gave more monetary return (Rs. 27054/-) next to the best treatment.

(Key words: Chickpea, micronutrients, bio-fertilizer, growth, yield attributes, yield and economics)

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is an important pulse crop growing all over the country in *rabi* season. In India, it is grown on an area of about 77.10 million hectares with an annual production of 56.60 million tones and average yield of 726 kg ha$^{-1.}$ (Anonymous, 2010). Madhya Pradesh is the largest producer of chickpea, which cover 24.30 lakh hectares area with the production of 17.30 lakh tonnes and productivity of 711.93 kg ha^{-1} (Anonymous, 2010). Pulses occupy a very important place in Indian diet because they constitute the major source of protein to the predominantly vegetarian population. Many legumes have the ability to form nitrogen (N_2) fixing root nodules with soil bacteria, collectively called rhizobia (Sprent, 2001) and thus, contribute to the biological fixation of N_2. Legume and their rhizobia are often introduced to agricultural ecosystems to improve soil fertility and farming systems flexibility. Molybdenum deficiencies are found mainly on acid, sandy soils in humid regions. Plant uptake of Mo increases with increased soil pH, which is opposite that of the other micronutrients. Crops sensitive to Mo deficiency are alfalfa, clover and some vegetable crops. Nitrogen is necessary for formation of amino acids, the building blocks of protein. Mo and Fe are important constituents of nitrogenase enzyme responsible for Biological Nitrogen Fixation (BNF) through *Rhizobium*. Molybdenum required to form the enzyme nitrate reductase which reduces nitrates to ammonium in plant. The micronutrients and biofertilizer will help to increase the growth and yield in chickpea. As use of biofertilizer will improve the soil health and will help to improve the quality of the chickpea seed. Iron deficiency generally decreased nodules formation, legheamoglobin production and nitrogenase activity, leading to low nitrogen concentration in the shoots in some legumes. A study reported that more iron is required for plants reliant on N_2 fixation than for plants supplied with mineral nitrogen.So it is necessary to study the comparative performance of Fe and Mo on yield of chickpea along with biofertilizer.

MATERIALS AND METHODS

The field experiment was carried out during *rabi* season of 2008-09 at research farm of R.A.K. College of Agriculture, Sehore to study the

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"Effect of micronutrients and biofertilizers on growth, yield attributing characters and yield of chickpea(*Cicer aritenum* L.)". The experiment was laid out in the field number 24 under the discipline of Soil Microbiology at All India Co-ordinated Research Project on Chickpea, Sehore, (Madhya Pradesh). The soil of experimental field was medium black Vertisol. The topography of field was uniform with the experimental soil was having low available N (180 kg ha^{-1}), medium available P (13.5 kg ha^{-1}) and high available K (438 kg ha^{-1}).The extractable Mo was less than (<0.016ppm) which was below the desired limit in soil. Organic carbon was also low (0.38%). Soil pH was 7.7 and E.C. was 0.16 dSm^{-1}.The total rainfall was 24.4 mm from October to February (2008-2009). During the experiment, the minimum temperature was 9.10°C and maximum temperature was 35.4°C. The experiment was conducted with Randomized Block Design with 10 treatments and 3 replications with gross plot size of 5.0 m x 2.4 m. The row to row and plant to plant spacing was 30 cm and 10 cm respectively. The chickpea variety JG-130 was sown on 22/10/2008. This variety is recommended for rainfed and irrigated conditions of Madhya Pradesh. The seed rate of 100 kg ha^{-1} was used and seeds were treated with Thirum @ 2 g kg^{-1} and Bavistin 1 g kg^{-1} seed. Inoculants of *Rhizobium*, Phosphorus Solubilizing Bacteria each @ 5 g kg^{-1} seeds were used for inoculating seed as per treatments. The experiment was conducted with 10 treatments.

The observations were recorded on randomly selected 5 samples and their mean were taken for analysis 90 days after sowing (DAS).Observations on plant height, branches $plant^{-1}$, pods $plant^{-1}$, seed yield, straw yield and harvest index were recorded at harvest stage and thereafter. The dry weight $plant^{-1}$ was determined by uprooting the whole plant at 90 days after sowing.

RESULTS AND DISCUSSION

Growth attributes :

The highest plant height (40.39 cm) was recorded with treatment RDF + 1.0 kg ammonium molybdate ha^{-1} as soil application + *Rhizobium* + PSB followed by RDF+2.0 g ammonium molybdate+1.0 g $FeSO_4$ kg^{-1} seed treatment + *Rhizobium* + PSB as compared to all other treatments. The increase in number of branches $plant^{-1}$ was observed with the advancement of growth stage under different treatments. The highest branches $plant^{-1}$ (5.98) and maximum dry weight (5.95 g) were recorded in the treatment of RDF + 1.0 kg ammonium molybdate ha^{-1} as soil application + *Rhizobium* + PSB followed by RDF+2.0 g ammonium molybdate+1.0 g $FeSO_4$ kg^{-1} seed treatment+ *Rhizobium* + PSB. Johnson *et al.* (2005) reported that addition of Mo and *Rhizobium* increased the growth and yield response of chickpea by about 37-90%.Thus, present finding conform these findings so far as utility of Molybdenum.

Yield attributing characters :

Among different treatments, the maximum number of pods $plant^{-1}$ (30.12) was recorded with RDF + 1.0 kg ammonium molybdate ha^{-1} as soil application + *Rh* + PSB followed by RDF + 2.0 g ammonium molybdate+1.0 g $FeSO_4$ kg^{-1} seed treatment + *Rh* + PSB (29.95) ,RDF + 2.0 g ammonium molybdate kg^{-1} seed treatment + *Rh* + PSB (29.75) and RDF+1.0 g ammonium molybdate+1.0 g $FeSO_4$ kg^{-1} seed treatment + *Rh* +PSB (29.10) .Singh *et al.*(2006) reported that application of *Rhizobium* resulted in high number of pods, test weight, seed yield, straw yield and protein content. Patil *et al.* (2001) reported that inoculation with *Rhizobium* significantly increased the number of seeds pod^{-1}, pods $plant^{-1}$, seed and straw yield. The treatment RDF + 1.0 kg ammonium molybdate ha^{-1} as soil application + *Rh* + PSB was superior over all other treatments. Thus, utility of *Rhizobium* is proved in the present finding. The maximum seed yield (5.01 g $plant^{-1}$ and 1503 kg ha^{-1}) was recorded with the treatment RDF + 1.0 kg ammonium molybdate ha^{-1} as soil application + *Rh* + PSB which was at par with the remaining treatments except RDF. Valenciano and Boto (2011) reported that application of Zn, Mo increased the seed yield of chickpea by 30-50%. The present finding conform these finding regarding importance Mo application. The highest seed index was recorded in the treatment RDF +1.0 kg ammonium molybdate ha^{-1} as soil application + *Rhizobium* + PSB followed by RDF + 2.0 g ammonium molybdate+1.0 g $FeSO_4$ kg^{-1} seed treatment + *Rhizobium* + PSB which were at par and superior over other treatments. The highest straw yield was recorded with RDF + 1.0 kg ammonium molybdate ha^{-1} as soil application + *Rhizobium* + PSB followed by RDF + 2.0 g ammonium molybdate kg^{-1} seed treatment + *Rhizobium* + PSB and with RDF +

Table 1. Treatment details for chickpea

Treatments	*Rabi* (chickpea)
T_1	RDF (Recommended dose of fertilizer N: P: K: S, 20:50:20:20 kg ha^{-1})
T_2	RDF+*Rhizobium* (*Rh*) +PSB
T_3	RDF+0.5 kg Ammo.molybdate ha^{-1} as soil application+*Rh*+PSB
T_4	RDF+1.0 kg Ammo.molybdate ha^{-1} as soil application+*Rh*+PSB
T_5	RDF+0.5 g Ammo.molybdate kg^{-1} as seed treatment with *Rh*+PSB
T_6	RDF+1.0 g Ammo.molybdate kg^{-1} as seed treatment with *Rh*+PSB
T_7	RDF+2.0 kg Ammo.molybdate kg^{-1} as seed treatment with *Rh*+PSB
T_8	RDF+0.5 g Ammo.molybdate+1.0 g Ferrous sulphate kg^{-1} seed treatment with *Rh*+PSB
T_9	RDF+1.0 g Ammo.molybdate+1.0 g Ferrous sulphate kg^{-1} seed treatment with *Rh*+PSB
T_{10}	RDF+2.0 g Ammo.molybdate+1.0 g Ferrous sulphate kg^{-1} seed treatment with *Rh*+ PSB

Table 2. Effect of micronutrients and bio-fertilizer on plant height, branches plant^{-1}, plant dry weight and total chlorophyll content

Tr. No.	Treatments	Plant height (cm) at harvest	Branches Plant^{-1} at harvest	Plant dry weight (g) plant^{-1} at 90 DAS
T_1	Control –RDF	38.52	4.17	4.22
T_2	RDF + *Rhizobium (Rh)*+ PSB	39.10	4.72	4.73
T_3	RDF + 0.5 kg Am.mo. ha^{-1} **Soil** application + *Rh* + PSB	40.20	5.77	5.69
T_4	RDF +1.0 kg Am.mo. ha^{-1} **Soil** application+ *Rh* +PSB	40.39	5.98	5.95
T_5	RDF + 0.5 g Am.mo. kg^{-1}**Seed** treatment + *Rh* +PSB	39.90	5.63	5.30
T_6	RDF + 1.0 g Am.mo. kg^{-1}**Seed** treatment + *Rh* + PSB	40.15	5.75	5.45
T_7	RDF + 2.0 g Am.mo. kg^{-1}**Seed** treatment + *Rh* + PSB	40.22	5.79	5.70
T_8	RDF + 0.5 g Am.mo. +1.0 g $FeSO_4$ kg^{-1} **Seed** treatment +*Rh* + PSB	40.10	5.70	5.36
T_9	RDF + 1.0 g Am.mo. +1.0 g $FeSO_4$ kg^{-1} **Seed** treatment +*Rh* + PSB	40.18	5.76	5.47
T_{10}	RDF+2.0 g Am.mo.+1.0 g $FeSO_4$ kg^{-1} **Seed** treatment + *Rh* +PSB	40.32	5.86	5.83
SEm±		0.68	0.13	0.15
CD at 5%		2.04	0.41	0.45

Table 3. Effect of micronutrients and bio-fertilizer on number of pods, seed yield, seed index, straw yield and harvest index

Tr. No.	Treatments	No. of pods plant^{-1}	Seed yield (kg ha^{-1})	Seed index (100 seed weight) (g)	Straw yield (kg ha^{-1})	Harvest index (%)
T_1	Control –RDF	22.52	985	21.15	940	51.16
T_2	RDF + *Rhizobium (Rh)*+ PSB	24.21	1127	23.52	1041	51.98
T_3	RDF + 0.5 kg Ammo.mo. ha^{-1} **Soil** application + *Rh* + PSB	29.93	1390	24.98	1190	53.87
T_4	RDF +1.0 kg Ammo.mo. ha^{-1} **Soil** application+ *Rh* +PSB	30.12	1503	25.92	1255	54.49
T_5	RDF + 0.5 g Ammo.mo. kg^{-1} **Seed** treatment + *Rh* +PSB	28.30	1247	24.82	1048	54.33
T_6	RDF + 1.0 g Ammo.mo. kg^{-1} **Seed** treatment + *Rh* + PSB	28.52	1373	24.90	1218	52.99
T_7	RDF + 2.0 g Ammo.mo. kg^{-1} **Seed** treatment + *Rh* + PSB	29.75	1473	25.00	1238	54.30
T_8	RDF + 0.5 g Ammo.mo. +1.0 g $FeSO_4$ kg^{-1} **Seed** treatment +*Rh* + PSB	28.70	1263	24.85	1055	54.48
T_9	RDF + 1.0 g Ammo.mo. +1.0 g $FeSO_4$ kg^{-1} **Seed** treatment +*Rh* + PSB	29.10	1387	25.10	1238	52.83
T_{10}	RDF+2.0 g Ammo.mo.+1.0 g $FeSO_4$ kg^{-1} **Seed** treatment + *Rh* +PSB	29.95	1443	25.25	1253	53.32
SEm±		0.43	39.86	0.34	31.79	1.02
CD at 5%		1.29	119.6	1.04	95.37	3.05

Table 4. Economics of micronutrients and bio-fertilizer treatments of chickpea

Tr. No.	Treatments	Total cost of cultivation (Rs.)	Gross monetary return (Rs.)	Net monetary return (Rs.)	B:C ratio
T_1	Control-RDF	8886	17730	8844	1.99
T_2	RDF +Rhizobium (*Rh)* + PSB	8936	20286	11350	2.27
T_3	RDF+0.5 kg Am.mo. ha^{-1} Soil application + *Rh* + PSB	9936	25020	15084	2.51
T_4	RDF+1.0 kg Am.mo. ha^{-1}Soil application+ *Rh* + PSB	10936	27054	16118	2.47
T_5	RDF+ 0.5 g Am.mo. kg^{-1}Seed treatment + *Rh* + PSB	9016	22446	13430	2.49
T_6	RDF+1.0 g Am.mo. kg^{-1} Seed treatment + *Rh* + PSB	9096	24714	15618	2.71
T_7	RDF+2.0 g Am.mo. kg^{-1} Seed treatment + *Rh* + PSB	9256	26524	17258	2.86
T_8	RDF+0.5 g Am.mo.+1.0 g $FeSO_4$ kg^{-1} Seed treatment + *Rh* + PSB	9032	22734	13702	2.51
T_9	RDF+1.0 g Am.mo.+1.0 g $FeSO_4$ kg^{-1} Seed treatment + *Rh* + PSB	9112	24966	15854	2.73
T_{10}	RDF+2.0 g Am.mo.+1.0 g $FeSO_4$ kg^{-1} Seed treatment + *Rh* +PSB	9272	24974	16702	2.80

2.0 g ammonium molybdate + 1.0 g $FeSO_4$ kg^{-1} seed treatment + *Rh* + PSB which were identical with each other. The maximum harvest index was recorded with RDF + 1.0 kg ammonium molybdate ha^{-1} as soil application + *Rhizobium* + PSB followed by RDF+2.0 g ammonium molybdate kg^{-1} seed treatment + *Rhizobium* + PSB and RDF + 2.0 g ammonium molybdate + 1.0 g $FeSO_4$ kg^{-1} seed treatment+ *Rhizobium* + PSB which were at par with each other and also with the remaining treatments except control.

Economics :

The data on economics of various treatments presented in table 4 revealed maximum net return was received from the treatment RDF+ 2.0 g ammonium molybdate kg^{-1} seed treatment + *Rhizobium* + PSB (Rs.17258 ha^{-1}) followed with RDF + 2.0 g ammonium molybdate kg^{-1} + 1.0 g $FeSO_4$ kg^{-1} seed treatment + *Rhizobium* + PSB (Rs. 16702 ha^{-1}) followed by RDF+1.0 kg Ammonium molybdate as soil application + *Rhizobium* +PSB. Hence, application of ammonium molybdate @ 2 g kg^{-1} seed treatment along with *Rh* + PSB was found the most profitable treatment. As regards B:C ratio, the maximum benefit: cost ratio (1:2.86) was recorded with RDF+ 2.0 g ammonium molybdate kg^{-1} as seed treatment + *Rh*+ PSB followed by RDF + 2.0 g ammonium molybdate + 1.0 g $FeSO_4$ kg^{-1} seed treatment + *Rh* + PSB (1:2.80). However, keeping in view the optimum net return with good B: C ratio the treatment RDF+ ammonium molybdate @ 2g kg^{-1} seed treatment + *Rh*+ PSB can be used for enhanced chickpea production with increased profit. The treatments having RDF+ 1 kg Ammo. molybdate ha^{-1} as soil application + *Rh*+ PSB and RDF+ 2.0 g Ammo.molybdate +1.0 g $FeSO_4$ seed treatment +PSB can also be recommended for use, as they provide more monetary returns.

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Rec. on 10.09.2011 & Acc. on 16.11.2011

J. Soils and Crops 22 (2) 292-296, Dec., 2012 ISSN 0971-2836

EVALUATION OF DIFFERENT RICE GENOTYPES FOR RESISTANCE TO BROWN PLANTHOPPER *Nilaparvata lugens* (Stal.)

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ABSTRACT

One hundred sixteen rice genotypes were screened against *Nilaparvata lugens* (Stal.) in glass house condition at IGKV during 2009-2010. Forty-five genotypes were categorized as resistant, seventeen as moderately resistant and remaining ones as susceptible to BPH infestation. Among the different resistant genotypes tested, the genotype MR 1523 had the lowest mean honeydew excretion value (7.72 mm^2) with highest probing marks 38.80, followed by R1723-1411-2-356-1 (9.22 mm^2) with probing mark value 36.00. More feeding marks and least honeydew excretion was found in all resistant genotypes as compared to TN1.With increase in plant age, feeding rate was found to decrease.

(Key words: Rice, *Nilaparvata lugens*, BPH)

INTRODUCTION

The Chhattisgarh state is popularly known as 'rice bowl' of the country as rice is the principal crop of this state. The productivity of rice in Chhattisgarh is comparatively lower than the national average due to several constraints and among these, insect pest is one of the most important factor limiting the rice production. Several important insect pests feed on phloem sap of rice. Among these, brown planthopper *Nilaparvata lugens* (Stal.) is the most common and become a major pest in the last two decades.

It was first reported in Kerala during 1958 in India. The first severe outbreak occurred in Kerala during 1973-74 damaging about 50000 ha of rice (Bai *et al.*, 1992). Recently severe outbreak of this pest was noticed during 2007 in parts of Cauvery command area in Karnataka and during 2008 in Haryana, Punjab and Delhi (Siddegowda, 2009). In Chhattisgarh, this insect has assumed greater importance due to its severe outbreak in 1975 and consequent yield losses reported were to the extent of 34.3 per cent (Gangrade *et al.*, 1978). In order to control this pest, increased use of insecticides had decimated natural enemies, leading to secondary pest outbreaks and the resurgence of planthoppers. In addition, excess use of insecticides leads to high residual effect in the environment and become a more dangerous pollutant. Due to this reason human health is affected. Therefore, considering the economic losses, pesticidal hazards, environmental pollution and human health, development and use of resistant variety is an effective tool in pest management.

Host plant resistance has played an important role in the management of pests successfully during past two decades. Several resistant varieties have been developed and grown in different areas of India (Mathur *et al.*, 1999 and Krishnaiah *et al.*, 1999). As a result, it contributed towards the suppression of the pest for nearly last fifteen years. Therefore, 116 rice genotypes were screened under glass house condition and resistant genotypes were selected for further evaluation.

MATERIALS AND METHODS

To get the regular supply of insect, the brown planthopper was mass reared at $30^0 \pm 5^0$C on potted TN1 (Taichung Native) variety and the population was maintained throughout the year in the air cooled glass house.

Screening of rice genotypes was carried out as per methodology suggested by Kalode *et al.* (1979). The study material of 116 genotypes consists of 50 resistant genotypes, six differentials and 60 PHS entries. The 50 resistant genotypes were rescreened to confirm the resistance. Out of 116 genotypes, 18 resistant genotypes including resistant and susceptible check were further evaluated for feeding test.

The honeydew excretion method or feeding test was carried out as per the method suggested by Sogawa and Pathak (1970), as honeydew excretion by planthoppers reflects feeding activity (Paguia *et al.*, 1980; Park and Song, 1988). Honeydew excretion was investigated at 30, 45 and 60 days old potted plants. Six replicates were maintained for each genotype.

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Probing mark test was carried out according to methodology adopted by Natio (1964).This test was carried out on 7 days old seedlings. Ten replicates were maintained for each rice genotype.

RESULTS AND DISCUSSION

Among rescreened fifty genotypes, 24 genotypes were categorized as resistant, while eight as moderately resistant and rest of the other as susceptible to BPH.

The average plant damage score of resistant genotypes was ranged from 0.33 to 2.88. The genotype R1723-1411-2-356-1 had the lowest plant damage score (0.33) followed by R 1244-1246-1-605-1 (0.42) and R1723-1413-3-357-1 (0.57). The resistant check Ptb 33 had the plant damage score of 1.31.

The average plant damage score of moderately resistant genotypes ranged from 3.15 to 4.86. Among moderately resistant genotypes tested, the genotype R-RF-43 showed least (3.15) plant damage score followed by Sambleshwari (3.18) and R1528-1058-1-110-1 (3.24).

Among 116 genotypes, six differentials were screened against Raipur BPH population. All these differentials showed resistant reaction to Raipur BPH population. The ARC 10550 (*bph5*) showed lowest plant damage score (0.64) followed by Sinna Sivappu (0.75), whereas it was (1.00) in both MO1 and Rathu Heenati (*bph3*).

Out of 60 PHS entries tested against brown planthopper, 15 rice genotypes were categorized as resistant, while 9 as moderately resistant and rest of them as susceptible to BPH population. The resistant genotypes exhibited plant damage score ranged from 0.25 to 2.77. The genotype MTU 1123 showed the least plant damage score (0.25) followed by CR 2713-8 (0.50) and CE 260 (0.96).

The average plant damage score of moderately resistant genotypes ranged from 3.15 to 4.88. Among the nine moderately resistant genotypes tested, the genotype CR 2712-229 showed the least plant damage score (3.15) followed by CB 06-555 (3.19) and MTU 1115 (3.55).

All the selected resistant genotypes exhibited average honeydew excretion values ranging from 14.00 to 47.00 mm^2 two^{-1} females at 30 days old plant (DOP), which was significantly lower than the susceptible check TN1. In TN1 susceptible check, honeydew excretion value was maximum (115.33 mm^2 two^{-1} females). The genotype Rathu Heenati had the lowest honeydew excretion value (14.00 mm^2) in 24 hrs two^{-1} females followed by INRC 3021 (14.50 mm^2) and MR 1523 (14.83 mm^2), while resistant check Ptb33 exhibited honeydew excretion value of 13.83 mm^2 which was lower than all resistant rice genotypes tested and also than the susceptible check TN1.

All resistant genotypes showed average honeydew excretion values ranging from 4.67 to 19.50 mm^2 two^{-1} females in 24 hrs at 45 DOP, which was significantly lower than the susceptible check TN1. It was maximum (61.83 mm^2 two^{-1} female) in TN1 susceptible check. Resistant check Ptb33 exhibited average honeydew excretion value of 7.67 mm^2 which was significantly lower than ten resistant genotypes and also than the susceptible check TN1. The genotype MR 1523 had the lowest honeydew excretion value (4.67 mm^2) followed by R1723-1411-2-356-1 (6.17 mm^2) and R 1243-1224-578-1 (7.67 mm^2), which was significantly lower than the susceptible check TN1.

All the resistant genotypes showed average honeydew excretion values ranging from 3.17 to 12.33 mm^2 two^{-1} females in 24 hrs at 60 DOP, which were significantly lower than the susceptible check TN1.Resistant check Ptb 33 showed honeydew excretion value of 6.00 mm^2 which was significantly lower than six genotypes, but, in general, it was higher than five resistant genotypes tested, while it was maximum (26.33 mm^2) in TN1.The genotype R1723-1411-2-356-1 had the lowest honeydew excretion value (3.17 mm^2) followed by the genotype MR 1523 (3.67 mm^2) and R1576-538-1-167 (4.83 mm^2). The overall mean indicated that the genotype MR 1523 had the lowest mean honeydew excretion value (7.72 mm^2) followed by R1723-1411-2-356-1 (9.22 mm^2) and R 1243-1224-578-1 (11.17 mm^2). With increase in plant age, feeding rate was found to decrease.

In all the selected resistant rice genotypes, the average probing marks values seedling^{-1} were ranged from 21.40 to 38.80. Although, in resistant check Ptb33, the probe marks was 32.00 seedling^{-1} female^{-1}.

The resistant genotype MR 1523 had the highest (38.80) average probing marks and had the mean honeydew excretion value of 7.72 mm^2 followed by R1723-1411-2-356-1 (36.00), having the mean honeydew excretion value of 9.22 mm^2. The average probing marks seedling^{-1} in resistant check Ptb 33 was found to be 32.0 which was significantly higher than seven genotypes, but significantly lower than the genotype MR 1523.

Wide array of chemical substances including inorganic chemicals, primary and intermediary metabolites and secondary plant substances are known to impart biochemical resistance in a host plant to a wide variety of insect pests. The occurrence of asparagines in minute quantities in Mudgo variety of rice considered to be primary cause of resistance against BPH (Sogawa and Pathak ,1970).

Similarly, Nanda *et al.* (2000) reported that resistant rice variety ARC 6650 had low level of amino acid percentage (5.27 %) and total starch content (5.75 %) as compared to 8.12 % amino acid and 7.98 % total starch content in susceptible TN1 30 days old potted plants.

There might be some nutrients in host plants which were correlated with the incidence of BPH. Sujatha *et al.* (1987) stated that phenol, silica, phosphorus, potassium, sulphur and iron contents were positively correlated with resistance against BPH while the protein, nitrogen, zinc and manganese contents were negatively correlated with BPH resistance in rice.

Soundararajan *et al*. (2002) attributed feeding rate of the planthopper as the capability to differentiate the resistance and susceptible genotypes of rice. Negative feeding response offered by plant itself as a defense mechanism by way of release of chemicals in the plant itself as a stimulant imposed by BPH stylet insertion for sucking the sap or due to absence of proper nutritional value required by BPH in the plant itself. Sadasivan and Thayumanavan (2003) stated that lectin and galanthus nivalis agglutinin (GNA) ingested by insect binds to the midgut epithelial cells. Results indicated that GNA bind to form glycopeptides in BPH gut and inhibit the digestive enzymes. As a result, insect takes out its stylet and tries again and again for further intake of food.

The presence of oxalic acid and salicylic acid acts as feeding deterrent to BPH. The present study indicated that at all the periods, feeding rate was least on all the resistant genotypes as compared to TN1 and feeding decreased with the increase in age i.e. higher in 30 days old plants than on 60 days old plants. The insect gets stimulated to make more feeding marks on the resistant genotypes in order to locate a suitable feeding site than in susceptible one (Alagar *et al*., 2008).

It is very clear that susceptible host has received less probe marks and excreted more honeydew, whereas in resistant host, the more probe marks and less honeydew excretion might be the indication of unsuitability of nutrition in the plant or presence of certain plant biochemicals which checks the feeding.

Table 1. Average plant damage score of different rice genotypes

Score	No. of genotypes	Genotypes	Remark
0-3	45	R1723-1411-2-356-1, R 1244-1246-1-605-1, R1723-1413-3-357-1, R 1473-521-249-1-1, R 1243-1224-578-1, R1600-1124-2-618-1, IR 64, R1576-538-1-167, Ganjeikalli, IR64, R1546-1321-3-178-1, R1243-1224-578-1, R1546-1328-1-90-1, R1576-570-1-182, R1519-773-1-579-1, R1519-773-3-581-1, R1576-1680-2-537-1, R1576-1682-1-540-1, R-RF-50, R1458-196-81-5-1-1, R1723-2271-1-1404-1, R1579-1828-3-681-1, R1574-1629-2-499-1, R1521-36-2-30-1, ARC 10550, Sinna Sivappu, INRC 3021, MR 1523, Rathu Heenati, MO1, MTU 1123, CR 2713-8, CE 260, RP 4687-52-2-1191, CR 2711-114, CR 2711-149, CB 06-563, RP4687-52-2-1188, RP 4686-47-1-931, CR 2712-2, CR 2711-76, CR 2712-11-13, CR 2714-2, CR 2711-139, CB 06-564,	**R**
3-5	17	R-RF-43, Sambleshwari, R1528 -1058-1-110-1, R 1518 -761-4-559-1, Mahamaya, R1539-1720-2-1255-1, R1576-1765-1-599-1, R1528-1010-2-100-1, CR 2712-229, CB 06-555, MTU 1115, ACC 2190, CB 0015 -24(Aerobic), CB 06-535, CR 2712-11-1, CB 06-803, MTU 1114,	**MR**

Table 2. Amount of honeydew and probing marks of BPH on resistant rice genotypes

Sr.No.	Designation	**Average probing marks	*Honeydew excretion in 24 hrs ($mm^2/2f$)			
			30 DOP	45 DOP	60 DOP	Mean
1.	R1576-538-1-167	26.90 (30.81)	34.17 (35.74)	10.33 (18.58)	4.83 (12.30)	16.44
2.	R1576-570-1-182	25.00 (29.59)	31.67 (33.99)	10.17 (18.43)	7.50 (15.80)	16.45
3.	R1723-1411-2-356-1	36.00 (36.68)	18.33 (24.78)	6.17 (14.12)	3.17 (9.80)	9.22
4.	R1723-1413-3-357-1	24.40 (29.37)	21.33 (27.41)	19.50 (26.02)	8.50 (16.85)	16.44
5.	R1600-1124-2-618-1	26.30 (30.60)	24.83 (29.64)	17.50 (24.67)	12.33 (20.51)	18.22
6.	IR 64	27.40 (31.43)	30.17 (33.12)	11.50 (19.73)	5.00 (12.23)	15.56
7.	R 1519-773-3-581-1	28.50 (32.18)	18.33 (25.16)	15.00 (22.65)	10.83 (19.08)	14.72
8.	R 1473-521-249-1-1	21.40 (27.23)	47.00 (43.24)	13.50 (21.53)	11.67 (19.94)	24.06
9.	R 1243-1224-578-1	31.40 (33.76)	19.83 (26.09)	7.67 (15.66)	6.00 (14.14)	11.17
10.	R 1244-1246-1-605-1	30.90 (33.41)	17.50 (24.61)	9.17 (17.54)	8.50 (16.86)	11.72
11.	MO1	25.10 (29.75)	26.50 (30.95)	14.67 (22.50)	9.33 (17.67)	16.83
12.	MR 1523	38.80 (38.47)	14.83 (22.56)	4.67 (12.09)	3.67 (10.81)	7.72
13.	Rathu Heenati	29.40 (32.64)	14.00 (21.92)	13.00 (20.97)	10.67 (18.37)	12.56
14.	Sinna Sivappu	29.60 (32.84)	20.83 (26.83)	11.33 (19.32)	5.00 (12.60)	12.39
15.	INRC 3021	31.10 (33.56)	14.50 (22.01)	13.50 (21.45)	7.33 (15.65)	11.78
16.	ARC 10550	26.50 (30.86)	25.00 (29.93)	16.50 (23.93)	11.67 (19.90)	17.72
17.	PTB 33	32.00 (34.30)	13.83 (21.66)	7.67 (15.81)	6.00 (13.89)	9.17
18.	TN 1	13.30 (20.87)	115.33 (80.98)	61.83 (51.96)	26.33 (30.84)	67.83
	SEm±	1.74	2.18	1.29	1.17	
	CD	4.87	6.13	3.63	3.29	

Average of *- six and **- ten replications.
Figures in the parentheses are arc sine transformed values

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Rec. on 10.06.2011 & Acc. on 05.09.2011

J. Soils and Crops 22 (2) 297-301, Dec., 2012 ISSN 0971-2836

SUITABILITY ASSESSMENT OF SOIL RESOURCES FOR MICRO LEVEL CROP PLANNING – A CASE STUDY

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ABSTRACT

Detailed soil resource characterization was carried out in representative soil of Indo-Gangetic plains of Haryana to evaluate soil resources for its suitability of growing different crops. Six soil series were identified alongwith eighteen mapping units. Majority of soils are very deep, brown to dark yellowish brown, well to moderately well drained, slightly acidic to slightly alkaline, low in organic carbon and low to medium in cation exchange capacity, clay loam to sandy loam and silty loam in textural variation and are taxonomically classified as fine loamy, calcareous/non-calcareous, *Typic Haplustepts/ Fluventic Haplustepts followed by* coarse loamy, calcareous/non-calcareous, *Typic Haplustepts*. Soils were low to medium in fertility status. Crop suitability assessment indicated that nearly 69 % area found suitable for wheat, 35 % for rice, 34 % for sugarcane, 67% for sorghum and mustard, 48% area moderately suitable for chickpea. Major soil constraints are soil texture, calcareousness, low organic carbon, salinity/sodicity and low fertility. Fine-loamy, Typic Haplustepts soils were suitable for growing crops like wheat, rice, sugarcane and pulses, while coarse-loamy, Typic Haplustepts were moderately suitable with slight limitations of soil physical conditions and soil fertility for growing rice-wheat cropping system. Fine-loamy, Fluventic Haplustepts soils were found to be moderately/marginally suitable for most of crops grown in region because of moderate to severe limitations of soil salinity/sodicity. Suitability class of these soils can be raised by providing better management practices. Fine-loamy soils were suitable for rice-wheat cropping system while coarse textured soils suitable for wheat-sugarcane/pulses based cropping system. Soil suitability evaluation for identification of growing suitable crops will be helpful for the micro-level crop planning.

(Key words: soil resource characterisation, soil suitability assessment, crop planning, micro level planning)

INTRODUCTION

The ability of land to produce is limited and set by soils, climate and their intrinsic characteristics and agro-ecological settings (Sehgal, 2002). Promoting optimal land use and assessment of their suitability are essential for planning and achieving self reliance in food production.

The optimum requirements of a crop are always region-specific. Climate and soil-site parameters play significant role to maximize crop yields (Mini *et al*., 2007). The soil suitability for crop production is based on soil properties affecting supply of moisture and nutrients and other factors like topography and climate (Sharma and Sharma, 1991). Management of soils resources on scientific principal is essential to maintain the present level of soils productivity (Sharma, 2004). In recent years increasing emphasis has been on characterisation of soils and developing rational scientific criteria for land evaluation and interpretation of soils for diverse land uses and crop planning (Sarkar, 2005 and Kannan, *et al.,* 2011). Hence for efficient crop planning, information relating to soil suitability for cultivation of different crops is necessary. The state of Haryana is one of the lead food grain producing states, where net sown area is about 86 %. Rice-wheat is predominant cropping system in the region. The yield of this sequential system is in platueing stage and poses several problems. It urgently needs to change this sequential cropping system (Chibba, 2010). Soil resource data helps in identifying different soils, their extent, problems and potentials and in working out suitability of land for crop planning. Keeping this in view, an attempt was made to evaluate soil resources for its suitability assessment for micro level crop planning.

MATERIALS AND METHODS

A case study was conducted in Sirsi village of Karnal district (Haryana) which is situated about 15 km from Karnal on Karnal-Kiathal road and lies on 26^{0} 43'N latitude and 76^{o} 56'E Longitude, covering an area of about 260 ha. Geologically, the area is tract of alluvial plains (Trans-Gangetic Plains). This is by the deposition of alluvial sediments brought down by the riverean action of river Yamuna and its tributaries. The area is a part of the nearly leveled to gently sloping old alluvial plain. The elevation of the area is 226 m above MSL. The climate of the area is hot semiarid with extreme summer and winter seasons.

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The area receives annual precipitation ranging between 650 to 700 mm which is distributed over a period of about 80 days. June is the hottest month while January is the coldest. The mean annual air temperature (MAAT) is 24.7 ^{0}C. The mean annual winter temperature (MAWT) is 15.3 ^{0}C while the mean annual summer temperature (MAST) is 28.5 ^{0}C (Anonymous, 2006). The estimated MSST is 30 ^{0}C and MWST is 15 ^{0}C and the difference is more than 5^{0}C, thus the area qualifies for *hyperthermic* temperature regime. The moisture regime is *ustic*. Mean annual potential evapo-transpiration (PET) ranges between 1200-1400 mm, indicating water deficit in the area. Relative Humidity varies from 11 - 95 % and wind speed is 3.5 kmh^{-1}. Length of growing period (LGP) is 90-120 days. The data under different crops/cropping systems and irrigation have been compiled from village revenue records as well as from the information given by the farmers. Almost entire area is double cropped and irrigated, and main sources of irrigation is tube wells and pumpsets (78%).The canal irrigated area is 21 %. Out of the total area (260 ha), 86.5% area is under cultivation and 10% area has been put under non-agricultural uses and other uncultivable land. The area is cultivated for rice, wheat, sugarcane, sorghum, maize, Mustard/Lentil and pearl millets crops. Rice-wheat is dominant cropping system. Seasonal vegetables and pulses were grown in few patches.

A systematic detailed soil investigation was carried out as per procedure outlined in Soil Survey Manual, AIS&LUS (Anonymous, 1970) by using the cadastral map on 1:2640 scale as base map. The horizon-wise soils from representative pedons were examined. Morphological features like colour, texture, structure, horizon sequence and movement of clay, mottles, presence of nodules and calcium carbonates etc., were studied as per the procedures prescribed in soil survey manual (Anonymous, 2000). Soil samples from each horizon were collected for analysis of important physical and chemical properties. The particle-size distribution was determined by international pipette method (Jackson, 1979) using sodium hexametaphosphate as dispersing agent. Soil pH were determined in 1:2.5 (soil: water) suspension using pH meter. Organic carbon was estimated by Walkley and Black rapid titration method (Jackson, 1973). The ammonium acetate method was used to determine the CEC of soils (Jackson, 1973). The available N was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956). Available phosphorus was determined by sodium carbonate method (Olsen *et al*., 1954). Potassium was determined by neutral ammonium acetate solution method (Jackson, 1973). The soils were correlated and classified according to soil taxonomy (Anonymous, 2006). Based on soil-site characteristics and crop requirements suitability for rice, wheat, sorghum, rapeseed and mustard, pigeon pea, chick pea, citrus, safflower were evaluated by following the frame work of land evaluation by Sys *et al*. (1993). The soil and other generated data, suitability data were processed, interpreted and integrated in GIS (year 2006) and suitability maps were prepared using ARC-GIS Software.

RESULTS AND DISCUSSION

Soil resource characteristics :

Based on field observations, laboratory characterization and correlation, six soils *viz*., Sirsi A to Sirsi F were identified and mapped along with their mapping units. Brief description of the soils-site characteristics are presented in table 1. Dominant soils of the area are very deep, well-drained, brown to dark yellowish brown, clay loam calcareous/non calcareous, mildly to moderately alkaline, classified as fine loamy, Typic Haplustepts (Sirsi A and B), followed by very deep, well drained, brown to yellowish brown, sandy loam, calcareous/non calcareous, moderately alkaline, classified as coarse loamy, Typic Haplustepts (Sirsi C & D) and very deep, well drained, brown to light olive brown in colour and sandy loam to loam in texture soils classified as fine loamy, Typic Haplustepts (Sirsi E). Very deep, moderately well drained, dark grayish brown to light olive brown, silt loam to silty clay loam, slightly saline/sodic soils occurred in Sirsi F (Fine loamy, Fluventic Haplustepts). The water holding capacity, nutrient retention capacity and productivity potential of soils of Sirsi A, B are good, Sirsi E are medium while Sirsi C, D and F are low to medium. Fertility assessment, nitrogen content of soils was found to be low to medium. Sirsi B soil had higher amount of nitrogen followed by soils of Sirsi C, A, D, E and F. The available phosphorus status these soils are in the medium category and found to be rich in the surface layer than subsurface soils. Soil series of Sirsi A, B, and C recorded more content of available P than other series. Available potassium status, soils series of Sirsi A, B, D, E and F had recorded medium content of available K.

Soil-site suitability evaluation:

On the basis of soil characteristics, site parameters and climate prevailing in the area, the soils were evaluated for their suitability for different crops grown in the area *viz.,* rice, wheat, sugarcane, mustard, pigeon pea, chickpea, sorghum, sunflower and citrus. The suitability of soil was evaluated by number and kind of limitations as per land evaluation framework (Sys *et al*., 1993) by considering S1 as highly suitable; S2 as moderately suitable and S3 as marginally suitable; N1 as unsuitable classes. These have been classified upto sub-class indicating factors for crop suitability (Table 2). For wheat cultivation, Soil series of Sirsi A, B, C, D were highly suitable for wheat cultivation with almost no discrete limitations. These soils are well drained and good in fertility status. Chibba (2010) also reported that for wheat crop needs a well-drained soil with good aeration for producing potential yield. However, soils of Sirsi E, F were moderately suitable for wheat cultivation with slight limitation of fertility and sodicity. Overall, 69.1 per cent area of the study area was found suitable, 21.2 per cent moderately suitable, 2.0 per cent under currently not suitable for wheat cultivation (Figure 1). For rice, soils of Sirsi A and B were found to be suitable whereas, soils of Sirsi C, D, E and F were moderately (46.1 % area) to marginally suitable (8.8 %) with the limitations of soil texture, low water holding capacity and low fertility (Figure 2). For sugarcane, soils of Sirsi A and B were suitable, whereas soils of Sirsi C, D, E and F were moderately suitable (Figure 3). Overall, 34.8 per cent area found suitable, 47.6 per cent moderately suitable whereas 7.85 per cent under marginally suitable with the limitations of low fertility and slight salinity. For mustard, Soil series Sirsi A, B and D were suitable but Sirsi E and F soils were moderately suitable because of problems of soil physical properties and wetness. In total 66.7 per cent area was found to be suitable and 23.6 per cent moderately suitable for the cultivation of mustard crop (Figure 4). For pigeon pea, Soil series of Sirsi A was suitable with slight limitations of fertility whereas soil series of Sirsi B, C, and D were moderately suitable and soils of Sirsi E and F were moderately to marginally suitable for this crop because of low soil fertility and slight salinity. Soil series of Sirsi A and B were moderately suitable for chick pea whereas Sirsi C to F soils were moderately to marginally suitable because of limitations of soil physical properties and low fertility (pH, OC). Presently, 48.9 per cent area was found moderately suitable, 30.5 per cent marginally suitable with limitations of salinity/sodicity and 10.8 per cent are presently unsuitable for cultivation of this crop (Figure 5). Two soils (Sirsi A and B) were moderately suitable (37.5 per cent area) and rests of the soils were marginally suitable for safflower/sunflower because of low soil fertility and soil condition and slight salinity. For citrus, Sirsi A soil was found suitable for this plantation whereas four soils (Sirsi B to E) were moderately suitable, and soils of Sirsi F was marginally suitable for this plantation because of low soil fertility, poor soil characteristics and salinity/sodicity. In total, 5.7 per cent area is presently unsuitable (but can be suitable after improvement) for this plant due to poor soil characteristics (Fig. 6). Sorghum is grown as fodder crops in the area, and presently, 66.7 per cent area is suitable and 23.6 per cent is moderately suitable for cultivation of sorghum crop.

It is observed that fine loamy soils of Sirsi A and B, have good potential for cropping for almost all the crops with limiting factor of medium fertility status. Sirsi C and D (Coarse loamy soils) soils are found to be suitable for sorghum, wheat, chickpea, and sugarcane and, but moderately suitable for pigeon pea with the limitations of calcium carbonate. Sirsi F (Fine loamy, Typic Haplustepts) are moderately to marginally suitable for cultivation of most of the crops because of its limitation of drainage, slight sodicity and calcareousness. However, suitability class of this soil can be raised after improving the drainage conditions and providing better management practices.

Crop planning :

A comprehensive crop plan was prepared to the Indo-Gangetic region of Karnal district. It is found that under assured irrigation and good management practices, fine loamy soils, rice-wheat/mustard and sugarcane-wheat cropping systems are most suited cropping system followed by *kharif* pulses-wheat/mustard, rice-wheat/gram, sugarcane-wheat.

Table 1. Soil-site characteristics of soils of Sirsi village, Karnal district, Haryana

Soil-site characteristics	Soils					
	Sirsi A	Sirsi B	Sirsi C	Sirsi D	Sirsi E	Sirsi F
Climate (C)						
Total Rainfall (mm)	720	720	720	720	720	720
LGP (days)	90-120	90-120	90-120	90-120	90-120	90-120
Mean max. temp. (^{o}c)	44	44	44	44	44	44
Mean Min. temp. (^{o}c)	12.9	12.9	12.9	12.9	12.9	12.9
Site Characteristics (t/w)						
Slope (per cent)	0-1	0-1	0-1	0-1,1-3	0-1,1-3	1-3
Erosion	e 0	e 0	e 1	e 0	e 0, e1	e 2
Drainage	wd	wd	wd	wd	wd-mwd	Impd
Soil Characteristics (s)						
Texture	cl	cl	sl	sl	sl, l	sil, sicl
Depth (cm)	>150	>150	>150	>150	<150	100
$CaCo_3$ (per cent)	Nil	0-4-3.9	nil	0-9-5.0	1.5-2.0	2.4-3.5
Soil Fertility (f)						
CEC(cmol (p+) kg^{-1})	9.15-14.3	8.9-11.4	5.9-7.8	6.7-7.9	9.4-11.5	10-12.2
Base saturation (%)	87	86	81	76	85	83
NPK ratings	LMM	MMM	LML	LMM	LMM	LLM
pH	7.8	8.2	8.1	8.3	8.8	9.5
Taxonomical Classification	Fine loamy, Typic Haplustepts	Fine loamy, (calcareous), Typic Haplustepts	Coarse loamy, Typic Haplustepts	Coarse loamy, (calcareous), Typic Haplustepts	Fine loamy, (calcareous), Typic Haplustepts	Fine loamy, (calcareous), Fluventic Haplustepts

Erosion: e0 - nil, e1-sligth, e2 - moderate; Drainage: wd - well drained, mwd -moderately well drained, impd - imperfectly drained; Texture: cl-clay loam, sl-sandy loam, scl - sandy clay loam, l -loam, sil - silty clay loam; NPK ratings: L-low, M-medium

Table 2. Comparative crop suitability of different soil units

Soil	Wheat	Rice	Mustard	Sugar - cane	Sorghu m	Pigeon Pea	Chick pea	Sunflow er	Safflower	Citrus
A	S1f	S1f	S1f	S1f	S1f	S1f	S2f	S2f	S2f	S1
B	S1fs	S1fs	S1f	S1f	S1f	S1f	S2f	S3f	S3sf	S2
C	S1f	S2sw	S2sw	S2sf	S2sf	S2sf	S3fs	S2fs	S2f	S2
D	S1s	S2sw	S1sw	S2sf	S2f	S2sf	S2f	S3fs	S3f	S2
E	S2sf	S2fs	S2sw	S2tf	S2f	S3fn	S3fs	S3fs	S2fn	S3
F	S3ns	S3ns	S2ns	S3nf	S3ns	S3nf	S3fn	N1fs	N1fn	N1

Limitations: w- wetness problem (drainage problem); s - problem of soil physical properties; f - problem of soil fertility; n - limitation due to salinity/alkalinity

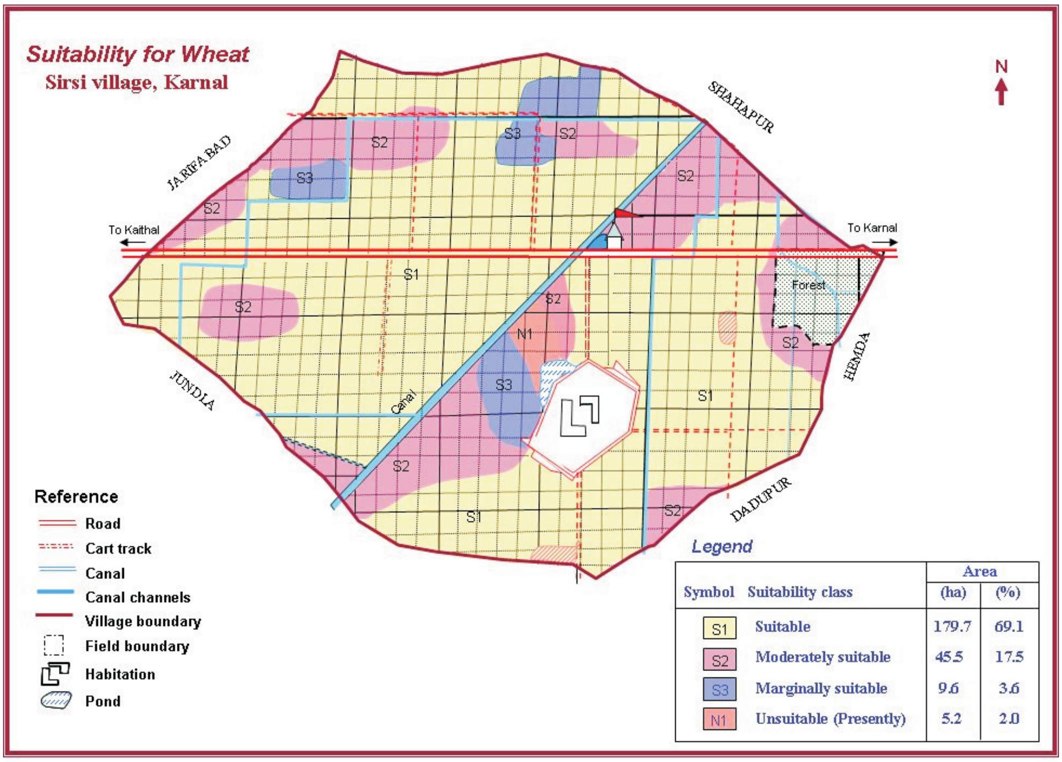

Figure 1. Suitability map for wheat

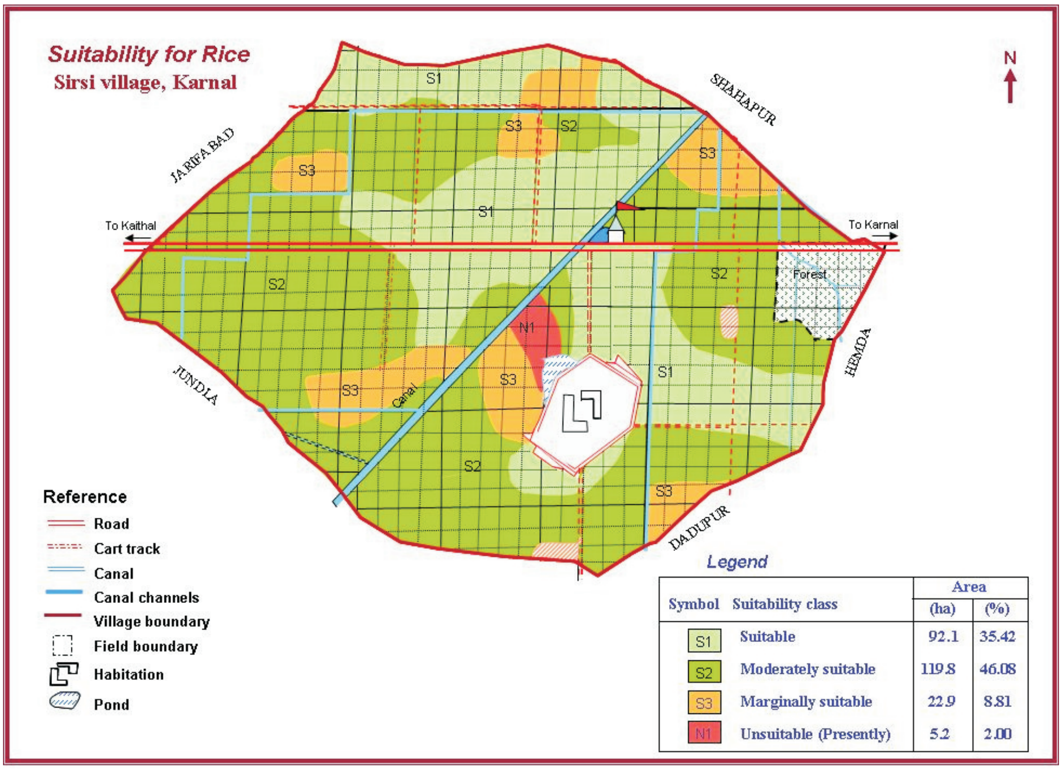

Figure 2. Suitability map for rice

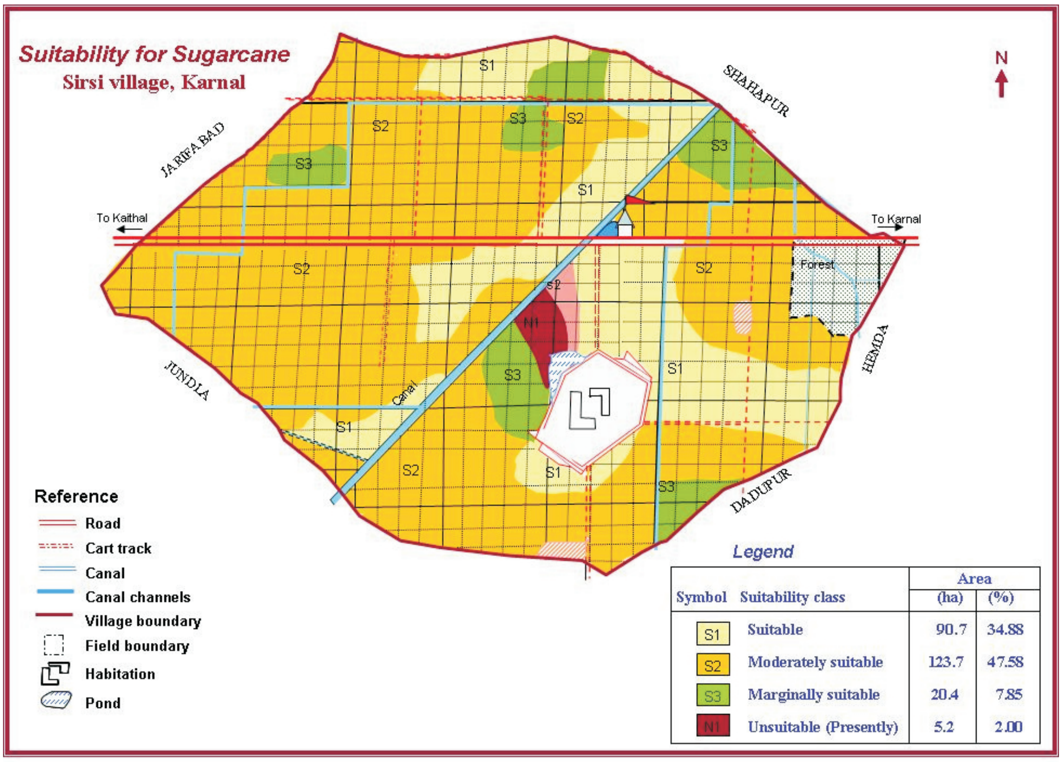

Figure 3. Suitability map for sugarcane

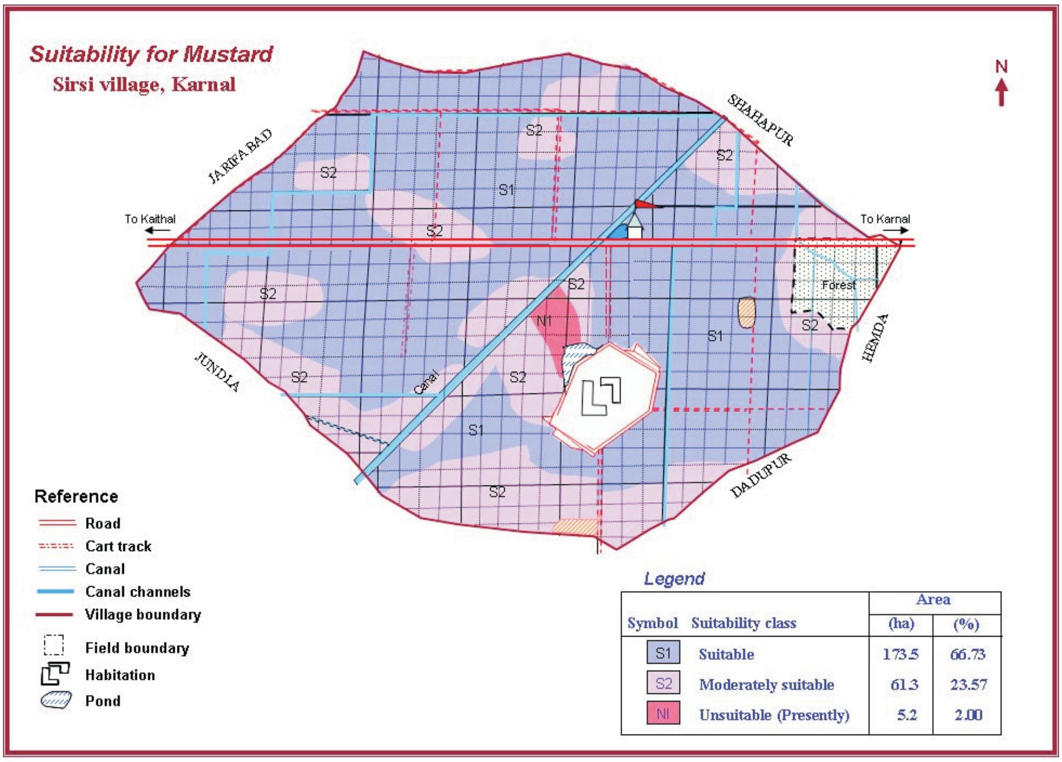

Figure 4. Suitability map for mustard

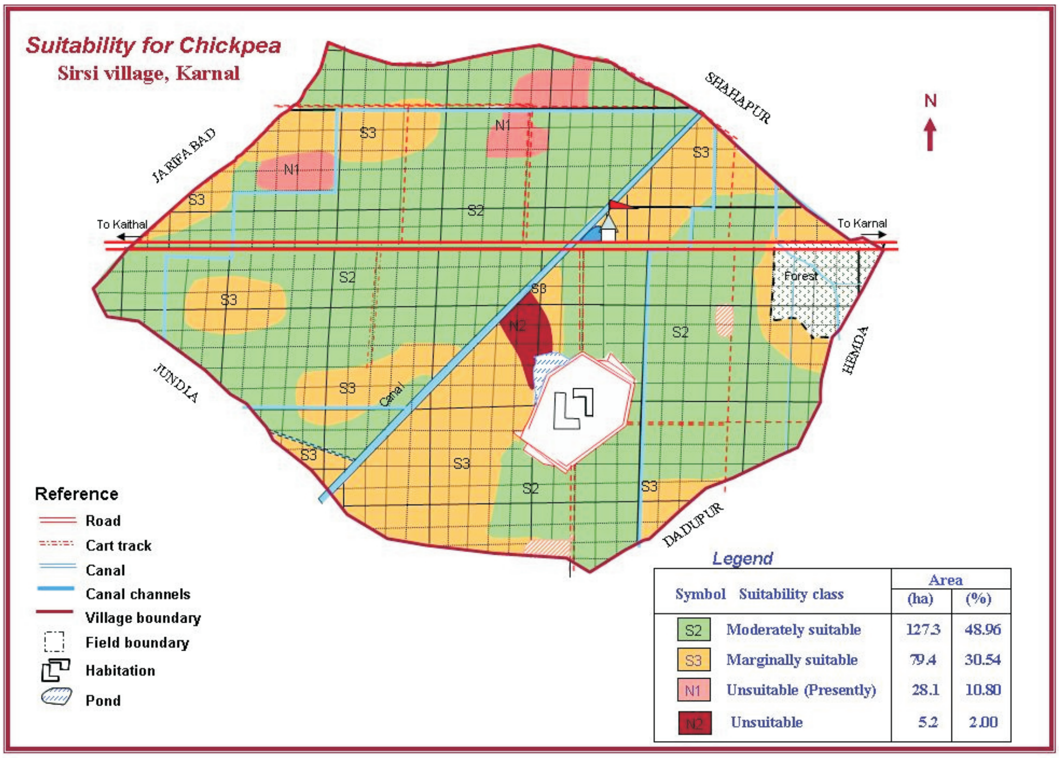

Figure 5. Suitability map for chickpea

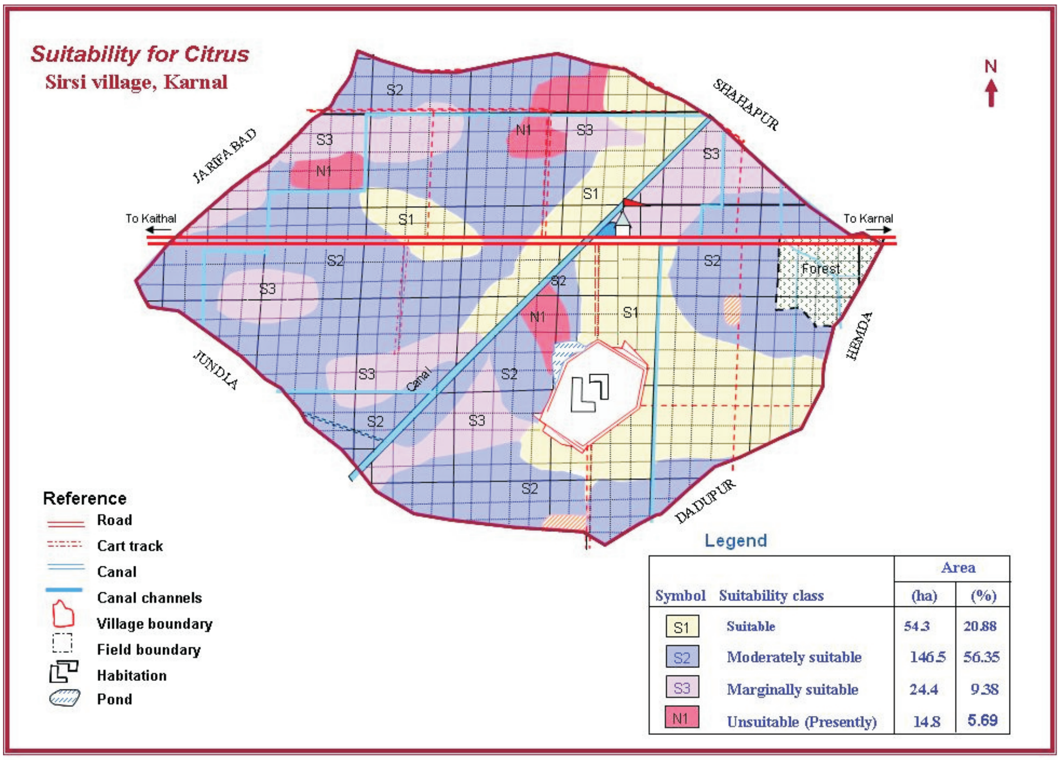

Figure 6. Suitability map for citrus

Sunflower/ safflower may also be preferred as alternate oilseed crops. As per the data, there is depletion of water table due to over exploitation of ground water and need proper care while withdrawing it. Coarse textured (coarse loamy) soils should be put under wheat, oilseeds, pulses. Rice should be avoided in these coarse textured soils. Since rice-wheat requires large number of irrigations than other crops, it is suggested that *kharif* pulses and oilseeds should be introduced in rice-wheat system to maintain the sustainability. Fine-loamy, Fluventic Haplustepts soils with slight limitation of salinity are good for cultivation of rice based cropping system with adopting good soil management practices. Citrus also has good potential to grow in the study area. Production of high value vegetables, flowers and fruit crops may be encouraged in the area having proximity to the towns as they are more profitable and consume less water.

Identification of suitable crops for different soil units will be helpful for micro level planning and suggest alternate land use options for each part and parcel of land. For micro-level planning, suitability evaluation of crops to be grown is bottom to top approach and will be helpful to the planners and decision makers to make strategies for regional and state level planning. The basic information generated in this study can effectively be used for soil, fertilizer and land management methods that help in suggesting suitable soil and crop management and land use decision options to the farmers and its governing institutions.

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J. Soils and Crops 22 (2) 302-308, Dec., 2012 **ISSN 0971-2836**

SOIL TEST BASED FERTILIZER RECOMMENDATION FOR TARGETED YIELD OF RICE-WHEAT CROPPING SEQUENCE AND ITS VALIDATION IN VERTISOL

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ABSTRACT

A field experiment was conducted on soil test crop response during 2007-08 with rice-wheat cropping sequence on a *Typic Haplustert* at the Research Farm of Department of Soil Science and Agricultural Chemistry, J.N. Krishi Vishwa Vidhyalaya, Jabalpur (M.P.). The correlations of predictability i.e. targeted yield equations between grain yield and soil available nutrients and inorganic fertilizer contribution with and without organic manure (FYM) developed by the department was validated. The findings showed that inorganic fertilizer application based on targeted yield along with organic manure (FYM) i.e. Integrated Plant Nutrient System (IPNS) approach, that consisted of application of 98 N: 103 P_2O_5: 27 K_2O kg ha^{-1} through chemical fertilizers + 46 N: 36 P_2O_5: 45 K_2O kg ha^{-1} through 5 t FYM ha^{-1} as organic manure, resulted in higher grain yield 4.04 t ha^{-1} of rice. The yield response of fertilizers, manure application (2430 kg ha^{-1}) and profit (11585 Rs ha^{-1}) were more in IPNS approach but B:C ratio (3.57) and yard stick value (9.82 kg of grain kg^{-1} of nutrient applied) were higher in Soil Test Crop Response (STCR) approach in rice over general recommended dose and control. Similarly, IPNS approach, that consisted of application of 150 N :174 P_2O_5 : 104 K_2O kg ha^{-1} through chemical fertilizers + 46 N : 36 P_2O_5 : 45 K_2O kg ha^{-1} through 5 t FYM ha^{-1} as organic manure resulted in higher grain yield 6.94 t ha^{-1} of wheat. The yield response of fertilizers, manure application (4800 kg ha^{-1}) and profit (37233 Rs ha^{-1}) were more in IPNS approach but B:C ratio (5.71) and yard stick value (9.55 kg of grain kg^{-1} of nutrient applied) were higher in STCR approach in wheat over general recommended dose and control. Thus, the practice of fertilizing a crop on the basis of yield targets is precise, meaningful and eco-friendly which needs to be popularized among farmers to enhance the integrated nutrient management taking into account balanced nutrients through the complementary and synergistic effect of combined use of mineral, organic and biological source of nutrients for sustained crop production.

(Key words: Rice-wheat cropping sequence, yield target, fertilizer calibration equations, B:C ratio, economic indices)

INTRODUCTION

Rice and wheat form the staple food for more than one billion people and a livelihood for millions of workers and farmers all over the world. The rice-wheat production system is one of the principal agriculture systems of the world. In India rice-wheat cropping system covers a large area of about 9.12 million hectares and contributes about 24% of total grain basket produce in the country (Anonymous, 2010 a). During the recent era, food grain production increases emanated mainly from increases in rice–wheat area as well as the production system. According to an estimate, India would need to double its food grain production i.e. 480 Mt by 2025 to feed its population that is expected to swell from the present 1.20 billion to 1.35 billion by that year (Chhibba, 2010). The wide scale adoption of rice-wheat system has ushered in increases in agriculture production, but this intensive system over a period of time and nature of the crops has set declining yield trends as well as deterioration in soil productivity even with optimum use of fertilizers (Prasad *et al.*, 2010).

In the recent past, the research on fertilizer use was mainly confined to the nutrient demands of individual crop and the fertilizer recommendations were made for a single crop. But it is well known fact that a crop is only a component of cropping system and as such it has to be grown in a given cropping sequence under a set of environment. Consequently, the fertilizer needs of an individual crop will vary depending upon the characteristics of the preceding crop in rotation. Therefore, there is an urgent need for efficient fertilizer management in a suitable cropping system and thereof residual effect of fertilizer nutrients in maintaining the sustainability of soil resource and production of crops.

Recently, work has been done under Integrated Plant Nutrient Supply System (IPNS) mode for the crops like lentil, pea, onion, sunflower and garlic (Anonymous, 2010 b). In India, during the last 35 years, the soil test based fertilizer requirements for targeted yield approach have been evolved for diversified soil-agro-climatic conditions (Subba Rao and Srivastava, 2001). But fertilizer recommendations applied through fertilizer adjustment equation for dominant cropping sequence i.e. rice-wheat is still under dormancy stage. Hence, it is important to assess the fertilizer adjustment

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equation under rice-wheat cropping sequence. In view of this, the studies were undertaken to evolve soil test based fertilizer recommendations to verify the targeted yield fertilizer calibration equations for specific yield targets and economic indices involved under rice-wheat cropping sequence in Vertisol.

MATERIALS AND METHODS

The field experiment was conducted on rice (JR-201) and wheat (GW-273) crops during 2007-08 at the Research Farm of the Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (23°10” N latitude and 79°57” E longitude). The experimental soil was medium black belonging to *Kheri* series of fine montmorillonitic hyperthermic family of Typic Haplustert and had neutral pH of 7.0, normal electrical conductivity of 0.23 dS m^{-1} (1 : 2.5 soil : water ratio), medium organic carbon (7.0 g kg^{-1}), low available N (160 kg ha^{-1}) and low available P (10 kg ha^{-1}) and medium available K (321 kg ha^{-1}). There were six treatments replicated four times in a randomized block design. Same plots and treatments randomization were used for cultivation in both the crops. Treatments schedule for rice-wheat cropping sequence comprised of T_1-control, T_2-general recommended dose (GRD), T_3-soil test crop response (STCR) recommendation for target yield-I (TY-I), T_4-STCR for TY-II, T_5- integrated plant nutrient system (IPNS) approach-I : STCR for TY-I + 5 t FYM ha^{-1}, T_6-IPNS approach-II : STCR for TY-II + 5 t FYM ha^{-1}. Manurial schedule for rice and wheat crops is given in the table 2.

Treated seeds of both rice and wheat were dibbled at proper spacing of 30.0 cm x 10.0 cm and 22.5 cm x 10.0 cm in the first week of July and November 2007, respectively after basal application of fertilizers as per treatments. The soil samples were collected before sowing and after the harvest of both rice and wheat crops during 2007-08 with the help of a tube auger (stainless steel) from each plot at 0-15 cm soil depth. Basic soil parameters viz., pH and EC were measured by glass electrode pH meter (Piper, 1967) and Solu–bridge method (Black, 1965) in 1:2.5 soil-water suspensions, respectively. Organic carbon was determined by Walkley and Black method (1934), available soil N by Alkaline potassium permanganate method (Subbiah and Asija, 1956), Olsen's P (Watanabe and Olsen, 1954) and Ammonium acetate extractable potassium was analyzed by standard routine procedure, as outlined by Muhr *et al.* (1963).

To compute fertilizer doses for any yield target based on soil test value fertilizer adjustment equations were used as per procedure of Ramamoorty *et al.* (1967). The targeted yields for rice 3 and 4 tonnes ha^{-1} and for wheat 4.5 and 6 tonnes ha^{-1} were fixed. The fertilizer materials used were urea, single super phosphate and muriate of potash. Full dose of P and K and half dose of N were applied and mixed thoroughly with soil at the time of sowing. The remaining half dose of N was top-dressed at tillering stage. The crops (initiated) rice and wheat were cultivated adopting proper package of practices. All climatic conditions were favourable for growth and development of both crops. The grain yields of rice and wheat were recorded at the harvest of each crop on maturity for each treatment and economic aspects of each treatment were worked out to draw suitable inference.

RESULTS AND DISCUSSION

Verification of fertilizer adjustment equations for yield targets under rice-wheat cropping sequence :

The applicability of the target yield equations developed for rice and wheat were tested by conducting a field experiment at the research farm, employing a fixed layout plan. The data presented in table 3 revealed that rice grain and straw yields were significantly influenced due to the application of various treatments. Rice recorded the highest grain and straw yields of 4.04 and 5.76 t ha^{-1} with TY 4 t ha^{-1} + 5 t FYM ha^{-1} (144 N :139 P_2O_5 : 72 K_2O) followed by TY 4 t ha^{-1} (98 N : 103 P_2O_5 : 27 K_2O) producing 3.85 t ha^{-1} grain and 5.71 t ha^{-1} straw. Control resulted in the lowest yield of 1.61 t ha^{-1} grain and 3.04 t ha^{-1} straw. The next in order was treatment TY 3 t ha^{-1} + 5 t FYM ha^{-1} (101 N : 103 P_2O_5 : 52 K_2O) giving yields of 3.15 t ha^{-1} grain and 4.14 t ha^{-1} straw followed by TY 3 t ha^{-1} (55 N : 67 P_2O_5 : 6 K_2O) which produced 3.85 t ha^{-1} grain and 5.17 t ha^{-1} straw, respectively. These all treatments are within ± 10% variation from affixed target. Similarly, wheat grain and straw yields were significantly affected due to different treatments applied. The highest grain and straw yield of 6.94 and 8.13 t ha^{-1} were found with TY 6 t ha^{-1} + 5 t FYM ha^{-1}

(196 N : 203 P_2O_5 : 149 K_2O) followed by TY 6 t ha^{-1} producing 6.03 t ha^{-1} grain and 6.77 t ha^{-1} straw, respectively over control of 2.41 t ha^{-1} grain and 3.66 t ha^{-1} straw. The next in order was TY 4.5 t ha^{-1} + 5 t FYM ha^{-1} (110 N : 132 P_2O_5 : 110 K_2O). In these treatments deviation from fixed target varied with ± 19%. Increase in yield due to FYM could be ascribed to steady supply of all nutrients including the micro-nutrients and improvement in physical condition of soil providing better aeration and microbial activities. Results are supported with the findings of Thakur *et al.* (2011) who reported that under soybean-wheat cropping sequence in Vertisol, the combined use of inorganic mineral fertilizer (20:80:20 kg ha^{-1} to soybean and 120:80:40 kg ha^{-1} to wheat) and 15 t FYM ha^{-1} (organic) resulted in 145 and 292 % increase in soybean and wheat yields, respectively over control. Similar findings were also reported by Kumar and Singh (2010) who showed that maximum yield of rice and wheat were obtained where the recommended dose of 100% NPK was applied along with 5 t FYM ha^{-1}, on calcareous soil of Bihar.

These results showed that a correspondence between targeted yields and yields actually obtained is an evidence of the usefulness of soil testing within limits of variation under field conditions.

Effect of different nutrient management practices on maximized production and economic indicator under rice-wheat cropping sequence:

The results presented in table 3 further indicated that treatments TY 4 t ha^{-1} + 5 t FYM ha^{-1}, TY 4 t ha^{-1} and TY 3 t ha^{-1} + 5 t FYM ha^{-1} resulted in higher response of 2430, 22240 and 1540 kg ha^{-1} grain of rice, respectively. The treatment TY 4 t ha^{-1} showed maximum profit of Rs 12255 ha^{-1} followed by TY 4 t ha^{-1} + 5 t FYM ha^{-1} resulted Rs 11585 ha^{-1} over control of Rs 2818 ha^{-1}. In case of B:C ratio, it was maximum 3.57 with TY 4 t ha^{-1} followed by 3.14 of TY 3 t ha^{-1}. Yard stick value i.e. kg grain kg^{-1} of nutrient applied which was maximum with TY 4 t ha^{-1} of 9.82 decreased in TY 3 t ha^{-1} to 9.45. GRD recorded the lowest value of 4.10.

In wheat maximum return of Rs 11585 ha^{-1} was recorded with TY 6 t ha^{-1} + 5 t FYM ha^{-1}. This was followed by the treatment TY 6 t ha^{-1} and TY 4.5 t ha^{-1} + 5 t FYM ha^{-1} giving 3620 and 2930 kg ha^{-1} response. The same treatments also resulted in higher profit of Rs 48000, 36200 and 29300 ha^{-1}, respectively. However, B:C ratio of 4.96 in TY 6 t ha^{-1} lowered to 4.63 in TY 4.5 t ha^{-1}. Maximum (9.55) yard stick value i.e. kg grain kg^{-1} of nutrient applied was found to be with treatment TY 4.5 t ha^{-1} followed by TY 6 t ha^{-1} + 5 t FYM ha^{-1} and TY 6 t ha^{-1} resulting in 8.64 and 8.45, respectively.

Use of inorganic fertilizer with organic manure i.e. FYM in both rice and wheat not only maximized of yield but also accelerated the profitability, which accompanied by lower B:C ratio and yard stick value over other practices of nutrient recommendation and thereby economizing nutrient dose for subsequent crops. These findings are in line with the observations recorded by Chand *et al.* (2006), who noticed that fertilizer application based on yield target (18 t ha^{-1}) gave higher B:C ratio (3.84 of mustard and 2.56 of rapeseed) and yard stick value (8.23-mustard and 5.01-rapeseed) over farmer's practices (N:P:K-75:0:0 kg ha^{-1}), under mustard-rapeseed sequence in Punjab.

Effect of different nutrient management practices on total yield of the system under rice-wheat cropping sequence :

The data presented in table 4 revealed that the total grain yields of rice-wheat cropping sequence, was the highest (10.98 t ha^{-1}), with the IPNS approach i.e. TY 4 t ha^{-1} + 5 t FYM ha^{-1} (144 N: 139 P_2O_5 : 72 K_2O) and TY 6 t ha^{-1} + 5 t FYM ha^{-1} (196 N :210 P_2O_5 : 149K_2O) . The next in order was STCR approach i.e. TY 4 t ha^{-1} (98 N: 103 P_2O_5: 52 K_2O) and TY 6 t ha^{-1} (105 N: 174 P_2O_5: 149 K_2O) producing 9.88 t ha^{-1} yield in the system followed by IPNS approach (8.46 t ha^{-1}) over control of 4.02 t ha^{-1}. The results are corroborated with the findings of Khan *et al.* (2004), who observed that the application of 100 kg N + 60 kg P_2O_5 + 30 kg K_2O + 7.5 t FYM ha^{-1} to rice and 120 kg N + 60 kg P_2O_5 + 40 kg K_2O ha^{-1} + 7.5 t FYM ha^{-1} to wheat resulted in maximum productivity (10.04 t ha^{-1}) of the rice-wheat system under Jabalpur condition.

Table 1. Basic data for targeted yield equation of rice and wheat

Parameter	Nutrient requirement (kg q^{-1})			Nutrient contribution from soil (%)			Nutrient contribution from fertilizer (%)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Rice (JR-201)	2.3	0.9	1.9	6.8	39.7	6.2	41.5	18.5	73.8
Wheat (GW-273)	2.6	0.6	1.8	6.3	42.3	11.5	46.4	12.5	70.2

Note: **Composition of FYM** : N–0.92%, P_2O_5–0.72% and K_2O–0.90%

Soil test value for rice-wheat cropping sequence

Crops	Available soil nutrients (kg ha^{-1})		
	N	P	K
Rice	160	10	321
Wheat	254	12	311

Fertilizer adjustment equations used for rice-wheat cropping sequence

Sr. No.	Rice	Wheat
1.	F N = 4.25 t - 0.45 SN	F N = 4.40 t - 0.40 SN
2.	F P_2O_5 = 3.55 t - 4.09 S P_2O_5	F P_2O_5 = 4.00 t - 5.73 S P_2O_5
3.	F K_2O = 2.10 t - 0.18 S K_2O	F K_2O = 2.55 t - 0.16 S K_2O

Where,

F N - Fertilizer nitrogen (kg ha^{-1})
F P_2O_5 - Fertilizer phosphorus (kg ha^{-1})
F K_2O - Fertilizer potassium (kg ha^{-1})
t - Desired yield target (q ha^{-1})
SN - Available soil nitrogen - Alkaline KMnO4 (kg ha^{-1}) -N
S P_2O_5 - Available soil phosphorus - Olsen's P (kg ha^{-1})
S K_2O - Available soil potassium - Neutral 1 N NH4O Ac-K (kg ha^{-1})

Table 2. Manurial schedule for rice-wheat cropping sequence

Treatment code	Treatment details	Nutrient supplied (kg ha^{-1})			FYM (t ha^{-1})
		N	P_2O_5	K_2O	
(a) *Kharif* (Rice)					
T_1	Farners practice (Control)	0	0	0	0
T_2	General recommended dose	80	70	40	0
T_3	STCR approach for yield target (3t ha^{-1})	55	67	6	0
T_4	STCR approach for yield target (4t ha^{-1})	98	103	27	0
T_5	IPNS approach for yield target (3t ha^{-1}) +5 t FYM ha^{-1}	101 (46)	103 (36)	52 (45)	5
T_6	IPNS approach for yield target (4t ha^{-1}) +5 t FYM ha^{-1}	144 (46)	139 (36)	72 (45)	5
(b) *Rabi* (Wheat)					
T_1	Farners practice (Control)	0	0	0	0
T_2	General recommended dose	100	60	30	0
T_3	STCR approach for yield target (4.5 t ha^{-1})	64	96	65	0
T_4	STCR approach for yield target (6 t ha^{-1})	150	174	104	0
T_5	IPNS approach for yield target (4.5 t ha^{-1}) + 5 t FYM ha^{-1}	110 (46)	132 (36)	110 (45)	5
T_6	IPNS approach for yield target (6 t ha^{-1}) + 5 t FYM ha^{-1}	196 (46)	210 (36)	149 (45)	5

(Figures within parentheses indicate amount of nutrients contribution by FYM source. It was applied to both the crops rice and wheat separately)

Table 3. Effect of different nutrient management practices on yield and economic indicators involved in rice-wheat cropping sequence

Treatments	Fertilizer dose (kg ha $^{-1}$)			Grain yield (t ha $^{-1}$)	Straw yield (t ha $^{-1}$)	Deviation from fixed target (± %)	Response (kg ha $^{-1}$)	Cost of fertilizer (Rs ha $^{-1}$)	Value of response (Rs ha $^{-1}$)	Net Profit (Rs ha $^{-1}$)	B:C ratio	Yard Stick Value (kg grain kg $^{-1}$ of nutrient applied)
	N	P_2O_5	K_2O									
Rice (JR-201)												
T_1 :Control	0	0	0	1.61	3.04	-	-	-	-	-	-	-
T_2 :GRD	80	70	40	2.31	3.52	-	700	2642	5460	2818	1.06	4.10
T_3 :TY 3 t ha $^{-1}$	55	67	6	2.82	4.42	-6	1210	2042	8470	6428	3.14	9.45
T_4 :TY 4 t ha $^{-1}$	98	103	27	3.85	5.17	-3	2240	3425	15680	12255	3.57	9.82
T_5 :TY 3 t ha $^{-1}$ + 5 t FYM ha $^{-1}$	101 (45)	103 (36)	52 (45)	3.15	4.14	+5	1540	4042	10780	6738	1.66	6.00
T_6 :TY 4 t ha $^{-1}$ + 5 t FYM ha $^{-1}$	144 (46)	139 (36)	72 (45)	4.04	5.76	+1	2430	5425	17010	11585	2.13	4.86
SEm ±				0.14	0.37							
CD				0.30	0.78							
Wheat (GW-273)												
T_1 :Control	0	0	0	2.41	3.66	-	-	-	-	-	-	-
T_2 :GRD	100	60	30	3.97	4.75	-	1560	2577	15600	13023	5.05	8.21
T_3 :TY 4.5 t ha $^{-1}$	64	96	65	4.56	5.50	+1	2150	3200	21500	18300	5.71	9.55
T_4 :TY 6 t ha $^{-1}$	105	174	104	6.03	6.77	+1	3620	6067	36200	30133	4.96	8.45
T_5 :TY 4.5 t ha $^{-1}$ + 5 t FYM ha $^{-1}$	110 (46)	132 (36)	110 (45)	5.34	6.81	+19	2930	5200	29300	24100	4.63	8.32
T_6 :TY 6 t ha $^{-1}$ + 5 t FYM ha $^{-1}$	196 (46)	210 (36)	149 (45)	6.94	8.13	+15	4800	8067	48000	37233	4.16	8.64
SEm ±				0.28	0.30							
CD				0.60	0.64							

(Figures in parenthesis indicate nutrients supplied through FYM)

Note: Cost of nutrient in Rs kg $^{-1}$: N-11.00, P_2O_5-20.75 and K_2O-7.75
Cost of FYM in Rs t $^{-1}$: 800.00
Cost of produce in Rs kg $^{-1}$: Rice – 7.00 and Wheat – 10.00

Table 4. Effect of different nutrient management practices on total yield of the system under rice-wheat cropping sequence

Nutrient management practices	Rice				Wheat				Total grain yield of the system ($t\ ha^{-1}$)
	Fertilizer dose ($kg\ ha^{-1}$)			Grain yield ($t\ ha^{-1}$)	Fertilizer dose ($kg\ ha^{-1}$)			Grain yield ($t\ ha^{-1}$)	
	N	P_2O_5	K_2O		N	P_2O_5	K_2O		
Control	0	0	0	1.61	0	0	0	2.41	4.02
GRD	80	70	40	2.31	100	60	30	3.97	6.36
STCR approach: I	55	67	6	2.82	64	96	65	4.56	7.38
STCR approach: II	98	103	27	3.85	105	174	104	6.03	9.88
IPNS approach : I	101 (45)	103 (36)	52 (45)	3.15	110 (46)	132 (36)	110 (45)	5.34	8.46
IPNS approach : II	144 (46)	139 (36)	72 (45)	4.04	196 (46)	210 (36)	149 (45)	6.94	10.98
				Mean					7.85

Note: STCR approach: I = Lower yield target ($t\ ha^{-1}$): Rice-3 and Wheat-4
STCR approach: II = Higher yield target ($t\ ha^{-1}$): Rice-4.5 and Wheat-6
IPNS approach: I = STCR approach: I + 5 t FYM ha^{-1}
IPNS approach: II = STCR approach: II + 5 t FYM ha^{-1}

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Rec. on 19.08.2011 & Acc. on 21.12.2011

J. Soils and Crops 22 (2) 309-313, Dec., 2012 ISSN 0971-2836

EFFECT OF FLY ASH ON AGRICULTURAL TOP SOIL

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ABSTRACT

Rapid industrialization for sustaining economic stability leads to pollution of environment due to disposal of untreated effluents. Land disposal of untreated industrial effluents causes soil pollution and soil becomes unproductive. Industrial effluents 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 optimum utilization of Fly ash on Agricultural Top soil. The potential of fly ash as a resource material in agriculture and related areas is now a well-established fact and more and more researchers are getting convinced with its utility potential in this field. In the present study, soil samples were collected from the agricultural fields adjoining a Thermal Power Plant and laboratory tests were done to estimate the optimum dosage of fly ash required as liming material for beneficial agricultural yields. The agricultural field was amended with fly ash at different doses and the crop chosen was cotton. The results obtained through this research indicated that the soil samples have an alkaline pH of 8 when amended with fly ash. The results obtained through this research indicated that the soil samples have an alkaline pH (8.0) with high calcium and aluminum content (2.44 and 24.17% respectively) with relatively lesser amount of potassium (1.6%). Bulk density was found to be as low as 1.48 g/cm^3 on addition of fly ash. An increase in electrical conductivity and water holding capacity was also observed. The observed values were found to be 0.28% and 63.55% respectively. Traces of arsenic (0.008%) were also found at the agricultural setup. Laboratory and field tests estimated the optimum dosage of fly ash as 20% w/w best suited for cotton crop, as liming material for agricultural use.

(Key words: Fly Ash, liming, cotton, optimum dosage)

INTRODUCTION

Industrial development of any country is the foundation stone of its prosperity. Rapid industrialization coupled with rapid growth of human population has brought about the hazards of environmental pollution as well as benefits (Rampal and Dorjey, 2001). This has gradually increased our concern about the side effects, which may arise from release of variety of chemicals into our immediate surroundings. The main sources of land pollution have been the industries like paper and pulp mills, thermal power plants, iron and steel plants, oil refineries etc. Most industrial furnaces give rise to fly ash, a powder residue of unburnt material, besides a huge amount of solid waste. Most pollution is caused by need to dispose of waste, which may be defined as any gaseous, liquid or solid material that is discharged because it has no further apparent use for the owner, industrial processor or manufacturer. Waste cannot be eliminated but must be disposed of and contained within the global environment. Thus, when waste materials are released into the atmosphere or dumped in land or discarded into streams, rivers or the sea, they effectively pollute the environment.

The major attribute, which makes Fly ash suitable for agriculture, is its texture and the fact that it contains almost all the essential plant nutrients except organic carbon and nitrogen.Fly ash improves the quality of degraded land. Sometimes soil loses fertility and quality due to environmental causes and unmanaged exploitation by human. For increasing soil productivity, waste fly ash can be used as exploitable resource for the management of degraded soils since it contains several similarities like soil and contains essential micro-nutrients (Fe, Mn, Zn, Cu, Co, B and Mo) and macro-nutrients (P, K, Ca, Mg and S). It can also be used in the reclamation of wastelands (sodic soil, acidic soil and mine spoil) as it possesses many of the functional properties of lime and gypsum (Kumar and Singh, 2003).

Fly ash can supply essential element to crops growing in nutrient deficient soil. Reclamation of wastelands through plantations and floriculture can also be done by application of fly ash (Thapliyal and Malik, 2006). Taking into consideration the above mentioned facts the present study was undertaken to study the effect of fly ash on agricultural top soil.

MATERIALS AND METHODS

Soil samples for analysis purpose were collected from agricultural fields adjoining Koradi Thermal Power Station, Koradi, situated at a distance of approximately 20.83 kms from Nagpur city. Soil samples were collected from a distance of 25m, 50m and 75m from the point of solid waste discharge. These samples were collected at a depth of about 10-

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15 cm from five different points on the fields, respectively. 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.

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.

The physico-chemical properties of fly ash are given in table 1.

The soil falling under the study sites was clayey Kali Soil or Black Cotton Soil, one of the six soil types found in Nagpur region. The various physical and chemical properties of this soil type are listed in table 2.

Mineralogically, fly ash is very much similar to soil but rich in macro and micro nutrients. Particle size distribution of fly ash improves physical conditions of soil, specifically black cotton significantly (Sivapullaiah *et al.,* 1996). Fly ash could be used effectively in the barren or sterile soil for improving quality and enhancing fertility (Pandey and Singh, 2010). Physico–chemical analysis of fly ash revealed the presence of both; macro (N, K, Ca, Mg and P) and micro nutrients (Fe, Mn, Zn and Cu), which can sustain plant growth. Its application in the agricultural land acts as a liming material and improves crop growth by neutralizing the soil acidity, increasing the water availability for the plants and supplement of nutrients.

The thermal power plant under study requires approximately 16,000 to 17,000 tonnes of coal day^{-1}, which annually generates 20-25 thousand tones of fly ash. This fly ash is disposed of at a distance of about 3-5 km from the power plant. Short-term laboratory and field studies had shown dose-based effect of coal fly ash on chemical properties of soil. 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. An increase in pH, electrical conductivity, water holding capacity, calcium and aluminium was observed in the soil with increasing dose and time. The values showed an increase from initial value 7.6, 0.28%, 63.55%, 2.39% and 24.07% to observed value of 8, 0.32%, 65%, 2.43% and 24.18% respectively. Bulk density value decreased from 1.56 to 1.48 g cm^{-3} suggesting an increase in the porosity and aeration of soil. 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. 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. Cotton productivity on an average increased to 12.5 %. In addition to increase in the yield of produce, significant increase in biomass yield was also found. The presence of calcium, magnesium and iron in most of the fly ash samples was found to improve the quality of cotton crop produced. The optimum soil and fly ash dosage range for cotton was found to be 0-120 tonnes ha^{-1}. The difference in yields of these crops on fly ash amended soil as against that of the yield of crops grown on control land was markedly of about 15-16% quintal ha^{-1}. The presence of essential plant nutrients and the physical properties of fly ash could be attributed for its favourable effects on yield of cotton as well as for the maintenance of soil fertility.

Table 1. Analysis of Fly ash

Physical properties	
pH	8.43
Electrical conductivity (MS/cm)	0.155
Bulk density (g/cm^3)	1.140
Water holding capacity (%)	46.00
Chemical Properties	
% Organic carbon	0.19
SiO_2 (%)	62.50
Al_2O_3 (%)	17.50
Fe_2O_3(%)	7.50
CaO (%)	1.75
MgO (%)	1.50
TiO_2(%)	1.293
P_2O_5(%)	0.261
K_2O (%)	0.81
Na_2O (%)	0.28
LOI (%)	0.72
Heavy Metals in Fly ash	
Copper (%)	0.55
Zinc (%)	0.64
Manganese (%)	0.40
Boron (%)	0.15
Molybdenum (%)	0.16
Selenium (%)	3.40
Arsenic (%)	1.30
Cobalt (%)	0.08
Chromium (%)	0.45
Lead (%)	0.30
Nickel (%)	1.10
Cadmium (%)	0.05

Table 2. Analysis of Black Cotton Soil

Physical properties	
pH	7.60
Electrical conductivity (dS m^{-1})	0.28
Sand (%)	24.00
Silt (%)	3.50
Clay (%)	72.80
Natural moisture content (%)	45.00
Bulk density (g cm^{-3})	1.56
Water holding capacity (%)	63.80
Chemical Properties	
% Organic carbon	0.62
SiO_2 (%)	63.10
Al_2O_3 (%)	24.07
Fe_2O_3 (%)	3.50
CaO (%)	2.39
MgO (%)	1.55
MnO_4 (%)	2.05
TiO_2 (%)	0.04
P_2O_5 (%)	0.08
K_2O (%)	1.60
NO_3 N (%)	0.05
Na_2O (%)	0.38
As_2O_3 (%)	0.002
ESP	5.00

Table 3. Changes in properties of soil on addition of Fly Ash

Physical properties	Initial value	Changed value
pH	7.60	8.00
Electrical conductivity (dSm^{-1})	0.28	0.32
Natural moisture content (%)	45.00	43.00
Bulk density (gcm^{-3})	1.56	1.48
Water holding capacity (%)	63.50	65.00
Chemical properties		
% Organic carbon	0.62	0.60
SiO_2 (%)	63.10	64.00
Al_2O_3 (%)	24.07	24.18
Fe_2O_3 (%)	3.50	3.90
CaO (%)	2.39	2.43
MgO (%)	1.55	1.58
MnO_4 (%)	2.05	2.06
TiO_2 (%)	0.04	0.05
P_2O_5 (%)	0.08	0.10
K_2O (%)	1.60	1.75
NO_3N (%)	0.05	0.045
Na_2O (%)	0.38	0.37
As_2O_3 (%)	0.002	0.008
CuO (%)	0.01	0.013
ZnO (%)	0.014	0.018
ESP	5.00	3.00

The observed values indicate that agricultural soil amended with fly ash has helped in reducing its bulk density, optimized the pH value, improved soil aeration, percolation and water retention, reduced crust formation, provided micro-nutrients (Fe, B, Cu, Mo and Zn etc.) and macro-nutrients (Ca, P, K etc.) (Table3). However, the high pH reduced the bio availability of some nutrients. .

Around 60 million tonnes of fly ash is being produced as a waste every year from different thermal power plants in India. Attempts have been made to use fly ash for its chemical composition for upgrading the wasteland for agriculture purpose. However, long use of fly ash may impart toxicity due to the hyper-accumulation of heavy metals in soil (Saxena *et al.*, 1998). Although fly ash cannot substitute the need of chemical fertilizers or organic manure it can be used in combination with these to get additional benefits in terms of improvement in soil physical characteristics, increased yields etc. As in the case with fertilizers and any other agriculture input, the amount and method of fly ash application would vary with the type of soil, the crop to the grown, the prevailing agroclimatic condition and also the type of fly ash available.Thus, our definite objective was to utilize fly ash in degraded soils to such an extent so as to gain increased fertility without affecting its quality and also reducing the accumulation of toxic metals in plants less than the critical levels for human health.

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Rec. on 05.11.2010 & Acc. on 20.02.2011

J. Soils and Crops 22 (2) 314-320, Dec., 2012 ISSN 0971-2836

HETEROSIS FOR SEED COTTON YIELD AND ITS CONTRIBUTING TRAITS IN UPLAND COTTON (*G. hirsutum* L.)

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ABSTRACT

An investigation was carried out in the research farm of Regional Research Station, Anand Agricultural University, Anand during the year 2010-11 to assess extent of heterosis over better parent and standard check for seed cotton yield and its contributing traits in cotton *(Gossypium hirsutum* L.). Fourty four crosses obtained by crossing four lines and eleven testers were raised in Randomized Block design with three replications. Parents and checks (G. Cot Hy. 12) were also raised adjacent to the crosses. The data were recorded on days to 50 % flowering, plant height, number of monopodia plant $^{-1}$, number of sympodia plant $^{-1}$, total number of bolls plant $^{-1}$, average boll weight and seed cotton yield plant $^{-1}$. The crosses BC 68-2 x MCU 11, BC 68-2 x AC 738, BN 1 x Riba B-50 had high mean performance for yield plant $^{-1}$ and other yield contributing traits. The mean squares due to the interaction effects of parents vs. crosses were found to be significant for all the characters except for plant height indicating possibility of heterotic effects for some of the characters. Three crosses namely BC 68-2 x MCU 11, BC 68-2 x AC 738, BN 1 x Riba B-50 were identified as promising crosses as they exhibited significant useful heterosis for yield and some important yield contributing traits. These crosses also had significant *per se* performance for their respective characters. The mean squares for lines were significant for days to 50 % flowering, plant height, number of monopodia plant $^{-1}$, total number of bolls plant $^{-1}$, average boll weight and seed cotton yield plant $^{-1}$, while testers were significant for all the seven characters. Out of fourty four crosses studied three crosses namely BC 68-2 x MCU 11, BC 68-2 x AC 738, BN 1 x Riba B-50 were identified as the most potential crosses for hybrid production on the basis of high *per se* performance and high significant useful heterosis and hence, it is suggested that these crosses can be practically exploited in heterosis breeding programme.

(Key words : Upland Cotton, heterobeltosis and standard heterosis)

INTRODUCTION

India is pioneer in commercialization of heterosis in cotton. Even though heterosis occurs in cotton, it has not been utilized widely as compared to maize and castor due to difficulties in producing cheap commercial F_1 hybrids seed production.

Cotton being a long duration crop grown over a wide range of environments, its productivity and production is not stable. For better exploitation of heterosis in cotton, development simple and economically variable of hybrid seed production technique is essential. Improvement in yield has been achieved through distant hybridization, particularly through intraspecific hybridization. The evolution of hybrid-4 (Patel, 1971) is a splendid example of successful utilization of hybrid vigour in cotton on commercial scale for the first time in the world. Evaluation of breeding materials to study the extent of heterosis for yield and yield contributing characters are prerequisites for any breeding programme aimed in development of hybrids. The breeding methods to be adopted for improvement of a crop depend on the nature of gene action involved in the inheritance of economically important traits. Such information is of practical value in formulating as well as executing efficient breeding programme for obtaining maximum gain with minimum resource and time. Therefore, the present investigation was undertaken to study the extent of heterosis over better parent and standard check hybrid using Line x Tester analysis.

MATERIALS AND METHODS

Four lines viz., L_1 (G. Cot-16), L_2 (BC-68-2), L_3 (BN 1), L_4 (76 IH-20) were crossed with eleven testers viz., T_1 (American nectariless), T_2 (MCU 11), T_3 (AC 738), T_4 (Surat Dwarf), T_5 (Riba-B-50), T_6 (Khandwa 2), T_7 (LRA 5166), T_8 (G. Cot 100), T_9 (G. Cot 10), T_{10} (Narsimha), T_{11} (Guj-247) by following Line x Tester mating design to produce 44 crosses in *kharif* 2009-10. These 44 crosses were grown in Randomized block design in three replications with the spacing of 120 cm x 45 cm. Fifteen parents and a standard check hybrid G. Cot Hy. 12 were also raised in three replications adjacent to the crosses for the estimation of heterosis. Recommended package of practices were followed to raise a good crop. The data were recorded on randomly selected plants from each genotype on seven characters viz., days to 50 % flowering, plant height, number of monopodia plant^{-1}, number of sympodia plant $^{-1}$, total number of bolls

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plant $^{-1}$, average boll weight and seed cotton yield plant $^{-1}$. Line x Tester mating design was used given by Kempthorne (1957) with fixed effect model (Model I) of Eisenhart (1947). The analysis of variance for the experimental design was analysed by the method given by Panse and Sukhatme (1978).

RESULTS AND DISCUSSION

The results of analysis of variance are presented in table 1. Considerable variability exhisted among the genotypes for all the characters studied as observed from the significant mean squares due to genotypes. The mean squares due to parents and crosses were found to be highly significant for all the seven characters. Mean squares due to parents v/s hybrids were also significant for all the traits except for plant height thereby suggesting differences between parents and hybrids and possibility of heterotic effects for some of the characters. Similar results were found by Ashokkumar and Ravikesavan (2008).

The utility of heterosis breeding approach lies in the identification of most heterotic and useful cross combinations in order to develop well adapted commercial hybrid. In the present investigation, the heterosis has been estimated over better parents and standard check hybrid G.Cot Hy.-12 for the traits under study. Thus, the aim of heterosis analysis in the present study was to identify promising hybrids which may give high degree of useful (economic) heterosis and characterization of parents for their prospects for future use in breeding programme.

On the basis of *per se* performance (Table 2) studied for yield and yield contributing characters among 44 crosses along with check G.Cot Hy.-12, the cross BC 68-2 x MCU 11 was identified as superior cross as it performed significantly superior over check G.Cot Hy.-12 for seed cotton yield plant $^{-1}$ (480.33g), total number of bolls plant^{-1} (118.67), average boll weight (5.29 g). This was followed by the cross BC 68-2 x AC 738 which performed significantly superior over check G.Cot Hy.-12 for seed cotton yield plant $^{-1}$ (477.67 g), total number of bolls plant $^{-1}$ (111.80), average boll weight (5.19 g) and the cross BN 1 x Riba B-50 exhibited significant superiority for grain yield plant^{-1} (467.67 g) and average boll weight (5.37g). These three crosses were identified as potential crosses for exploiting heterosis on the basis *per se* performance.

The expression of heterosis was worked out for all the characters over better parents and standard check and are presented in (Table 2). Negative heterosis for days to first flowering is a desirable feature as it confers earliness. Hybrid 76 IH-20 x MCU 11(-15.26) recorded the highest negative heterobeltiosis for days to 50 per cent flowering. Hybrid BC-68-2 x Khandwa 2 recorded maximum heterobeltiosis(32.95) for plant height. Heterobeltiosis for number of monopodia plant $^{-1}$ was highest for hybrid G. Cot-16 x Riba-B-50 (25.71). Hybrid 76 IH-20 x Guj-247 (50.00) exhibited significant and positive heterobeltiosis for number of sympodia plant $^{-1}$. For the trait, total number of bolls plant^{-1} hybrid BC-68-2 x AC 738 showed significantly higher heterobeltiosis (49.60). Hybrid BC-68-2 x MCU 11 (44.97) recorded maximum heterobeltiosis for average boll weight. The heterotic response over better parent in cotton was also reported by Singh and Narayanan (1990), Khan *et al*., (2003) and Ganpathy and Nadarajan (2008).

Seed cotton yield plant $^{-1}$ is very important attribute which the breeder attempt to improve by evolving high yielding hybrids. Hybrids BC-68-2 x AC 738 and BC-68-2 x MCU 11 recorded significant and positive heterobeltiosis (104.78) and standard heterosis (14.55 %) over check G. Cot. Hy.12, respectively. Similar to the above results Muthu *et al*. (2005), Verma *et al*. (2006) and Ashokkumar and Ravikesavan (2008) also reported positive significant and standard heterotic effect for seed cotton yield.

Among the 44 hybrids evaluated, hybrid 76 IH-20 x AC 738 exhibited significant negative heterosis (-21.14 %) over G. Cot Hy.12 for days to 50 per cent flowering. For plant height, BC-68-2 x Khandwa 2 (31.27 %) showed significant positive standard heterosis over standard check. None of the hybrids had significant positive standard heterosis for number of monopodia plant $^{-1}$. Hybrids 76 IH-20 x Guj-247 (50.00 %) and BC-68-2 x MCU 11 (31.86 %) recorded significant positive standard heterosis over standard check for number of sympodia plant $^{-1}$ and total number of bolls plant $^{-1}$, respectively. For average boll weight, hybrid BN 1 x Riba-B-50 exhibited significant and positive heterosis (30.34 %)

Table 1. Analysis of variance for experimental design

Source of variation	d.f.	Days to 50 % flowering	Plant height(cm)	Number of monopodia plant $^{-1}$	Number of sympodia plant $^{-1}$	Total no. of bolls plant $^{-1}$	Average boll weight (g)	Seed cotton yield plant $^{-1}$ (g)
Replications	2	0.42	62.98	0.16	2.56	48.13	0.01	260.65
Genotypes	59	50.71**	1318.47**	0.69**	50.20**	682.79**	0.97**	18815.66**
Parents (P)	14	39.78**	716.98**	0.82**	18.81**	328.98**	0.33**	4448.85**
Females (F)	3	25.44**	1944.64**	0.727**	7.60	344.55**	0.39**	6939.07**
Males (M)	10	46.98**	414.85**	0.93**	23.13**	340.20**	0.27**	3400.03**
F Vs M	1	10.76*	55.31	0.06	9.20	170.09	0.77**	7466.62**
Hybrids (H)	43	54.42**	1566.40**	0.57**	49.58**	787.73**	1.02**	20739.96**
P Vs H	1	36.20**	33.00	3.11**	539.40**	1253.59**	8.53**	112228.00**
Checks Vs Hybrids	1	65.55**	337.45	1.61**	11.82	431.62*	0.04	33674.15**
Error	118	2.02	90.55	0.06	4.40	73.762	0.03	449.34

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

Table 2. Heterosis over better parents and standard hybrid for various characters in *G. hirsutum* L.

Hybrids	Days to 50 % flowering			Plant height (cm)			Number of monopodia plant $^{-1}$		
	Mean	HB	SH	Mean	HB	SH	Mean	HB	SH
L_1 x T_1	64.00	4.92**	-1.04	152.33	-22.93**	-8.40	1.50	-45.12**	-52.08**
L_1 x T_2	55.00	-9.84**	-14.95**	195.63	-1.03	17.64**	2.23	-44.17**	-28.65**
L_1 x T_3	58.33	-1.69	-9.80**	174.80	-11.57**	5.11	2.83	23.19**	-9.48
L_1 x T_4	59.33	7.23**	-8.25**	117.33	-40.64**	-29.44**	2.47	1.37	-21.19**
L_1 x T_5	56.00	-8.20**	-13.41**	169.67	-14.17**	2.02	2.93	25.71**	-6.28
L_1 x T_6	54.00	-11.48**	-16.50**	137.70	-30.34**	-17.20**	3.27	24.05**	4.37
L_1 x T_7	56.00	-8.20**	-13.41**	185.00	-6.41	11.24*	2.23	-17.28*	-28.65**
L_1 x T_8	62.67	2.73	-3.10	168.37	-14.82**	1.24	2.53	-2.56	-19.06**
L_1 x T_9	59.33	4.71*	-8.25**	167.40	-15.31**	0.66	2.60	-3.70	-16.93**
L_1 x T_{10}	52.67	-4.24*	-18.56**	173.43	-12.26**	4.29	2.23	-30.21**	-28.65**
L_1 x T_{11}	55.00	-9.84**	-14.95**	149.83	-24.20**	-9.90*	2.60	13.04	-16.93**
L_2 x T_1	61.67	9.47**	-4.64**	157.33	-13.46**	-5.39	2.63	-21.00**	-15.87*
L_2 x T_2	63.33	12.43**	-2.07	194.13	4.09	16.74**	2.70	-32.50**	-13.74*
L_2x T_3	60.67	7.69**	-6.19**	195.90	25.18**	17.80**	3.13	-6.00	0.11
L_2x T_4	62.00	12.05**	-4.13*	181.00	-2.62	8.84	2.73	-18.00**	-12.67*
L_2x T_5	64.67	14.79**	-0.01	210.00	15.53**	26.28**	2.37	-29.00**	-24.39**
L_2x T_6	63.67	13.02**	-1.55	218.30	32.95**	31.27**	2.20	-34.00**	-29.71**
L_2x T_7	64.00	13.61**	-1.04	167.27	-10.23*	0.58	2.20	-34.00**	-29.71**
L_2x T_8	63.00	11.83**	-2.58	195.17	15.10**	17.36**	2.80	-16.00**	-10.54
L_2x T_9	63.67	13.02**	-1.55	191.53	-2.23	15.17**	2.20	-34.00**	-29.71**
L_2x T_{10}	65.67	19.39**	1.54	195.73	14.37**	17.70**	2.43	-27.00**	-22.26**
L_2 x T_{11}	59.67	5.92**	-7.74**	197.97	6.41	19.04**	2.23	-33.00**	-28.65**
L_3 x T_1	60.33	0.56	-6.71**	172.50	-10.84**	3.73	2.80	-6.67	-10.54
L_3x T_2	60.00	0.00	-7.22**	196.67	1.65	18.26**	2.47	-38.33**	-21.19**
L_3x T_3	66.33	11.80**	2.57	198.00	2.34	19.06**	2.80	-6.67	-10.54
L_3x T_4	64.00	15.66**	-1.04	155.87	-19.43**	-6.27	2.63	-12.22	-15.87*
L_3x T_5	61.33	2.22	-5.16**	200.23	3.50	20.40**	2.77	-7.78	-11.61
L_3x T_6	54.00	-10.00**	-16.50**	187.37	-3.15	12.67**	3.20	6.67	2.24
L_3x T_7	62.33	3.89*	-3.61*	176.53	-8.75*	6.15	2.57	-14.44*	-18.00**
L_3x T_8	56.00	-6.67**	-13.41**	195.87	1.24	17.78**	2.40	-20.00**	-23.32**
L_3x T_9	53.00	-6.47**	-18.05**	178.30	-8.98*	7.22	2.60	-13.33*	-16.93**
L_3x T_{10}	62.33	13.33**	-3.61*	166.97	-13.70**	0.40	2.47	-22.92**	-21.19**
L_3 x T_{11}	64.00	6.67**	-1.04	138.03	-28.65**	-17.00**	2.00	-33.33**	-36.10**
L_4 x T_1	61.67	-2.63	-4.64**	127.63	-29.79**	-23.25**	1.53	-43.90**	-51.01**
L_4x T_2	53.67	-15.26**	-17.01**	193.27	3.63	16.22**	2.20	-45.00**	-29.71**
L_4x T_3	51.00	-14.04**	-21.14**	195.30	13.86**	17.44**	1.47	-38.89**	-53.14**
L_4x T_4	52.00	-6.02**	-19.59**	156.03	-16.05**	-6.17	1.73	-28.77**	-44.62**
L_4x T_5	61.00	-3.68*	-5.67**	195.53	7.57	17.58**	2.47	2.78	-21.19**
L_4x T_6	62.67	1.08	-3.10	201.73	17.61**	21.31**	2.20	-16.46*	-29.71**
L_4x T_7	65.67	3.68*	1.54	187.93	0.86	13.01**	2.20	-18.52*	-29.71**
L_4x T_8	63.67	0.53	-1.55	147.37	-14.09**	-11.39*	1.73	-33.33**	-44.62**
L_4x T_9	56.67	0.00	-12.38**	165.80	-15.36**	-0.30	1.50	-44.44**	-52.08**
L_4x T_{10}	57.67	4.85*	-10.83**	160.83	-6.24	-3.29	2.20	-31.25**	-29.71**
L_4 x T_{11}	63.67	0.53	-1.55	195.53	5.11	17.58**	2.20	-8.33	-29.71**
S.Ed. (±)	**0.82**	**1.16**	**1.16**	**5.49**	**7.81**	**7.81**	**0.15**	**0.20**	**0.20**

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

Table 2 Contd….

Hybrids	Number of sympodia plant $^{-1}$			Total number of bolls plant $^{-1}$			Average boll weight (g)		
	Mean	HB	SH	Mean	HB	SH	Mean	HB	SH
L_1 x T_1	16.33	-20.71*	-32.87**	46.20	-37.88**	-48.67**	3.83	-4.73	-7.04*
L_1 x T_2	29.13	41.42**	19.74**	67.40	-30.80**	-25.11**	3.92	7.21	-4.85
L_1 x T_3	27.07	31.39**	11.25	83.87	12.22	-6.81	4.05	10.86**	-1.70
L_1 x T_4	17.13	-23.96**	-29.58**	48.20	-35.56**	-46.44**	4.22	15.51**	2.43
L_1 x T_5	24.60	19.42*	1.11	79.13	5.14	-12.08	3.77	3.19	-8.50*
L_1 x T_6	20.60	0.00	-15.33*	59.67	-19.77*	-33.70**	3.56	-2.65	-13.59**
L_1 x T_7	24.33	18.12*	0.01	87.27	17.35	-3.03	3.93	6.02	-4.61
L_1 x T_8	21.87	3.47	-10.12	65.00	-21.69**	-27.78**	4.26	11.43**	3.40
L_1 x T_9	26.93	30.74**	10.70	67.47	-9.28	-25.03**	3.99	-1.32	-3.16
L_1 x T_{10}	28.67	39.16**	17.82*	57.73	-22.37*	-35.86**	4.36	6.96*	5.83
L_1 x T_{11}	20.70	0.49	-14.92*	77.93	3.31	-13.41	4.01	9.76*	-2.67
L_2 x T_1	16.13	-20.39*	-33.69**	74.37	19.69	-17.37*	4.64	15.60**	12.62**
L_2 x T_2	26.97	33.06**	10.84	118.67	21.83**	31.86**	5.29	44.97**	28.40**
L_2x T_3	28.67	41.45**	17.82*	111.80	49.60**	24.22**	5.19	42.41**	25.97**
L_2x T_4	22.60	0.30	-7.11	86.27	15.33	-4.14	4.64	27.33**	12.62**
L_2x T_5	17.93	-11.51	-26.29**	103.80	37.91**	15.33*	5.03	38.03**	22.09**
L_2x T_6	17.33	-14.47	-28.76**	61.33	-9.09	-31.86**	5.10	39.85**	23.79**
L_2x T_7	17.53	-13.49	-27.94**	61.00	1.78	-32.22**	4.76	28.30**	15.53**
L_2x T_8	26.33	24.61**	8.23	74.47	-10.28	-17.26*	4.73	23.82**	14.81**
L_2x T_9	21.00	3.62	-13.69	68.17	5.74	-24.26**	4.81	18.88**	16.75**
L_2x T_{10}	26.13	28.95**	7.41	73.43	8.63	-18.41*	3.55	-12.85**	-13.83**
L_2 x T_{11}	27.73	36.84**	13.99*	99.27	31.60**	10.30	4.66	27.70**	13.11**
L_3 x T_1	16.33	-8.58	-32.87**	54.73	-31.92**	-39.19**	4.66	10.51**	13.11**
L_3x T_2	20.00	3.81	-17.80*	76.27	-21.70**	-15.26*	4.22	0.16	2.43
L_3x T_3	20.37	13.99	-16.29*	90.07	12.02	0.08	3.40	-19.29**	-17.48**
L_3x T_4	19.63	-12.87	-19.30**	82.00	1.99	-8.89	3.21	-23.87**	-22.09**
L_3x T_5	22.73	27.24**	-6.56	93.00	15.67	3.33	5.37	27.27**	30.34**
L_3x T_6	18.80	5.22	-22.73**	94.00	16.92*	4.44	3.32	-21.34**	-19.42**
L_3x T_7	20.97	11.13	-13.82*	85.00	5.72	-5.56	3.69	-12.57**	-10.44**
L_3x T_8	22.97	8.68	-5.60	97.00	16.87*	7.78	5.12	21.50**	24.27**
L_3x T_9	17.70	-10.91	-27.25**	89.33	11.11	-0.74	4.83	14.62**	17.23**
L_3x T_{10}	16.33	-8.58	-32.87**	73.40	-8.71	-18.44*	3.59	-14.78**	-12.86**
L_3 x T_{11}	15.60	-19.86*	-35.88**	58.73	-26.95**	-34.74**	3.34	-20.87**	-18.93**
L_4 x T_1	22.53	28.52**	-7.38	63.67	2.25	-29.26**	3.87	-10.63**	-6.07
L_4x T_2	22.13	14.88	-9.03	75.27	-22.72**	-16.37*	3.99	-7.78*	-3.16
L_4x T_3	24.47	39.54**	0.56	72.73	-2.68	-19.19*	4.02	-7.09*	-2.43
L_4x T_4	21.10	-6.36	-13.28	72.07	-3.65	-19.92**	3.70	-14.41**	-10.19**
L_4x T_5	24.20	38.02**	-0.53	76.93	2.21	-14.52	4.20	-2.93	1.94
L_4x T_6	24.43	39.35**	0.42	68.33	1.28	-24.08**	4.75	9.71**	15.29**
L_4x T_7	26.13	38.52**	7.41	72.07	15.74	-19.92**	4.01	-7.40*	-2.67
L_4x T_8	27.53	30.28**	13.17	85.23	2.69	-5.30	3.99	-7.86*	-3.16
L_4x T_9	21.53	8.39	-11.49	77.00	19.44	-14.44	4.11	-5.01	-0.24
L_4x T_{10}	21.90	24.90	-9.99	95.20	40.83**	5.78	4.16	-3.78	0.97
L_4 x T_{11}	29.20	50.00**	20.02**	101.80	34.95**	13.11	5.03	16.18**	22.09**
S.Ed. (±)	**1.21**	**1.71**	**1.71**	**4.96**	**6.81**	**6.81**	**0.11**	**0.14**	**0.14**

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

Table 2 Contd….

Hybrids	Seed cotton yield plant^{-1} (g)		
	Mean	HB	SH
L_1 x T_1	150.62	-45.34**	-64.08**
L_1 x T_2	273.29	-4.28	-34.83**
L_1 x T_3	288.98	4.88	-31.09**
L_1 x T_4	189.46	-31.24**	-54.82**
L_1 x T_5	264.42	-4.03	-36.94**
L_1 x T_6	209.87	-23.83**	-49.95**
L_1 x T_7	331.36	20.26**	-20.98**
L_1 x T_8	241.02	-20.33**	-42.52**
L_1 x T_9	308.48	11.95	-26.44**
L_1 x T_{10}	233.53	-18.17**	-44.31**
L_1 x T_{11}	327.83	18.98**	-21.82**
L_2 x T_1	314.11	35.34**	-25.09**
L_2 x T_2	480.33	68.24**	14.55**
L_2 x T_3	477.67	104.78**	13.91**
L_2 x T_4	388.41	54.91**	-7.37
L_2 x T_5	410.00	63.93**	-2.22
L_2 x T_6	334.72	46.29**	-20.18**
L_2 x T_7	285.77	34.27**	-31.85**
L_2 x T_8	370.86	22.58**	-11.56*
L_2 x T_9	336.87	39.37**	-19.66**
L_2 x T_{10}	263.77	-7.58	-37.10**
L_2 x T_{11}	423.37	98.36**	0.96
L_3 x T_1	228.05	-30.79**	-45.62**
L_3 x T_2	366.83	11.32*	-12.52**
L_3 x T_3	294.27	-10.70*	-29.82**
L_3 x T_4	210.73	-36.05**	-49.75**
L_3 x T_5	467.67	41.92**	11.53*
L_3 x T_6	312.18	-5.26	-25.55**
L_3 x T_7	260.86	-20.84**	-37.79**
L_3 x T_8	444.33	34.84**	5.96
L_3 x T_9	299.54	-9.10	-28.57**
L_3 x T_{10}	252.78	-23.29**	-39.72**
L_3 x T_{11}	190.70	-42.13**	-54.52**
L_4 x T_1	262.28	-7.97	-37.45**
L_4 x T_2	252.19	-11.67*	-39.86**
L_4 x T_3	295.67	3.74	-29.49**
L_4 x T_4	282.84	-0.76	-32.55**
L_4 x T_5	331.14	16.19**	-21.03**
L_4 x T_6	246.53	-13.50*	-41.21**
L_4 x T_7	373.79	31.15**	-10.86*
L_4 x T_8	220.58	-27.09**	-47.40**
L_4 x T_9	404.85	42.05**	-3.45
L_4 x T_{10}	402.11	40.90**	-4.11
L_4 x T_{11}	431.67	51.46**	2.94
S.Ed. (±)	**12.24**	**16.95**	**16.95**

over standard check. The significant positive standard heterosis over standard check cotton hybrid were also reported by Patil *et al*. (2012), Balu *et al*. (2012).

The overall study of heterosis and *per se* performance indicated that the hybrid combinations like BC-68-2 x MCU 11, BC-68-2 x AC 738 and BN 1 x Riba B-50 were found to be outstanding in respect of seed cotton yield plant $^{-1}$ and important yield contributing traits like plant height, total number of bolls plant $^{-1}$ and average boll weight. These may be exploited commercially after critical evaluation for its superiority in performance with stability across the location over years.

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Rec on 20.10.2011 & Acc. on 27.12.2011

J. Soils and Crops 22 (2) 321-326, Dec., 2012 ISSN 0971-2836

EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON YIELD ATTRIBUTES, YIELD AND QUALITY OF SOYBEAN (*Glycine max* (L.) Merill)

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ABSTRACT

A field experiment was conducted during the rainy season of 2009 at the Research Farm, Department of Agronomy, College of Agriculture, Latur to study the effect of integrated nutrient management in soybean (*Glycine max* (L.) Merill) on its yield attributes, seed yield and quality attributes. The treatments studied were *viz.,* 100 % recommended dose of nitrogen, phosphorus and potassium (30:60:30 kg NPK ha^{-1}), 75% NPK + *Rhizobium*, 75 % NPK + Phosphorus solubilizing biofertilizer (PSB), 75 % NPK + Farm yard manure (FYM) @ 5 t ha^{-1}, 75% RDF + *Rhizobium* + PSB, 75% RDF + *Rhizobium* + PSB + FYM @ 5 t ha^{-1}and *Rhizobium* + PSB + FYM @ 5 t ha^{-1}. Application of *Rhizobium* and PSB was done @ 25 g kg^{-1} of seed . The application of 75% NPK with FYM and biofertilizers *Rhizobium* and PSB showed superiority for pod yield plant^{-1}, seed yield plant^{-1}, 100 seed weight, seed yield, protein and oil yield in soybean seed over all other treatments except the sole application of recommended NPK level i.e. 100% NPK which was at par with the treatment. Maximum seed yield, straw yield and biological yield were observed at 75 per cent RDF applied with *Rhizobium,* PSB and FYM at 5 t ha^{-1}(T_7). This treatment was found on par with application of 100 per cent RDF(T_2) and 75 per cent RDF applied with FYM @ 5 t ha^{-1} (T_5) and was found significantly superior over rest of the treatments including control (T_1). The highest harvest index was observed when 100 per cent RDF (T_2) was applied to soybean crop and lowest was observed in control (T_1) treatment. Thus, the combined use of manures and inorganic fertilizer along with biofertilizers played a significant role in increasing yield attributes, yield and quality of soybean.

(Key words : Integrated nutrient management, yield, quality, soybean)

INTRODUCTION

A wonder crop soybean (*Glycine max* (L.) Merill) is a leguminous crop and belongs to family leguminoaceae with sub family papillionaceae. Soybean is originated in China and it is introduced in India in recent years. It is basically a pulse crop but gained the importance as an oilseed crop as it contains 20 per cent cholesterol free oil. In India, the area under soybean cultivation during 2009-10 was 96.7 lakh hectare with total production of 97.2 lakh metric tonne with an average productivity of 1006 kg hectare^{-1} resulting in about 10.1 per cent decline in production as compared to production in 2008-2009 due to late arrival of monsoon in *kharif* 2009-2010. Average consumption of soybean in India is 4812 thousand metric tonne gaining the sixth rank in largest consumer of soybean in world (Anonymous, 2010).

Organic matter forms a very important source of plant nutrients. They used to supply both macro and micronutrients to crop plant. Use of organic manures improves the physical, chemical and biological conditions of the soil but they sustain the soil fertility at low level of production and can not be considered as the alternative to mineral fertilizers. Mineral fertilizers are commonly used to supply major plant nutrients and higher yields can not be obtained without use of these fertilizers. But the continuous use of mineral fertilizers destroyed the soil structure, turned the soil acidic and brought about nutrient imbalances in soil.

Biofertilizers are commonly called as microbial inoculants *Rhizobium* and PSB inoculants helps to increase yield of legume crop by fixing atmospheric nitrogen in root nodules of legume crop and by converting the insoluble phosphate into soluble form respectively. *Rhizobium* inoculant is recommended to ensure adequate nodulation and N_2 fixation for maximum growth and yield of pulse crop. Biological nitrogen fixation offers an economically attractive and ecologically sound means of reducing external inputs and improving the quality and quantity of internal resources of nitrogen. In soybean, nitrogen fixation is through a symbiotic association between the bacteria of the genus *Bradyrhizobium* and soybean crop. It is estimated that the nitrogen fixed by soybean crop ranges between 49-450 kg nitrogen hectare^{-1}. Though the biofertilizers helps to provide nutrient elements to crop plants, these can not replace the mineral fertilizers. Application of organic manures alone sustain the fertility of soil but are unable to fulfill the increasing food demands of

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growing population, whereas application of mineral fertilizers alone helps to get higher yields but they can not sustain the fertility of soil on a long term basis. Also the fertilizer use efficiency is low in all mineral fertilizers and organic manures when used separately or alone. So to overcome all these constraints 'Integrated Nutrient Management' is the best approach to adopt (Prasad, 1996; Singh and Dwivedi, 1996).

Integrated nutrient management is basically the complementary use of organic, inorganic and biological sources of plant nutrients to maintain and sustain soil fertility and enhance crop productivity in a framework of an ecologically compatible, socially acceptable and economically viable situation. Combined use of organic manures and mineral fertilizers increases fertilizer use efficiency, cation retention and nutrient availability. It results in higher return to investment and better cost:benefit ratios without deteriorating the fertility of soil. There is a substancial increase in command area of soybean in last two to three decades and thereby intensive cropping. It has resulted in increase in cost of fertilizers. Low purchasing power of farmers has restricted the use of fertilizer for increasing crop production. Under such conditions; it is essential to use all the available resources of plant nutrients in a judicious way to minimize fertilizer use and at the same time to sustain soil fertility and productivity on a long term basis. Therefore, efficient management of organic and inorganic sources with biofertilizers is a prerequisite for achieving continuous productivity of crops in an economically and ecologically sustainable manner. Hence, the present investigation was undertaken to study the effects of judicious and combined use of inorganics (N, P and K), organic (FYM) and biofertilizers (*Rhizobium* and PSB) on yield attributes, yield and quality of soybean.

MATERIALS AND METHODS

The present field experiment was conducted during *kharif* season of 2009-2010 at the Experimental Farm, Agronomy Section, College of Agriculture, Latur (Maharashtra). The experiment was laid out in Randomized Block Design (RBD) with eight treatments *viz.,* no fertilizer and manure (T_1), 100 per cent NPK through fertilizer (T_2), 75 % NPK + *Rhzobium* (T_3), 75 % NPK + PSB (T_4), 75% NPK + FYM @ 5 t ha^{-1} (T_5), 75% NPK + *Rhizobium* + PSB (T_6), 75% NPK + *Rhizobium* + PSB + FYM @ 5 t ha^{-1} (T_7) and *Rhizobium* + PSB + FYM @5t ha^{-1}(T_8) with three replications. The recommended dose of N : P_2O_5 : K_2O (100% RDF) used for soybean were 30 : 60 : 30 kg ha^{-1}. Entire dose of nitrogen, phosphorus and potassium were applied at sowing through urea, single super phosphate and muriate of potash, respectively. Application of *Rhizobium* and PSB was done @ 25 g kg^{-1} of seed .The FYM was also spread uniformly and mixed immediately in the soil as per treatment in the required plots fifteen days prior to the sowing date

Soybean (MAUS-71) was sown at 45 cm x 5 cm spacing in first week of July during *kharif* and harvested at 93 days in first week of October. The plants selected for biometric observations were used for generating the data on yield attributes *viz.,* seed yield $plant^{-1}$ and 100 seed weight. For seed yield the plants from each net plot were harvested and threshed and seeds were cleaned by winnowing and weight of seed net $plot^{-1}$ was recorded. Weight of sun dried total biological yield from each net plot was recorded before threshing . The seed weights were subtracted from total biological yield and remaining weights were counted as straw yield. Biological yield was calculated by sum of seed yield and straw yield. The Harvest Index (HI) was calculated by dividing seed yield with biological yield. Oil content in soybean seed as estimated by Nuclear Magnetic Resonance (NMR) instrument at Agriculture research station, Raichur Karnataka (Anonymous, 2005). Nitrogen percentage was estimated by micro kjeldhal method (Anonymous, 1975), protein percentage of seed was estimated by multiplying the nitrogen percentage by 6.25.

Data obtained on various variables were analysed by analysis of variance method (Panse and Sukhatme, 1967). The total variance (S_2) and degree of freedom (n-1) were partitioned into different possible sources. The variance due to various treatments of fertilizer application along with biofertilizers were compared with error of variance to find out 'F' values and ultimately for testing the significance at p = 0.05. The standard error for the treatment based on error variance were calculated. Whenever, the results were found to be significant, critical differences were also calculated for comparison of treatment means at 5 per cent level of significance (CD at P = 0.05).

RESULTS AND DISCUSSION

Yield attributes :

Data on yield contributing characters *viz.,* pod yield plant^{-1} (g), seed yield plant^{-1} (g) and 100 seed weight (g) are presented in table 1. It is seen from table 1 that the average pod yield plant^{-1}, seed yield plant^{-1} and 100 seed weight were 17.47, 14.02 and 119.41 g, respectively. The highest pod yield plant^{-1} (20.25 g), seed yield plant^{-1} (16.12 g) and 100 seed weight (121.67 g) were recorded when 75 per cent NPK applied along with *Rhizobium*, PSB and FYM @ 5 t ha^{-1} (T_7) to soybean crop. This treatment was found at par with the 100 per cent NPK application (T_2) and 75 per cent NPK with FYM @ 5 t ha^{-1} (T_5) and was significantly superior over rest of the treatments including control also. Application of 75 % NPK + *Rhzobium* (T_3), 75 % NPK + PSB (T_4) and 75% NPK + *Rhizobium* + PSB (T_6) were also found significantly superior over control in case of yield attributing characters. Alam *et al*. (2010) observed similar results. They reported that integrated nutrient management with application of recommended doses of urea, TSP, MOP, Gypsum and biofertilizer (Brady*rhizobium*) significnalty increased most of the parameters in soybean, such as plant height, number of nodules plant^{-1}, nodules dry weight plant^{-1}, pods plant^{-1}, grains pod^{-1} and grain yield.

Yield :

Data on seed yield, straw yield, biological yield and harvest index as influenced by different treatments are presented in table 2. It is observed from the table 2 that the mean seed yield, straw yield, biological yield and harvest index were 1479.5, 2412.8, 3892.2 kg and 37.92 respectively

The lowest seed, straw, biological yield and harvest index was observed in control treatment. The data also showed that the application of 75% NPK + *Rhizobium* + PSB + FYM @ 5 t ha^{-1} (T_7) to soybean crop produced significantly higher seed yield (1742 kg ha^{-1}), straw yield (2762 kg ha^{-1}) and biological yield (4504 kg ha^{-1}) over rest of the treatments except treatments with 100 per cent NPK (T_2) and 75% NPK + FYM @ 5 t ha^{-1} (T_5). Application of 75 % NPK + *Rhzobium* (T_3), 75 % NPK + PSB (T_4) and 75% NPK + *Rhizobium* + PSB (T_6) were also found significantly superior over control in case of seed, straw , biological yield and harvest index. Vidyavathi *et al*. (2011) observed similar results. They reported that integrated nutrient management practices recorded significantly higher uptake of N, P and K by the *kharif* and *rabi* crops when compared to inorganic and organic nutrient management practices. The response of crops to integrated nutrient management was due to higher availability of these nutrients in soil reservoir which contributed to higher yield of *kharif* and *rabi* crops ultimately. Data on harvest index presented in table 2 revealed that the highest harvest index was observed in treatment when 100 % NPK (T_2) was applied to soybean crop and lowest was recorded when there was no manure and fertilizer application. Singh *et al.,* (2005) revealed similar results. They reported that sole or dual inoculation of soybean with biofertilizer, application of FYM and recommended dose of fertilizer (RDF) significantly increased the plant growth, nodulation, seed and straw yields as well as N and K uptake over the control.

Quality attributes :

Data on protein content, protein yield, oil content and oil yield are presented in table 3 showed that the application of 100 % NPK (T_2) recorded highest per cent protein content (40.27%) and oil content (21.09%) in soybean seed and this treatment was found significantly superior over rest of the treatments except treatment 75 per cent NPK + *Rhizobium* + PSB + FYM @ 5 t ha^{-1} (T_7). This treatment produced higher protein yield (697 kg ha^{-1}) and oil yield (366 kg ha^{-1}) due to higher seed yield ha^{-1} though its oil content and protein content was less than 100 % NPK treatment. Aziz *et al*. (2011) observed similar results. They reported that the lysine content in soybean was found superior with application of 75 per cent recommended inorganic fertilizers over other levels, linoleic acid content increased with increasing levels of recommended inorganic fertilizers. Dual inoculation with *rhizobium* + PSB showed significantly superior seed quality over control.

Over all, the combined use of manures and inorganic fertilizes with biofertilizers played a significant role in increasing the yield attributes, yield and quality attributes of soybean crop.

Table 1. Pod yield plant^{-1} (g), seed yield plant^{-1} (g), 100 seed weight (g) as influenced by different treatments

Treatments	Pod yield plant^{-1} (g)	Seed yield plant^{-1} (g)	100 seed weight (g)
T_1- Control	12.04	10.24	117.23
T_2- 100 % NPK (30:60:30 kg ha^{-1})	19.86	15.78	121.36
T_3- 75 % NPK + *Rhizobium*	18.19	14.47	118.96
T_4- 75 % NPK + PSB	17.78	14.06	118.45
T_5- 75 % NPK+FYM @ 5 t ha^{-1}	19.23	15.24	120.48
T_6- 75 % NPK+ *Rhizobium*+ PSB	18.69	14.89	119.29
T_7- 75 % NPK + *Rhizobium* + PSB + FYM @ 5 t ha^{-1}	20.25	16.12	121.67
T_8- *Rhizobium* + PSB + FYM @ 5 t ha^{-1}	13.79	11.42	117.85
S E ±	0.43	0.36	0.37
C D at 5%	1.29	1.08	1.12
General Mean	17.47	14.02	119.41

Table 2. Seed yield (kg ha^{-1}), straw yield (kg ha^{-1}) and biological yield (kg ha^{-1}) as influenced by different treatments

Treatments	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index
T_1- Control	1023	1743	2766	36.98
T_2- 100 % NPK (30:60:30 kg ha^{-1})	1697	2652	4349	39.02
T_3- 75 % NPK + *Rhizobium*	1514	2502	4016	37.69
T_4- 75 % NPK + PSB	1471	2469	3940	37.33
T_5- 75 % NPK +FYM @ 5 t ha^{-1}	1631	2611	4242	38.44
T_6- 75 % NPK + *Rhizobium*+ PSB	1565	2550	4115	38.03
T_7- 75 % NPK + *Rhizobium* + PSB + FYM @ 5 t ha^{-1}	1742	2762	4504	38.67
T_8- *Rhizobium* + PSB + FYM @ 5 t ha^{-1}	1193	2013	3206	37.21
S E ±	44.10	59.87	100.40	-
C D at 5%	132.36	179.69	301.20	-
General Mean	1479.5	2412.8	3892.2	37.92

Table 3. **Protein content (%), protein yield (kg ha^{-1}), oil content (%) and oil yield (kg ha^{-1}) as influenced by different treatments**

Treatments	Seed yield (kg ha^{-1})	Protein content (%)	Yield of protein (kg ha^{-1})	Oil content (%)	Yield of oil (kg ha^{-1})
T_1- Control	1023	38.15	390	19.95	204
T_2- 100 % NPK (30:60:30 kg ha^{-1})	1697	40.27	683	21.09	357
T_3- 75 % NPK + *Rhizobium*	1514	39.54	598	20.41	309
T_4- 75 % NPK + PSB	1471	39.38	579	20.48	301
T_5- 75 % NPK +FYM @ 5 t ha^{-1}	1631	39.83	649	20.87	340
T_6- 75 % NPK + *Rhizobium*+ PSB	1565	39.76	622	20.64	323
T_7- 75 % NPK + *Rhizobium* + PSB + FYM @ 5 t ha^{-1}	1742	40.05	697	21.02	366
T_8- *Rhizobium* + PSB + FYM @ 5 t ha^{-1}	1193	38.71	462	20.11	239
S E $\pm$	44.10	0.09	-	0.18	-
C D at 5%	132.36	0.27	-	0.55	-
General Mean	1479.50	39.46	585	20.57	304.88

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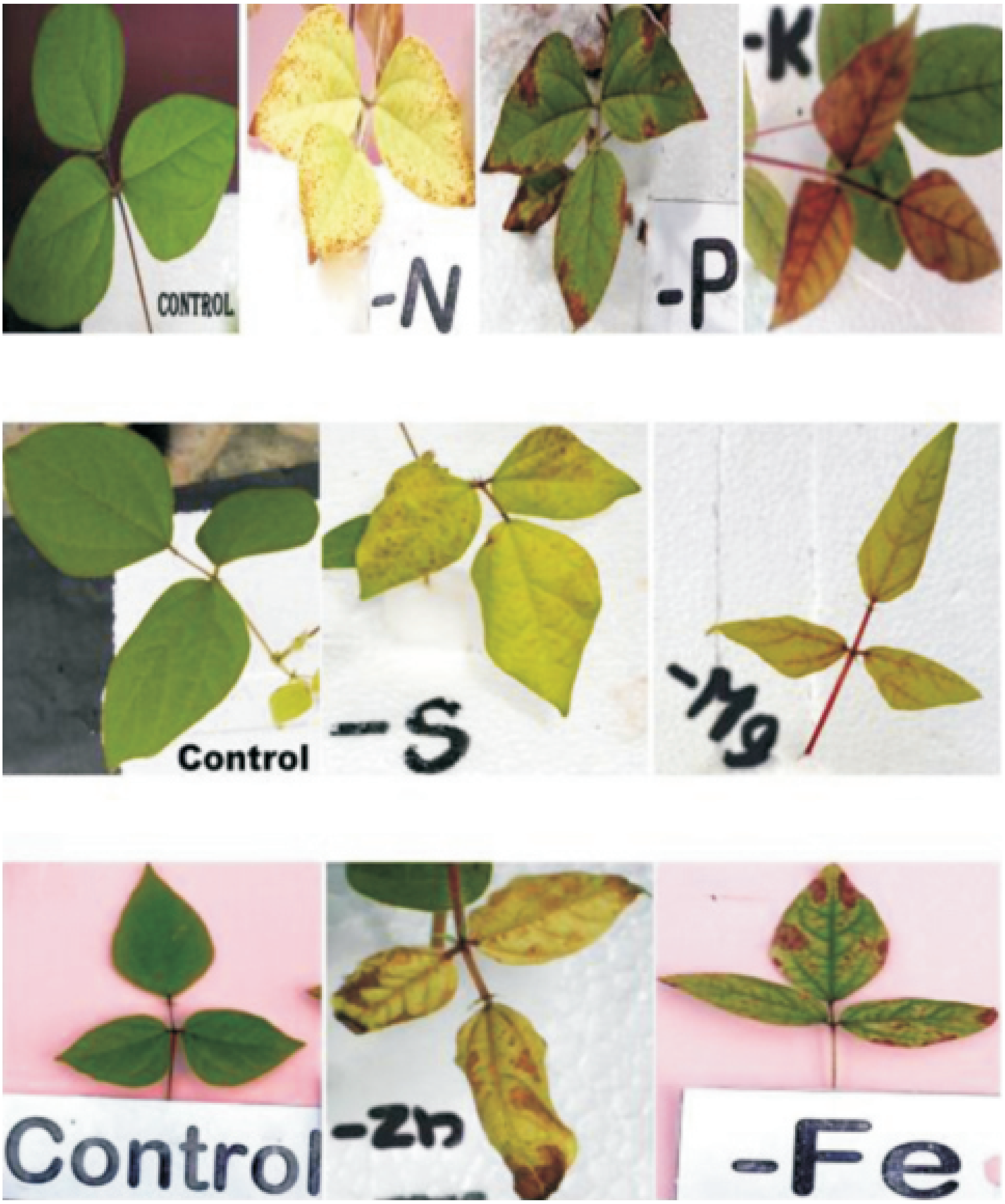
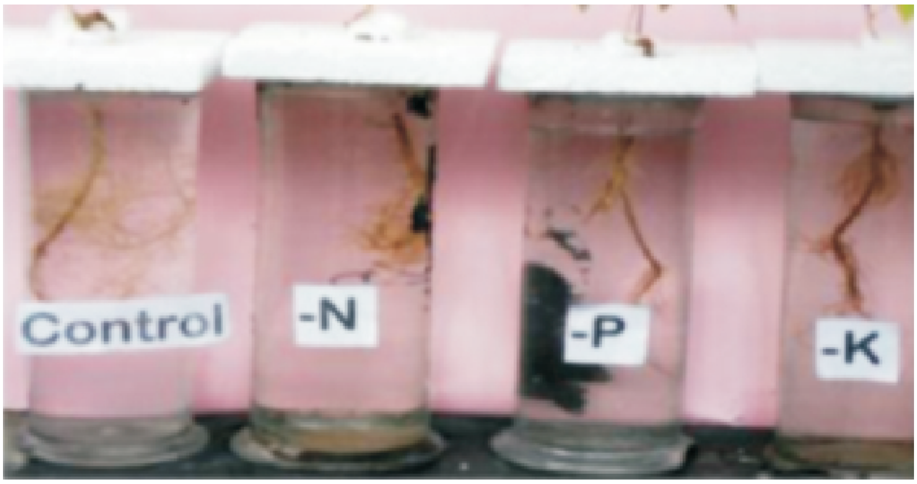
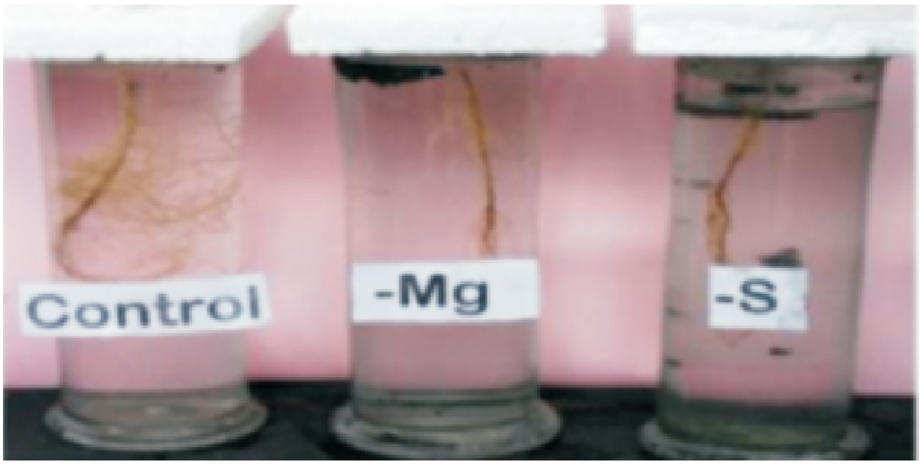


Specific deficiency symptoms of different mineral elements on leaf:

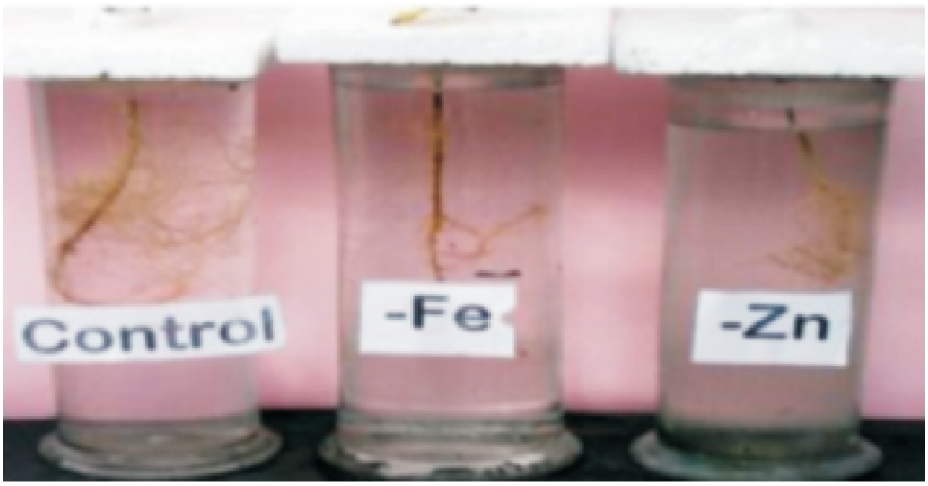
-N: Yellowing, -P : Yellowing with necrotic spots, -K : Firing of leaves, -S : Yellowing of leaves with dull green colour, -Mg : Chlorosis with browning of leaves, -Zn : Curling, Misshape leaves with irregular spots, -Fe : Interveinal chlorosis of leaves.



Effect of deficiency of N,P and K on root growth of green gram



Effect of deficiency of Mg and S on root growth of green gram



Effect of deficiency of Fe and Zn on root growth of green gram

J. Soils and Crops 22 (2) 327-333, Dec., 2012 ISSN 0971-2836

IMPACT OF INTEGRATED NUTRIENT MANAGEMENT ON MICROBIAL POPULATION AND AVAILABILITY OF NUTRIENTS IN *KHARIF* SORGHUM

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ABSTRACT

Studies were undertaken on *kharif* sorghum at Marathwada Agricultural University, Parbhani during year 2005-06 to know the response of FYM, wheat straw, glyricidia and subabul loppings on microbial population and availability of nutrients. The following treatments were tried: Control, 50% RD of NPK, 75% RD of NPK, 100% RD of NPK, 50% RD of NPK + 50% N through FYM, 75% RD of NPK + 25% N through FYM, 50% RD of NPK + 50% N through wheat straw, 50% RD of NPK + 50% N through Subabul, 50% RD of NPK + 50% N through Glyricidia, 75% RD of NPK + 25% N through Glyricidia, Farmers practice 40:20:20 and seeds without treatment, 75% RD of NPK + 25% N through Subabul, 75% RD of NPK + 25% N through wheat straw. The highest bacterial (415) and fungal (57.67) population was recorded with application of 50% RD of NPK + 50% N through FYM in treatment T_5. While the highest population of actinomycets (74.33 x 10^4) was recorded with application of 75% RD of NPK + 25% N through wheat straw. The highest availability of N and P through out the experimentation was found with T_5 only with the application of 50% RD of NPK + 50% N through FYM. The highest values for available potassium at all intervals was found highest in T_8 which received 75% RD of NPK + 25% N through wheat straw.

(Key words: Sorghum, INM, bacteria, fungi, actinomycetes, available N,P and K)

INTRODUCTION

Soil microorganisms exist in large numbers in the soil as long as there is a carbon source for energy. A large number of bacteria in the soil exist, but because of their small size, they have a smaller biomass. Actinomycetes are a factor of 10 times smaller in number but are larger in size so they are similar in biomass to bacteria. Fungus population numbers are smaller but they dominate the soil biomass when the soil is not disturbed. Bacteria and actinomycetes hardy and can tolerate more soil disturbance than fungal populations so they dominate in tilled soils while fungal populations tend to dominate in untilled or no-till soils. Microbes need regular supplies of active SOM in the soil to survive in the soil. Dead plant residues and plant nutrients become food for the microbes in the soil. Soil organic matter (SOM) is basically all the organic substances (anything with carbon) in the soil, both living and dead. SOM includes plants, blue green algae, microorganisms (bacteria, fungi, actinomycetes, etc.) and the fresh and decomposing organic matter from plants, animals and microorganisms.

The abundance of soil microorganisms in nature gives an indication of their possible role in decomposition of organic matter, phosphate solubilization, transformation of nitrogen in nature, humification of organic residues etc. Microorganisms *viz.,* fungi, bacteria and actinomycetes biodegrade the incorporated organic matter in soil for their carbon energy and other nutritional requirements. As a consequence nutrients are made available in soil as long as their supply exceeds the microbiological demand. The activity of soil microflora in mineralization of N is a link in making it available to plants (Rangaswami, 1966). Fe, Mn and S transformed from unavailable to available forms by microbial oxidation and reduction. Soil microbial population a living phase of soil is predominantly influenced by magnitude of soil organic matter in soil and hence quantification of their abundance and the species prevailing determines the over all biological processes and soil health at large. Considering the above facts regarding soil microorganisms and their role in mineralization of nutrients present investigation was undertaken to study the effect of different organic residues on soil microbial population and availability of nutrients.

MATERIALS AND METHODS

The present study was framed to investigate the impact of integrated nutrient management on microorganism population and availability of

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nutrients in *kharif* sorghum, at Marathwada Agricultural University, Parbhani during year 2005-06. The experiment was conducted in survey No.124 block at Central Farm, Marathwada Agricultural University, Parbhani by Cropping System Research Scheme since 1983-1984 (Marathwada lies in the South eastern part of Indian Union). In all there were 13 treatment combinations, involving NPK fertilizers alone and also in combination with FYM, glyricidia, wheat straw and subabul. The treatment details are given in table 1.

Organic sources viz., FYM, wheat straw, glyricidia and subabul leaves were incorporated in soil before sowing of *kharif* crop and chemical fertilizers were applied to sorghum (CSH-9) through straight fertilizers like urea, single super phosphate and muriate of potash at the time of sowing. The method of application of fertilizers adopted was drilling.

To study soil chemical and biological properties surface soil samples (0-15 cm depth) in the bulk were collected from Cropping System Research Farm, Marathwada Agricultural University, Parbhani. The soil was air dried and passed through 2 mm sieve and was then used for further analysis. Chemical composition of organic materials used is mentioned in table 2.

On the basis of their N content (Table 2) the doses of these organic materials were decided. For supplying 50% of N through FYM and wheat straw 6.6 tonnes of FYM and wheat straw was used while for 25% N through FYM and wheat straw 3.3 tonnes of FYM and wheat straw ha^{-1} was used. Similarly 1.1 and 1.9 tonnes of glyricidia leaves and subabul were applied to supply 50% N. While 0.5 and 0.94 tonnes of glyricidia leaves and subabul were applied to supply 25% N.

Available nitrogen was estimated by alkaline $KMnO_4$ method where the organic matter in soil was oxidized with hot alkaline $KMnO_4$ solution. The ammonia (NH_3) evolved during oxidation was distilled and trapped in boric acid mixed indicator solution. The amount of NH_3 trapped was estimated by titrating with standard acid (Subbaiah and Asija, 1956). Available phosphorus was extracted with sodium bicarbonate (0.5 *M*) at pH 8.5 (Olsen's reagent) as described by Olsen *et al*. (1954). Available potassium was extracted with neutral normal ammonium acetate and determined using flame photometer (Jackson, 1967). For isolation of fungi actinomycetes and bacteria from soil three different media were used viz., Rose Bengal Agar Medium for fungi, Yeast extract mannitol Agar for bacteria, Kenknight Medium for actinomycetes. Dilution plate technique was used for isolation and enumeration of soil born fungi, actinomycetes and bacteria as described by Dhingra and Sinclair (1993).

RESULTS AND DISCUSSION

Microbial population:

The microbial counts were taken at harvest of sorghum, which shows that there was positive influence of various integrated nutrient management treatments along with, climatic and soil characteristics. The results revealed that the lowest microorganism population of all the three types of microorganisms was found in the plot without supply of any fertilizer or organic source while the combined effect of organic manures and inorganic fertilizers was found significant by influencing the bacterial population. The highest bacterial and fungal population was recorded with the application of 50% RD of NPK + 50% N through FYM in treatment T_5. This might be due to addition of sufficient organic matter from FYM to the soil surface which helped in multiplication of microbes by maintaining optimum temperature and moisture. Catherine *et al.* (2010) also found that the microbial population and their activity influenced by use of FYM alone and also in combination with chemical fertilizers. Jagathjothi *et al.* (2008) also reported the same findings. They reported that microbial population viz., bacteria, fungi and actinomycetes were enhanced with the addition of integrated use of organics and inorganics after harvest of finger millet. The highest bacteria, fungi and actinomycetes were registered with enriched FYM 2 t ha^{-1} + 100 % of recommended N and K than the application of inorganic fertilizers alone. Manna and Ganguli (2001) reported that incorporation of FYM increased the soil microbial biomass than chemical fertilizers. Shirale (2004) and Badole (2000) also reported maximum bacterial and fungal population with the application of FYM as compared to other organic sources as well as inorganic sources. The highest population of actinomycets (74.33×10^4) was recorded with the application of 75% RD of NPK + 25% N through wheat straw. The higher rate of actinomycetes population in this treatment was mainly attributed to the higher return of organic matter to the soil as a result of straw decomposition. Microbial population in rhizosphere as influenced by high input rates of fertilizer application to sorghum was also studied by Patil and Deshpande (1999). They found that population of fungi, bacteria and actinomycetes were affected significantly with different rates of fertilizer treatments.

Availability of nutrients:

The data on ammoniacal nitrogen (Table 4) revealed that there was increase in ammoniacal nitrogen content of soil from sowing upto 60 days after sowing, and afterwards it declined upto harvest. While the results of nitrate nitrogen revealed that there was continuous decrease in the nitrate nitrogen content of soil during experiment period. The ammoniacal and nitrate nitrogen content of soil at 30 DAS ranged from 11.52 to 26.19 mg kg^{-1} and 9.93 to 14.70 mg kg^{-1} respectively. At 60 DAS, the values ranged from 10.84 to 24.3 mg kg^{-1} and 9.39 to 14.55 mg kg^{-1}. The ammoniacal and nitrate N content of soil ranged from 12.52 to 30.68 mg kg^{-1} and 10.11 to 16.96 mg kg^{-1} at 90 DAS, while it showed its lowest values from 10.62 to 23.82 mg kg^{-1} and 9.00 to 15.11 mg kg^{-1} at the time of harvest. The maximum N content of soil through out the experiment was found in T_5 receiving 50% N through FYM and 50% RD of NPK, while the lowest values were observed in control plot with no fertilizer application. Among inorganic treatments the plot supplying 100% RD of NPK stood first among all inorganic treatments while treatment T_2 supplying 50% RD of NPK gave lowest ammoniacal and nitrate content at all growth stages.

The decreasing trend of NH_4^+-N and NO_3^-- N from sowing to harvest might be due to increased uptake of available N by growing plants as compared to early stage of crop growth. Gupta *et al.* (2000) reported decrease in concentration of NO_3^-- N in soil profile with the increasing crop growth in each of the manuring phase, irrespective of the fertilizer treatment. Pathak (2005) also reported decrease in NH_4^+-N and NO_3^--N concentration at 30, 60, 90 DAS and at harvest of crop.

The data on effect of different INM treatments on periodical availability of phosphorus are given in table 5. The data revealed that there was gradual decrease in the available phosphorus content of soil from 30 DAS upto harvest of sorghum. The available phosphorus ranged from 11.03 to 12.30 mg kg^{-1}, the highest values available P found in T_5 receiving 50% RD of NPK + 50% N through FYM (12.30 mg kg^{-1}). While, it ranged from 10.40 to 12.32 mg kg^{-1} and 10.91 to 12.20 mg kg^{-1} at 60 and 90 DAS respectively. The highest available P was found with T_5 only (50% RD of NPK + 50% N through FYM). The availability of phosphorus decreased from sowing of the crop up to its harvest. At harvest of crop the available phosphorus came to its lowest values. It ranged from 10.28 mg kg^{-1} to 11.44 mg kg^{-1} at the time of harvest. As the plant grows it need for nutrients and this might be the reason behind continuous decrease in the availability of phosphorus from sowing to harvest.

The data of available potassium at harvest of sorghum are presented in table 6. The periodical availability of potassium at 30, 60 and 90 DAS indicated gradual increase. The available potassium at 30 DAS varied significantly from 390.14 to 450.05 kg ha^{-1}. The available potassium content of soil varied from 391.93 to 450.96 kg ha^{-1} at 60 DAS while it was found 393.80 to 449.01 kg ha^{-1} at 90 DAS and at harvest of crop it decreased significantly with range of 401.92 to 449.09 kg ha^{-1}.

The highest values for available potassium at all intervals was found highest in T_8 which received 75% RD of NPK + 25% N through wheat straw followed by treatment T_7 supplied with 50% RD of NPK + 50% N through wheat straw, while, control plot showed lowest availability of potassium at all intervals. Mujiyati (2009) concluded that when manures and fertilizers used for long time to increase the fertility of soil it increases nutrient availability in the soil.

From the above discussion it can be seen that with the application of FYM with inorganic fertilizers increased the microbial population and there by it increased availability of nutrients like nitrogen and phosphorus in the soil. While wheat straw application increased the potassium availability as compared to other treatments. This might be due to mineralization

Table 1. Treatment details

T_1	Control
T_2	50% RD of NPK
T_3	75% RD of NPK
T_4	100% RD of NPK
T_5	50% RD of NPK + 50% N through FYM
T_6	75% RD of NPK + 25% N through FYM
T_7	50% RD of NPK + 50% N through wheat straw
T_8	75% RD of NPK + 25% N through wheat straw
T_9	50% RD of NPK + 50% N through Glyricidia
T_{10}	75% RD of NPK + 25% N through Glyricidia
T_{11}	Farmers practice 40:20:20 kg N:P:K ha^{-1} and seeds without treatment
T_{12}	75% RD of NPK + 25% N through Subabul
T_{13}	50% RD of NPK + 50% N through Subabul

Table 2. Chemical composition of organic materials

Organic source	Nutrient composition (%)		C:N ratio
	C	N	
FYM	36.50	0.6011	60.83
WS	48.12	0.5989	80.20
GM	36.40	4.5430	24.30
SB	41.50	2.1189	19.66

Table 3. Effect of integrated nutrient management on population of microorganisms (X 10_4) of soil at harvest of sorghum

	Treatments	Bacteria	Actinomycets	Fungi
T_1	Control	106	21.00	25.00
T_2	50% RD of NPK	186	23.67	37.33
T_3	75% RD of NPK	241	25.33	36.00
T_4	100% RD of NPK	240	26.67	44.33
T_5	50% RD of NPK + 50% N through FYM	415	26.00	57.67
T_6	75% RD of NPK + 25% N through FYM	394	50.67	51.00
T_7	50% RD of NPK + 50% N through wheat straw	329	37.67	52.00
T_8	75% RD of NPK + 25% N through wheat straw	272	74.33	54.67
T_9	50% RD of NPK + 50% N through glyricidia	306	52.33	54.83
T_{10}	75% RD of NPK + 25% N through glyricidia	240	28.33	48.67
T_{11}	Farmers practice 40:20:20 and seeds without treatment	257	39.33	33.67
T_{12}	75% RD of NPK + 25% N through subabul	278	35.33	52.33
T_{13}	50% RD of NPK + 50% N through subabul	243	27.67	51.00
	S E $\pm$	10.29	22.86	2.01
	C D at 5%	29.89	66.36	5.84

Table 4.Effect of long term integrated nutrient management on Nitrogen fractions (mg kg^{-1}) (2004-05)

Treatments		N fractions (mg kg^{-1})							
		30 DAS		60 DAS		90 DAS		At harvest	
		NH^+_4-N	NO^-_3-N	NH^+_4-N	NO^-_3-N	NH^+_4-N	NO^-_3-N	NH^+_4-N	NO^-_3-N
T_1	Control	11.52	9.93	12.02	10.23	10.84	9.39	10.77	9.97
T_2	50% RD of NPK	12.51	11.77	12.89	11.76	12.13	11.55	12.05	10.66
T_3	75% RD of NPK	21.75	12.56	22.12	12.71	20.49	12.22	20.48	11.15
T_4	100% RD of NPK	21.67	13.89	22.12	15.04	20.17	14.13	20.48	12.53
T_5	50% RD of NPK + 50% N through FYM	26.19	14.70	26.07	15.32	24.21	14.55	24.42	12.92
T_6	75% RD of NPK + 25% N through FYM	26.11	14.42	25.31	14.88	24.31	13.62	24.37	12.38
T_7	50% RD of NPK + 50% N through wheat straw	24.98	11.42	24.86	11.44	22.31	11.02	24.63	11.76
T_8	75% RD of NPK + 25% N through wheat straw	22.08	10.88	22.97	10.23	21.79	9.94	21.48	10.89
T_9	50% RD of NPK + 50% N through glyricidia	26.01	11.28	25.91	11.47	22.21	11.04	24.13	11.21
T_{10}	75% RD of NPK + 25% N through glyricidia	24.56	13.18	24.74	12.93	23.16	12.74	23.03	11.89
T_{11}	Farmers practice 40:20:20 and seeds without treatment	20.53	10.17	20.17	10.28	19.41	10.11	19.39	10.68
T_{12}	75% RD of NPK + 25% N through subabul	24.96	10.60	25.14	9.88	23.28	10.01	23.09	11.29
T_{13}	50% RD of NPK + 50% N through subabul	25.76	14.33	25.19	14.19	22.22	13.67	23.59	12.65
	S E ±	0.76	0.36	0.69	0.47	0.74	0.41	0.68	0.40
	C D at 5%	2.19	1.00	2.00	1.35	2.16	1.18	1.97	1.17

Table 5.Effect of long term integrated nutrient management on available Phosphorus (mg kg^{-1})

Treatments		Available P (mg kg^{-1}) 2004-2005			
		30 DAS	60 DAS	90 DAS	At harvest
T_1	Control	11.03	10.40	10.91	10.28
T_2	50% RD of NPK	11.14	11.11	11.00	10.42
T_3	75% RD of NPK	11.36	11.38	11.27	10.69
T_4	100% RD of NPK	12.11	12.18	12.00	10.98
T_5	50% RD of NPK + 50% N through FYM	12.30	12.32	12.20	11.44
T_6	75% RD of NPK + 25% N through FYM	11.91	11.92	11.78	11.28
T_7	50% RD of NPK + 50% N through wheat straw	11.71	11.72	11.61	10.88
T_8	75% RD of NPK + 25% N through wheat straw	11.95	11.96	11.85	11.16
T_9	50% RD of NPK + 50% N through glyricidia	11.95	11.96	11.84	11.13
T_{10}	75% RD of NPK + 25% N through glyricidia	11.59	11.61	11.49	11.34
T_{11}	Farmers practice 40:20:20 and seeds without treatment	11.29	11.31	11.19	10.94
T_{12}	75% RD of NPK + 25% N through subabul	11.95	11.83	11.85	11.40
T_{13}	50% RD of NPK + 50% N through subabul	11.95	11.87	11.85	11.21
	SE $\pm$	0.06	0.12	0.06	0.35
	CD at 5%	0.18	0.34	0.18	1.02

Table 6. Effect of long term integrated nutrient management on available Potassium (kg ha^{-1})

Treatments		Available K (kg ha^{-1}) 2004-2005			
		30 DAS	60 DAS	90 DAS	At harvest
T_1	Control	390.14	391.93	393.80	401.92
T_2	50% RD of NPK	391.81	393.57	393.19	406.52
T_3	75% RD of NPK	419.51	420.33	417.12	442.74
T_4	100% RD of NPK	444.60	445.45	441.71	443.28
T_5	50% RD of NPK + 50% N through FYM	442.30	433.68	440.65	439.93
T_6	75% RD of NPK + 25% N through FYM	433.19	433.15	442.48	439.25
T_7	50% RD of NPK + 50% N through wheat straw	442.30	448.42	445.05	449.09
T_8	75% RD of NPK + 25% N through wheat straw	450.05	450.96	449.01	443.73
T_9	50% RD of NPK + 50% N through glyricidia	431.76	432.58	434.19	442.79
T_{10}	75% RD of NPK + 25% N through glyricidia	436.06	303.50	438.13	444.80
T_{11}	Farmers practice 40:20:20 and seeds without treatment	426.48	426.94	443.00	441.99
T_{12}	75% RD of NPK + 25% N through subabul	432.25	433.08	440.20	432.13
T_{13}	50% RD of NPK + 50% N through subabul	443.11	434.02	450.16	455.15
	SE$\pm$	8.69	6.05	8.29	6.02
	C D at 5%	25.21	18.04	24.07	17.47

of added FYM which helped in increasing the available nitrogen and phosphorus status of soil. In FYM treated plot increased nitrogen and phosphorus status may be attributed to the high nitrogen content and faster mineralization of nitrogen from due to its narrow C:N ratio. On the other hand the wider C:N ratio of wheat straw was responsible for lower mineralization of potassium and higher immobilization of mineral K by microorganisms.

From above discussion it can be inferred that the growth of soil microorganisms is sustained under integrated nutrient management practices compared to chemical fertilizers alone which also shown significant effect on availability of nutrients through out growing season.

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Rec. on 25.08.2011 & Acc. on 20.11.2011

J. Soils and Crops 22 (2) 334-336, Dec., 2012 ISSN 0971-2836

STUDIES ON IDENTIFICATION OF NUTRIENT DEFICIENCY SYMPTOMS IN GREEN GRAM

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ABSTRACT

Studies on deficiency symptoms of N, P, K, S, Mg, Fe and Zn were undertaken on green gram plant in pot culture using Hoagland solution deficient in any above mentioned nutrients. The deficiency symptoms recorded for each of the above elements are briefly described here under. N deficiency symptoms started appearing at 10 days after transplanting and showed yellowing of leaf, complete degradation of chlorophyll and poor root systems. P deficiency symptoms started appearing at 12 DAT and showed pale yellow leaves with necrosis and poor root system. K deficiency symptoms started appearing at 13 DAT. Firing and browning of leaves from lamina to base and root system also affected. S deficiency symptoms started appearing at 11 DAT with poor growth having yellowing of leaves with dull green colour. Weak root system was also observed. Mg deficiency symptoms started appearing at 10 DAT with poor growth, chlorosis with browning of leaves. Poor root system was also observed. Zn deficiency symptoms started appearing at 12 DAT having yellowing and curling, misshapen of leaves with irregular spots. Root system also affected. Fe deficiency symptoms started appearing at 10 DAT with poor growth having interveinal chlorosis of leaves. Very weak root system was developed in Fe deficient plants.

(Key words: Green gram, pot culture, deficiency symptoms, macro and micro elements)

INTRODUCTION

Green gram is one of the important pulse crops in India. Green gram is a protein rich staple food. It contains about 25% protein, which is almost three times that of cereals. It supplies protein requirement of vegetarian population of the country. Green gram productivity depends upon nutrients available to them. Deficiency of one or more elements ultimately results in low production, less accumulation of nutrients in seed thus, affecting its nutrition quality of green gram (like protein). Amongst the seventeen elements essential for plant growth, out of this carbon, hydrogen, and oxygen are directly available through atmosphere and remaining fourteen elements are referred to be as the essential mineral nutrients which are divided into macronutrients like nitrogen, phosphorus, potassium, sulphur, calcium, magnesium and micronutrients like iron, manganese, copper, zinc, molybdenum, boron, chlorine and nickel.

Kumar and Purohit (1996), Miranda *et al.* (2010) and Turkey (1997) have reported the influence of deficiency of nutrients on crop growth and yield. However, definite deficiency symptoms exhibited by these elements in plants, particularly leaves of green gram are not identified and documented from Vidarbha region of Maharashtra state. Hence, studies were under taken to identify the deficiency symptoms exhibited independently by some macro and micronutrients.

MATERIALS AND METHODS

With a view to identifying nutrient deficiency symptoms of some macro and micro nutrients, pot culture experiment was carried out in glass house of Botany Section, College of Agriculture, Nagpur during 2011-2012. In this experimental studies on identification of deficiency symptoms of N, P, K, Mg, S, Fe and Zn were under taken in comparison with control plants. Green gram cultivar PKV mung 8802 was used and sowing was done on 14th July 2011. Design used was CRD with three replications. Seedlings were transplanted after 20 days in glass jar having silica sand and Hoagland solution. Three pots were allotted for each treatment in each replication; there were 24 pots in each replication. Initially stock solutions using analar grade chemicals were prepared. From this stock solution required quantity of various chemicals were taken and prepared deficient culture solutions of N, P, K, Mg, S, Zn and Fe with control. Similarly, the micronutrient solution or supplementary solution was also prepared. Initially the seedlings were grown in 1/4th Hoagland solution for 7 days. Thereafter, the concentration of solution was increased to full Hoagland. The pots were aerated daily using air compressor and network of rubber tubings. The temperature in glass house was controlled by using humidifier, exhaust fans and cooler. The solutions were changed every after 10 days. Daily observations were recorded on the appearance of deficiency symptoms if any in each of the nutrient deficient pots for test elements separately

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till the plants became exhausted or matured. The observations on initial appearance of symptoms and total number of days survival were recorded for the plant deficient in N, P, K, Mg, S, Zn and Fe and are presented here under.

RESULTS AND DISCUSSION

The deficiency symptoms recorded for the elements viz., N, P, K, Mg, S, Zn and Fe are briefly described below.

Nitrogen:

Deficiency symptoms of nitrogen started appearing from basal leaves at 10 DAT and spread towards upper leaves. Leaves became pale yellow initially. Leaf started yellowing from leaf margin and spread over towards midrib. At later stage, there was complete interveinal chlorosis of leaves. Complete degradation of chlorophyll started from leaf margin towards midrib in advanced stage. Root system was poor. The roots were blackish in colour. Root volume was also decreased. However, the plant survival up to 46 DAT. Jain (2010) also opined that deficiency of nitrogen reduced protein content, cell division and cell elongation in plants and affected plant growth. These might be the reasons for poor growth in the present investigation. Smith *et al*. (1993) also reported poor root system in peanut.

Phosphorus:

The symptoms of phosphorus deficiency started appearing from second leaf at 12 DAT and spread towards upper leaves. At initial stage leaves became pale yellow but leaf veins and sub veins showed brown colour. Leaves showed necrotic, browned and black spots in advanced stage. It might be due to less availability of carbohydrate to the cell (Smith *et al*., 1993). Root system was affected, but root length was more than control. Paliwal and Deotale (2004) also reported poor root system in P deficient soybean plant. Experiment terminated after 43 days after transplanting.

Potassium:

Potassium deficiency symptoms appeared from third leaf at 13 DAT and spread towards upper leaves because K is mobile element and hence, symptoms first appeared on matured leaves. The browning and yellowing of leaves started from leaf margin. In later stage, midrib and veins showed slightly green to brown coloured. The root system was affected, root length was increased as compared with control, but root volume was decreased. As per Das (2011), potassium utilized in plant is concerned with formation of carbohydrate and protein, photosynthesis, transpiration regulation, enzyme action, synthesis of nucleic acid and chlorophyll oxidative photophosphorylation, translocation of solute etc. Smith *et al*. (1993) also reported that K deficiency decreased the translocation of amino acids, organic acids and sugars to roots. The above stated reasons justified for poor growth in the present investigation. Experiment terminated after 45 days after transplanting.

Sulphur:

Deficiency of sulphur first appeared in upper leaves and it is due to immobility of sulphur (Jain, 2010). The symptoms of deficiency appeared at 11 DAT. Leaves were pale yellow with dull green colour. In later sage, there was tip necrosis and complete yellowing of upper leaves including veins, arrested the terminal growth of the plant. Sinclair (1993) and Paliwal and Deotale (2004) also reported pale yellow leaves with tip necrosis in soybean plant. Root system was very poorly developed. Paliwal and Deotale (2004) and Deotale and Dhopte (2005) also reported poor root development in soybean and mustard respectively. Sulphur deficiency caused accumulation of nitrate, amide and carbohydrate which retarded the formation of chlorophyll resulting in poor metabolism (Sinclair, 1993). Experiment was terminated after 39 DAT.

Magnesium:

Magnesium is a constituent of chlorophyll and therefore, is essential for its formation. It is readily mobile when its deficiency occur. It is apparently transferred from older to younger tissue where it can be reutilized in growth processes, as a result deficiency symptoms developed first on older leaves (Jain, 2010 and Das, 2011). In present investigation, yellowing with dead necrotic patches appeared on leaves at 10 DAT and later on leaf expansion arrested with outward curling of leaves. Root system was poorly developed. Epstein (1972) also reported that Mg was a constituent of chlorophyll and activator of numerous enzymes. Its deficiency affected plant metabolism, abnormalities in structure of chloroplast, mitochondria thus affects photosynthesis and root surface development. These might be the reasons for poor root development due to Mg deficiency in the present study. Experiment was terminated after 37 DAT.

Zinc:

Zinc deficiency symptoms started from upper leaves at 12 DAT. It might be due to immobility of this element. Yellowing of leaves started from lamina to base, veins and sub veins remained green. Later on, yellowing and necrotic brown spots were developed on all leaves. Sinclair (1993) and Borkert and Sfredo (1994) also reported yellowing of leaves with necrotic brown spots in soybean plant. Curling of the leaves was noticed in advanced stage. Deotale and Dhopte (2005) also reported the similar results. They noted curling of leaves with yellow veins in mustard. Root system was poor with decreased root volume. Deotale and Dhopte (2005) also recorded fibrous and weak root system in mustard plant due to zinc deficiency. Experiment terminated after 38 DAT.

Iron:

Iron is a relatively immobile in plant tissue and its mobility was affected by several factors. Such as presence of Mg in K deficiency. A lack of mobility accounted for iron deficiency, first developing in younger leaves (Pandey and Sinha, 1972). In present study deficiency symptoms started in younger leaves at 10 DAT. Leaves became pale yellow initially. Main veins and sub veins remained green. Later on there was defoliation of leaves. Similarly Deotale *et al.* (2007) also reported interveinal chlorosis and defoliation of leaves in groundnut plant. Bennett (1993) also reported that iron was essential for synthesis of chlorophyll. Iron is involved in N fixation, photosynthesis and electron transfer. Deficiency of iron affects chlorophyll synthesis. Thus, reduction in photosynthesis or chlorophyll synthesis, faded greenness in leaf. Main root system was also arrested. Fe is involved in electron transfer system of oxidative anabolism. Deficiency of Fe affects carbohydrate synthesis and also protein synthesis (Wutcher and Smith, 1993). These might be the reasons for poor root system due to deficiency of Fe in the present investigation. Experiment terminated after 36 DAT.

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Rec. on 30.05.2012 & Acc. on 30.06.2012

J. Soils and Crops 22 (2) 337-344, Dec., 2012 ISSN 0971-2836

HETEROSIS STUDIES FOR GRAIN YIELD AND BIOCHEMICAL CHARACTERS IN QUALITY PROTEIN MAIZE (*Zea mays* L.)

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ABSTRACT

Studies on heterosis in maize (*Zea mays* L.) was undertaken to assess the possibility of estimating the extent of heterosis for grain yield plant^{-1}, yield contributing and quality parameters in the research farm of Department of Genetics and Plant Breeding. Anand Agriculture University, Anand during the year 2010-11. Fourty-five hybrids obtained by crossing fifteen lines with three testers were raised in Randomized Block design with three replications. The data were recorded on days to 50% tasselling, days to 50% silking, plant height, length of ear, width of ear, number of kernels row^{-1}, shelling cent^{-1}, grain yield plant^{-1}, 1000-kernel weight, protein content, lysine in protein and trypotphan in protein. Considerable variability existed among the genotypes for all the characters studied as observed from the significant mean squares due to genotypes. The crosses 1-07-8-4 x CLQ-47, 1-07-56 x CLQ-47 and 1-07-10-1 x HKI-163 had high mean performance for grain yield plant^{-1}, yield contributing and quality parameters. The mean squares due to interaction effects of parents vs. hybrids were found to be significant for width of ear, shelling cent^{-1}, grain yield plant^{-1}, 1000-kernel weight, protein content, lysine in protein and tryptophan in protein indicating the choice of exploitation of heterosis. The results revealed that, among the fourty-five hybrids the hybrids 1-07-8-4 x CLQ-47, 1-07-56 x CLQ-47 and 1-07-10-1 x HKI-163 were identified as superior hybrids as it recorded high percentage of relative heterosis and heterobeltiosis for grain yield plant^{-1}, yield contributing characters and quality parameters. These hybrids also had significant *per se* performance for their respective characters.

(Key words : Quality protein maize (QPM), relative heterosis and heterobeltiosis)

INTRODUCTION

The maize is a vital food source in many areas of the developing world, particularly in poor rural communities. The protein content in maize grains is about 9.5% and the 42 million tons of maize protein approximately produced account for 15% of the world protein production. However, zein - the main maize grain protein is poor in lysine and tryptophan. The Opaque 2 (o2) gene increases significantly the lysine and tryptophan contents in the endosperm (Mertz *et al.,* 1964), but expresses negative pleiotropic effects on the grain quality, such as lower density, susceptibility to pests and diseases and a floury appearance (Vasal, 1994).

The International Maize and Wheat Improvement Center (CIMMYT) sought to solve these problems by introducing modifier genes for denser and more vitreous endosperm. The improved populations, which were called QPM (Quality Protein Maize), presented protein with a greater biological value, as well as yield and agronomic characteristics which were closer to normal cultivars. Maize is a highly cross pollinated crop and there is a wide scope for exploitation of hybrid vigor. Already this phenomenon has been successfully exploited and still there is tremendous potential to develop several high yielding hybrids and composites. Hence, an attempt was made to assess the heterosis among the various hybrids produced through line x tester analysis.

MATERIALS AND METHODS

The Present Investigation was carried out at department of Genetics and Plant Breeding, Anand Agriculture University, Anand (Gujarat), India. Fifteen lines L_1 (I-07-7-1), L_2 (I-07-7-4), L_3 (I-07-7-11), L_4 (I-07-8-4), L_5 (I-07-8-5), L_6 (I-07-8-6), L_7 (I-07-9-9), L_8 (I-07-10-1), L_9 (I-07-13-1), L_{10} (I-07-54-1), L_{11} (I-07-56-4), L_{12} (I-07-56-7), L_{13} (I-07-56-8), L_{14} (I-07-57-5), L_{15} (I-57-6) were crossed with three testers T_1 (KHI-163), T_2 (CLQ-30), T_3 (CLQ-47) in *kharif* 2010. The fourty-five hybrids and eighteen parents were evaluated in *kharif* 2011 by raising the experimental material in Randomized Block design with three replications with spacing of 60 cm x 20 cm. Recommended package of practices were followed to raise a good crop.

The data were recorded on five randomly selected plants from each genotypes on twelve characters viz., days to 50% tasselling, days to 50% silking, plant height, length of ear, width of ear, number of kernels row^{-1},shelling per cent, grain yield

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plant^{-1}, 1000 kernl weight, protein content, lysine in protein and tryptophan in protein. The analysis of variance for the experimental design was analyzed by the method given by Panse and Sukhatme (1954). Protein content was estimated by Micro-kjeldahl's method given by Hawk (1951), while lysine and tryptophan in protein by colorimetric method given by Tsai *et al.* (1972). Relative heterosis was estimated for hybrids as per Turner (1953) and heterobeltiosis as per Fonseca and Patterson (1968) with fixed effect model (Model I) of Eisenhart (1974).

RESULTS AND DISCUSSION

The results of analysis of variance are presented in table 1. Considerable variability existed among the genotypes for all the characters studied as observed from the significant mean squares due to genotypes. The mean squares due to parents were found to be highly significant for all the characters except number of kernels row^{-1}. Significant mean squares for the hybrids were recorded for all the characters. The mean squares due to parents vs. hybrids was found to be significant for width of ear, shelling cent^{-1}, grain yield plant^{-1}, 1000-kernel weight, protein content, lysine in protein and tryptophan in protein which indicated that the parents chosen were diverse and with a different genetic background and also revealed the presence of average heterosis due to the significant differences in the mean performance of hybrids and parents. These results were in confirmation with the results of Hemavathy and Balaji (2008), Wali *et al.* (2010), Premlatha *et al.* (2011) and Sundararajan and Shenthil (2011) who also reported that occurance of heterosis due to differences in the performance of hybrids and parents in maize.

On the basis of *per se* performance (Table 2) studied for grain yield plant^{-1} and yield contributing characters among 45 hybrids, the hybrid I-07-8-4 x CLQ-47 was indentified as superior hybrid as it performed significantly superior over the relative heterosis and heterobeltiosis for grain yield plant^{-1} (134.8 g), days to 50% tasselling (54.7), days to 50% silking (59.0), plant height (176.0 cm), number of kernels row^{-1} (33), lysine in protein (3.30%). While hybrid I-07-56-4 x CLQ-47 which performed significantly superior over the relative heterosis and heterobeltiosis for grain yield plant^{-1} (133.0 g), days to 50% tasselling (49.0), days to 50% silking (53.3d), shelling cent^{-1} (79.0%), tryptophan in protein (0.92%), lysine in protein (3.57%) and the hybrid I-07-10-1 x HKI-163 exhibited significantly superiority for grain yield plant^{-1} (148.4g), plant height (129cm), 1000-kernel weight (239.3g), and tryptophan in protein (0.73%). These three crosses were identified as potential crosses for exploiting heterosis on the basis of *per se* performance.

The expression of heterosis was worked out for all the characters for relative heterosis and heterobeltiosis are presented in table 2. Negative heterosis for days to 50% tasselling and silking is desirable feature as it confers earliness I-07-54-1 x CLQ-47 recorded highest negative relative heterosis (-13.45%) and heterobeltiosis (-11.90%) for days to 50% tasselling. For days to 50% silking hybrids I-07-13-1 x CLQ-47 and I-07-8-4 x HKI-163 recorded maximum negative relative heterosis (-14.04%) and heterobeltiosis (-13.14%) respectively. The hybrid I-07-56-8 x CLQ-47 recorded maximum negative heterobeltiosis (-21.93%) for plant height.

The hybrid I-07-10-1 x CLQ-30 exhibited significant and positive relative heterosis (32.54% and heterobeltiosis (25.42%) for length of ear. The hybrid I-07-57-6 x CLQ-30 exibited significant positive relative heterosis (11.04%) and heterobeltiosis (10.04%) for width of ear and relative heterosis (48.49%) and heterobeltiosis (44.32%) for shelling cent^{-1}. The hybrid I-07-10-1 x CLQ-30 exhibited significant and positive relative heterosis (25.26%) and heterobeltiosis (22.73%) for number of kernels row^{-1}. For 1000-kernel weight hybrid I-07-7-1 x CLQ-30 recorded maximum positive relative heterosis (36.23%) and heterobeltiosis (26.99%) respectively.

The hybrid I-07-7-4 x HKI-163 exhibited significant and positive relative heterosis (15.68%) and heterobeltiosis (11.12%) for protein content. For lysine in proteiin hybrid I-07-7-4 x CLQ-47 exhibited significant positive relative heterosis (150.53%) and heterobeltiosis (120.37%) respectively. The hybrid I-07-56-7 x HKI-163 recorded highest significant positive relative heterosis (42.78%) and the hybrid I-07-54-1 x HKI-163 recorded highest significant positive heterobeltiosis (27.69%) for tryptophan in protein.

Table 1. Analysis of variance for experimental design

Source of variation	d.f.	Days to 50 % tasselling	Days to 50 % silking	Plant height (cm)	Width of ear (cm)	Length of ear (cm)	No. of kernels row^{-1}	Shelling $cent^{-1}$	Grain yield $plant^{-1}$ (g)	1000-kernel weight (g)	Protein content (%)	Lysine in protein (%)	Tryptophan in protein (%)
Replications	2	0.47	1.24	30.26	0.11	0.73	0.10	13.25	23.25	18.91	0.09	0.07	0.00
Genotypes	65	34.63**	42.43**	2362.73**	2.52**	5.31**	8.45**	208.66**	375.32**	1923.95**	1.23**	1.54**	0.06**
Parents	17	20.19**	22.12**	2940.00**	1.84**	3.38**	2.73	230.75**	298.74**	917.97**	1.85**	1.65**	0.07**
Hybrids	44	40.30**	49.13**	1810.31**	2.90**	6.30**	8.77**	188.80**	391.31**	2440.05**	1.05**	0.36**	0.03**
Parents vs. Hybrids	1	0.04	0.75	10.25	3.20*	0.28	2.64	180.37**	2040.6**	1278.00**	0.60**	55.71**	1.09**
Error	130	1.16	1.79	27.60	0.80	1.68	4.26	11.29	122.75	60.14	0.03	0.02	0.00

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

Table2. Performance of hybrids for mean, relative heterosis (RH) and heterobeltiosis (HB)

Hybrids	Days to 50% tasselling			Days to 50% silking			Plant height (cm)		
	Mean	RH	HB	Mean	RH	HB	Mean	RH	HB
L_1 X T_1	48.7	-10.15**	-9.88**	50.3	-13.22**	-12.72**	234	-3.16*	-2.47
L_1 X T_2	58.7	3.53**	7.98**	62.7	3.87*	8.67**	230	-4.83**	-4.27*
L_1 X T_3	51.3	-8.61**	-5.52**	54.3	-9.94**	-5.78**	227	-2.00	2.01
L_2 X T_1	54.7	0.31	1.23	59.7	1.70	2.29	226	-7.16**	-6.92**
L_2 X T_2	58.0	1.75	5.45**	61.0	0.00	3.39	220	-9.34**	-9.23**
L_2 X T_3	60.7	7.37**	10.30**	65.3	7.10**	10.73**	243	4.79**	9.59**
L_3 X T_1	50.0	-5.36**	-3.23	51.3	-10.98**	-9.94**	238	-0.74	1.06
L_3 X T_2	57.0	3.01*	10.32**	59.0	-1.67	3.51	231	-3.28*	-1.66
L_3 X T_3	55.3	0.91	7.10**	59.0	-1.67	3.51	183	-19.76**	-1.39**
L_4 X T_1	47.7	-13.33**	-11.73**	50.7	-13.64**	-13.14**	240	0.22	1.98
L_4 X T_2	60.3	4.93**	7.74**	61.7	1.09	4.52*	237	-0.95	0.67
L_4 X T_3	**54.7**	**-4.09****	**-2.38**	**59.0**	**-3.28***	**0.00**	**176**	**-23.06****	**-20.76****
L_5 X T_1	52.0	-5.17**	-3.70*	54.0	-10.25**	-7.43**	210	-12.32**	-10.90**
L_5 X T_2	53.3	-6.9800	-4.19**	57.0	-8.80**	-8.06**	233	-2.71	-1.27
L_5 X T_3	50.7	-10.85**	-8.98**	55.0	-12.00	-11.29**	205	-10.45**	-7.64**
L_6 X T_1	52.3	0.64	4.67**	56.7	0.89	4.94*	189	-18.2**	-13.46**
L_6 X T_2	55.0	0.92	10.00**	60.0	2.56	11.11**	236	2.47	8.26**
L_6 X T_3	59.3	9.88**	18.67**	64.0	9.4**	18.52**	240	8.83**	9.75**
L_7 X T_1	49.0	-8.98**	-8.70**	53.0	-8.88**	-8.62**	239	18.94**	51.59**
L_7 X T_2	52.0	-7.69**	-3.11	58.0	-4.13**	0.00	234	17.05	48.94**
L_7 X T_3	50.7	-9.25**	-5.59**	56.3	-6.89**	-2.87	232	22.11**	47.25**
L_8 X T_1	54.0	3.18**	6.58*	59.0	4.12*	7.27**	129	**-35.64****	-17.59**
L_8 X T_2	52.3	-4.56**	3.29	58.0	-1.69	5.45**	178	-10.99**	13.79**
L_8 X T_3	53.0	-2.45	4.61**	58.0	-1.69	5.45**	243	28.53**	55.68**
L_9 X T_1	56.0	6.33**	9.09**	60.0	5.26**	7.78**	234	-2.03	-0.17
L_9 X T_2	57.7	4.53**	12.34**	62.7	5.62**	12.57**	242	1.13	2.91
L_9 X T_3	50.0	-8.54**	-2.60	51.0	-14.04**	-8.38**	216	-5.45**	-2.75
L_{10} X T_1	55.0	0.00	1.85	58.0	-1.14	-0.57	233	12.43	36.06**
L_{10} X T_2	56.7	-1.45	1.19	60.7	-0.55	2.82	225	8.47**	31.07**
L_{10} X T_3	49.3	-13.45**	-11.90**	54.7	-10.38**	-7.34**	198	0.42	15.21**
L_{11} X T_1	52.0	-2.50	-1.27	56.7	-0.58	1.80	232	-5.97**	-4.62**
L_{11} X T_2	56.0	0.30	6.33**	59.0	-0.56	5.99**	238	-3.68*	-2.17
L_{11} X T_3	**49.0**	**-11.45****	-6.96**	53.3	**-10.11****	-4.19*	241	2.04	8.61**
L_{12} X T_1	62.7	18.24**	20.51**	66.7	17.30**	14.29**	220	-6.19**	-2.23
L_{12} X T_2	57.0	2.7*	9.62**	60.7	2.54	9.64**	227	-2.89	1.08
L_{12} X T_3	51.0	-7.27**	-1.92	54.3	-8.17**	-1.81	215	-3.55*	-2.99
L_{13} X T_1	54.7	0.00	1.23	58.7	-0.28	0.57	192	-21.48**	-21.30**
L_{13} X T_2	57.3	0.29	3.61*	63.3	3.54*	6.74**	223	-8.64**	-8.30**
L_{13} X T_3	56.3	-0.59	1.81	60.0	-1.91	1.12	173	-25.73**	-21.93**
L_{14} X T_1	51.0	-8.11*	-5.56**	56.3	-5.06**	-3.43	245	14.21**	32.26**
L_{14} X T_2	56.7	-2.30	-0.58	59.7	-3.24*	-1.10	234	9.16**	26.23**
L_{14} X T_3	53.3	-7.25**	-6.43**	58.3	-5.41**	-3.31	220	8.18**	18.97**
L_{15} X T_1	49.0	-7.26**	-5.16**	51.0	-10.53**	-8.38**	233	-4.45**	-4.32*
L_{15} X T_2	59.0	6.63**	14.19**	65.0	9.55**	16.77**	255	4.64**	4.91**
L_{15} X T_3	53.0	-3.34*	2.58	58.3	-1.69	4.79*	239	2.64	7.77**
S.Ed. (±)	**0.62**	**0.76**	**0.88**	**0.77**	**0.95**	**1.10**	**3.03**	**3.77**	**4.35**

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

Table 2. Conted...

Hybrids	Width of ear (cm)			Length of ear (cm)			No of kernels row^{-1}		
	Mean	RH	HB	Mean	RH	HB	Mean	RH	HB
L_1 X T_1	14.6	-3.52	-4.78	13.3	-19.92**	-22.48**	29	-1.92	-5.34
L_1 X T_2	14.0	-5.41	-6.25	15.1	-13.28**	-14.50*	28	-2.63	-4.82
L_1 X T_3	14.5	-3.00	-3.33	17.7	2.71	2.71	28	-0.12	-0.59
L_2 X T_1	14.3	-5.31	-6.96	16.7	2.14	0.40	29	1.44	-3.92
L_2 X T_2	14.5	-1.36	-1.80	14.5	-15.42**	-17.89**	28	-0.76	-4.82
L_2 X T_3	14.7	-1.45	-2.22	17.0	0.39	-1.16	29	4.74	3.20
L_3 X T_1	16.3	9.03*	6.30	18.1	16.86**	12.63*	29	-2.23	-6.65
L_3 X T_2	13.5	-7.64	-7.95	17.1	4.80	-3.39	28	-4.34	-7.50
L_3 X T_3	12.0	-18.69**	-19.96**	14.4	-10.58	-16.47**	27	-5.06	-5.68
L_4 X T_1	13.1	-11.88**	-14.57**	15.7	2.40	-2.69	29	-1.69	-5.13
L_4 X T_2	14.4	-1.15	-2.05	14.8	-8.07	-16.38**	27	-5.96	-8.06
L_4 X T_3	14.1	-4.42	-6.43	15.0	-5.36	-12.79*	**33**	**14.96****	**14.42***
L_5 X T_1	14.5	0.69	-5.22	17.2	12.05*	6.83	29	-0.98	-6.22
L_5 X T_2	14.4	1.89	-2.05	17.1	5.88	-3.39	30	3.33	-0.90
L_5 X T_3	15.3	6.88	1.5	14.5	-9.01	-15.89**	26	-6.55	-7.93
L_6 X T_1	13.6	-8.54*	-11.52*	15.9	-4.41	-7.38	27	-6.26	-10.25
L_6 X T_2	15.5	6.67	5.45	17.1	-1.72	-3.20	28	-2.42	-5.38
L_6 X T_3	14.4	-1.70	-3.99	15.6	-9.41	-9.50	29	2.97	2.60
L_7 X T_1	13.6	-9.15*	-11.52*	16.6	4.19	2.90	28	-5.07	-9.16
L_7 X T_2	15.2	4.11	3.64	17.2	2.79	-3.01	28	-1.33	-4.37
L_7 X T_3	15.3	3.72	2.00	17.4	5.98	1.36	29	4.58	4.14
L_8 X T_1	14.4	2.49	-5.87	16.3	2.40	1.45	28	-6.43	-9.49
L_8 X T_2	14.3	4.00	-2.50	22.2	**32.54****	**25.42****	37	**25.26****	**22.73****
L_8 X T_3	13.5	-3.11	-10.20*	16.3	-1.01	-5.04	33	14.69**	13.89*
L_9 X T_1	13.3	-12.66**	-13.04**	14.8	-8.36	-8.64	28	-4.55	-8.40
L_9 X T_2	12.2	-18.08**	-193.52**	17.4	2.65	-1.69	28	-1.61	-4.37
L_9 X T_3	13.8	-8.71*	-9.21	16.4	-1.80	-4.65	27	-2.37	-2.49
L_{10} X T_1	14.9	0.45	-2.83	13.6	-12.7*	-15.32*	29	0.00	-4.91
L_{10} X T_2	13.6	-6.44	-7.50	16.3	-0.51	-7.72	29	1.86	-1.90
L_{10} X T_3	13.9	-5.11	-7.32	16.3	1.03	-5.04	28	-0.36	-1.42
L_{11} X T_1	14.4	-3.69	-6.30	14.7	-11.78*	-14.84*	27	-7.06	-10.25
L_{11} X T_2	13.4	-8.34*	-8.86	16.8	-3.81	-4.90	29	-1.77	-3.92
L_{11} X T_3	14.5	-2.03	-3.77	15.5	-10.34*	-10.60	29	3.59	3.04
L_{12} X T_1	13.8	-8.22*	-10.22*	16.9	10.24	4.76	28	-6.82	-6.87
L_{12} X T_2	14.3	-2.50	-2.50	16.3	1.24	-7.91	29	-4.04	-5.24
L_{12} X T_3	15.3	3.03	1.77	16.2	2.00	-6.01	29	0.17	-3.71
L_{13} X T_1	15.2	1.78	-0.65	15.0	-4.86	-6.83	27	-6.75	-10.36
L_{13} X T_2	15.7	7.29	7.05	16.8	1.21	-5.27	27	-6.84	-9.29
L_{13} X T_3	12.5	-15.41**	-16.63**	14.2	-13.18*	-17.64**	27	-3.37	-3.43
L_{14} X T_1	16.1	0.10	-4.17	15.4	-7.04	-9.59	28	-3.03	-7.52
L_{14} X T_2	14.0	-10.92**	-16.50**	15.6	-10.17*	-11.86*	28	-3.07	-6.38
L_{14} X T_3	15.2	-4.40	-9.34*	16.8	-1.85	-2.33	30	8.17	7.34
L_{15} X T_1	14.9	-1.32	-2.61	16.1	0.73	-0.21	28	-4.50	-7.52
L_{15} X T_2	16.4	**11.04****	**10.04***	16.5	-1.49	-6.78	28	-3.08	-4.93
L_{15} X T_3	15.5	3.67	3.33	15.8	-4.04	-7.95	29	2.70	1.86
S.Ed. (±)	**0.52**	0.62	0.72	0.75	0.89	1.03	1.19	1.46	1.68

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

Table 2. Conted...

Hybrids	Shelling per cent			Grain yield plant-1			1000-kernel weight		
	Mean	RH	HB	Mean	RH	HB	Mean	RH	HB
L_1 X T_1	67.1	-7.11*	-13.69**	124.8	3.25	2.74	179.0	-5.29	-12.25**
L_1 X T_2	65.2	2.20	-2.42	134.9	5.19	-0.09	255.7	**36.23****	**26.99****
L_1 X T_3	72.7	1.01	-5.74	123.2	5.07	1.43	212.3	6.26*	-5.91*
L_2 X T_1	76.4	10.46**	-1.82	102.7	-12.85	-14.67	230.3	9.34**	5.98*
L_2 X T_2	71.7	18.21**	17.94**	143.0	14.24**	5.88	193.3	-7.64**	-11.04**
L_2 X T_3	82.3	19.70**	6.81*	113.4	-0.70	-1.65	228.3	3.09	1.18
L_3 X T_1	79.4	13.91**	2.11	128.4	13.38	6.69	217.0	-0.76	-7.00*
L_3 X T_2	56.8	-7.24	-7.92	129.2	7.11	-4.37	180.3	-17.02**	-22.71**
L_3 X T_3	81.1	16.92**	5.23	127.0	15.86*	12.29	247.7	7.92**	6.14*
L_4 X T_1	68.5	-15.51**	-18.80**	121.7	7.21	1.14	220.0	13.79**	7.84*
L_4 X T_2	65.5	-9.69**	-22.32**	124.6	3.11	-7.72	226.3	17.88**	12.42**
L_4 X T_3	85.1	5.45	0.91	134.8	**22.67****	**19.20***	188.0	-7.92**	-16.69**
L_5 X T_1	72.7	-5.62	-6.56	112.8	-8.16	-10.03	201.3	5.50	-1.31
L_5 X T_2	82.5	20.40**	8.18*	115.1	-11.65	-14.81*	224.0	18.21**	11.26**
L_5 X T_3	78.2	2.05	1.49	117.4	-1.54	-6.38	177.0	-12.23**	-21.57**
L_6 X T_1	71.5	-10.31**	-12.39**	105.5	-14.74*	-17.01*	254.0	23.80**	23.10**
L_6 X T_2	66.4	-6.75*	-18.64**	145.3	10.88	7.60	203.3	-0.25	-1.45
L_6 X T_3	68.1	-14.20**	-16.55**	121.7	1.37	-4.21	163.7	-24.23**	-27.47**
L_7 X T_1	65.1	-7.29	-16.25	119.5	6.52	-0.68	236.7	14.52**	13.06**
L_7 X T_2	74.1	20.06**	18.16**	131.3	9.86	-2.76	204.3	-0.49	-2.39
L_7 X T_3	68.1	-2.55	-11.61**	117.2	7.92	3.60	255.9	17.66**	13.40**
L_8 X T_1	71.4	-8.29**	-8.36*	148.4	**18.70****	14.39*	239.3	19.17**	**17.32****
L_8 X T_2	75.7	9.24**	-2.78	133.6	0.94	-1.05	224.3	12.45**	11.42**
L_8 X T_3	76.1	-1.80	-2.31	129.4	6.57	-0.26	167.3	-20.94**	-25.85**
L_9 X T_1	73.5	-3.62	-5.46	133.8	13.90*	11.24	256.5	20.31**	15.35**
L_9 X T_2	61.3	-9.60**	-18.09**	137.2	9.89	1.60	214.7	1.34	-3.45
L_9 X T_3	82.9	9.11**	7.50*	105.4	-7.43	-8.08	188.7	-15.77**	-16.40**
L_{10} X T_1	77.2	3.06	-0.77	115.4	3.08	-4.07	270.7	27.37**	22.47**
L_{10} X T_2	69.9	5.33	-2.89	134.4	12.64	-0.46	200.0	-5.29*	-9.50**
L_{10} X T_3	86.5	16.04**	12.21**	123.8	14.29**	9.52	184.7	-17.31**	-18.17**
L_{11} X T_1	73.3	4.40	-5.75	134.9	17.85**	12.17	182.7	-15.63**	-20.23**
L_{11} X T_2	69.8	13.17**	11.46**	124.3	1.94	-8.00	226.3	5.19*	-1.16
L_{11} X T_3	79.0	**13.11****	2.52	**133.0**	**19.94****	17.62*	194.4	-14.49**	-15.11**
L_{12} X T_1	64.9	-18.09**	-19.58**	110.7	-8.61	-9.21	186.7	-10.51**	-12.43**
L_{12} X T_2	68.8	-2.70	-14.72**	124.4	-3.15	-7.86	243.3	17.41**	14.15**
L_{12} X T_3	62.7	-20.49**	-2.28**	134.6	14.57*	10.41	224.2	2.16	-0.66
L_{13} X T_1	77.4	5.79	-0.54	117.9	5.22	-2.00	170.3	-20.96**	-24.96**
L_{13} X T_2	82.2	27.26**	20.09**	103.3	-13.54*	-23.55**	210.7	-1.63	-7.20*
L_{13} X T_3	80.4	10.52**	4.35	111.0	2.33	-1.87	256.7	13.40**	13.07**
L_{14} X T_1	59.0	-14.69**	-24.18**	135.7	10.52	8.34	184.3	-8.67**	-9.64**
L_{14} X T_2	70.3	15.94**	15.67**	112.4	-13.67*	-16.80*	219.7	9.56**	9.11**
L_{14} X T_3	71.5	3.96	-7.25*	117.4	-1.45	-6.23	192.7	-9.40**	-14.62**
L_{15} X T_1	55.5	-17.81**	-28.60**	115.2	0.98	-4.25	200.0	-2.83	-3.69
L_{15} X T_2	87.7	**48.49****	**44.32****	110.6	-8.97	-18.15**	255.0	24.69**	22.79**
L_{15} X T_3	61.3	-8.80**	-20.48**	112.2	1.60	-0.76	240.3	10.92**	6.50*
S.Ed. (±)	1.94	2.27	2.63	6.39	7.96	9.20	4.48	5.56	6.42

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

Table 2. Conted...

Hybrids	Protein content (%)			Lysine in protein (%)			Tryptophan in protein (%)		
	Mean	**RH**	**HB**	**Mean**	**RH**	**HB**	**Mean**	**RH**	**HB**
L_1 X T_1	8.63	1.89	-3.14*	3.13	9.30*	-13.76**	0.85	21.24**	4.96*
L_1 X T_2	7.88	-13.05**	-14.50**	3.47	23.08**	-1.89	0.82	9.37**	-9.59**
L_1 X T_3	7.76	-9.85**	-12.94**	2.63	35.04**	25.40**	0.93	24.55**	2.95
L_2 X T_1	8.93	**15.68****	**11.12****	3.30	32.00**	-9.17*	0.67	-2.90*	-16.94**
L_2 X T_2	9.31	12.03**	0.98	3.23	31.97**	-8.49*	0.77	4.74**	-14.39**
L_2 X T_3	8.57	9.11**	3.17	3.97	150.53**	120.37**	0.87	18.28**	-3.32
L_3 X T_1	8.32	-1.96	-6.90**	3.53	34.18**	-2.75	0.86	26.29**	6.20**
L_3 X T_2	7.37	-18.84**	-20.10**	3.33	29.03**	-5.66	0.72	-1.38	-20.66**
L_3 X T_3	8.32	-3.42*	-6.83**	3.10	80.58**	72.22**	0.86	18.81**	-4.43*
L_4 X T_1	8.64	7.78**	7.55**	3.23	25.16**	-11.01**	0.66	-21.67**	-24.52**
L_4 X T_2	8.48	-1.47	-7.99**	3.07	21.05**	-13.21**	0.88	-0.38	-2.21
L_4 X T_3	7.39	-9.34**	-11.00**	**3.30**	**98.00****	**83.33****	0.83	-6.39**	-8.21**
L_5 X T_1	7.73	-3.76*	-3.82*	2.80	12.00**	-22.94**	0.59	-3.28*	-26.86**
L_5 X T_2	7.67	-11.08**	-16.85**	2.90	18.37**	-17.92	0.63	-3.80**	-29.89**
L_5 X T_3	8.13	-0.37	-2.05	2.63	66.32**	46.30**	0.67	1.77	-25.83**
L_6 X T_1	8.90	5.53**	0.75	2.77	3.75	-23.85**	0.74	3.98**	-8.26**
L_6 X T_2	7.73	-14.33**	-16.12**	2.60	-0.64	-26.42**	0.64	-16.23**	-29.52**
L_6 X T_3	7.44	-13.13**	-15.74**	3.33	90.48**	85.19**	0.81	6.58**	-10.33**
L_7 X T_1	8.22	7.62**	2.32	3.17	19.50**	-12.84	0.83	16.71**	2.48
L_7 X T_2	9.07	10.22**	-1.59	3.37	29.49**	-4.72	0.97	28.63**	7.75**
L_7 X T_3	7.63	-1.80	-8.07**	2.80	61.54**	55.56**	0.72	-4.41**	-19.93**
L_8 X T_1	8.57	-2.28	-9.82**	2.77	6.41	-23.85**	0.73	**5.52****	-9.09**
L_8 X T_2	8.42	-10.08**	-11.40**	2.60	1.96	-26.42**	0.69	-7.62**	-23.99**
L_8 X T_3	8.24	-7.43**	-13.26**	3.43	103.96	90.74**	0.81	8.97**	-10.33**
L_9 X T_1	7.67	-3.36*	-4.56**	2.67	-20.79**	-26.61**	0.69	9.47**	-14.05**
L_9 X T_2	8.28	-2.89*	-10.20**	3.10	-6.53*	-12.26**	0.86	26.16**	-4.80*
L_9 X T_3	6.70	-17.00**	-19.35**	3.30	34.69**	6.45	0.88	29.10**	-2.58
L_{10} X T_1	7.62	-11.43**	-16.91**	2.67	0.00	-26.61**	0.58	-13.37**	**27.69****
L_{10} X T_2	8.30	-9.72**	-9.98**	2.80	7.01	-20.75**	0.76	5.31**	-15.87**
L_{10} X T_3	7.52	-13.95**	-18.00**	2.70	54.29**	50.00**	0.68	-5.31**	-24.35**
L_{11} X T_1	8.13	-3.41**	-7.61**	3.43	29.56**	-5.50	0.70	-7.93**	-13.64**
L_{11} X T_2	8.62	-4.37**	-6.54**	3.33	28.21**	-5.66	0.92	14.29**	1.85
L_{11} X T_3	8.63	0.95	-1.89	3.57	105.77**	98.15**	0.92	14.70**	2.21
L_{12} X T_1	7.90	-4.57**	-7.31**	3.40	34.21**	-6.42	0.87	**42.78****	8.26**
L_{12} X T_2	9.08	2.39	-1.48	2.63	6.04	-25.47**	0.85	29.29**	-5.54**
L_{12} X T_3	8.92	6.06**	4.69**	2.67	64.95**	48.15**	0.66	0.51	-26.57**
L_{13} X T_1	7.53	0.87	-6.22**	3.20	30.61**	-11.93**	0.87	27.49**	8.26**
L_{13} X T_2	7.48	-7.17**	-18.84**	3.70	54.17**	4.72	0.86	17.73**	-4.43*
L_{13} X T_3	8.73	14.86**	5.18**	3.33	117.39**	85.19**	1.01	37.27**	11.44**
L_{14} X T_1	7.07	-6.19**	-12.03**	2.83	17.24**	-22.02**	0.83	21.57**	2.48
L_{14} X T_2	7.89	-2.87	-14.39**	2.80	18.31**	-20.75**	0.59	-19.45**	-35.06**
L_{14} X T_3	8.57	11.71**	3.17	3.00	100.00**	66.67**	0.85	17.16**	-5.54**
L_{15} X T_1	7.51	-5.44**	-6.56**	3.23	19.75**	-11.01**	0.83	29.84**	2.48
L_{15} X T_2	8.40	-1.54	-8.89**	3.53	33.33**	0.00	0.86	25.06**	-5.17**
L_{15} X T_3	7.73	-4.21**	-6.86**	2.80	57.01**	55.56	0.78	13.38**	-14.02**
S.Ed. (±)	0.10	0.12	0.14	0.10	0.11	0.13	0.01	0.015	0.017

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

The hybrids I-07-8-4 x CLQ-47, I-07-56-4 x CLQ-47 and I-07-10-1 x HKI-163 were recorded high percentage of relative heterosis (22.67%), (19.94%), (18.70%) and heterobeltiosis (19.20%), (17.62%), (14.39%) for grain yield plant^{-1} respectively. Hybrid I-07-8-4 x CLQ-47 had considerable higher desirable relative heterosis for days to 50% tasselling (-4.09%), days to 50% silking (-3.28%), plant height (-23.06), number of kernels row^{-1} (14.96%), lysine in protein (98.00%) and desirable heterobeltiosis for plant height (-20.76%), number of kernels row^{-1} (14.42%), lysine in protein 83.33%). While hybrid I-07-56-4 x CLQ-47 had considerable higher desirable relative heterosis for days to 50% tasselling (-11.45%), days to 50% silking (-10.11%), shelling per cent (13.11%), tryptophan in protein (14.70%), lysine in protein (105.77%) and desirable heterobeltiosis for days to 50% tasselling (-6.96%), days to 50% silking (-4.19%) and lysine in protein (98.15%). While hybrid I-07-10-1 x HKI-163 had considerable desirable relative heterosis for plant height (-35.64%), 1000-kernel weight (19.17%), tryptophan in protein (5.52%) and desirable heterobeltiosis for plant height (-14.59%), 1000-kernel weight (17.32%). These three hybrids besides having significant relative heterosis and heterobeltiosis for different yield, yield contributing and quality characters also had significant *per se* performance for respective characters.

The level of heterosis observed in these hybrids justified the development of commercial hybrids in maize. Such potential of maize hybrids for commercial exploitation of heterosis have been reported by many maize breeders like Hemavathy and Balaji (2008), Laude and Salazar (2008), Saidaiah *et al.* (2008), Abdel-Moneam *et al.* (2009), Premalatha *et al.* (2011), Sundararajan and Shenthil (2011).

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Rec. on 15.10.2011 & Acc. on 29.12.2011

J. Soils and Crops 22 (2) 345-351, Dec., 2012 ISSN 0971-2836

CORRELATION AND PATH ANALYSIS OF GROWTH, YIELD AND QUALITY TRAITS IN GLADIOLUS

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ABSTRACT

Studies on correlation and path analysis in gladiolus was carried out at Main Garden, Department of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) during *rabi* season of the years 2008-09 and 2009-10 in split plot design with three gladiolus varieties *viz.,* Phule Neelrekha (V_1), Phule Tejas (V_2) and Phule Ganesh (V_3) as main factor and five foliar spray treatments of plant growth regulators *viz.,* P_1 – GA_3 100 ppm, P_2- GA_3 150 ppm, P_3 - NAA 200 ppm, P_4 – NAA 300 ppm and P_5 – control (water spray) as sub factor with three replications. Observations on height and leaves at 70 DAP, leaf area, days for first spike emergence, opening of first pair of florets and 50 per cent flowering, spike length, florets spike^{-1}, longevity of flowers on plant, diameter of corm, weight of corms plant^{-1}, cormels plant^{-1}, corms plant^{-1} and spike yield hectar^{-1} were recorded. Correlation and path coefficient analysis were estimated. Phenotypic correlation coefficient of spike yield ha^{-1} was found to be positive and significant for longevity of flowers on plant, leaf area and height at 70 DAP. Path analysis among the characters studied at phenotypic level indicated that, longevity of flowers on plant exerted maximum direct effect which was also supported by high positive correlation with spike yield ha^{-1}. Leaf area and height at 70 DAP influenced spike yield ha^{-1} indirectly to the maximum. Considering the criteria of maximum height at 70 DAP, leaf area, longevity of flowers on plant and spike yield ha^{-1} the varieties Phule Tejas and Phule Ganesh when treated with foliar spray of GA_3 150 ppm were identified to be the superior for yield and quality of gladiolus spikes, respectively.

(Key words: Gladiolus, correlation, path-analysis, direct effect, indirect effect)

INTRODUCTION

Gladiolus is an elegant cut flower of commercial importance. It has great demand in the world flower market and it ranks second best cut flower in Netherlands. Gladiolus plants produce magnificiant inflorescence which has long keeping quality. In India, gladiolus is one of the most important commercial cut flowers of export potential grown during winter season in the plains. Flower yield is a polygenetically controlled complex character and is determined by a number of component characters. The growth analyzing technique helps in understanding the growth pattern and also contribution of various plant parts to economic yield. It also helps in finding out the yield and yield contributing characters. Thus, growth analysis forms the basis for manipulation of productivity of crop. Yield being complex character is influenced by several other characters known as yield contributing characters which may have positive or negative effect on this trait. It is important to examine the contribution of each of the trait in order to give more attention to those having greatest influence on yield. Therefore, information on the degree of association of different characters with yield is of great importance to define selection criteria in terms of yield. Assessment of different characters of gladiolus including spike length, florets spike^{-1}, longevity of flowers on plant and their association with other component of characters are important for high yield of better quality flowers. The direct and indirect effect of characters and their relative contribution to the yield are the key factors for gladiolus cultivation. The present study was, therefore, undertaken to ascertain the association and contribution of different characters which is an important aspect of selection of the yield contributing characters.

MATERIALS AND METHODS

An experiment was carried out at Main Garden, Department of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) during *rabi* season of the years 2008-09 and 2009-10. The experiment was laid out in split plot design with four replications and fifteen treatment combinations. The main factor comprised of three gladiolus varieties *viz.,* Phule Neelrekha (V_1), Phule Tejas (V_2) and Phule Ganesh (V_3) and sub factor comprised of five foliar spraying treatments of plant growth regulators *viz.,* P_1 – GA_3 100 ppm, P_2- GA_3 150 ppm, P_3 - NAA 200 ppm, P_4 – NAA 300 ppm and P_5 – control (water spray). After preparing the land, the field was laid out with the beds of 45 cm spaced ridges and furrows. The

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rested, cold stored, uniform and bigger size gladiolus corms of three varieties were selected and placed at room temperature for 15 days and treated with 0.3% captaf fungicide for 15 minutes before planting. After drying in shade, the corms were planted 20 cm apart. Solution of plant growth regulators was sprayed as per the treatment along with control (water spray) at 30^{th} and 60^{th} day after planting. The observations on various growth, flowering and corm characters were recorded. Height and leaves plant^{-1} were recorded at 70 DAP, whereas, leaf area, spike length, florets spike^{-1} and spike yield hectare^{-1} were recorded at spike harvesting stage. Diameter of corm, weight of corms plant^{-1}, cormels plant^{-1} and corms plant^{-1} were recorded at corm harvesting stage. Days for first spike emergence, opening of first pair of florets and 50 per cent flowering and longevity of flowers on plant were also recorded. Two years data was pooled together and correlation analysis was done as per the method suggested by Singh and Choudhary (1994), whereas, path analysis was done as per the method given by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Correlation between the different characters with spike yield of gladiolus gives an idea of growth and yield attributes, promotion of which helps in realization of higher productivity. Usefulness of information obtained from correlation can be enhanced by partitioning them into direct and indirect effect by path coefficient analysis. Therefore, the phenotypic correlation coefficient between the different characters and spike yield of gladiolus were worked out and are presented in table 1. Out of the fourteen quantitative characters studied in gladiolus, spike yield ha^{-1} is considered to be the economic character and hence considered for discussion. The result on correlation analysis indicated that, spike yield ha^{-1} recorded positive significant correlation for longevity of flowers on plant (0.5248), leaf area (0.4523) and height at 70 DAP (0.4380). Negative significant correlation with spike yield ha^{-1} was observed for days for first spike emergence (-0.5858), days for 50 per cent flowering (-0.5858) and days for opening of first pair of florets (-0.5756). Katwate *et al.* (2002) carried out similar type of studies and observed that, the plant height, leaves plant^{-1} and days to flowering were significantly and positively correlated with the florets spike^{-1} in gladiolus under Pune (M.S.) conditions. However, Kumar *et al.* (2011) noted that, floret diameter had significant and positive correlation with marketable spikes corm^{-1} of gladiolus.

The correlation studies revealed that, strength and direction of correlation in different character combinations depend on the nature of the experimental material and environmental conditions in which they have been studied. Highly significant association of longevity of flowers on plant, leaf area and height at 70 DAP with spike yield ha^{-1} in gladiolus indicated that, an increase in any one of these characters can result in increase in the spike yield ha^{-1}. Hence, it is stressed from this study that, more emphasis should be given for the above mentioned traits while identifying the superior treatment combination.

In order to obtain developmental relations, the causes and effect of relationship between spike yield ha^{-1} and yield contributing characters were studied in gladiolus through path coefficient analysis and these results are presented in table 2. The direct and indirect effect estimated for different yield contributing characters and spike yield ha^{-1} of gladiolus indicated positive and negative values, respectively. The residual effect estimated in this study was 0.7029 which indicates that, traits considered for the analysis were not sufficient enough and still more traits to consider. The characters which contributed maximum indirect effects were alone considered here for discussion (Table 3).

Path analysis among the characters studied at phenotypic level indicated that, longevity of flowers on plant (0.6019 %) exerted maximum direct effect followed by days required for opening of first pair of florets (0.4824 %) and weight of corms plant^{-1} (0.1059 %). Out of these characters only longevity of flowers on plant was supported by very high positive correlation with spike yield ha^{-1}. Raj *et al.* (1997) also recorded a positive direct effect of durability of spike with number of florets spike^{-1} in gladiolus. However, Neeraj *et al.* (2001) reported highly positive direct effect of days to first floret showing colour upon number of florets spike^{-1} followed by duration of flowering in gladiolus.

The indirect effect of leaf area on spike yield through different yield components was found to be

Table 1. Phenotypic correlation coefficient for different characters and their correlation with spike yield of gladiolus

Characters	Height at 70 DAP	Leaves at 70 DAP	Leaf area	Days for first spike emergence	Days for opening of first pair of florets	Days for 50 % flowering	Spike length	Florets spike^{-1}	Longevity of flowers on plant	Diameter of corm	Weight of corms plant^{-1}	Cormels plant^{-1}	Corms plant^{-1}	Spikes yield hectare^{-1}
Height at 70 DAP	1.00	-0.3219**	0.6319**	-0.5103**	-0.5174**	-0.4952**	0.3153*	0.4563**	0.7635**	0.3247*	-0.1674**	0.2657*	-0.4541**	0.4380**
Leaves at 70 DAP		1.00	-0.4166**	0.1136	0.1319	0.0692	-0.5821**	-0.4212**	-0.1184	-0.6129**	0.1535	-0.7483**	0.7066**	0.0682
Leaf area			1.00	-0.7440**	-0.7430**	-0.7145**	-0.0390	0.2070	0.4703**	0.5773**	0.1344	0.5557**	-0.4187**	0.4523**
Days for first spike emergence				1.00	0.9901**	0.9383**	0.2934*	-0.0723	-0.5050**	-0.0605	0.1683	-0.0843	0.3351**	-0.5858**
Days for opening of first pair of florets					1.00	0.9438**	0.2718*	-0.1047	-0.5176**	-0.0626	0.1808	-0.0956	0.3453**	-0.5756**
Days for 50 % flowering						1.00	0.2824*	-0.0808	-0.5163**	-0.0295	0.1719	-0.0377	0.2888*	-0.5858**
Spike Length							1.00	0.6695**	0.3535**	0.2236	-0.3902**	0.2751*	-0.4767**	-0.2146
Florets spike^{-1}								1.00	0.5164**	0.1615	-0.2672*	0.1895	-0.4181**	0.0221
Longevity of flowers on plant									1.00	0.0092	-0.2944*	-0.0294	-0.3298**	0.5248**
Diameter of corm										1.00	0.4271**	0.8701**	-0.3400**	0.0175
Weight of corms plant^{-1}											1.00	0.2916*	0.4398**	-0.0016
Cormels plant^{-1}												1.00	-0.4712**	-0.0209
Corms plant^{-1}													1.00	-0.1338
Spikes yield hectare^{-1}														1.00

*,** Significant at 5% and 1% level, respectively
Table r = at 5%: 0.250 and 1%: 0.325

Table 2. Phenotypic path analysis between yield contributing characters and spike yield of gladiolus

Characters	Height at 70 DAP	Leaves at 70 DAP	Leaf area	Days for first spike emergence	Days for opening of first pair of florets	Days for 50 % flowering	Spike length	Florets spike^{-1}	Longevity of flowers on plant	Diameter of corm	Weight of corms plant^{-1}	Cormels plant^{-1}	Corms plant^{-1}
Height at 70 DAP	<u>**0.0314**</u>	0.0050	-0.1039	0.2737	-0.2496	0.1113	-0.1059	-0.0409	0.4595	0.0120	-0.0177	0.0152	0.0479
Leaves at 70 DAP	-0.0101	<u>**-0.0156**</u>	0.0685	-0.0610	0.0636	-0.0156	0.1955	0.0378	-0.0713	-0.0226	0.0163	-0.0428	-0.0746
Leaf area	0.0198	0.0065	<u>**-0.1644**</u>	0.3991	-0.3584	0.1606	0.0131	-0.0186	0.2830	0.0213	0.0142	0.0318	0.0442
Days for first spike emergence	-0.0160	-0.0018	0.1223	<u>**-0.5364**</u>	0.4777	-0.2109	-0.0986	0.0065	-0.3039	-0.0022	0.0178	-0.0048	-0.0354
Days for opening of first pair of florets	-0.0162	-0.0021	0.1221	-0.5311	<u>**0.4824**</u>	-0.2122	-0.0913	0.0094	-0.3115	-0.0023	0.0192	-0.0055	-0.0364
Days for 50 % flowering	-0.0155	-0.0011	0.1175	-0.5033	0.4553	<u>**-0.2248**</u>	-0.0949	0.0073	-0.3108	-0.0011	0.0182	-0.0220	-0.0305
Spike Length	0.0099	0.0091	0.0064	-0.1574	0.1311	-0.0635	<u>**-0.3360**</u>	-0.0601	0.2127	0.0083	-0.0413	0.0157	0.0503
Florets spike^{-1}	0.0143	0.0066	-0.0340	0.0388	-0.0505	0.0182	-0.2249	<u>**-0.0897**</u>	0.3108	0.0060	-0.0283	0.0106	0.0441
Longevity of flowers on plant	0.0240	0.0019	-0.0773	0.2709	-0.2497	0.1161	-0.1187	-0.0463	<u>**0.6019**</u>	0.0003	-0.0312	-0.0017	0.0348
Diameter of corm	0.0102	0.0096	-0.0949	0.0325	-0.0302	0.0066	-0.0751	-0.0145	0.0055	<u>**0.0369**</u>	0.0452	0.0498	0.0359
Weight of corms plant^{-1}	-0.0053	-0.0024	-0.0221	-0.0903	0.0872	-0.0386	0.1311	0.0240	-0.1772	0.0158	<u>**0.1059**</u>	0.0167	-0.0464
Cormels plant^{-1}	0.0083	0.0117	-0.0913	0.0452	-0.0461	0.0085	-0.0924	-0.0170	-0.0177	0.0321	0.0309	<u>**0.0572**</u>	0.0497
Corms plant^{-1}	0.0143	-0.0110	0.0688	-0.1797	0.1666	-0.0649	0.1602	0.0375	-0.1985	-0.0125	0.0466	-0.0270	<u>**-0.1055**</u>

Residual – 0.7029
Black with underlined values denote direct effect

Table 3. Direct and indirect effect of yield contributing characters on spike yield of gladiolus

Sr. No.	Characters	Correlation coefficient with spike yield ha^{-1}	Direct effect	Indirect effect	Major contributing characters
1	Height at 70 DAP	0.4380	0.0314	0.4066	Longevity of flowers on plant, Days for opening of first pair of florets, Days for 50 % flowering, Diameter of corm
2	Leaves at 70 DAP	0.0682	-0.0156	0.0838	Spike length, Leaf area, Days for opening of first pair of florets, Florets $spike^{-1}$
3	Leaf area	0.4523	-0.1644	0.6167	Days for first spike emergence, Longevity of flowers on plant, Days for 50 % flowering, corms $plant^{-1}$
4	Days for first spike emergence	-0.5858	-0.5364	-0.0494	Days for opening of first pair of florets, Leaf area, Weight of corms $plant^{-1}$, Florets $spike^{-1}$
5	Days for opening of first pair of florets	-0.5756	0.4824	-0.5399	Leaf area, Weight of corms $plant^{-1}$, Florets $spike^{-1}$
6	Days for 50 % flowering	-0.5858	-0.2248	-0.3610	Days for opening of first pair of florets ,Leaf area, Weight of corms $plant^{-1}$, Florets $spike^{-1}$
7	Spike length	-0.2146	-0.3360	0.1214	Longevity of flowers on plant, Days for opening of first pair of florets, Corms $plant^{-1}$, Cormels $plant^{-1}$
8	Florets $spike^{-1}$	0.0221	-0.0897	0.1118	Longevity of flowers on plant, Corms $plant^{-1}$, Days for first spike emergence, Days for 50 % flowering,
9	Longevity of flowers on plant	0.5248	0.6019	-0.0771	Days for first spike emergence, Days for 50 % flowering, Corms $plant^{-1}$, Height at 70 DAP
10	Diameter of corm	0.0175	0.0369	-0.0194	Cormels $plant^{-1}$, Weight of corms $plant^{-1}$, Corms $plant^{-1}$, Days for first spike emergence
11	Weight of corms $plant^{-1}$	-0.0016	0.1059	-0.1075	Spike length, Days for opening of first pair of florets, Florets $spike^{-1}$, Cormels $plant^{-1}$
12	Cormels $plant^{-1}$	-0.0209	0.0572	-0.0781	Corms $plant^{-1}$, Days for first spike emergence, Diameter of corm, Weight of corms $plant^{-1}$
13	Corms $plant^{-1}$	-0.1338	-0.1055	-0.0283	Days for opening of first pair of florets, Spike length, Leaf area, Florets $spike^{-1}$

Table 4. Performance of fifteen treatment combinations in gladiolus

Treatment combinations	Longevity of flowers on plant (days)	Leaf area (cm^2)	Height at 70 DAP (cm)	Spike yield ha^{-1}
V_1P_1 (Phule Neelrekha + GA_3 100 ppm)	14.75	126.90	67.10	1.67
V_1P_2 (Phule Neelrekha + GA_3 150 ppm)	15.28	131.87	70.08	1.71
V_1P_3 (Phule Neelrekha + NAA 200 ppm)	12.63	118.40	62.12	1.38
V_1P_4 (Phule Neelrekha + NAA 300 ppm)	11.80	116.82	60.28	1.25
V_1P_5 (Phule Neelrekha + water spray)	12.43	117.92	61.67	1.41
V_2P_1 (Phule Tejas + GA_3 100 ppm)	14.48	157.18	66.70	2.03
V_2P_2 (Phule Tejas + GA_3 150 ppm)	14.85	159.59	68.83	2.15
V_2P_3 (Phule Tejas + NAA 200 ppm)	12.83	138.61	63.97	1.66
V_2P_4 (Phule Tejas + NAA 300 ppm)	11.50	137.10	62.17	1.47
V_2P_5 (Phule Tejas + water spray)	12.60	138.50	63.36	1.73
V_3P_1 (Phule Ganesh + GA_3 100 ppm)	14.73	163.65	69.86	1.69
V_3P_2 (Phule Ganesh + GA_3 150 ppm)	14.93	167.56	71.85	1.77
V_3P_3 (Phule Ganesh + NAA 200 ppm)	13.18	147.03	66.03	1.55
V_3P_4 (Phule Ganesh + NAA 300 ppm)	12.13	146.19	64.43	1.53
V_3P_5 (Phule Ganesh + water spray)	12.93	147.22	65.29	1.51

maximum (0.6167 %) followed by plant height at 70 DAP (0.4066 %), spike length (0.1214 %) and florets spike^{-1} (0.1118 %) as observed from table 3. The leaf area contributed to spike yield ha^{-1}of gladiolus mainly through days for first spike emergence (0.3991), longevity of flowers on plant (0.2830), days for 50 per cent flowering (0.1606) and corms plant^{-1} (0.0442). Similarly, plant height improved spike yield indirectly through the characters like longevity of flowers on plant (0.4595), days for first spike emergence (0.2737), days for 50 per cent flowering (0.1113), corms plant^{-1} (0.0479) and diameter of corm (0.0120). Spike length contributed to increase in spike yield indirectly through major characters like longevity of flowers on plant (0.2127), days for opening of first pair of florets (0.1311), corms plant^{-1} (0.0503) and cormels plant^{-1} (0.0157). Florets spike^{-1} contributed to spike yield through longevity of flowers on plant (0.3108), corms plant^{-1} (0.0441), days for first spike emergence (0.0388) and days for 50 per cent flowering (0.0182). From the results of indirect effect the major contributors to the total indirect effect were corms plant^{-1}, florets spike^{-1}, days for opening of first pair of florets, days for first spike emergence, weight of corms plant^{-1} and leaf area.

The study on path analysis indicated that, longevity of flowers on plant, days for opening of first pair of florets and weight of corms plant^{-1} were found to exert high positive direct effect with spike yield. The characters like corms plant^{-1}, days for opening of first pair of florets, days for first spike emergence, weight of corms plant^{-1} and leaf area also showed their significance through indirect contribution to the spike yield.

The studies on correlation and path analysis indicated the need for giving weightage for plant height, leaf area and longevity of flowers on plant for improving spike yield of gladiolus. Neeraj *et al.* (2001) also reported the importance of these characters *viz.,* plant height and longevity of flowers on plant for getting good number of florets spike^{-1} in gladiolus.

From the correlation and path analysis studies it was observed that, the characters like height at 70 DAP, leaf area and longevity of flowers on plant should be given due weightage for identification of promising gladiolus variety and growth regulator combination. The mean performance of fifteen treatment combinations were compared along with spike yield and presented in table 4. Considering the above mentioned characters the treatment combinations of V_2P_2 ((Phule Tejas + GA_3 150 ppm)) and V_3P_2 ((Phule Ganesh + GA_3 150 ppm) were identified to be the superior combinations in respect of yield and quality of gladiolus spikes, respectively. It is therefore, concluded from this study that, the gladiolus varieties Phule Tejas and Phule Ganesh when treated with foliar spray of GA_3 150 ppm showed superior performance for yield and quality of spikes, respectively.

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Rec. on 10.09.2011 & Acc. on 28.12.2011

J. Soils and Crops 22 (2) 352-357, Dec., 2012 ISSN 0971-2836

LONG TERM IMPACT OF INTEGRATED NUTRIENT MANAGEMENT ON ACTIVE POOL OF SOIL ORGANIC CARBON AND NUTRIENTS IN SORGHUM UNDER SORGUM-WHEAT CROPPING SYSTEM IN VERTISOL

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ABSTRACT

Studies were undertaken on *kharif* sorghum at Marathwada Agricultural University, Parbhani during year 2005-06 to know the response of FYM, wheat straw, glyricidia and subabul loppings on active pool of soil organic carbon and nutrients. The treatment details are as follows: Control, 50% RD of NPK, 75% RD of NPK, 100% RD of NPK, 50% RD of NPK + 50% N through FYM, 75% RD of NPK + 25% N through FYM, 50% RD of NPK + 50% N through wheat straw, 50% RD of NPK + 50% N through Subabul, 50% RD of NPK + 50% N through Glyricidia, 75% RD of NPK + 25% N through Glyricidia, Farmers practice 40:20:20 kg NPK ha^{-1} and seeds without treatment, 75% RD of NPK + 25% N through Subabul, 75% RD of NPK + 25% N through wheat straw. Within various treatments 50% RD of NPK + 50% N through FYM gave significantly higher grain (29.18 kg ha^{-1}) and straw yields (30.87 kg ha^{-1}). The highest content of SMBC (703.52), SMBP (17.94)and SMBS (8.49) were found in plots receiving 50% RD of NPK + 50%N through FYM. While the values for SMBN (16.96) was recorded its peak in treatment receiving 50% RDF + 50% N through FYM. Active pool was found low in all the inorganic treatments. Among these treatments treatment receiving 100% RDF (T_4) showed highest values for active pool of organic carbon and nutrients while control plot showed lowest response to active pool.

(Key words: Sorghum, INM, active pool)

INTRODUCTION

Soil organic matter is known to represent the primary origin of energy for micro-organisms and can be divided into several fractions that vary in turn from hours to thousand of years. The active fraction of organic matter consisted of amino acids, group of proteins and carbohydrates representing dynamic portion of huge and slowly changing background of stable organic matter. Active pool of soil organic carbon and nutrients consists of microbial biomass and their metabolites. This liable pool is readily available for microbial use and is stored by microorganisms. A portion of such kind of organic substances can be quantified as an indicator of actual amount of microbial population. There has been increasing interest to define measurements of soil microbial biomass. This fraction gives up mineral nutrients and it gives up life to the soil. Active pool of soil organic matter constitutes the most important fractions, which contribute most towards nutrition of growing plants.

The major fractions of active pool includes soil microbial biomass carbon (SMBC), soil microbial biomass nitrogen (SMBN), soil microbial biomass phosphorus (SMBP) and soil microbial biomass sulphur (SMBS). The soil microbial biomass comprising about 2-3% of the total organic carbon in soil, is a relatively labial fraction of soil organic matter. It is, therefore, more important repository of plant nutrients than its small size might indicate. Hence, there has been an increasing interest to define measurements of soil microbial biomass.

MATERIALS AND METHODS

The study was framed to investigate the long term impact of integrated nutrient management on active pool of soil organic carbon and nutrients, in Marathwada Agricultural University, Parbhani during year 2005-06. The experiment was conducted in survey No.124 block at Central Farm, Marathwada Agricultural University, Parbhani by Cropping System Research Scheme since 1983-1984. Marathwada lies in the South eastern part of Indian Union.

The major soils of Parbhani district are derived from "deccan trap" (basalt) which is rich in iron, lime and magnesium (Gajbe *et al*., 1976). On the basis of morphology, soil depth and texture, these soils are considered to be identical to that of Parbhani series (Typic Haplusterts) as classified by Malewar

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(1976). The topography of experimental plot was fairly leveled. The soil was medium, deep, well drained and calcareous in nature which was developed from weathered basalt. This experimental soil was categorically placed under typic halpusters of Parbhani.

The experiment was laid in randomized block design with 13 treatments involving NPK fertilizers alone and also in combination with FYM, glyricidia, wheat straw and subabul. Treatment details are given in table 1.

To evaluate the impact of Integrated Nutrient Management on active pool of soil organic carbon and nutrients in Sorghum-wheat sequence, organic sources *viz.,* FYM, wheat straw, glyricidia and subabul leaves were incorporated in soil before sowing of *kharif* crop and chemical fertilizers were applied to sorghum (CSH-9) through straight fertilizers like urea, single super phosphate and muriate of potash (recommended dose of fertilizers for *kharif* sorghum is 80:40:40 kg NPK ha^{-1}). The method of application of fertilizers adopted was drilling.

Surface soil samples (0-15 cm depth) in the bulk were collected from Cropping System Research Farm, Marathwada Agricultural University, Parbhani. The soil was air dried and passed through 2 mm sieve and was then used for further analysis. Chemical composition of organic materials used is as below:

Chemical composition of organic materials

Organic source	C	N	C:N ratio
	Nutrient composition (%)		
FYM	36.5	0.6011	60.83
WS	48.12	0.5989	80.20
GM	36.4	4.543	24.3
SB	41.5	2.1189	19.66

The doses of these organic materials were decided on the basis of their N content. For supplying 50% of N through FYM and wheat straw 6.6 tonnes of FYM and wheat straw was used while for 25% N through FYM and wheat straw, 3.3 tonnes of FYM and wheat straw ha^{-1} was used. Similarly 1.1 and 1.9 tonnes of glyricidia leaves and subabul were applied to supply 50% N. While 0.5 and 0.94 tonnes of glyricidia leaves and subabul were applied to supply 25% N.

Standard procedures were used to determine available nutrients in the soil. Chloroform fumigation method (Jenkinson and Powlson, 1976) was followed for determination of soil microbial biomass carbon, nitrogen. SMBC was determined by CO_2 evolution from fumigated and unfumigated soils, whereas steam distillation of fumigated and unfumigated soil samples was accomplished with K_2SO_4 soil extracts for SMBN as described by Brookes *et al.* (1985). The fumigated and unfumigated sets were extracted with 0.5 M $NaHCO_3$, containing P (as KH_2PO_4) equivalent to 25 µg inorganic P g^{-1} oven dry soil (Brookes *et al.*, 1982). Similarly for determination of SMBS both $CHCl_3$ fumigated and non-fumigated soil samples were extracted using 10 mM $CaCl_2$ in 1:5 (Soil: Solution ratio) as described by Saggar *et al.* (1981).

RESULTS AND DISCUSSION

Sorghum grain and straw yields :

The crop growth and yield was very low due to low rainfall and other adverse climatic conditions in Parbhani District. The results depicted in Fig.1 and 2 indicated that grain and straw yield of sorghum was significantly increased due to application of NPK fertilizers alone and in combination with organic sources over control during experimentation. Within various treatments 50% RD of NPK + 50% N through FYM gave significantly higher grain (15.77 q ha^{-1}) and straw yields (35.16 q ha^{-1}). In the present study, response of recommended (14.70 and 37.90 q ha^{-1}), ½ recommended (8.77 and 27.62 q ha^{-1}) and ¾ recommended NPK (8.28 and 23.67 q ha^{-1}) application showed significantly higher grain and straw yield of sorghum over control (no NPK) (0.40 and 1.58 q ha^{-1}). Among inorganic fertilizer treatments highest grain yield was observed in plot receiving 100% RD of NPK.

In other set of treatment combinations of inorganic fertilizers with FYM, glyricidia, wheat straw and subabool leaves as a source of organic material further added to grain and straw yield of sorghum. Among organic sources, FYM followed by wheat straw have proved the superiority over other organic materials and increasing the grain and straw yields of sorghum by their complementary effect on increased the availability and efficiency of inorganic fertilizers as well as release of inorganic forms of nutrients on its decomposition. The relatively higher efficiency of sorghum recorded significantly higher yield compared with FYM and RDF alone. Bayu *et al.* (2006) also found that combined application of FYM and RDF increased the grain and straw yield of sorghum by 36% and 21 % respectively.

Active pool of soil organic carbon and nutrients :

Results indicated that continuous application of fertilizers and organic sources improved the active pool of nutrients and these active pools are sustained under long term use of balanced fertilization along with manures. Soil microbial biomass carbon (SMBC) ranged from 298.00 to 703.52 mg kg^{-1}. The highest value for SMBC was found in the treatment receiving 50 % RD of NPK + 50 % N through FYM, followed by the treatment receiving 75 % RD of NPK + 50 % N through FYM. The fertilizer application substantially increased the SMBC content over control plot but FYM application showed a marked increase in it. The higher biomass C in soil at harvest was probably due to higher availability of substrates as carbon from applied FYM, intense rooting activity and better soil water status. It confirms that organic amendments like FYM increases the microbial biomass in the soil and there by increases the soil microbial biomass carbon. The similar results were confirmed by Tariq *et al.* (2005). They found that substituting half dose of fertilizers by FYM showed marked increase in the SMBC. They also observed significant effect of temperature on decomposition of organic matter in months of June to October which contributed to high level of SMBC.

The results on nitrogen revealed that Soil microbial biomass nitrogen (SMBN) and Soil microbial biomass phosphorus (SMBP) responded differently in different treatments. SMBN and SMBP ranged from 9.04 to 16.96 mg kg^{-1} and 8.02 to 17.94 mg kg^{-1} respectively. The highest content of SMBN (16.96 mg kg^{-1}) was found in 50% RD of NPK + 50% N through glyricidia followed by the treatment with application of 75 % RD of NPK + 25 % N through glyricidia (16.39 mg kg^{-1}). SMBP was found highest (17.94 mg kg^{-1}) with the treatment receiving 50% RD of NPK + 50% N through FYM while 75% RD of NPK + 25% N through subabul ranked second (17.86 mg kg^{-1}). The highest content of SMBP was observed in FYM treated plot and subabul ranked second, this may be because FYM had provided decomposed residue and subabul as applied fresh may caused immobilization of phosphorus, thus giving less content of SMBP. The research findings thus, showed that addition of organic residues sharply increased the SMBN and SMBP.

The highest value of SMBN was obtained in glyricidia. This might be attributed to stimulated suitable conditions for microbial growth, where development had acted as a good substratum for microbial activity. Thakare and Ravankar (2004) also observed high values of SMBC, SMBN, SMBP and SMBS in NPK + FYM treated plots followed by NPK, PN, N and control in Vertisol. This might be due to improvement of water soluble fractions in these treatments. Saini *et al.* (2004) also reported good response of FYM in increasing microbial biomass phosphorus immobilization under decomposing organic residue.

Soil microbial biomass sulphur (SMBS) content of experimental plot varied from 4.27 to 8.49 mg kg^{-1}. Highest values (8.49 mg kg^{-1}) of SMBS were found with application of 50% RD of NPK + 50% N through FYM in T_5 . Treatment T_5 was followed by treatment receiving 75% RD of NPK + 25% N through glyricidia. Organic residues like gylricidia and FYM may have added nitrogen which stimulated the synthesis of SMBS in the soil. On the other side addition of crop residue like wheat straw and subabul may be immobilized the sulphur and hence in other treatments its content was found low. These findings are corresponding to conclusions published by Shahsavani and Gholami (2009) who found that the supply of N can limit S immobilization in soil, particularly during rapid growth of the microbial biomass.

Among inorganic treatments, the active pool of soil organic carbon and nutrients was found the highest in 100% RD of NPK which was found significantly superior over other two treatments. While the control plot without any fertilizer application showed the lowest SMBC content.

The improvement of active pool of nutrients helps in nutrient supply to the growing plants. In long term fertilizer experiment, NPK + FYM application significantly influenced the SMBN,SMBP,SMBC and SMBS contents in Vertisol of Akola (Anonymous,2004). Manna *et al.* (1996) also reported significant increase in SMBC, SMBN and

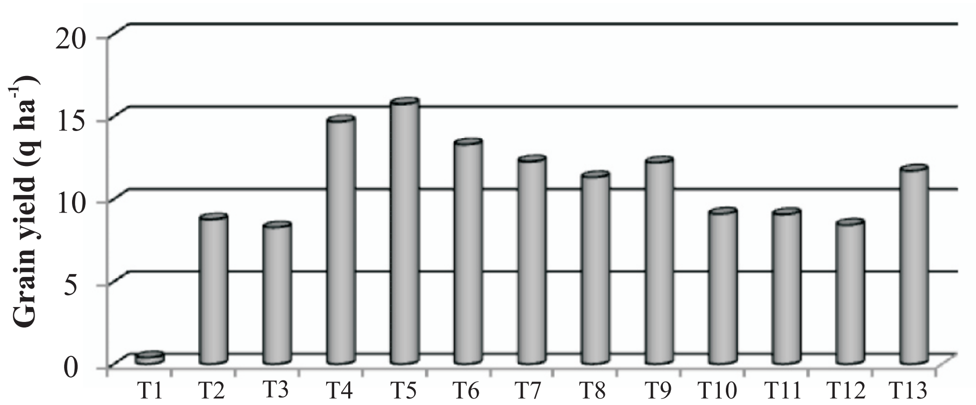

Fig. 1 Long term impact of integrated nutrient management on grain yield of Sorghum

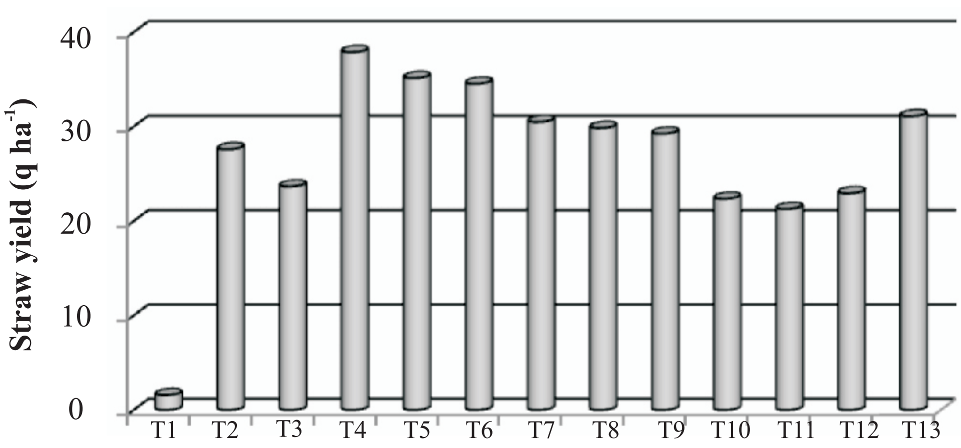

Fig. 2 Long term impact of integrated nutrient management on straw yield of Sorghum (q ha^{-1})

Table 1 Treatment Details

T_1	Control
T_2	50% RD of NPK
T_3	75% RD of NPK
T_4	100% RD of NPK
T_5	50% RD of NPK + 50% N through FYM
T_6	75% RD of NPK + 25% N through FYM
T_7	50% RD of NPK + 50% N through wheat straw
T_8	75% RD of NPK + 25% N through wheat straw
T_9	50% RD of NPK + 50% N through Glyricidia
T_{10}	75% RD of NPK + 25% N through Glyricidia
T_{11}	Farmers practice 40:20:20 kg NPK ha^{-1} and seeds without treatment
T_{12}	75% RD of NPK + 25% N through Subabul
T_{13}	50% RD of NPK + 50% N through Subabul

Table 2. Long term impact of integrated nutrient management on grain and straw yield of sorghum (q)

	Treatments	2005 -06	
		Grain	Straw
T_1	Control	0.40	1.58
T_2	50% RD of NPK	8.77	27.62
T_3	75% RD of NPK	8.28	23.67
T_4	100% RD of NPK	14.70	37 .90
T_5	50% RD of NPK + 50% N through FYM	15.77	35.16
T_6	75% RD of NPK + 25% N through FYM	13.31	34.56
T_7	50% RD of NPK + 50% N through wheat straw	12.28	30.50
T_8	75% RD of NPK + 25% N through wheat straw	11.32	29.86
T_9	50% RD of NPK + 50% N through glyricidia	12.21	29.27
T_{10}	75% RD of NPK + 25% N through glyricidia	9.11	22.38
T_{11}	Farmers practice 40:20:20 kg NPK ha^{-1} and seeds without treatment	9.08	21.29
T_{12}	75% RD of NPK + 25% N through subabul	8.44	22.95
T_{13}	50% RD of NPK + 50% N through subabul	11.72	31.11
	SE±	0.93	3.04
	C D at 5%	2.57	8.42

Table 3. Long term impact of integrated nutrient management on Soil Microbial Biomass Carbon, nitrogen phosphorus and sulphur at harvest of sorghum

	Treatments	SMBC	SMBN	SMBP	SMBS
T_1	Control	298.00	9.04	8.02	4.27
T_2	50% RD of NPK	363.54	11.38	8.40	5.13
T_3	75% RD of NPK	405.33	13.96	11.08	6.90
T_4	100% RD of NPK	469.26	16.01	11.14	8.16
T_5	50% RD of NPK + 50% N through FYM	703.52	16.45	17.94	8.49
T_6	75% RD of NPK + 25% N through FYM	638.77	16.02	17.40	8.38
T_7	50% RD of NPK + 50% N through wheat straw	596.61	15.83	17.33	7.63
T_8	75% RD of NPK + 25% N through wheat straw	599.36	15.90	17.02	7.21
T_9	50% RD of NPK + 50% N through glyricidia	579.39	16.96	15.37	8.28
T_{10}	75% RD of NPK + 25% N through glyricidia	526.37	16.39	17.50	8.42
T_{11}	Farmers practice 40:20:20 kg NPK ha^{-1} and seeds without treatment	521.57	14.21	16.01	7.17
T_{12}	75% RD of NPK + 25% N through subabul	583.74	15.44	17.86	8.15
T_{13}	50% RD of NPK + 50% N through subabul	530.86	15.75	17.72	8.32
	SE ±	0.67	0.30	0.08	0.26
	CD at 5%	1.96	0.88	0.24	0.79

SMBP with increase FYM may be attributed to the narrow C:N ratio. Comparing the effects of fertilizers alone and in combination with organic manures, it could be pointed out that 100% RD of NPK through fertilizers and 50% RD of NPK through fertlizers + 50% N through FYM were on par with each other. Arjun Sharma and Anil Kumar (2009) also concluded that application of FYM @ 5 t ha^{-1} along with RDF to *rabi* in FYM levels. Santhy *et al.* (1999) reported that integrating FYM along with NPK increased biomass C by 31% over the amount recorded with optimal NPK. Biomass N was also found increased with combined application of FYM and NPK fertilizers.

The results showed that the total yield of sorghum (grain and straw) and microbial biomass was increased in soils treated with organic residues and fertilizers, than fertilizers alone. It also showed that the plots receiving combined application of organic residue and fertilizers contains more microbial biomass nutrients than in control soils. This suggests that there would be greater cycling and fluxes of nutrients through the microbial biomass in soil supplied with organic residues and fertilizers.

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Rec. on 07.09.2011 & Acc. on 19.12.2011

J. Soils and Crops 22 (2) 358-361, Dec., 2012 ISSN 0971-2836

EFFECT OF FOLIAR APPLICATION OF GA_3 AND KNO_3 ON GROWTH AND YIELD OF TUBEROSE

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ABSTRACT

An experiment was laid out to study the effect of two sprays (30 and 60 days after planting) of GA_3 (100 and 200 ppm) and KNO_3 (1 and 1.5%) on growth and yield of tuberose during the *kharif* season of 2010-11. It is evident from experimental findings that, height of plants was increased with the foliar spray of GA_3 - 200 ppm at 30 and 60 days after planting. However, the number of leaves plant^{-1}, number of clumps hill^{-1} and leaf area were observed maximum with foliar application of GA_3 - 200 ppm in combination with KNO_3 1.5%. Minimum days required for first spike initiation (98.00 days) was obtained in the treatment combination of GA_3 - 200 ppm with KNO_3 1.5% when compared with control (106.60 days). Foliar spray of GA_3 at 200 ppm in combination with KNO_3 1.5% at 30 and 60 days after planting also resulted in higher spike yield ha^{-1} and number of florets spike^{-1}.

(Key words : Tuberose, GA_3, KNO_3, growth and yield)

INTRODUCTION

Tuberose (*Polianthes tuberosa* L.) belongs to family Amarllidaceae, is native of Mexico. It is one of the popular and commercially imporant bulbous flower crops and occupies a prime position in the domestic and international market. It is a multipurpose flower, which is in a great demand as a cut flower, loose flower and for its aromatic value.

The horticulture science is a 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, thus, modifying 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 growth and yield of tuberose.

MATERIALS AND METHODS

An investigation entitled, "Effect of foliar application of GA_3 and KNO_3 on growth and yield of tuberose" was carried out at the Farm of Horticulture Section, College of Agriculture, Nagpur during *kharif* season 2010-11. 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 - 100 ppm, GA_3 - 200 ppm, KNO_3 - 1%, KNO_3 - 1.5%, GA_3 - 100 ppm + KNO_3 - 1%, GA_3 - 100 ppm + KNO_3 - 1.5%, GA_3 - 200 ppm + KNO_3 - 1%, GA_3 - 200 ppm + KNO_3 - 1.5% and control (water spray). Farm yard manure was applied at 20 t ha^{-1}. A fertilizer dose of 200:300:200 kg NPK ha^{-1} was applied. Growth substances were sprayed 30 days after planting. The second spray was given 30 days after the first spray. The plant sprayed with water served as control. The plot size was 2 m x 1.2 m with plant to plant spacing of 20 cm. Observations on growth (Plant height, Number of leaves plant^{-1} , Number of clumps hill^{-1} and Leaf area plant^{-1}), flowering (Spike emergence in days) and spike yield (number of florets spike^{-1}, number of spikes plot^{-1} and ha^{-1}) were recorded. The data were statistically analyzed as per method suggested by Gomez and Gomez (1984) for randomized block design.

RESULTS AND DISCUSSION

The growth parameters included plant height, number of leaves plant^{-1}, number of clumps hill^{-1} and leaf area plant^{-1} (cm^2). The observations recorded on growth parameters are given in table 1.

The significantly maximum plant height was noted in the treatment T_2 - GA_3 200 ppm (60.91 cm)

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over all other treatments except T_8 - GA_3 200 ppm + KNO_3 1.5% (60.38 cm) and T_7 - GA_3 200 ppm + KNO_3 1% (60.20 cm), which were at par with each other. While the minimum plant height (48.82 cm) was recorded under the treatment T_9 control (water spray).

It is evident from the data that, the plant height was influenced by higher concentration of GA_3 treatment and was superior over all other treatments. It might be due to stem elongation by stimulating cell division and cell elongation. Significant effects were observed due to GA_3, while KNO_3 had little effect on height of plant.

Sagar *et al.* (2005) reported that foliar spray of GA_3 200 ppm increased plant height (55.93 cm) as compared to other treatments in tuberose. Devadanam *et al.* (2007) tested different concentrations of GA_3 viz., (50, 100 and 150 ppm) and reported that foliar application of GA_3 150 ppm gave significantly maximum plant height (59.13 cm) in tuberose cv. Single.

The different concentrations of GA_3 and KNO_3 had a significant effect on number of leaves plant^{-1}, number of clumps hill^{-1} and leaf area plant^{-1} (cm^2). The treatment GA_3 - 200 ppm + KNO_3 1.5% was found most effective in increasing leaves plant^{-1}, number of clumps hill^{-1} and leaf area plant^{-1} (cm^2). The next effective treatments in this respect were GA_3 - 200 ppm + KNO_3 1% and GA_3 - 200 ppm, while the least values were recorded under the treatment T_9 control (water spray).

It is inferred from the data that, the different concentrations of GA_3 in combination with KNO_3 as foliar spray influenced the development of leaves plant^{-1}, clumps hill^{-1} and leaf area plant^{-1} (cm^2). It clearly showed that GA_3 stimulate vegetative growth by cell multiplication and cell elongation, thereby resulted in increase in leaves plant^{-1}, clumps hill^{-1} and leaf area plant^{-1}. KNO_3 also played important role in enhancing vegetative growth by assimilating N and K through foliar spray.

The results obtained during this investigation are in agreement with Patil *et al.* (2004) in golden rod with GA_3 application. They reported that, maximum number of leaves plant^{-1} (71.00) was obtained with GA_3 spray at 200 ppm as compared to other treatments in golden rod (*Solidago conedensis* L.).

The results obtained on flowering and on spike yield are presented in table 2.

The data regarding number of days required for initiation of first flower stalk (spike) indicated that, the treatment T_8 (GA_3 – 200 ppm + KNO_3 1.5%) required least number of days (98.00) for stalk emergence. However, late initiation of flower spike (106.6) was recorded under the treatment T_9 (control).

The foliar application of GA_3 and KNO_3 in combination showed early spike emergence than control. It might be due to early production of floringine in GA_3 and enhancement of vegetative growth due to KNO_3 as it plays important role in providing N and K to the plant growth. Both GA_3 and KNO_3 had a significant shortening effect on time of emergence of spike as compared to control.

The results are in conformity with the findings of Chaphale *et al.* (2001) in tuberose with the application of GA_3. He conducted an experiment to study the effect of GA_3 at different concentrations viz., (0, 50, 100 and 150 ppm) on tuberose cv. Single and observed that GA_3 150 ppm recorded significantly superior results in respect of early emergence of spike. Karaguzel and Doron(2000) stated that both GA_3 at 100 ppm and application of KNO_3 25 g per m^2 (5 times) as additional fertilizer at weekly interval shortened time from planting to flowering and increased flowering in gladiolus.

The significantly more number of florets spike^{-1} (38.00) was found under the treatment T_8 (GA_3– 200 ppm + KNO_3 1.5%) as compared to control water spray (30.13). This might be due to greater dry matter accumulation, better photosynthetic activities, other metabolic activities and uptake of nutrients from soil.

Baskaran and Misra (2007) reported that the number of florets spike^{-1} was increased over control under spraying treatment of GA_3 at all concentrations (200, 500, 1000 ppm) in gladiolus.

With the increase in concentration of GA_3 in combination with KNO_3 spike yield ha^{-1} increased.

Table 1. Influence of GA_3 and KNO_3 on growth parameters in tuberose

Tr. No.	Treatments	Plant height (cm)	Number of leaves plant^{-1}	Clumps hill^{-1}	Leaf area plant^{-1} (cm^2)
T_1	GA_3 -100 ppm	54.02	56.40	22.86	45.46
T_2	GA_3 – 200 ppm	60.91	63.51	25.46	48.13
T_3	KNO_3 -1%	50.57	51.13	19.20	43.86
T_4	KNO_3 -1.5%	51.08	51.53	19.60	44.60
T_5	GA_3 -100 ppm + KNO_3 -1%	54.83	56.66	23.00	46.13
T_6	GA_3 -100 ppm + KNO_3 -1.5%	55.85	59.93	23.66	46.80
T_7	GA_3 -200 ppm + KNO_3 -1%	60.20	63.79	26.80	48.47
T_8	GA_3 -200 ppm + KNO_3 -1.5%	60.38	64.23	27.53	48.80
T_9	Control (W.S.)	48.82	50.26	19.13	43.20
	SE (m)	0.21	0.26	0.29	0.12
	CD at 5%	0.61	0.76	0.87	0.36

Table 2. Influence of GA_3 and KNO_3 on flowering and on spike yield in tuberose

Tr. No.	Treatments	Spike emergence (days)	Number of florets spike^{-1}	Spike yield	
				Plot^{-1} (2.4 m^2)	Ha^{-1} (lakh)
T_1	GA_3 -100 ppm	104.80	32.86	167.26	3.81
T_2	GA_3 – 200 ppm	99.06	36.33	255.13	5.81
T_3	KNO_3 -1%	105.73	30.26	154.20	3.51
T_4	KNO_3 -1.5%	105.06	31.60	188.20	4.29
T_5	GA_3 -100 ppm + KNO_3 -1%	102.86	33.66	215.86	4.92
T_6	GA_3 -100 ppm + KNO_3 -1.5%	102.93	34.20	225.46	5.14
T_7	GA_3 -200 ppm + KNO_3 -1%	98.80	37.26	286.46	6.53
T_8	GA_3 -200 ppm + KNO_3 -1.5%	98.00	38.00	301.13	6.86
T_9	Control (W.S)	106.60	30.13	137.46	3.13
	SE (m)	0.47	0.27	8.35	0.21
	CD at 5%	1.37	0.80	24.34	0.62

The significantly maximum number of spikes $plot^{-1}$ and $hectare^{-1}$ was recorded in the treatment T_8 (GA_3 – 200 ppm + KNO_3 1.5%) followed by treatment T_7 (GA_3 – 200 ppm + KNO_3 1%) and T_2 (GA_3 – 200 ppm) respectively. However, minimum number of spikes $plot^{-1}$ and $hectare^{-1}$ was observed in the treatment T_9 control (water spray). Number of spikes $hectare^{-1}$ ranged from 3.13 lakhs in control plants to 6.86 lakhs in plants treated with GA_3 – 200 ppm + KNO_3 1.5%. Higher concentration of GA_3 in combination with KNO_3 applied as foliar spray resulted more number of spikes $plant^{-1}$ and number of florets $spike^{-1}$ as compared to untreated plants. It is also evident that vegetative growth of plant was also found more in combine treatment of GA_3 and KNO_3 as compared to other treatments. This might be due to more production of food material in leaves, due to enhanced physiological activities by both GA_3 and KNO_3 treatments resulted in development of more number of spikes $plot^{-1}$ and $hectare^{-1}$ over all other treatments.

Katkar *et al.* (2005) concluded that number of flowers $plant^{-1}$ and yield of flowers $hectare^{-1}$ were recorded more under the treatment of GA_3 at 200 ppm in China aster.

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Rec. on 21.05.2011 & Acc. on 27.08.2011

J. Soils and Crops 22 (2) 362-369, Dec., 2012 ISSN 0971-2836

SCREENING OF MUSTARD PARENTS AND CROSSES FOR DROUGHT TOLERANCE

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ABSTRACT

An experiment was conducted in mustard with the objective to identify superior drought tolerant crosses for recombination breeding and to study the correlation between the different traits. Thirty crosses obtained by crossing two testers (drought tolerant donors) with fifteen lines along with their parents were evaluated in factorial randomized complete block design replicated twice with three stress treatments i.e. control (C), moderate stress (MS) and severe drought stress (SS) in pot experiment during *rabi* 2009-2011. Observations on days to first flower, days to maturity, plant height, number of branches plant^{-1}, number of siliqua plant^{-1}, root length, root volume at maturity, leaf relative water content, proline content, yield plant^{-1} and drought tolerant efficiency were recorded on five randomly selected plants from each treatment. The genotypes differed significantly for all the characters studied except number of branches plant^{-1} under both normal and drought condition. The genotype x treatment interaction were significant for all the traits except days to 50% flowering and number of branches plant^{-1}. Severe stress treatment allowed flower and siliqua formation only in very few genotypes. The mean performance of all the traits were affected either on the higher or lower side due to stress. Number of siliqua plant^{-1} and seed yield plant^{-1} were the most affected traits due to stress. Moderate stress resulted in 11.7, 38.87, 34.72, 73.69, 40.77, 7.26 and 63.67 per cent reduction for days to maturity, plant height, number of branches plant^{-1}, number of siliqua plant^{-1}, root volume, LRWC and seed yield plant^{-1} respectively and 3.11%, 60.47% increase for root length and proline accumulation due to stress. Correlation study under control and stress revealed that seed yield plant^{-1} was positive and significantly correlated with plant height, number of siliqua plant^{-1} under control condition and with plant height and proline content under stress condition. The parents RH-819, Geeta, Kranti, JD-6 and Pusabold and the crosses Varuna x RH-819, Ashirvad x RH-819, JD-6 x Geeta, ACN-9 x Geeta were identified as superior parents and crosses respectively for drought tolerance, based on high DTE, high mean seed yield under stress, less per cent reduction for yield and number of siliqua plant^{-1} and high per cent increase for proline content. These five parents RH-819, Geeta, Kranti, JD-6 and Pusabold and four crosses Varuna x RH-819, Ashirvad x RH-819, JD-6 x Geeta, ACN-9x Geeta identified will be exploited in breeding for drought tolerance.

(Key words: Mustard, drought tolerance, yield)

INTRODUCTION

Rapeseed is an important oilseed crop in agricultural system of many arid and semi arid areas where its yield is often restricted by water deficit and high temperature during the reproductive growth. Seed yield can be primarily limited even by the relatively short period of soil moisture shortage during the reproductive development. The effect of water stress on crop is a function of genotype, intensity and duration of stress, weather condition and development stages of rapeseed. The occurrence time is more important than the water stress intensity. Seed yield potential of *Brassica* crop depends on the event occurring prior to and during the flowering stage, while the reproductive period is more susceptible to stress. Severe stress decreases the duration of reproductive growth and stress during the flowering or ripening stage results in large yield losses. Water stress occurring at any time during reproductive growth can result a drastic change in seed yield.

In India mustard is grown as a rainfed crop on conserved moisture received from monsoon rains in 37% of the total area under the crop. Drought is also observed in the irrigated areas due to insufficient supply of water and canal closure. In response to the water stress plant faces physiological changes including loss of cell turgour, closing of stomata, reduction in cell enlargement and reduced leaf surface area. All these abnormalities ultimately decreases photosynthesis and respiration and as a result overall production of crop is reduced (Sadaqat *et al.,* 2003). It is the need of the time to develop varieties which can tolerate water stress to increase area and yield of the oilseed crop. Therefore, an attempt was made in this study to identify the superior parents and crosses for their use in breeding mustard for developing drought tolerance varieties.

MATERIALS AND METHODS

Screening of mustard parents and crosses for drought tolerance was carried out during 2009-2011 at the experiment farm of Botany section, College of Agriculture, Nagpur. The experimental material

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comprised of two drought tolerant donors Geeta and RH-819 and fifteen lines viz., ACN-9, Pusa bold, BIO-902, Urvashi, JD-6, GM-2, Sej-2, Laxmi, Seeta, Ashirwad, Kranti, Vardan, Varuna, PCR-7, Pusabahar.

These fifteen lines were crossed with two testers during *rabi* 2009-10 to obtain thirty crosses. These thirty crosses alongwith 17 parents were evaluated in factorial randomized complete block design replicated twice with three stress treatments in pot experiment during *rabi* 2010-2011. The three stress treatments for the experiment consisted of (i) control(C) in which plants were regularly watered according to the standard practice, (ii) moderate stress (MS) in which drought was induced by withholding water after germination upto flowering, one watering was then given followed by withholding of water till harvesting and (iii) severe drought stress (SS) in which drought was stimulated by withholding water after germination throughout the growing season. Observations were recorded on days to first flower, days to maturity, plant height (cm), number of branches plant^{-1}, number of siliqua plant^{-1}, root length (cm), root volume at maturity (cm^3), leaf relative water content(%), proline content (µ mole g^{-1} tissue) , yield plant^{-1} (g), and drought tolerant efficiency (%). Leaf relative water content (LRWC) was estimated by relative turgidity technique, given by Barrs and Weatherly (1992) and Proline content was determined by nin-hydrine method given by Bates *et al*. (1973). Drought tolerance efficiency (DTE) was calculated by using the formula (yield under stress/ yield under control) X 100. The data were subjected to analysis of variance for FRBD as per the method suggested by Panse and Sukhatme (1954) and simple correlation (r) between different traits were estimated using the formula given by Singh and Choudhary (2004).

RESULTS AND DISCUSSION

The analysis of variance for experimental design were analyzed and mean squares for different characters are presented in table 1. The mean squares due to treatments were significant for all the ten characters studied except number of branches plant $^{-1}$ i.e. days to first flower, days to maturity, plant height, number of siliqua plant^{-1}, yield plant^{-1}, root length, root volume, leaf relative water content, proline content and drought tolerance efficiency. The mean squares due to factor A i.e., genotypes (parents and crosses) were significant for all the characters studied except number of branches plant^{-1}. The mean squares due to factor B (different stress treatments) were found to be significant for all the characters studied except days to 50% flowering. Genotype X treatment interaction was also significant for all the traits except days to 50% flowering and number of branches plant^{-1}. The analysis of variance revealed that the genotypes differed significantly for all the characters except number of branches plant^{-1} in both normal and drought condition. The significant variability among the genotypes for yield and yield components under normal and stress condition were also reported by Sadaqat *et al.*(2003) and Singh and Choudhary (2003). The significant genotype x environment interaction observed for most of the characters except number of branches plant^{-1} and days to 50% flowering satisfied the basic requirement for comparing the expression of different genotypes under different environment. Such type of significant interaction were also reported by Sadaqat *et al.*(2003) and Ahmadi and Bahrani (2009) in mustard.

The mean performance of all the traits were affected either on the higher or lower side due to stress. Severe stress treatment allowed flower formation in very few genotypes but moderate stress treatment allowed the flower formation in all the genotypes and hence, the effect of moderate stress alone has been considered over control for discussion in this paper. Number of siliqua plant^{-1} and seed yield plant^{-1} were the most affected traits due to stress. The stress treatment did not affect much on days to first flower.

The results on the effect of moisture stress on different traits are presented in table 2. The highest reduction for days to maturity was recorded by the parent Kranti (14.58%) followed by Ashirvad (14.51%) and Pusa bahar (13.09%). Per cent reduction for days to maturity was found to be maximum in the cross Pusa Bahar x Geeta (17.17%) followed by Urvashi x RH-819 (16.84%) and Bio-902 x RH-819 (15.90%) and Pusa bahar x RH-819 (15.81%). Similar to this result Ahmadi and Barhani (2009) reported that abiotic stress (moisture) at flowering and reproductive stage can result in source limitation for seed yield by inducing leaves shedding and hastening maturity. Singh and Chaudhary (2003) also reported an average reduction of 9.4% for days to maturity due to drought.

The least reduction in plant height due to moderate stress was recorded by RH-819 (12.57%), followed by Geeta (20.71%), Bio-902 (22.12%) among parents and Bio-902 x RH-819 (10.45%), Varuna x RH-819 (13.03%) and Pusa bahar x Geeta (17.17%) among the crosses. In accordance with this result Singh and Chaudhary (2003) also reported that the mean performance of genotypes for plant height was comparatively low under stress condition and reported 15.7% reduction due to stress for plant height. Per cent reduction for number of siliqua plant^{-1} was found to be minimum in the parent Geeta (40.24%) followed by RH-819 (47.97%), Kranti (51.16%) and PCR-7 (54.01%) among the parents. Among the crosses low per cent reduction for number of siliqua plant^{-1} was recorded by Bio-902 x RH-819 (32.88%) followed by Pusa bahar x Geeta (45.37%), Varuna x RH-819 (45.90%) and Seeta x Geeta (58.96%). Siliqua plant^{-1} was observed to be the most sensitive water stress. It appears here that water stress hampered flowering and reduced the probability of developing flowering and reduced the probability of developing flowers to pod and its occurrence during flowering and pod formation resulted in pod abortion (Ahmadi and Bahrani, 2009). Singh and Chaudhary (2003) also reported an average reduction of 15.4% for siliqua plant^{-1} due to drought.

ACN-9 (22.73%) followed by Urvashi (19.48%), Vardan (18.95%) among parents and GM-6 x RH-819 (32.24%) followed by Seeta x Geeta (29.68%), Urvashi x Geeta (27.65%) among crosses exhibited maximum per cent increase for root length. Studies on association of soil mass with root as indicated by root volume revealed significant reduction with stress application. Maximum per cent reduction for root volume was exhibited by the parent Kranti (66.53%) followed by RH-819 (62.45%) and PCR-7 (58.08%). Among the crosses maximum reduction was recorded by Urvashi x RH-819 (72.25%) followed by Bio-902 x Geeta (64.88%) and Pusa bold x RH-819 (60.82%).

Minimum per cent reduction for leaf relative water content was recorded by parent RH-819 (2.54%) followed by Geeta (2.86%) and Bio-902 (3.14%). The cross Bio-902 x RH-819 (2.95%) followed by Varuna x RH-819 (2.02%) and ACN-9 x Geeta (2.80%) exhibited minimum per cent reduction for leaf relative water content. Under moisture stress condition the amino acid proline increases in concentration, more than any other amino acid. Proline seems to aid drought tolerance, acting as a storage pull for nitrogen (Stewart, 1982). In this study it was revealed that proline content increased significantly due to moisture stress. Per cent increase in proline was found to be maximum for RH-819 (74.94%) followed by Bio-902 (69.53%) and Geeta (68.38%) among the parents and for Bio-902 x RH-819 (75.97%) followed by Varuna x RH-819 (73.26%) and Seeta x Geeta (68.65%) among the crosses. Din *et al*. (2011) also reported that drought stress significantly enhanced accumulation of proline in the leaf of all the cultivars. Proline accumulation during drought stress in an adaptive response that enhances survival and tissue water status, hence the genotypes recording high proline content under stress condition can tolerate drought.

Seed yield plant^{-1} is a cumulative effect of various yield components like plant height, number of branches plant^{-1}, number of siliqua plant^{-1} etc. Minimum per cent reduction was exhibited by the parent RH-819 (33.33%) followed by Geeta (39.07%), Varuna (41.51%) and crosses Bio-902 x RH-819 (31.42%) followed Varuna x RH-819 (36.3%), Pusa bahar x Geeta (38.24%). In accordance with this study Singh and Chaudhary (2003) reported 18.7% reduction in overall mean performance of seed yield plant^{-1} due to drought. Singh and Singh (1991) also observed that seed yield was significantly affected due to moisture stress during reproductive stage of growth in different genotypes. This decrease in seed yield was mainly, because of poor development of various yield components under moisture stress. Highest reduction due to stress was recorded for number of seeds pod^{-1} (62.5%) followed by number of siliqua plant^{-1} (56%) as reported by Singh and Singh (1991) in mustard. This suggested that the moisture stress during reproductive stage of growth had substantial influence on the seed yield through poor setting of siliqua and seed in mustard. Such differences in seed yield in response to various moisture stress treatment might be due to differences in phenomorphological behavior, developmental plasticity and mobilization of photosynthates from vegetative plant parts to grains. In general, the higher seed yield recorded in short duration genotypes under severe moisture stress condition at reproductive phase suggests the role of drought escape mechanism in stabilizing productivity of mustard in dry land areas.

The data related to drought tolerant efficiency (DTE) are also presented in table 2. Out of 17 parents studied RH-819 exhibited maximum DTE of 66.67% followed by Geeta (60.93%), Varuna (58.49%) and Vardan (55.45%). Among the crosses Bio-902 x RH-819 recorded maximum drought tolerant efficiency (DTE) of 68.58% which exceeded the drought tolerant donors. Besides this the cross Varuna x RH-819 (63.64%) followed by Pusa bahar x Geeta (61.76%) and Seeta x Geeta (56.39%) were found to exhibit high DTE. The significant difference for drought tolerance efficiency among the genotypes was also reported by Singh and Chaudhary (2003). The highest value indicated the highest level of drought tolerance and vice versa.

The correlation coefficient of different traits with yield was estimated both under control and stress condition and are presented in table 3. Seed yield plant^{-1} was observed to be highly significant and positively correlated with plant height (r=0.375) and number of siliqua plant^{-1} (r=0.711) under control condition. Under stress condition seed yield plant^{-1} was highly significantly and positively correlated with plant height (r=0.388), number of siliqua plant^{-1} (r=0.595) and proline content (r=0.309). Positive correlation of number of siliqua plant^{-1}, plant height and proline content under stress condition observed in this study indicated that less number of siliqua plant^{-1}, low plant height and low proline content results in low seed yield under stress condition. Similar type of significant association was also observed by Sadaqat *et al.* (2003). Therefore, seed yield plant^{-1} can be increased by increasing number of siliqua plant^{-1}, plant height and proline content under drought stress condition.

The most dependable diagnosis of drought tolerance is the direct method of studying the effect of drought under phytotron and/or field condition. Several methods have been used for measuring drought tolerance that is water potential, relative turgidity, diffusion pressure deficit, proline accumulation, drought tolerant efficiency, root length etc. (Chhabra *et al.*, 1981). As in this study number of siliqua plant^{-1}, plant height and proline content were significantly correlated with yield, these characters alongwith drought tolerance efficiency are to be given due importance in selection of superior parents and crosses for drought tolerance. Singh and Chaudhary (2003) and Chaudhary *et al.* (1991) have also reported importance of the above three traits and drought tolerance efficiency in the screening for drought tolerant genotypes.

Clarke *et al.* (1984) suggested that selecting for yield under drought condition should alone be more productive for improvement of drought tolerance, until more rapid and more effective screening procedure would be developed. As drought tolerance efficiency is a ratio, a genotype would have high value of this index even when its mean seed yield under drought condition is significantly lower than the better performing genotypes. Therefore, high mean seed yield along with high drought tolerance efficiency values should be given importance while making selection. The criteria followed for selection of parents and crosses for drought tolerance in this study was high drought tolerance efficiency, high seed yield under stress, less per cent reduction for yield, high per cent increase for proline content, less per cent reduction for number of siliqua plant^{-1}. On this basis parents RH-819, Geeta, Kranti, JD-6 and Pusabold were found to fulfill the above criteria and among the crosses studied the crosses Varuna x RH-819, Ashirvad x RH-819, JD-6 x Geeta and ACN-9 x Geeta were found to fulfill the selection criteria. Hence, these four crosses Varuna x RH-819, Ashirvad x RH-819, JD-6 x Geeta and ACN-9 x Geeta and five parents RH-819, Geeta, Kranti, JD-6 and Pusabold were identified as the drought tolerant crosses and parents which can be further exploited for developing drought tolerant varieties. The parents may be used in developing intermating population involving all possible crosses among the selected parents and then subjected to biparental mating and the crosses identified may be forwarded to next generation for making selection.

Table 1. Analysis of variance characters in mustard

Sources of variation	Degrees of freedom	Mean squares				
		Plant height (cm)	Root volume (cm^3)	Root length (cm)	Proline content (μ moleg^{-1} tissue)	LRWC (%)
Replication	1	220.390	0.222	137.062*	0.360	25.636
Treatments	140	2614.214**	5.860**	65.901**	785.947**	184.333**
Factor A	46	687.468**	3.769**	80.137**	332.068**	156.843**
Factor B	2	148158.615**	237.772**	174.344**	43830.240**	6451.510**
A x B	92	413.579**	1.875**	56.429**	77.135**	61.839**
Error	140	213.840	0.528	13.806	2.193	12.751

Sources of variation	Degrees of freedom	Mean squares				
		Days to first flower	Days to maturity	No. of branches $plant^{-1}$	No. of siliqua $plant^{-1}$	Seed yield $plant^{-1}$
Replication	1	0.194	12.253	11.750	586.655	1.482
Treatments	140	25.166**	71.607**	5.283	9285.854**	7.978*
Factor A	46	40.169**	13.629**	3.392	1910.820**	3.821*
Factor B	1 #	2.126	5687.00**	170.438	518138.624**	439.448**
A x B	92	10.671	7.527**	3.571	1911.355	2.748*
Error	140	14.706	3.456	4.384	337.014	0.272*

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

The degrees of freedom is 1 because the plants available in severe stress did not produce any flowers, branches and yield and hence and were not considered for analysis

Table 2. Effect of moisture stress on different traits

Sr. No.	Crosses	% reduction due to stress							% increase due to stress		Drought tolerance efficiency (%)	Mean seed yield $plant^{-1}$ (g)
		Days to maturity	Plant height (cm)	No. of branches	No. of siliqua $plant^{-1}$	LRWC (%)	Root volume (cm^3)	Seed yield $plant^{-1}$ (g)	Root length (cm)	Proline (mole g^{-1} tissue)		
1	ACN-9 X Geeta	10.70	37.91	25.00	86.95	2.80	29.68	54.66	-	58.41	45.34	4.49
2	Pusabold x Geeta	9.47	58.54	63.66	85.17	7.78	22.00	72.02	-	52.74	27.98	3.09
3	Bio-902 x Geeta	11.23	38.17	25.00	81.15	10.60	64.88	71.43	17.36	60.79	28.57	3.15
4	Urvashi x Geeta	4.26	39.31	41.67	78.86	9.39	46.08	69.80	27.65	54.26	30.20	3.29
5	JD-6 x Geeta	10.44	34.33	36.36	78.52	5.89	35.00	60.18	2.17	56.92	39.82	3.86
6	GM-6 x Geeta	11.70	48.54	54.55	79.50	4.07	19.59	69.61	18.01	58.88	30.39	2.95
7	Sej-2 x Geeta	12.83	37.10	30.00	77.22	9.68	33.00	63.01	21.80	60.45	36.99	2.50
8	Laxmi x Geeta	13.54	35.53	50.00	89.07	3.67	43.20	77.29	-	44.84	22.71	4.19
9	Seeta x Geeta	13.99	50.80	73.33	58.96	3.05	16.76	43.61	29.68	68.65	56.39	2.60
10	Ashirvad x Geeta	12.95	43.30	30.00	68.99	4.50	50.68	52.67	-	62.69	47.33	2.41
11	Kranti x Geeta	14.58	50.00	50.00	83.06	5.88	18.10	62.03	-	52.33	37.97	2.73
12	Vardan x Geeta	13.85	40.18	44.44	86.36	4.55	10.98	57.52	-	57.16	42.48	2.01
13	Varuna x Geeta	17.17	37.27	40.00	78.22	5.83	17.03	56.06	20.86	60.94	43.94	2.38
14	PCR-7 x Geeta	14.66	37.99	50.00	72.99	5.70	77.46	52.55	-	59.49	47.45	2.53
15	Pusabahar x Geeta	11.86	17.17	36.36	45.37	2.88	27.06	38.24	20.00	68.56	61.76	2.06
16	ACN-9 x RH-819	15.90	30.11	33.33	83.77	16.73	52.20	70.56	12.50	60.74	29.44	3.46
17	Pusabold x RH-819	16.84	32.48	60.00	75.43	9.75	60.82	66.45	-	62.02	33.55	2.59
18	Bio-902 x RH-819	7.87	10.45	30.00	32.88	2.05	20.90	31.42	11.11	75.97	68.58	1.91
19	Urvashi x RH-819	11.64	56.33	20.00	83.10	5.46	72.25	73.02	-	52.34	26.98	3.77
20	JD-6 x RH-819	11.70	56.37	45.45	88.32	15.26	42.22	77.91	-	54.34	22.09	3.80
21	GM-6 x RH-819	10.33	48.75	40.00	78.36	5.48	16.76	69.44	32.24	55.44	30.56	3.53
22	Sej-2 x RH-819	8.33	58.69	28.57	87.08	20.99	59.52	85.15	-	43.16	14.85	6.58
23	Laxmi x RH-819	12.30	50.48	54.55	86.99	7.87	29.32	78.07	6.04	57.36	21.93	3.48
24	Seeta x RH-819	13.83	30.04	15.38	75.36	7.67	18.52	66.67	14.39	58.55	33.33	3.50
25	Ashirvad x RH-819	10.64	39.06	27.27	65.81	3.66	22.90	58.16	14.96	64.71	41.84	3.48

Contd...

Table 2. Contd....

Sr. No.	Crosses	% reduction due to stress							% increase due to stress		Drought tolerance efficiency (%)	Mean seed yield plant^{-1} (g)
		Days to maturity	Plant height (cm)	No. of branches	No. of siliqua plant^{-1}	LRWC (%)	Root volume (cm^3)	Seed yield plant^{-1} (g)	Root length (cm)	Proline (mole g^{-1} tissue)		
26	Kranti x RH-819	13.83	50.64	22.22	84.03	8.56	19.27	78.20	-	54.98	21.80	3.73
27	Vardan x RH-819	10.64	58.74	58.33	90.76	12.25	31.70	80.17	-	41.86	19.83	3.63
28	Varuna x RH-819	12.11	13.03	25.00	45.90	2.20	38.91	36.36	15.32	73.26	63.64	4.05
29	PCR-7 x RH-819	12.37	53.02	53.85	78.77	10.21	31.82	73.11	-	53.54	26.89	3.36
30	Pusabahar x RH-819	15.82	31.34	11.11	67.70	7.76	26.71	60.34	-	58.64	39.66	3.04
31	ACN-9	8.05	45.28	20.00	79.92	7.54	14.34	71.09	22.73	54.79	28.91	4.74
32	Pusabold	8.89	48.77	18.18	65.45	6.86	47.50	58.97	-	64.73	41.03	4.13
33	Bio-902	4.81	22.12	37.50	69.62	3.14	21.01	45.02	-	69.53	54.98	2.26
34	Urvashi	9.78	39.73	27.27	62.21	11.39	37.76	62.96	19.48	50.78	37.04	2.78
35	JD-6	10.38	37.69	11.11	59.31	8.64	29.55	53.30	14.12	63.85	46.70	4.16
36	GM-6	10.00	27.39	38.46	62.06	10.14	56.04	68.95	8.89	54.03	31.05	3.59
37	Sej-2	11.17	45.66	40.00	65.01	6.17	38.50	57.89	-	63.07	42.11	3.38
38	Laxmi	11.41	43.20	27.27	67.78	8.44	14.81	68.32	17.11	59.12	31.68	4.99
39	Seeta	11.48	38.03	42.86	69.50	13.95	42.80	64.86	8.36	60.01	35.14	3.13
40	Ashirvad	14.51	43.03	60.00	75.71	5.11	52.35	66.67	-	51.74	33.33	4.15
41	Kranti	14.58	22.92	41.67	51.16	4.58	66.53	52.40	6.78	59.11	47.60	4.61
42	Vardan	11.70	28.25	0.00	56.55	3.50	54.31	44.55	18.95	54.89	55.45	2.14
43	Varuna	10.81	23.14	27.27	58.52	6.99	37.63	41.51	17.53	64.02	58.49	2.10
44	PCR-7	12.23	35.25	45.45	54.01	8.93	58.08	54.79	14.18	61.24	45.21	1.33
45	Pusabahar	13.09	40.93	50.00	86.06	13.37	47.76	72.25	-	56.56	27.75	3.34
46	Geeta	8.33	20.71	63.64	40.24	2.86	48.29	39.07	9.93	68.38	60.93	3.04
47	RH-819	10.42	12.57	58.33	47.97	2.54	62.45	33.33	16.15	74.94	66.67	3.06
	Mean	11.70	38.87	34.72	73.69	7.36	40.77	63.61	3.11	60.47	-	-

Table 3. Correlation coefficient values (r)of different characters with yield under control and stress condition

Characters	Yield (Control)	Yield (stress)
Days to 50% flowering	- 0.316	- 0.247
Daysto maturity	- 0.297	0.043
Number of branches plant^{-1}	0.256	0.130
Plant height	0.375 **	0.388 **
Number of siliqua plant^{-1}	0.711 **	0.595 **
Root length	0.135	- 0.060
Root volume	0.177	- 0.107
LRWC	- 0.0819	0.198
Proline content	- 0.230	0.309**

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

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Rec. on 20.07.2011 & Acc. on 25.10.2011

J. Soils and Crops 22 (2)370-374, Dec., 2012 ISSN 0971-2836

DETECTION OF SEED ASSOCIATED BACTERIA AND NEMATODE FROM RICE SEEDS

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ABSTRACT

The present investigation was carried out during 2008-2009 in the laboratory, Deptt. of Plant Pathology at JNKVV, Jabalpur. The rice crop suffers due to number of microflora that includes bacteria (*Xanthomonas compestris, X. translucens, Erwinia sp., Bacillus sp. and Clavibacter sp.*), fungi (*Rhizoctonia solani, Ustilaginoidea virens and Neovossia horrida*) and nematode (*Aphlenchoides besseyi, Pratylenchus branchyurus* and *Helicotylenchus sp.*) diseases that adversely affect the yield. Out of these microganisms in our experiment only one bacteria (*Xanthomonas compestris*) and one nematode (*Aphlenchoides besseyi*) were observed on seeds of rice varieties and hybrids. 22 rice varieties and 7 hybrids were analyzed for the bacterial and nematode association. The association of bacteria (*Xanthomonas compestris*) was observed only in 8 varieties viz., Surekha (1.50%), Sugandha-5 (0.75%), Chandra Hasini (1.25%), P 1401 (1.25%), JGL-3844 (1.50%), Pusa 1121 (1.75%), Kranti (1.75%) and IR 36 (2.00% seed infection) and remaining rice varieties viz. Pratiksha, Kavya, Varlu, Mahamaya, Karma Masuri, Pusa Basmati, P 1460, MTU 1010, WGL 14, WGL 21, WGL 32100, WGL 32183, Erramallelu, MR 219 were free from the infection. While, in case of hybrids out of 7 hybrids, only 5 exhibited bacterial association of *Xanthomonas compestris* viz., JRH 5 (2.75%), JRH 8 (1.00%), JRH 4 (1.25%), JRH 11 (1.00% seed infection) and JRH 14 (0.25%) and remaining two rice hybrids viz., JRH 10 and JRH 13 were free from the infection. Maximum association was recorded in IR 36 (2.00%) while the least in Sugandha 5 (0.75%) varieties. In case of hybrids maximum association was observed in JRH 5 (2.75%) and minimum association was observed in JRH 14 (0.25%).

The association of nematode (*Aphlenchoides besseyi*) was observed in 21 rice varieties and 7 hybrids. Maximum association of nematode in infected seeds was recorded in Pratiksha (28.67%) followed by Varlu (20.00%), Kavya (19.33%), Sugandha 5 (18.67%), WGL 32100 (18.67%), WGL 14 (17.33%), Karma Masuri (16.67%), P 1460 (16.67%), MR 219 (16.67%), P 1401 (16.00%), WGL 32183 (16.00%), Chandra Hasini (15.33%), IR 36 (14.67%) JGL 3844 (14.00%), WGL 21 (14.00%), MTU 1010 (13.33%), Surekha (11.33%), Pusa Basmati (8.67%), Pusa 1121 (8.67%), Erramallelu (8.00%) and Kranti (6.67%). Mahamaya was free from the nematode infection. Maximum nematode (*Aphlenchoides besseyi*) population was observed in seeds of hybrid JRH 4 (16.67%) followed by JRH 11 (14.67%), JRH 10 (12.00%), JRH 14 (12.00%), JRH 13 (11.33%), JRH 5 (10.67%), while least association was observed in JRH 8 (8.00%).

(Key words: Rice varieties and hybrids, Detection, *Xanthomonas compestris* and *Aphlenchoides besseyi*)

INTRODUCTION

Rice (*Oryza sativa* L.) being a staple food crop of India, plays significant role in the food security system. In 2009-10 the rice crop was cultivated in an area of 44.62 m ha with annual production of 93.08 m t with productivity of 2.0 t ha^{-1} that contributes 44.0 per cent of total food grain production. On the basis of current growth rate of population, it is estimated that the India shall require 140 million tons of rice by 2020. In Madhya Pradesh total area was 15.50 lakh ha and annual production was 15.58 lakh t (Anonymous, 2011).

The rice crop suffers due to number of microflora that includes bacteria (*Xanthomonas compestris, X. translucens, Erwinia sp., Bacillus sp. and Clavibacter sp.*), fungi (*Rhizoctonia solani, Ustilaginoidea virens and Neovossia horrida*), nematode (*Aphlenchoides besseyi*), virus and mycoplasma diseases that adversely affect the yield. Rice crop is subjected to many diseases in its growth period. Many diseases are important on account of their prevalence all over the country as well as the losses associated with their occurrence. Every year 10 to 15 % loss in yield is caused by the important diseases. Majority of the serious diseases of rice in India are caused by fungi. Potential disease problem include blast (*Magnaporthe grissea*), sheath blight (*Rhizoctonia solani*), false smut (*Ustilaginoidae virens*), kernel smut (*Neovossia horrida*), bacterial diseases (*Xanthomonas* sp.) and grain discolorations (Chahal and Pannu, 2008). In recent years, plant parasitic nematodes (*Aphlenchoides besseyi*) also have been reported to be associated with paddy crop. (Sharma, 2006).

Bacteria (*Xanthomonas compestris*) and nematode (*Aphlenchoides besseyi*) have been found associated with rice seeds. The microorganisms are responsible for causing various diseases as seed rot, seedling decay, seedling abnormalities, seed

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discoloration, chaffiness, pre and post emergence mortality. These have been encountered by various workers in different agro-ecological zones and farming situations in the country and world. These microorganisms also have adverse effect on sowing seed quality (Mew and Gonzalers, 2002).

Use of hybrid rice production technology can provide an additional yield of rice up to 1.0 ton ha^{-1} over the conventional varieties. Rice variety in the field is infected by fugal, bacterial and nematode diseases with a view to reducing the disease intensity of seed borne (both external and internal) pathogens, application of the seed treatment is most important control measures. Such seeds of plants enhance the growth and show no disease symptoms and that are supplementary to increasing productivity.

MATERIALS AND METHODS

The present investigation was carried out during 2008-2009 in the laboratory, Department of Pathology at JNKVV, Jabalpur. The microorganisms that were associated with diseases were identified based upon the symptoms and colony growth produced either under lab or field conditions.

The bacteria and nematode associated with seeds of rice varieties and hybrids were determined by using Standard Agar-plate method (Anonymous, 1993). The observations on developing bacteria and nematode were recorded after incubation of 5 days and 8 hr respectively under stereo binocular microscope.

Association of *Xanthomonas compestris* (bacteria) *and Aphlenchoides besseyi* (nematode) with seeds of rice varieties (25) and hybrids (7) was determined.

Following varieties and hybrids were tested for the association of the diseases under Jabalpur conditions.

Varieties (25)	Pratiksha, Kavya, Varlu, Surekha, JR 201, Sugandha 5, Sugandha 3, Mahamaya, Karma Masuri, Chandra Hasini, Pusa Basmati, P 1460, P 1401, MTU 1010, WGL 14, WGL 21, WGL 32100, WGL 32183, JGL 3844, Erramallelu, MR 219, Pusa 1121, IR 64, Kranti, IR 36
Hybrids (07)	JRH 4, JRH 5, JRH 8, JRH 10, JRH 11, JRH 13, JRH 14

Collection of seeds :

The seeds of rice varieties and hybrids were procured from Plant Breeder (Rice), JNKVV, Jabalpur. The seeds were drawn from the produce of the *kharif* 2007 making a composite sample for the use of detection of associated bacteria and nematode. The collected seeds were placed in a butter paper envelope and stored at low temperature (4°C) to avoid any further deterioration. The required seeds were drawn from the sample from time to time for carrying out laboratory studies on association of a bacteria and a nematode.

Detection of *Xanthomonas compestris* associated with seeds by Standard Agar-plate method :

The association of bacteria was determined by standard agar plate method. The agar plate method has been recommended for the seed associated bacteria. In this method, potato sucrose agar (PSA) medium was used. The medium was transferred in each pre-sterilized Petri dish (90 mm). Ten seeds were placed in each pre-sterilized petriplates on 18-20 ml solidified and cooled PSA at equal distance. The seeds were placed in a manner so that eight were in a outer ring and two in the centre. In all such 20 petriplates were considered for recording observation. Observations on the associated bacterial growth was recorded on fifth day after incubation. It was identified on the basis typical colony growth as observed under stereo binocular microscope.

Detection of seed associated nematode, *Aphlenchoides besseyi* :

Detection of seed associated nematode was done as per the method recommended by Tiwari (1979). The seed associated nematodes were extracted from the seeds with kernel and husks removed method, as detailed below.

Preparation of assembly for nematodes extraction:

An aluminium molded mesh was loosely fitted into a shallow plastic cup having a diameter of 95 mm, over which two square sheets of soft tissue papers were placed and moistened with sterile distilled water. The assembly was placed over 100 mm Petri dish containing sterile distilled water enough to touch to lower surface of aluminium molded mesh fitted into a shallow cup.

Preparation of the seed material :

The kernel of rice seed and hull was removed / separated manually. The hull and kernel were completely deassociated without making any damage. Such 25 dehulled seeds were placed on moistened tissue paper placed over shallow cup. Such eight dishes (cup)were covered with enamel trays. This was done to provide the darkness and to prevent loss of moisture. The nematode emerged from the soaked dehulled seeds of rice in the water kept in the cup. Eight hours after placement of seed on soft tissue paper over molded mesh in a cup, the nematode extracted in the water were observed under stereo binocular microscope by counting the number of nematodes by using the Haemocytometer. Calculation was done to compute total number of nematodes extracted for 200 seeds.

RESULTS AND DISCUSSION

Detection of *Xanthomonas compestris* pv. *oryzae* with rice seeds :

Determination of association of bacteria with seeds of rice varieties and hybrids was made as per the method given by (ISTA, Anonymous, 1993).

Association with seeds of rice varieties :

In all, seeds of 22 rice varieties were analyzed for the bacterial association. Data presented in table 1 indicate that the association of bacteria was found in 8 varieties only. The per cent seed infection ranged from 0.75 to 2.0% (Table 1). Maximum association was recorded in IR 36 (2.00%), followed by Pusa 1121 (1.75%), Kranti (1.75%), JGL 3844 (1.50%), Surekha (1.50%), P 1401 (1.25%), Chandra Hasini (1.25%), while the least in Sugandha 5 (0.75%) and remaining viz. Pratiksha, Kavya, Varlu, Mahamaya, Karma Masuri, Pusa Basmati, P 1460, MTU 1010, WGL 14, WGL 21, WGL 32100, WGL 32183, Erramallelu, MR 219 were free from the bacterial association.

Association with seeds of rice hybrids:

In case of hybrids, out of 7 hybrids only 4 exhibited bacterial association of *Xanthomonas compestris* viz. JRH 5 (2.75%), JRH 4 (1.25%), JRH 8 (1.00%), JRH 11 (1.00% seed infection), JRH 14 (0.25%) and remaining rice hybrids viz. JRH 10 and JRH 13 were free from the infection. Maximum association was recorded in IR 36 (2.00%) while the least in Sugandha 5 (0.75%) varieties. Maximum association was observed in JRH 5 (2.75%) and minimum association was observed in JRH 14 (0.25%) (Table 2).

Detection of *Aphlenchoides besseyi* with rice seeds:

Determination of association of nematode *A. besseyi* with seeds of rice varieties and hybrids was made as per the method advocated by Tiwari (1979).

Association with seeds of rice varieties :

In all, seeds of 22 rice varieties were analyzed for the association of nematode. Data presented in table 3 indicate that the association of the nematode ranged from 6.67% to 28.67% in seeds of rice varieties. Maximum association of nematode in infected seeds were recorded in Pratiksha (28.67%) followed by Varlu (20.00%), Kavya (19.33%), Sugandha 5 (18.67%), WGL 32100 (18.67%), WGL 14 (17.33%), Karma Masuri (16.67%), P 1460 (16.67%), MR 219 (16.67%), P 1401 (16.00%), WGL 32183 (16.00%), Chandra Hasini (15.33%), IR 36 (14.67%) JGL 3844 (14.00%), WGL 21 (14.00%), MTU 1010 (13.33%), Surekha (11.33%), Pusa Basmati (8.67%), Pusa 1121 (8.67%), Erramallelu (8.00%) while the least in Kranti (6.67%). Mahamaya was the only variety free from the nematode infection. Similar nematode *Aphlenchoides besseyi* was observed by Prasad *et al.* (2002) on rice seeds.

Association with seeds of rice hybrids :

In all, seeds of 7 hybrids were tested for the association of nematode. All the test hybrids were found infected with nematode. The mean number of nematodes ranged from 16.67% to 8.00% in seeds of rice hybrids. Maximum association of nematodes was recorded in JRH 4 (16.67%) followed by JRH 11 (14.67%), JRH 10 (12.00%), JRH 14 (12.00%), JRH 13 (11.33%) and JRH 5 (10.67%) whereas, minimum nematode was observed in seeds of JRH 8 (8.00%). (Table 4).

Table 1. Association of *Xanthomonas compestris* pv. *oryzae* with seeds of rice varieties

Variety	Number of infected seeds Set I	Set II	Total	% seed infection
Pratiksha	0	0	0	0.00
Kavya	0	0	0	0.00
Varlu	0	0	0	0.00
Surekha	3	3	6	1.50
Sugandha 5	2	1	3	0.75
Mahamaya	0	0	0	0.00
Karma Masuri	0	0	0	0.00
Chandra Hasini	1	4	5	1.25
Pusa Basmati	0	0	0	0.00
P 1460	0	0	0	0.00
P 1401	3	2	5	1.25
MTU 1010	0	0	0	0.00
WGL 14	0	0	0	0.00
WGL 21	0	0	0	0.00
WGL 32100	0	0	0	0.00
WGL 32183	0	0	0	0.00
JGL 3844	4	2	6	1.50
Erramallelu	0	0	0	0.00
MR 219	0	0	0	0.00
Pusa 1121	2	5	7	1.75
Kranti	5	2	7	1.75
IR 36	3	5	8	2.00

*200 seed per set

Table 2. Association of *Xanthomonas compestris* pv. *oryzae* with seeds of rice hybrids

Variety	Number of infected seeds		Total	% seed infection
	Set I	Set II		
JRH 5	08	03	11	2.75
JRH 8	01	03	04	1.00
JRH 4	03	02	05	1.25
JRH 10	00	00	00	0.00
JRH 11	00	04	04	1.00
JRH 13	00	00	00	0.00
JRH 14	01	00	01	0.25

*200 seed per set

Table 3. Association of *Aphlenchoides besseyi* with seeds of rice varieties

Variety	Number of nematodes		Mean	% Seed infection
	Set I	Set II		
Pratiksha	46	40	43	28.67
Kavya	35	23	29	19.33
Varlu	25	35	30	20.00
Surekha	30	39	17	11.33
Sugandha 5	23	33	28	18.67
Mahamaya	00	00	00	0.00
Karma Masuri	30	20	25	16.67
Chandra Hasini	30	15	23	15.33
Pusa Basmati	10	15	13	8.67
P 1460	30	20	25	16.67
P 1401	23	25	24	16.00
MTU 1010	14	26	20	13.33
WGL14	20	31	26	17.33
WGL 21	19	23	21	14.00
WGL 32100	30	25	28	18.67
WGL 32183	31	16	24	16.00
JGL 3844	21	20	21	14.00
Erramallelu	05	19	12	8.00
MR 219	33	17	25	16.67
Pusa 1121	11	15	13	8.67
Kranti	05	15	10	6.67
IR 36	21	22	22	14.67

*150 seeds per set

Table 4. Association of *Aphlenchoides besseyi* with seeds of rice hybrids

Variety	Number of nematodes		Mean	% Seed infection
	Set I	Set II		
JRH 5	15	17	16	10.67
JRH 8	09	14	12	8.00
JRH 4	22	27	25	16.67
JRH 10	16	20	18	12.00
JRH 11	21	22	22	14.67
JRH 13	16	17	17	11.33
JRH 14	17	19	18	12.00

*150 seeds per set

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Rec. on 25.07.2011 & Acc. on 20.10.2011

J. Soils and Crops 22 (2) 375-378, Dec., 2012 ISSN 0971-2836

FLOWER YIELD AND QUALITY OF AFRICAN MARIGOLD AS INFLUENCED BY NITROGEN AND PINCHING

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ABSTRACT

An investigation was carried out during 2009-2010 at Horticulture Section, College of Agriculture Nagpur to study the effect of nitrogen and pinching on flower yield and quality of marigold var. African double Orange. The treatments comprised of the four nitrogen levels *viz.,* 0 kg N ha^{-1}, 50 kg N ha^{-1}, 100 kg N ha^{-1} and 150 kg N ha^{-1} as main factor and four pinching treatments *viz.*, no pinching, pinching at 30 DAT, pinching at 45 DAT and double pinching at 30 and 45 DAT as sub factor with three replications. The results obtained in the present investigation indicated that, the treatment of 0 kg N ha^{-1} recorded earlier first flower bud initiation as well as opening of flowers; however, maximum total flowering span was noted under the treatment of 150 kg N ha^{-1}. The treatment differences of pinching were found non significant in respect of days to first flower bud initiation and days to opening of flower bud emergence, whereas, double pinching at 30 and 45 DAT exhibited maximum total flowering span in marigold.

The treatment of 100 kg N ha^{-1} and pinching at 30 DAT significantly increased diameter and weight of fully opened flower. As regards the yield contributing parameters *viz.*, Number of flowers plant^{-1}, flower yield plant^{-1} and hectare^{-1} the treatment of 150 kg N ha^{-1} and pinching at 30 DAT was found to be superior than other treatments.

(Key words: Marigold, nitrogen, pinching, yield, quality)

INTRODUCTION

Marigold has gained popularity among the flower growers because of its easy cultivation and wide adaptability. The growers are attracted towards the cultivation of marigold flowers because of its habit of free flowering, short duration of crop and good keeping quality of flowers. It is an important raw material for perfume industry. The oil from marigold acts as a repellent to flies also. In Vidarbha region of Maharashtra State, marigold is cultivated on large scale but the productivity is low as there is no proper recommendation based on latest technology to increase the yield potential. Farmers are unable to regulate the supply of flowers to market so as to assure better price to their produce. Hence, the present study was carried out to find out suitable dose of nitrogen and time of pinching for the production of higher yield of better quality flowers of marigold.

MATERIALS AND METHODS

The investigation was carried out at Horticulture Section, College of Agriculture, Nagpur during 2009-2010. Seed of marigold variety African Double Orange was sown on raised beds and the uniform sized and healthy seedlings were selected for transplanting on 23rd Nov. 2009. The experiment was laid out in Factorial Randomized Block Design with four nitrogen levels *viz.,* 0 kg N ha^{-1}, 50 kg N ha^{-1}, 100 kg N ha^{-1} and 150 kg N ha^{-1} and four pinching treatments *viz.,* No pinching, pinching at 30 DAT, pinching at 45 DAT and double pinching at 30 and 45 DAT replicated thrice. Pinching was done by knipping approximately three cm of terminal growing shoots. The single pinching was done at 30th day and at 45th day after transplanting; however, the double pinching was done at 30th day and repeated at 45th day of the transplanting as per treatments. Various observations *viz.*, days to first flower bud initiation, days to opening of flower from bud emergence, total flowering span (days), diameter (cm) and weight of fully opened flower (g), length of flower stalk (cm), number of flowers plant^{-1}, flower yield plant^{-1} (g), and flower yield ha^{-1} (t) were recorded and the data was analyzed as per the method give by Panse and Sukhatme (1978).

RESULTS AND DISCUSSION

Effect of Nitrogen:

The data presented in table 1 showed that, the treatment of 0 kg N ha^{-1} recorded significantly earlier (25.72 days) first flower bud initiation and opening of flower from bud emergence (5.50 days) which was followed by the treatment of 50 kg N ha^{-1}. Whereas, the treatment of 150 kg ha^{-1} took maximum (28.55 days) for first flower bud initiation and opening of flower from bud emergence (7.98 days). This might have been due to increased vegetative growth of plant

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at higher level of nitrogen which might have decreased C: N ratio and thereby delayed the flower bud initiation. These findings can be correlated with that of Jamkhande *et al.* (2001) in china aster, who stated that, application of increasing dose of N viz., 50, 100, 150 and 200 kg N ha^{-1} increased the flower bud initiation in China aster.

The treatment 150 kg N ha^{-1} found significantly superior over all other treatments in respect of total flowering span (45.40 days), number of flowers plant^{-1} (27.28), flower yield plant^{-1} (240.13 g) and flower yield hectare^{-1} (14.23 t) and it was followed by treatment of 100 kg N ha^{-1}. However, the treatment of 0 kg N ha^{-1} recorded significantly minimum total flowering span (38.48 days), number of flowers plant^{-1} (19.22), flower yield plant^{-1} (110.10 g) and flower yield hectare^{-1} (6.52 t). The maximum total flowering span and higher yield of flower in marigold were recorded due to the treatment receiving the higher dose of nitrogen i.e. 150 kg N ha^{-1} which might be due to the better vegetative growth of the plant. A similar increase in flower yield due to higher dose of nitrogen (150 kg N ha^{-1}) was also recorded by Sehrawat *et al.* (2003) and Jadhav *et al.* (2002) in marigold.

However, the treatment of 100 kg N ha^{-1} was found significantly superior over all other treatments in respect of the diameter and weight of fully opened flower (7.32 cm and 9.83 g, respectively) and length of flower stalk (8.77 cm), whereas, the treatment no application of nitrogen produced significantly minimum diameter and weight of fully opened flower (4.68 cm and 5.68 g, respectively) and length of flower stalk (5.52 cm). This might have been due to increased photosynthetic activity, due to better vegetative growth of plant with optimum nitrogen dose might have developed better quality flowers on the plant. These results are in close conformity with the findings of Acharya and Dashora (2004) who noted that, application of 150 kg N ha^{-1} were obtained better quality marigold flowers as compared to other treatments v*iz*., 0 kg N ha^{-1}, 50 kg N ha^{-1}, 100 kg N ha^{-1} and 200 kg N ha^{-1}.

Effect of pinching:

The data revealed that, the effect of pinching on days required for first flower bud initiation and days to opening of flower from bud emergence was found to be non-significant. However, the treatment of pinching at 30 DAT (27.25 days) and 30 and 45 DAT (6.56 days) took minimum days to first flower bud initiation and days to opening of flower from bud emergence, respectively. Similar results also reported by Dorajeerao *et al.* (2011) noted that pinching of chrysanthemum plant at 20 Days after transplanting during *kharif* and *rabi*, recorded delay in days to flower bud initiation.

The treatment of pinching at 30 and 45 DAT was found significantly superior over all other treatments in respect of total flowering span (47.67 days), it was followed by the treatment of pinching at 45 DAT (45.02 days). Khandelwal *et al.* (2003) also opined that, early pinching ((20 and 30 DAT) in marigold plant was found to be better in respect of days to first flower bud initiation and days to opening of flower from bud emergence.

However, the treatment of pinching at 30 DAT recorded the maximum diameter (6.62 cm) and weight of flower (8.74 g). Similarly, in respect of yield parameters, the pinching treatment at 30 DAT recorded the maximum number of flowers plant^{-1} (24.67), flower yield plant^{-1} (219.35 g) and flower yield hectare^{-1} (13.00 t) and it was followed by the treatment of no pinching. Whereas, the minimum diameter (5.40 cm) and weight of flower (7.38 g), number of flowers plant^{-1} (20.20), flower yield plant^{-1} (152.45 g) and flower yield ha^{-1} (9.03 t) were obtained from the treatment of double pinching at 30 and 45 DAT.

However, significantly maximum stalk length (8.657 cm) was recorded under the treatment of no pinching which was followed by the pinching treatment at 30 DAT (7.88 cm). However, minimum length of flower stalk (6.10 cm) was recorded in the treatment of double pinching at 30 and 45 DAT. This might be due to the fact that, under control treatment the plants continued their longitudinal growth of pedicel which might have resulted into longer flower stalk. Similar results have also been obtained by Bholane (1998) in chrysanthemum who reported that, the pinching treatment reduce plant height and also flower stalk length in marigold.

This might be due to the development of large number of auxiliary shoots and vigorous branching which might have favoured to develop maximum

Table1. Effect of nitrogen and pinching on growth, flower yield and quality of African marigold

Treatments	Days to first flower bud initiation (days)	Days to opening of flower from bud emergence (days)	Total flowering span (days)	Diameter of fully opened flower (cm)	Weight of fully opened flower (g)	Length of flower stalk (cm)	Number of flowers $plant^{-1}$	Flower yield $plant^{-1}$ (g)	Flower yield ha^{-1} (t)
Nitrogen (N)									
N_1 - 0 kg ha^{-1}	25.72	5.50	38.48	4.68	5.68	5.52	19.22	110.10	6.52
N_2 - 50 kg ha^{-1}	27.77	6.33	41.00	5.87	7.74	6.80	20.75	161.62	9.58
N_3 - 100 kg ha^{-1}	28.47	7.12	43.18	7.32	9.83	8.77	23.23	229.37	13.59
N_4 - 150 kg ha^{-1}	28.56	7.98	45.40	6.50	8.77	8.38	27.28	240.13	14.23
SE (m)	0.240	0.113	0.322	0.069	0.055	0.107	0.206	2.466	0.146
CD at 5%	0.692	0.326	0.930	0.200	0.158	0.308	0.595	7.114	0.421
Pinching (P)									
P_1 - No pinching	29.97	6.80	33.75	6.28	8.33	8.65	23.60	199.92	11.85
P_2 - 30 DAT	27.25	6.77	41.63	6.62	8.74	7.88	24.67	219.35	13.00
P_3 - 45 DAT	27.67	6.80	45.02	6.07	5.57	6.83	22.02	169.50	10.04
P_4 - 30 and 45 DAT	27.62	6.56	47.67	5.40	7.78	6.10	20.20	152.45	9.03
SE (m)	0.240	0.113	0.322	0.069	0.055	0.107	0.206	2.466	0.146
CD at 5%	-	-	0.930	0.200	0.158	0.308	0.595	7.114	0.421
Interaction (N x P)									
SE (m)	0.480	0.226	0.644	0.138	0.110	0.214	0.413	4.932	0.292
CD at 5%	-	-	-	-	-	-	-	-	-

DAT - Days after transplanting

number of better quality flowers of marigold. The results are in close agreement with Khandelwal *et al.* (2003) in marigold who reported that, pinching of plants at 30 days after transplanting was more effective for increasing the yield of marigold flower with increased dose of N.

Interaction effect:

Interaction effect of nitrogen and pinching was found to be non-significant in respect of all vegetative as well as yield parameters *viz.,* number of flowers plant^{-1} , flower yield plant^{-1} and flower yield hectare^{-1}.

It can be inferred from the results that, application of 150 kg N ha^{-1} and pinching at 30 DAT was found to be better for obtaining higher yield of better quality marigold flowers.

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Rec. on 13.05.2010 & Acc. on 25.01.2011

J. Soils and Crops 22 (2) 379-386, Dec., 2012 ISSN 0971-2836

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

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ABSTRACT

The genetic study of F_2 crosses in mustard was undertaken with a view to identify the potential F_2 crosses for their use in individual plants selection. Ten F_2 crosses along with seven parents (Sej-2, Ashirwad, Varuna, Urvashi, Geeta, ACN-9 and RH-819) were raised during *rabi* 2011-2012 and data were recorded on six characters i.e. days to first flower, days to maturity, plant height (cm) at maturity, number of primary branches plant^{-1}, number of silqua plant^{-1} and yield plant^{-1}. The mean square due to genotype (crosses + parents) were significant for days to first flower, plant height at maturity, number of siliqua plant^{-1} and yield plant^{-1} and non-significant for days to maturity and number of primary branches plant^{-1}. The high genotypic coefficient of variation was recorded for yield plant^{-1} and number of siliqua plant^{-1}. High heritability estimates were recorded for number of siliquae plant^{-1} (40.70-91.70%) and yield plant^{-1} (55.80-94.10%). The expected genetic advance among all the F_2 population indicated significant progress under selection for plant height at maturity, number of silqua plant^{-1} and yield plant^{-1} which was ranging from 16.95 to 40.79, 25.67 to 155.69 and 3.18 to 10.34 respectively whereas the expected genetic advance for days to first flower was very low (0.03 to 3.52). The eight F_2 population i.e. Sej-2 x Geeta, Sej-2 x RH-819, Ashirwad x RH-819, Varuna x Geeta, ACN-9 x Geeta, ACN-9 x RH-819, Urvashi x Geeta and Urvashi x RH-819 were identified on the basis of high mean, genotypic coefficient of variation, heritability in broad sense and genetic advance for economic characters like number of silqua plant^{-1} and yield plant^{-1} which were subjected to individual plant selection. Per cent individual plant selected in the above eight crosses were 13.80, 14.70, 13.80, 12.38, 12.85, 13.13, 17.14 and 11.90 respectively for number of silqua plant^{-1} and 13.13, 14.76, 12.85, 15.23, 13.13, 12.38, 11.90 and 13.13 respectively for yield plant^{-1}. These selected plants are recommended for forwarding to the next generation for evaluating the progeny performance.

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

INTRODUCTION

Mustard (*Brassica juncea*) is a second important oil seed crop in India after groundnut in area and production. Oil content of Indian mustard seed varies from 30 to 48 %. In Maharashtra the sole crop of mustard is seldom grown but with its low cost of production and high yielding potential it can be grown in Vidarbha. Designing efficient and desirable plant type requires the existence of genetic variability in the material. In order to incorporate desirable characters to maximize economic yields, the information on the nature and extent of genetic variability present in a population for desirable characters, their association and relative contribution to yield constitutes are the basic requirement. F_2 generation provides an active breeding material from which desirable plants may be selected.

MATERIALS AND METHODS

The experimental material comprised of ten F_2 crosses selected on the basis of drought tolerance efficiencies of F_1 and their seven parents viz., Sej-2, Geeta, RH-819, Ashirwad, Varuna, ACN-9 and Urvashi. Ten F_2 crosses and seven parents involved in the crosses were grown during *rabi*, 2011-2012 in randomized complete block design with three replication. Ten rows for each F_2 cross and two rows for each parent were allotted. Each row consisted of twenty plants. Sowing was taken up with spacing of 45 cm x 15 cm. The observations were recorded on 200 plants from each individual F_2 cross and five randomly selected plants in each parents for the following six characters. i.e. days to first flower, days to maturity, plant height (cm) at maturity, number of primary branches at maturity, number of silqua plant^{-1} and yield plant^{-1}.

The data recorded were subjected to the statistical and biometrical analysis. Analysis of variance was done by the method given by Panse and Sukhatme (1954) and the estimation of genetic parameters in each F_2 population were done by the method given by Burton (1952), Allard (1960) and Johnson *et al*. (1955).

RESULTS AND DISCUSSION

The data regardings analysis of variance for six different characters are presented in table 1. Mean squares due to genotypes (crosses + parent) were significant for all four characters studied except for number of primary branches plant^{-1} and days to maturity indicating a substantial genetic variability among the genotypes. This reveals that except

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number of primary branches plant^{-1} and days to maturity the genetic parameters can be estimated for the other four characters i.e. days to first flower, plant height at maturity, number of siliqua plant^{-1} and yield plant^{-1}. Similar to this result Bansod (2006) also reported significant variability among the genotypes (F_2 crosses and parents) for all the above mentioned characters in mustard.

The measure of effectiveness with which selection can be expected to exploit the genetic variability is the measure of expected progress under selection and it depends on the magnitude of genetic variation in the population, heritability and genetic advance. Therefore, it is imperative to estimate these parameters in the segregating population to determine the progress under selection and hence, were estimated. The mean performance of parents, range of parents and the mean performance, range, variance, genotypic coefficient of variation and phenotypic coefficient of variation, heritability and genetic advance of each F_2 cross for days to first flower, plant height at maturity, number of siliqua plant^{-1} and yield plant^{-1} are presented in table from 2 to 5. Other characters were not considered for discussion as their genotypic mean squares were non- significant.

Days to first flower:

Among the seven parents ACN-9 flowered earliest (37 days) followed by Varuna (41.20 days) and Urvashi (42.47 days) as observed from table 2. The F_2 cross of ACN-9 x RH-819 flowered earlier (38.65 days) followed by ACN-9 x Geeta (39.61 days) and Sej-2 x RH-819 (39.97 days). The maximum range for days to first flower was recorded in F_2 cross of Urvashi x Geeta (40-49 days) followed by Sej-2 x Geeta (39-47 days), Varuna x Geeta (38-45) and Urvashi x RH-819 (39-46 days). The highest F_2 variance was observed in Urvashi x Geeta (4.72) followed by Sej-2 x Geeta (4.67) and Varuna x Geeta (4.48). Genotypic coefficient of variation was found to be maximum in F_2 cross of Sej-2 x Geeta (4.51%) followed by Urvashi x Geeta (3.94%) and Urvashi x RH-819 (3.89%). The F_2 cross Varuna x Geeta recorded maximum phenotypic coefficient of variation (5.13%) followed by Sej-2 x Geeta (5.07%) and Urvashi x Geeta (4.88%). Estimates of heritability was maximum in ACN-9 x RH-819 (93.9%) followed by Sej-2 x RH-819 (82.3%), Sej-2 x Geeta (79.1%), Ashirwad x RH-819 (75.8%) and Urvashi x RH-819 (73.6%). Maximum genetic advance was observed in Sej-2 x Geeta (3.52 days) followed by Urvashi x Geeta (2.92 days) and Urvashi x RH-819 (2.88 days).

Most of the crosses had high genetic coefficient of variation and heritability, the genetic advance were found to be low indicating significant role of non-additive gene action and high heritability observed in these crosses might due to the influence of environment and hence, this character was not effective for making selections for early flowering plants in early segregating F_2 generation. Similar to these results Raj *et al.* (1998) also reported ineffectiveness of selection for days to first flower in F_2 generation.

Plant height at maturity (cm):

The parent RH-819 (169.47 cm) recorded maximum plant height followed by Urvashi (156.13 cm) and Geeta (155.80 cm) and F_2 cross Ashirwad x Geeta recorded highest plant height (161.34 cm) followed by Urvashi x Geeta (152.85 cm) and Sej-2 x Geeta (150.05 cm). The maximum range for plant height was observed in F_2 cross of Ashirwad x RH-819 (64-186 cm) followed by Sej-2 x Geeta (91-210 cm) and Sej-2 x RH-819 (91-195 cm). The F_2 variance and genotypic coefficient of variation was recorded maximum in the F_2 cross of Varuna x Geeta (577.12 and 14.95% respectively) followed by Sej-2 x Geeta (462.57 and 12.87% respectively) and Sej-2 x RH-819 (425.02 and 12.59% respectively). The phenotypic coefficient of variation was recorded maximum in Varuna x Geeta (16.46%) followed by Sej-2 x RH-819 (14.48%) and Sej-2 x Geeta (14.33%). Maximum heritability estimate was observed in the F_2 cross of Varuna x Geeta (82.4%) followed by ACN-9 x Geeta (82.2%) and Ashirwad x Geeta (81.6%). Maximum genetic advance was recorded in F_2 cross of Varuna x Geeta (40.79%) followed by Sej-2 x Geeta (35.75%) and Sej-2 x RH-819 (32.13%).

The genetic parameters calculated for plant height at maturity revealed the presence of significant variation among the F_2 population of all the 10 crosses. The crosses Sej-2 x Geeta, Sej-2 x RH-819 and Varuna x Geeta exhibited high heritability with high genetic advance along with high F_2 variance and genetic coefficient of variation indicating effectiveness of selection for plant height in this crosses. In accordance with this result Bansod (2006) also observed wide variation for plant height in mustard.

Number of siliqua plant^{-1}:

Number of siliqua plant^{-1} is an important yield contributing character in mustard. Varuna (124.07) followed by ACN-9 (108.07) and Sej-2 (104.13) had the highest number of siliqua among the parents studied. The maximum number of siliqua plant^{-1} were produced in F_2 cross i.e. Varuna x Geeta (115.26) followed by Sej-2 x Geeta (106.18) and ACN-9 x RH-819 (103.10). The F_2 crosses Sej-2 x Geeta recorded maximum range (36-548) followed by Varuna x Geeta (24-485), Urvashi x RH-819 (29-439) and Sej-2 x RH-819 (24-426). The F_2 cross of Varuna x RH-819 showed the lowest range (24-277) for the number of siliqua plant^{-1}. The F_2 variance was maximum in the F_2 cross of Varuna x Geeta (6795.47) followed by Sej-2 x Geeta (4798.52) and Sej-2 x RH-819 (2602.28). The genotypic coefficient of variation were found to be maximum in F_2 cross of Varuna x Geeta (68.47%) followed by Sej-2 x Geeta (61.33%), Ashirwad x RH-819 (51.18%) and Sej-2 x RH-819 (49.36%). The F_2 cross of Varuna x Geeta recorded maximum phenotypic variation (71.51%) followed by Sej-2 x Geeta (65.23%), Sej-2 X RH-819 (55.62%) and Ashirwad x RH-819 (54.29%). The maximum heritability estimate was recorded by Varuna x Geeta (91.7%) followed by ACN-9 x RH-819 (89.4%), Ashirwad x RH-819 (88.9%), Sej-2 x Geeta (88.4%) and ACN-9 x Geeta (87.9%). Maximum genetic advance was observed in Varuna x Geeta (155.69) followed by Sej-2 x Geeta (126.11) and ACN-9 x RH-819 (93.59).

The results on number of siliqua plant^{-1} revealed that the F_2 means were close to the midparental value except for the cross Varuna x RH-819, this cross had minimum number of siliqua plant$^{-1.}$ The F_2 generation showed continuous variation which had either one or two peaks. More frequencies of low performing transgrates were there as compared to high performing transgrates for number of siliqua in all the crosses. The crosses Varuna x Geeta, Sej-2 x Geeta, Ashirwad x RH-819, ACN-9 x Geeta and Sej-2 x RH-819 had high F_2 variance, genetic coefficient of variation, heritability and genetic advance. The presence of high heritability with high genetic advance in the above crosses indicates the predominance of additive gene action for this trait, thereby suggesting amenability of this character through selection. Low heritability was associated with low genetic advance along with low genetic coefficient of variation and F_2 variance in the cross Varuna x RH-819 and similarly low genetic advance with high heritability in the cross Ashirwad x Geeta suggested the predominant role of G x E interaction in expression of this character and thus, not effective for selection. Similar to this result Chauhan *et al*. (2001) and Sadat *et al*. (2010) also reported the significance of number of siliqua plant^{-1} in F_2 crosses with high heritability and high genetic advance for making selection.

Yield plant^{-1} (g):

In parents, Sej-2 yielded highest seed yield plant^{-1} (10.49 g) followed by Varuna (9.63 g), ACN-9 (8.37 g) and Geeta (8.16 g). The maximum seed yield plant^{-1} was recorded in the F_2 cross of Urvashi x Geeta (8.69 g) followed by Ashirwad x RH-819 (7.93 g), Ashirwad x Geeta (7.67 g) and Sej-2 x Geeta (7.62 g). The maximum range for seed yield plant^{-1} was observed in the F_2 cross of Sej-2 x RH-819 (1.80 - 49.70) followed by Sej-2 x Geeta (2.00 - 43.10), ACN-9 x RH-819 (1.90 - 32.00) and Urvashi x Geeta (2.60-32.50). The highest variance of F_2 was observed in the F_2 cross of Sej-2 x RH-819 (31.73) followed by Sej-2 x Geeta (25.68), Varuna x Geeta (23.96) and Urvashi x Geeta (23.41). The genotypic coefficient of variation and phenotypic coefficient of variation found to be maximum in the F_2 cross of Sej-2 x RH-819 (69.96%) and 74.08% respectively) followed by Urvashi x RH-819 (64.93% and 67.19% respectively) and Sej-2 x Geeta (60.47% and 66.47% respectively). The maximum heritability estimates was exhibited by Ashirwad x RH-819 (94.1%) followed by Urvashi x RH-819 (93.4%), ACN-9 x RH-819 (91.8%), Urvashi x Geeta (90.9%) and Sej-2 x RH-819 (89.2%). The maximum genetic advance was observed in F_2 population of Sej-2 x RH-819 (10.34) followed by Urvashi x Geeta (9.06) and Sej-2 x Geeta (8.63). The results on the estimates of genetic parameters on seed yield plant^{-1} indicated the presence of large range of variability in all F_2 crosses. As expected F_2 population of all the 10 crosses was continuous and peaks were for low performing transgrates for yield plant^{-1}. Heritability estimates were high and also associated with high genetic advance in crosses Sej-2x RJH-819,

Table 1. Analysis of variance for six characters in mustard

Source of variation	d.f.	Mean Square					
		Days to first flower	Days to maturity	No. of primary branches plant^{-1}	Plant height at maturity (cm)	No. of siliqua plant^{-1}	Yield plant^{-1} (g)
Replications	2	2.535	0.258	0.184	148.71	867.205	7.439
Genotypes	16	13.425**	2.235	0.380	231.526**	1945.37**	7.749*
Error	32	2.303	0.141	0.298	103.048	761.39	3.493

**Significant at 1%

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

F_2 crosses/ Parents	Mean $\pm SE_{(m)}$	Range	VF_2	GCV (%)	PCV (%)	h^2(%)	Genetic Advance
Sej-2 X Geeta	42.64 $\pm$ 2.16	8.00 (39-47)	4.67	4.51	5.07	79.1	3.52
Sej-2 X RH-819	39.97 $\pm$ 1.29	4.00 (38-42)	1.67	2.94	3.24	82.3	2.19
Ashirwad X Geeta	3.34 $\pm$ 1.04	4.00 (41-45)	1.08	-	-	-	-
Ashirwad X RH-819	41.11 $\pm$ 1.65	6.00 (38-44)	2.73	3.40	4.01	75.8	2.58
Varuna X Geeta	41.24 $\pm$ 2.11	7.00 (38-45)	4.48	3.84	5.13	56.1	2.44
Varuna X RH-819	41.49 $\pm$ 1.42	4.00 (40-44)	1.30	0.32	2.75	1.4	0.03
ACN-9 X Geeta	39.61 $\pm$ 1.02	3.00 (38-41)	1.04	1.32	2.57	26.5	0.55
ACN-9 X RH-819	38.65 $\pm$ 1.18	4.00 (37-41)	1.39	2.95	3.05	93.9	2.28
Urvashi X Geeta	44.51 $\pm$ 2.17	9.00 (40-49)	4.72	3.94	4.88	65.3	2.92
Urvashi X RH-819	41.94 $\pm$ 1.90	7.00 (39-46)	3.62	3.89	4.54	73.6	2.88
Sej-2	43.53	-	-	-	-	-	-
Ashirwad	42.80	-	-	-	-	-	-
Varuna	41.20	-	-	-	-	-	-
ACN-9	37.00	-	-	-	-	-	-
Urvashi	42.47	-	-	-	-	-	-
Geeta	43.13	-	-	-	-	-	-
RH-819	44.60	-	-	-	-	-	-
Grand mean	41.79						
$SE_{(m)}\pm$	1.47						
C V (%)	4.31						

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

F_2 crosses/ Parents	Mean$\pm$S $E_{(m)}$	Range	VF_2	GCV (%)	PCV (%)	h^2 (%)	Genetic Advance
Sej-2 X Geeta	150.05 $\pm$ 21.05	119 (91-210)	462.57	12.87	14.33	80.7	35.75
Sej-2 X RH-819	142.34 $\pm$ 20.61	104 (91-195)	425.02	12.59	14.48	75.7	32.13
Ashirwad X Geeta	161.34 $\pm$ 16.23	86 (116-202)	263.71	9.09	10.06	81.6	27.30
Ashirwad X RH-819	147.70 $\pm$ 15.99	122 (64-186)	255.88	9.41	10.83	75.5	24.88
Varuna X Geeta	145.89 $\pm$ 24.02	101 (99-200)	577.11	14.95	16.46	82.4	40.79
Varuna X RH-819	141.90 $\pm$ 17.30	94 (85-179)	299.30	9.55	12.19	61.4	21.89
ACN-9 X Geeta	137.61 $\pm$ 16.67	96 (94-190)	277.95	10.98	12.11	82.2	28.23
ACN-9 X RH-819	132.40 $\pm$ 16.88	80 (90-170)	285.09	11.24	12.75	77.7	27.03
Urvashi X Geeta	152.85 $\pm$ 16.82	100 (101-201)	282.92	9.58	11.00	75.9	26.30
Urvashi X RH-819	140.02 $\pm$ 14.07	79 (96-175)	198.07	7.68	10.05	58.5	16.95
Sej-2	140.67	-	-	-	-	-	-
Ashirwad	146.93	-	-	-	-	-	-
Varuna	155.40	-	-	-	-	-	-
ACN-9	144.47	-	-	-	-	-	-
Urvashi	156.13	-	-	-	-	-	-
Geeta	155.80	-	-	-	-	-	-
RH-819	169.47	-	-	-	-	-	-
Grand mean	148.30						
S.$E_{(m)}\pm$	7.29						
C.V.(%)	8.52						

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

F_2 crosses/ Parents	Mean$\pm$S $E_{(m)}$	Range	VF_2	GCV (%)	PCV (%)	h^2 (%)	Genetic Advance
Sej-2 X Geeta	106.18 $\pm$ 69.27	512 (36-548)	4798.52	61.33	65.23	88.4	126.11
Sej-2 X RH-819	91.71 $\pm$ 51.01	402 (24-426)	2602.28	49.39	55.62	79.8	82.88
Ashirwad X Geeta	83.25 $\pm$ 34.97	256 (23-279)	1222.97	36.81	42.00	76.8	55.32
Ashirwad X RH-819	91.75 $\pm$ 49.81	288 (32-320)	2481.47	51.18	54.29	88.9	91.20
Varuna X Geeta	115.26 $\pm$ 82.43	461 (24-485)	6795.74	68.47	71.51	91.7	155.69
Varuna X RH-819	65.65 $\pm$ 30.65	203 (24-277)	939.71	29.77	46.68	40.7	25.67
ACN-9 X Geeta	99.80 $\pm$ 48.13	337 (32-369)	2316.81	45.21	48.23	87.9	87.12
ACN-9 X RH-819	103.10 $\pm$ 50.80	290 (33-323)	2581.57	46.60	49.28	89.4	93.59
Urvashi X Geeta	85.84 $\pm$ 39.68	210 (37-247)	1575.06	39.66	46.23	73.6	60.18
Urvashi X RH-819	91.49 $\pm$ 47.92	410 (29-439)	2296.80	47.50	52.38	82.2	81.20
Sej-2	104.13	-	-	-	-	-	-
Ashirwad	82.80	-	-	-	-	-	-
Varuna	124.07	-	-	-	-	-	-
ACN-9	108.07	-	-	-	-	-	-
Urvashi	102.33	-	-	-	-	-	-
Geeta	97.47	-	-	-	-	-	-
RH-819	90.87	-	-	-	-	-	-
Grand mean	96.20						
S $E_{(m)}\pm$	16.86						
C V (%)	30.35						

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

F_2 crosses/ Parents	Mean $\pm$ S $E_{(m)}$	Range	VF_2	GCV (%)	PCV (%)	h^2 (%)	Genetic Advance
Sej-2 X Geeta	7.623 $\pm$ 5.06	41.10 (2.0-43.1)	25.68	60.47	66.47	82.7	8.63
Sej-2 X RH-819	7.604 $\pm$ 5.63	47.90 (1.8-49.7)	31.73	69.96	74.08	89.2	10.34
Ashirwad X Geeta	7.678 $\pm$ 3.82	26.50 (2.60-29.1)	14.60	45.93	49.77	85.2	6.70
Ashirwad X RH-819	7.931 $\pm$ 4.43	23.10 (2.70-25.8)	19.63	54.18	55.86	94.1	8.58
Varuna X Geeta	7.519 $\pm$ 4.89	25.00 (2.0-27.0)	23.96	58.85	65.10	81.7	8.23
Varuna X RH-819	5.313 $\pm$ 2.76	19.70 (2.0-21.7)	7.66	38.90	52.08	55.8	3.18
ACN-9 X Geeta	6.410 $\pm$ 3.73	25.30 (1.60-25.3)	13.91	53.05	58.19	83.1	6.38
ACN-9 X RH-819	6.911 $\pm$ 4.06	30.10 (1.90-32.0)	16.51	56.33	58.79	91.8	7.68
Urvashi X Geeta	8.697 $\pm$ 4.83	29.90 (2.60-29.9)	23.41	53.05	55.63	90.9	9.06
Urvashi X RH-819	6.168 $\pm$ 4.14	28.20 (1.90-28.2)	17.17	64.93	67.17	93.4	7.97
Sej-2	10.49	-	-	-	-	-	-
Ashirwad	6.17	-	-	-	-	-	-
Varuna	9.63	-	-	-	-	-	-
ACN-9	8.37	-	-	-	-	-	-
Urvashi	8.08	-	-	-	-	-	-
Geeta	8.16	-	-	-	-	-	-
RH-819	6.87	-	-	-	-	-	-
Grand mean	7.64						
S $E_{(m)}\pm$	1.15						
C V (%)	26.23						

Urvashi x Geeta, Sej-2 x Geeta, Ashirwad x RH-819, Urvashi x RH-819, ACN-9 x RH-819, Varuna x Geeta. These crosses also exhibited high F_2 variance and genetic coefficient of variation. This trend of genetic parameters observed in the above seven crosses allowed the scope for selection in these crosses. Chauhan *et al*. (2001) also observed similar association for high heritability with high genetic advance for yield plant^{-1} in mustard and also reported the scope of making individual plant selection in such situation. However, the F_2 population of Ashirwad x Geeta and ACN-9 x Geeta showed high heritability with low genetic advance and Varuna x RH-819 showed low heritability with low genetic advance indicating the influence of environment. Similar to this result Raj *et al*. (1998) and Sadat *et al*. (2010) also observed high heritability for seed yield plant^{-1} associated with low genetic advance in mustard.

Any appraisal of the breeding material permitting early elimination of material of low potential is clearly advantageous because all improvement programmes have limitations and elimination of poor material enhances the probability of finding superior segregants in the remaining material (Allard, 1960). One of the criteria as suggested by Hansan *et al*. (1956) for identification of potential F_2 cross was high mean yield, high genetic variance, high heritability and high expected genetic advance. Since only the genetic portion of the total variability contributes to gain under selection, the importance of information about the parameter of genotype enrichment complex should be clear to the breeder. As better estimates of these parameters are obtained for variety of plant materials, the breeder should be able to anticipate the gain he can expect from different intensity of selection (Allard, 1960). Therefore, in an actual breeding programme with limited facilities, the highest advance may result from such crosses. F_2 population of 10 crosses evaluated for important genetic parameters for four characters, exhibited high coefficient of variation for number of siliqua plant^{-1} (30.35%) and seed yield plant^{-1} (26.23%) where as days to first flower (4.31%) and plant height (8.52%) showed low coefficient of variation. Hence, only number of siliqua plant^{-1} and seed yield were considered as objective of selection in this study. Sej-2 x Geeta, Sej-2 x RH-819, Ashirwad x RH-819, Varuna x Geeta , ACN-9 x Geeta, ACN-9 x RH-819, Urvashi x Geeta, and Urvashi x RH-819 were observed to record high mean, variance, heritability and genetic advance for both number of siliqua plant^{-1} and yield plant^{-1} or any one of these two traits. Hence, these eight crosses were identified and subjected to individual plant selection. Similar to this finding Chauhan *et al.* (2001) also reported the scope of single plant selection in F_2 in mustard. Criteria for making individual plants selection was based on general mean $\pm$ S.E. Plants exhibiting the value greater than general mean $\pm$ S.E for number of siliqua plant^{-1} and yield plant^{-1}. The percentage of selected plants ranged from 11.90% to 17.14% for number of siliqua plant^{-1} and from 11.90% to 18.23% for seed yield plant^{-1}. Per cent individual plant selected in the above eight crosses were 13.80, 14.70, 13.80, 12.38, 12.85, 13.13, 17.14 and 11.90 respectively for number of siliqua plant^{-1} and 13.13, 14.76, 12.85, 15.23, 13.13, 12.38, 11.90 and 13.13 respectively for yield plant^{-1}. These selected plants are recommended for forwarding to the next generation for evaluating the progeny performance.

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Rec. on 30.04.2012 & Acc. on 15.06.2012

J. Soils and Crops 22 (2) 387-391, Dec., 2012 ISSN 0971-2836

CORRELATION AND PATH ANALYSIS OF MORPHOPHYSIOLOGICAL, BIOCHEMICAL AND YIELD CONTRIBUTING TRAITS OF LOCAL COLLECTIONS IN MUSTARD

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ABSTRACT

The experiment to study the correlation and path analysis of morpho-physiological, biochemical and yield contributing characters using 12 mustard local collections viz., ACNM10-1, ACNM10-2, ACNM10-3, ACNM10-4, ACNM10-5, ACNM10-6, ACNM10-10, ACNM10-11, ACNM10-15, ACNM10-17, ACNM10-21, ACNM10-22 and two popular varieties ACN-9 and Pusa bold was conducted during *rabi* 2011-2012. Observations on plant height, number of primary branches, leaf area, total dry matter production, relative growth rate (RGR), net assimilation rate (NAR), chlorophyll and N, P, K, content in leaves, oil content in seed, number of siliqua plant^{-1}, 1000-seed weight, number of seeds 20^{-1} siliqua, seed yield plant^{-1}, plot^{-1} and ha^{-1} were recorded. The fourteen genotypes of mustard showed significant variation among them for all the characters studied. The correlation studies revealed significant positive correlation of all morpho-physiological, chemical and biochemical parameters and yield components with seed yield except number of seeds 20^{-1} siliqua. Path coefficient analysis indicated the need for giving weightage to plant height, number of siliqua plant^{-1}, dry matter production, 1000 seed weight, phosphorus content at 65 DAS and potassium content at 65 DAS for improving seed yield in mustard. The significance of weightage should be given to number of siliqua plant^{-1}, 1000 seed weight and dry mater production, to increase seed yield in mustard. The mean performance of fourteen genotypes when compared for above characters along with seed yield it was found that Pusa bold ranked first followed by ACN-9. Similarly next to above two genotypes two local genotypes i.e., ACNM10-6 and ACNM10-5 were also identified as superior over remaining ten genotypes under study. Hence, these two genotypes were also recommended for breeding programme and testing in yield trial.

(Key words: Mustard, path analysis, morphophysiological and biochemical parameters)

INTRODUCTION

Mustard (*Brassica juncea*) is a second important *rabi* oilseed crop in India after groundnut in area and production. In recent years there has been increase in production of rapeseed mustard. The average productivity in India is low in comparison to that of the developed countries. There is direct need to develop high yielding varieties of *Brassica* to further enhance its productivity in country (Khan *et al*., 2005).

The growth analysis technique helps in understanding the growth pattern and also contribution of various plant parts to economic yield. It also helps in finding out the yield and yield contributing characters. Thus, growth analysis forms the basis for manipulation of productivity of crop. Seed yield is a complex character and is influenced by several other characters known as yield contributing characters which may have positive or negative effect on this trait. It is important to examine the contribution of each of the trait in order to give more attention to those having greatest influence on seed yield. Therefore, information on the association of characters with seed yield is of great importance to define selection criteria for mustard in terms of yield. Correlation between the different morpho-physiological parameters, chemical and biochemical parameters, and yield components with yield gives an idea of growth and yield attributes, promotion of which helps in realization of higher productivity. Usefulness of information obtained from correlation can be enhanced by partitioning them into direct and indirect effect by path coefficient analysis.

Therefore, the present study with 14 genotypes (12 local collections + 2 varieties) of *Brassica juncea* was planned to study the morpho-physiological, chemical, biochemical and yield contributing parameters with yield, to partition the correlation into direct and indirect effect and to identify promising genotypes for cultivation.

MATERIALS AND METHODS

This experiment was conducted to study the correlation and path analysis of morpho-physiological, biochemical and yield contributing characters with yield in mustard during *rabi* 2011-2012 at the farm of Agricultural Botany Section, College of Agriculture, Nagpur. The experimental material consisted of 14 mustard genotypes (ACNM10-1, ACNM10-2, ACNM10-3, ACNM10-4,

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ACNM10-5, ACNM10-6, ACNM10-10, ACNM10-11, ACNM10-15, ACNM10-17, ACNM10-21, ACNM10-22, ACN-9 and Pusa bold). Seeds were sown at the rate of 5 to 6 kg ha^{-1} by dibbling method at a spacing 45 cm x 15 cm on 30th October 2011 after receiving the sufficient rainfall. Thinning was carried out after full emergence so as to maintain required number of plants $plot^{-1}$. Intercultural operations were also undertaken as and when required.

The observations on dry matter production and leaf area were recorded on 25 day's old plant and thereafter, two observations at an interval of 20 days were also recorded. Plant height and number of primary branches $plant^{-1}$ were recorded at three different stages viz., 25, 45 and 65 DAS. Relative growth rate and net assimilation rate were also calculated at an interval of 20 days based on total dry matter accumulation and period of accumulation. The leaf samples were analyzed for their chlorophyll (colorimetric method, Bruinsm, 1982), nitrogen (micro-kjeldahl's method, Somichi *et al*.,1972), phosphorus (vanadomolybdate yellow colour method, Jackson, 1967), and potassium content (flame photometer by di-acid extract method, Jackson 1967), at 25, 45 and 65 DAS. Seed oil content was also estimated using the Soxhlet's method given by Sankaran (1965). Observations on the yield and yield contributing characters like number of siliqua $plant^{-1}$, number of seeds 20^{-1} siliqua, 1000-seed weight and seed yield $plant^{-1}$, $plot^{-1}$ and ha^{-1} were also recorded. The data collected were subjected to statistical analysis suggested by Panse and Sukatme (1954). Simple correlations of different traits with yield were calculated by using the formulas given by Singh and Choudhary (1994), and Path coefficient analysis was carried out by the method suggested by Dewey and Lu (1959).

RESULTS AND DISCUSSION

The correlation coefficient (r) calculated in this study revealed significant positive correlation of all morpho-physiological, chemical and biochemical parameters and yield components with seed yield except number of seeds 20^{-1} siliqua. In order to obtain the developmental relations, the causes and effect of relationship between yield, morpho-physiological, chemical, biochemical and yield components were studied in mustard through path coefficient analysis. The direct and indirect effect estimated for morpho-physiological, chemical, biochemical and yield components indicated positive and negative values for both direct and indirect effect. The characters which contributed maximum indirect effects were alone considered for discussion (Table 1).

Path analysis among the characters studied at genotypic level indicated that potassium content in leaves at 65 DAS (57.90%), exerted maximum direct effect followed by dry matter production at 65 DAS (56.17%), phosphorus content at 65 DAS (52.48%), number of siliqua $plant^{-1}$ (31.17), plant height at 65 DAS (17.00), 1000 seed weight (13.32%) and relative growth rate at 65-45 DAS (1.60%) which were also supported by very high positive correlation with seed yield.

The indirect effect of net assimilation rate at 65-45 DAS on yield through different yield components was found to be maximum i.e. (134.61%) followed by leaf area at 65 DAS (130.17%), total chlorophyll content in leaves at 65 DAS (119.80%), nitrogen content in leaves at 65 DAS (118.49%), oil content (112.29), number of seeds 20^{-1} siliqua (108.12%), number of primary branches $plant^{-1}$ at 65 DAS (103.50%), relative growth rate at 65 DAS (98.39%),1000 seed weight (86.67%), plant height at 65 DAS (82.99%) , number of siliqua $plant^{-1}$ (68.28%), phosphorus content in leaves at 65 DAS (47.53%), dry matter production at 65 DAS (43.28%) and potassium content in leaves at 65 DAS (42.09%).The major contributor to the total indirect effect were potassium content in leaves at 65 DAS, phosphorus content at 65 DAS, dry matter production, number of siliqua $plant^{-1}$ and 1000 seed weight.

The study on path analysis indicated that morpho-physiological parameters like dry matter production and plant height , biochemical components like phosphorus and potassium content at 65 DAS, yield components like number of siliqua $plant^{-1}$ and 1000 seed weight were found to exert high positive direct effect on seed yield. This reveals that morpho-physiological, biochemical, yield components should be given equal weightage for selection of promising genotypes. In contradictory to this result Uke *et al*. (2011) reported that weightage

Table 1. Direct and total indirect effect of different parameters on seed yield plant $^{-1}$ in mustard

Sr. no.	Characters	Correlation coefficient (r)	Direct effect	% Direct effect	Total indirect effect	% Indirect effect	% Major contributing characters (at 65 DAS)
1.	Plant height	0.7964	0.1354	17.00	0.661	82.99	Phosphorus content (49.39), Potassium content (45.36), Dry matter (37.83), Number of siliqua (26.77), 1000 seed weight (10.66)
2.	No. of primary branches plant $^{-1}$	0.8645	-0.0303	-3.50	0.8948	103.50	Potassium content (50.89), Dry matter (46.08), Phosphorus content (55.08), Number of siliqua (26.33) Plant height (11.97)
3.	Dry matter production	0.9075	0.5147	56.17	0.3928	43.28	Potassium content (57.59), Phosphorus content (49.49), Number of siliqua (21.30), 1000 seed weight (12.88), Plant height (8.72)
4.	Leaf area	0.9037	-0.2727	-30.17	1.1764	130.17	Potassium content (56.37), Dry matter (51.67), Phosphorus content (51.30), Number of siliqua (21.55), 1000 seed weight (12.90)
5.	RGR	0.6835	0.011	1.60	0.6725	98.39	Dry matter (59.50), Potassium content (59.06), Phosphorus content (53.54), Number of siliqua (21.21), 1000 seed weight (14.17)
6.	NAR	0.8322	-0.2881	-34.61	1.1203	134.61	Dry matter (59.46), Potassium content (57.85), Phosphorus content (50.74), Number of siliqua plant $^{-1}$ (22.57), 1000 seed weight (12.80)
7.	Chlorophyll content in leaves	0.9332	-0.1848	-19.80	1.118	119.80	Potassium content (55.52), Phosphorus content (51.02), Dry matter (50.10), Number of siliqua plant $^{-1}$ (23.79), 1000 seed weight (12.24)
8.	Nitrogen content in leaves	0.9404	-0.1739	-18.49	1.1143	118.49	Potassium content (57.06), Dry matter (50.82), Phosphorus content (49.76), Number of siliqua plant $^{-1}$ (22.20), 1000 seed weight (12.61)
9.	Phosphorus content in leaves	0.954	0.5005	52.48	0.4535	47.53	Potassium content (52.52), Dry matter (48.48), Number of siliqua plant $^{-1}$ (24.22), 1000 seed weight (19.97), Plant height (11.15)

Contd....

Table 2 - Contd....

Sr. no.	Characters	Correlation coefficient (r)	Direct effect	% Direct effect	Total indirect effect	% Indirect effect	% Major contributing characters (at 65 DAS)
10.	Potassium content in leaves	0.9518	0.5511	57.90	0.4007	42.09	Dry matter (51.30), Phosphorus content (47.81), Number of siliqua plant^{-1} (22.29), 1000 seed weight (12.81), Plant height (9.32)
11	Oil content	0.9157	-0.1126	-12.29	1.0283	112.29	Potassium content (52.41), Phosphorus content (49.25), Dry matter (48.33), Plant height (25.27), 1000 seed weight (12.12)
12	No. of siliqua plant^{-1}	0.8803	0.2792	31.71	0.6011	68.28	Potassium content (47.57), Phosphorus content (47.06), Dry matter (40.48), Plant height (11.74), 1000 seed weight (10.63)
13	Number of seeds 20^{-1} siliqua	0.3201	-0.026	-8.12	0.3461	108.12	Phosphorus content (56.04), Number of siliqua plant^{-1} (40.17), Potassium (29.02), Plant height (22.18), Dry matter (20.49)
14	1000 seed weight	0.9433	0.1257	13.32	0.8176	86.67	Potassium content (56.69), Dry matter (50.72), Phosphorus content (48.17), Number of siliqua plant^{-1} (22.03), Plant height (9.68)

Table 2. Mean performance of promising genotypes for selected traits

		Mean performance								
Sr. No.	Name of genotypes	Plant height (cm)	Dry matter production (g)	Phosphorus content at 65 DAS (%)	Potassium content at 65 DAS (%)	1000 seed weight (g)	Number of siliqua plant^{-1}	Seed yield plant^{-1} (g)	Seed yield plot^{-1} (kg)	Seed yield ha^{-1} (q)
1	Pusa bold	152.17	34.62	0.24	1.98	3.54	205.67	6.53	0.65	9.72
2	ACN-9	141.53	31.64	0.23	1.89	3.35	200.10	5.95	0.59	8.81
3	ACNM10 -6	132.64	28.62	0.21	1.88	3.18	225.64	5.66	0.56	8.40
4	ACNM10 -5	130.07	26.64	0.21	1.84	3.16	217.87	5.53	0.55	8.19
	SE(m) ±	8.45	1.12	0.006	0.03	0.09	11.93	0.30	0.03	0.44

on morpho-physiological and yield components should be given more importance as compared to chemical and biochemical characters.

The studies on correlation and path coefficient analysis indicated the need for giving weightage to plant height, number of siliqua plant^{-1}, dry matter production, 1000 seed weight, phosphorus content at 65 DAS and potassium content at 65 DAS for improving seed yield in mustard. The significance of weightage should be given to number of siliqua plant^{-1}, 1000 seed weight and dry mater production, to increase seed yield in mustard were also reported by Khan *et al. (*2005), Gangapur *et al*. (2009), Uke *et al.(*2011) and Yadava *et al.* (2011).

From this study, it was observed that the characters like plant height, number of siliqua plant^{-1}, dry matter production at 65 DAS and 1000-seed weight should be given preference. The mean performance of fourteen genotypes when compared for above four characters along with seed yield it was found that Pusa bold ranked first followed by ACN-9 (Table 2). Similarly next to above two genotypes two local genotypes i.e., ACNM10-6 and ACNM10-5 were also identified as superior over remaining ten genotypes under study. Hence, these two genotypes were also recommended for breeding programme and testing in yield trial.

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Rec. on 30.05.2012 & Acc. on 30.06.2012

J. Soils and Crops 22 (2) 392-396, Dec., 2012 ISSN 0971-2836

AVAILABLE MICRONUTRIENT STATUS OF RIDHORA WATERSHED IN NAGPUR DISTRICT OF MAHARASHTRA

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ABSTRACT

The soil samples were collected during year 2009-10 from Ridhora watershed in Nagpur district of Maharashtra from 31 pedons of different soil types were analyzed for available micronutrient content's using DTPA as an extractant. The results revealed that available Cu, Fe, Zn and Mn contents vary from 0.17 to 5.12 mg kg^{-1}, 1.37 to 17.92 mg kg^{-1}, 0.03 to 0.93 mg kg^{-1} and 6.67 to 16.98 mg kg^{-1}, respectively. In general, the decreasing trend of these micronutrients content down the profile was observed in all the soils.

(Key words : Watershed, micronutrient, pedon, DTPA)

INTRODUCTION

During the last decade, at large number of sites, normal growth of high yielding varieties of crops could not be obtained inspite of liberal application of N, P and K fertilizers. In all such cases field trials showed that insufficient availability of zinc was the main limiting factor for crop production. In years to come the deficiency of zinc would further magnify and that of other micronutrients would come up if the soils are continuously exploited even at this level of production. As micronutrient play an important role not only in growth and yield but quality of crops. The assessment of soil resource for micronutrient contents, as precise as possible would be much advantageous to planners, extension workers, fertilizer dealers and to individual farmers. Considering these facts, the present study was undertaken to assess the micronutrient status of soils of Ridhora watershed in Nagpur district of Maharashtra.

MATERIALS AND METHODS

Thirty one soil pedons were collected from Ridhora watershed representing the different physiographic units, land use/land cover and different slopes were studied. The Ridhora watershed area extends from 21^{0}10^1 to 21^{0}14^1 N latitude and 78^{0}33^1 to 78^{0}38^1 E longitude. The average elevation of the watershed varies from 440 to 520 m from mean sea level. Soils of the area thus developed from basalt. The climate of the area is semi-arid sub-tropical with an annual rainfall of 1050 mm.

Available micronutrients viz., Fe, Mn, Cu, and Zn were determined by using DTPA extractant (Lindsay and Norvell, 1978). The extracts were analyzed for Zn, Cu, Fe and Mn in an atomic absorption spectrophotometer and as per Singh(2008) the pedons results were classified into different critical limits. The critical limits are given in table1.

RESULTS AND DISCUSSION

In the present day agriculture when emphasis is being laid on intensive cropping and heavy usage of high analysis fertilizers for obtaining higher yield unit^{-1} and area unit^{-1} of time, the use of micronutrients can not be ignored. In view of this, the available micronutrients viz., Zn, Cu, Fe and Mn were extracted with DTPA and their concentration was determined with atomic absorption spectrophotometer.

Available Zinc :

Available zinc (Table 2) varied from 0.03 to 0.93 mg kg^{-1} in deep, medium and shallow soils in study area. The highest content of zinc was observed in pedon -20 (0.93 mg kg^{-1}) where as lowest content in pedon-14 (0.03 mg kg^{-1}). Distribution of available zinc showed three classes of Zn i.e. very low (<0.30 mg kg^{-1}) in pedons- 5, 10,12,13,14,18,23 and 31, low (0.30-0.60 mg kg^{-1}) in pedons-1,2,3,4,6,7,8,9,16,19,21,22,25,27,28,29 and 30 (i.e. major area of Ridhora watershed) and marginal (0.60-1.20 mg kg^{-1}) in pedon-11,15,17,20,24 and 26. As per critical limit of zinc (Singh,2008), the soils varied from very low to marginal in Zn content. Similar findings were reported by Ambegaonkar and Bharambe (2007). They reported that available Zn varied from 0.5 to 3.0 mg kg^{-1}in Jayakwadi command area. In general, the decreasing trend of zinc content

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Table 1. Critical levels for available secondary and micronutrients

Sr. No.	Nutrient elements	Category					
		Very low	Low	Marginal	Adequate	Moderately high	High
1	Zinc (mg kg^{-1})	<0.30	0.30 – 0.60	0.60 - 1.20	1.20 – 1.80	1.80 – 2.40	> 2.40
2	Iron (mg kg^{-1})	<2.50	2.50 – 4.50	4.50 – 9.0	9.0 – 18.0	18.0 – 27.0	>27.0
3	Manganese (mg kg^{-1})	<1.0	1.0 – 2.0	2.0 – 4.0	4.0 – 8.0	8.0 – 16.0	>16.0
4	Copper (mg kg^{-1})	<0.10	0.10 – 0.20	0.20 – 0.40	0.40 – 0.80	0.80 – 1.20	> 1.20

down the profile was observed in all the soils, which might be because of manures and fertilizers application at the surface soils. Similar findings were also reported by Gajbhiye *et al*. (1993). They classified soils in India into three classes for zinc viz,. deficient, marginal and adequate levels for shallow to deep black soils of Maharashtra.

Available Copper :

DTPA extractable copper (Table 2) varied from 0.17 to 5.12 mg kg^{-1}in deep, medium and shallow soils in study area. The highest content of copper was observed in pedon -6 (5.12 mg kg^{-1}) where as lowest in pedon-13 (0.17 mg kg^{-1}).Available Cu from table 2 showed its distribution in three classes viz*.,* high (>1.20 mg kg^{-1}) in pedons-1,3,4,5,5,7,8,10,11, 14, 15,16,17,18, 19,20, 21,22,23,24,25, 26, 28 and 29, moderately high (0.80-1.2 mg kg^{-1}) in pedons- 2,9,12, ,27 and 31 and low (0.1 to 0.2 mg kg^{-1}) in pedons-13 and 30 of Ridhora watershed area. When availability of copper compared with the critical values (Singh, 2008), maximum soils were found high to moderately high of available copper content. Similar results were reported by Malewar and Randhawa (1978). They reported that soil were high in copper content in the citrus growing area of Maharashtra. Similarly, Kirmani *et al*.(2011) also reported high copper content in soil of Budgam district. In general, the decreasing trend of copper content down the profile was observed in all the soils.

Available Iron :

The data presented in table 2 showed that available iron content varied from 1.37 to 17.92 mg kg^{-1} in soils of study area. The highest content of iron was observed in pedon -24 (17.92 mg kg^{-1}) where as lowest content in pedon-2 (1.37 mg kg^{-1}). The data showed the occurrence of available iron in four classes very low (<2.5mg kg^{-1}) in pedons-2 , low (2.5-4.5 mg kg^{-1}) in pedons-1, 3,9,10,30 and 31, marginal (4.5-9.0 mg kg^{-1}) in pedons-5,7,8,11,1314,16,17,18,24 and 25 and adequate (9.0-18.0 mg kg^{-1}) in pedons-6,13,15,20,21,22,24,26,27, 28 and 29. It was found that the soils were varied from low to adequate levels in Fe content as per Singh,(2008). In general, the decreasing trend of iron content down the profile was observed in all the soils, which might be because of manures and fertilizers application at the surface soils. Similar results were reported by Abrahim *et al.* (2011). They reported that soils of Billari local area were adequate in iron content.

Available Manganese :

Available manganese (Table 2) varied from 6.67 to 16.98 mg kg^{-1}in deep, medium and shallow soils in study area. The highest content of manganese was observed in pedon -17 (16.98 mg kg^{-1}) where as lowest in pedon-30 (6.67 mg kg^{-1}).The data revealed presence of three classes of available manganese viz*.,* adequate (4.0-8.0 mg kg^{-1}) content in pedons-13 and 30, moderately high (8.0-16.0 mg kg^{-1}) in pedons-1,2,3,4,5,6,7,8,9,10,11 ,12,14,15,16, 18,19,21, 22,23, 24,25,26,27,28,29 and 31, and high (>16.0 mg kg^{-1}) in pedons- 17 and 20. Thus, all the soils varied from adequate to moderately high levels in manganese content (Singh, 2008).Similar findings were reported

Table 2. Available micronutrient status of soils

Horizon	Depth (cm)	Avail.– Cu (mg kg^{-1})	Avail.– Fe (mg kg^{-1})	Avail.– Zn (mg kg^{-1})	Avail.– Mn (mg kg^{-1})
Pedon 1		***Fine clayey, smectitic, hyperthermic(calcareous) Typic Haplustepts***			
Ap	0-28	1.20	3.23	0.46	8.98
Bw1	28-65	1.08	2.44	0.21	8.53
Bw2k	65-90	0.47	1.70	0.16	8.35
Bw3k	90-118	0.29	1.70	0.14	8.19
Pedon 2		***Fine clayey, smectitic, hyperthermic (calcareous) Typic Haplustepts***			
Ap	0-11	0.83	2.47	0.32	10.92
Bw1k	11 - 40	0.77	2.42	0.31	10.52
Bw2k	40-70	0.77	1.37	0.21	10.52
Pedon 3		***Fine loamy mixed, hyperthermic Typic Ustorthents***			
Ap	0-17	2.12	3.66	0.42	10.38
Pedon 4		***Very fine clayey, smectitic, hyperthermic Typic Ustorthents***			
Ap	0 - 17	3.36	8.55	0.31	9.23
Pedon 5		***Very fine clayey, smectitic, hyperthermic (calcareous) Typic Haplustepts***			
Ap	0-17	0.70	4.82	0.25	8.36
Aw1	17- 38	0.67	2.85	0.19	8.32
Aw2k	38 -75	0.68	2.08	0.14	7.88
Pedon 6		***Fine loamy mixed, hyperthermic Typic Ustorthents***			
Ap	0 -15	5.12	10.18	0.44	9.68
Pedon 7		***Fine loamy mixed, hyperthermic (calcareous) Typic Ustorthents***			
Ap	0 - 12	1.64	5.99	0.31	9.86
Bw1	12 - 30	2.00	5.68	0.45	9.67
Pedon 8		***Very fine clayey, smectitic, hyperthermic (calcareous) Typic Haplusterts***			
Ap	0 - 27	2.59	7.01	0.34	9.23
Bw1	27 - 52	2.51	6.19	0.33	8.87
Bss1	52 - 85	2.16	4.24	0.32	8.16
Bss2	85 - 107	2.14	4.08	0.22	8.27
Bw2	107 - 140	2.09	3.21	0.27	7.87
Pedon 9		***Very fine clayey, smectitic, hyperthermic (calcareous) Typic Haplusterts***			
Ap	0 -27	0.89	4.37	0.43	11.11
Bw1k	27 -50	0.86	4.16	0.22	10.36
Bss1	50 - 67	0.79	3.87	0.14	9.12
Bss2	67 -94	0.60	3.45	0.15	9.48
Bw2	94 -130	0.34	2.90	0.14	9.23
Pedon 10		***Fine clayey, smectitic, hyperthermic (calcareous) Typic Ustorthents***			
Ap	0 -15	1.50	3.99	0.23	8.64
Bw1	15 - 27	1.49	2.57	0.20	7.92
Pedon 11		***Fine clayey, smectitic, hyperthermic Typic Ustorthents***			
A	0 - 10	1.62	8.78	0.65	8.16
Pedon 12		***Fine clayey, smectitic, hyperthermic Typic Ustorthents***			
Ap	0 - 13	1.11	4.64	0.22	9.28
Pedon 13		***Fine loamy mixed, hyperthermic Typic Ustorthents***			
Ap	0 -12	0.17	10.86	0.06	7.37

Contd....

Table 2. - Contd....

Horizon	Depth (cm)	Avail.– Cu (mg kg^{-1})	Avail.– Fe (mg kg^{-1})	Avail.– Zn (mg kg^{-1})	Avail.– Mn (mg kg^{-1})
Pedon 14		***Fine clayey, smectitic, hyperthermic(calcareous) Vertic Haplustepts***			
Ap	0 - 20	2.88	7.55	0.25	9.22
Bw1	20 - 33	2.77	4.11	0.24	8.86
Bw2	33 - 82	1.91	3.74	0.20	8.78
Bw3	82 - 115	1.81	2.90	0.03	7.62
Pedon 15		***Fine clayey, smectitic, hyperthermic Typic Ustorthents***			
Ap	0 -8	2.90	13.51	0.66	12.78
Pedon 16		***Fine clayey, smectitic, hyperthermic Typic Haplustepts***			
Ap	0 -20	2.30	8.74	0.38	12.34
Bw1	20 - 36	2.22	5.56	0.31	11.98
Pedon 17		***Very fine clayey,smectitic, hyperthermic(calcareous) Typic Haplusterts***			
Ap	0 -21	2.68	6.90	0.66	16.98
Bw1	21 -60	2.42	5.95	0.48	16.52
Bss1	60 - 90	1.46	5.13	0.42	15.56
Bss2	90 - 115	1.34	4.88	0.33	15.36
Bw2	115 - 150	1.12	3.30	0.38	15.38
Pedon 18		***Fine clayey, smectitic, hyperthermic Typic Ustorthents***			
Ap	0 - 15	1.26	6.22	0.23	8.41
Pedon 19		***Fine loamy mixed, hyperthermic Typic Ustorthents***			
Ap	0 - 14	2.44	10.17	0.50	12.58
Pedon 20		***Fine clayey, smectitic, hyperthermic Typic Ustorthent***			
Ap	0 - 17	3.98	15.80	0.93	16.37
Pedon 21		***Fine loamy mixed, hyperthermic Typic Ustorthents***			
Ap	0 -20	2.35	9.82	0.51	12.83
Pedon 22		***Fine loamy mixed, hyperthermic Typic Ustorthents***			
A	0 - 20	2.12	12.49	0.34	10.38
Pedon 23		***Very fine clayey, smectitic, hyperthermic Typic Ustorthents***			
Ap	0 - 23	1.59	5.07	0.27	9.57
Pedon 24		***Fine loamy mixed, hyperthermic Typic Ustorthents***			
A	0 - 8	1.36	17.92	0.79	13.97
Pedon 25		***Very fine clayey, smectitic, hyperthermic (calcareous) Vertic Haplustepts***			
Ap	0 - 18	2.26	5.86	0.31	8.76
Bw1	18 - 23	2.70	5.09	0.30	8.36
Bw2	53 - 79	2.25	4.13	0.26	7.95
Bw3	79 - 120	1.29	2.93	0.21	7.78
Pedon 26		***Very fine clayey, smectitic, hyperthermic (calcareous) Typic Haplustepts***			
Ap	0 -13	3.59	12.88	0.83	8.48
Bw1	13 -42	2.06	3.16	0.23	7.90
Bw2	42 -75	1.91	3.13	0.21	7.57
Pedon 27		***Fine loamy mixed, hyperthermic Typic Ustorthent***			
A	0 - 12	0.68	10.78	0.43	13.69
Pedon 28		***Fine loamy mixed, hyperthermic Typic Ustorthents***			
Ap	0 - 13	2.48	11.36	0.34	12.61
Bw1	13 - 30	2.37	7.98	0.21	11.37
Pedon 29		***Fine loamy mixed, hyperthermic Typic Ustorthents***			
A	0 - 10	2.54	9.81	0.42	9.56
Pedon 30		***Fine clayey, smectitic, hyperthermic Typic Ustorthent***			
Ap	0 - 15	0.18	4.11	0.37	6.67
Pedon 31		***Fine clayey, smectitic, hyperthermic Typic Ustorthent***			
Ap	0 -23	0.61	3.23	0.19	9.25

by Kirmani *et al*.(2011). They reported soils of Budgam district were moderately high in manganese content. In general, the decreasing trend of manganese content down the profile was observed in all the soils, which might be because of manures and fertilizers application at the surface soils. Similar findings were also reported by Gajbhiye *et al*. (1993). They classified soils in India into three classes for manganese viz,. deficient, marginal and adequate levels for shallow to deep black soils of Maharashtra In general, the decreasing trend of all these micronutrients content down the profile was observed in all the soils, which might be due to manures and fertilizers application at the surface soils.

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Rec. on 21.12.2011 & Acc. on 05.02.2012

J. Soils and Crops 22 (2) 397-403, Dec., 2012 ISSN 0971-2836

PREDICTION OF PRECIPITATION BY DEVELOPMENT OF GROWTH MODEL FOR PUSAD STATION

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ABSTRACT

The study of prediction of precipitation by development of growth model was undertaken for pusad taluka of Yavatmal district in Central Agro climatic zone for which daily point rainfall data for a period of 31 years (1970 to 2000) were collected from IMD, Pune and used for probability analysis following Weibulls method (Rane and Thakur, 1995). The Logistic model was developed and weekly cumulative precipitation values were predicted and the same were tested with observed precipitation for the period from 2002-2006 at probability level of 25%, 50% and 75%. The Logestic model gave reliable prediction at 25% probability levels when compared with actual data. The weekly cumulative precipitation at 25% , 50% and 75% probability level for Pusad taluka was found to be 561.63, 99.44 and 88.89 mm respectively and predicted weekly cumulative precipitation at 25%, 50% and 75% by using logistic model were found to be 419.58, 77.18 and 43.62 mm. The weekly cumulative precipitation predicted value at 25% probability levels was 419.58 mm and the average observed value for subsequent five years (2002-2006) was 824.13 mm.

INTRODUCTION

Rainfall varies not only with the time but also with geographical areas. It plays important role in agricultural and non-agricultural operation. Presence and absence of certain amount of rainfall at critical stage of crop growth can determine the success and failure of that crop. Hence, irrigation planning is essential for successful agricultural system. For planning an irrigation, water supply system, is essential to estimate the irrigation water requirement during different weeks of crop growing period. It will naturally depend upon rainfall in the concerned week and evapotranspiration in the same week. Thus, the information on rainfall which is likely to occur in different weeks is necessary to estimate the irrigation water requirement in concerned week. Different growth models are developed by Prasad *et al.* (2007) for prediction of precipitation. These models are location specific, meaning thereby the constants in these models vary from region to region depending on the rainfall pattern (Tiwari and Singh,1985). One such good model is Logistic model. In the present study efforts were made to develop Logistic model for Pusad taluka of Yavatmal district following the standard procedure and test its suitability in this area by comparing it with actual rainfall data.

MATERIALS AND METHODS

Daily point rainfall data for a period of 31 years (1970 to 2000) for Pusad taluka of Yavatmal district were collected from IMD, Pune and transformed into corresponding data of 52 standard meteorological weeks. To develop the constants of logistic model, weekly values of precipitation were arranged in descending order of magnitude.

The most commonly used Weibulls (1939) formula was applied for probability analysis for each standard meteorological week. The rainfall values were plotted against corresponding computed probability on normal probability paper and for all these weeks the precipitatio probability curves were drawn.

The expected precipitation magnitude at 25%, 50% and 75% probability levels were estimated. Afterward the cumulative precipitation at different probability levels were analysed using Logistic model for prediction.

The Logistic model can be expressed as follows.

Logistic Model $1/Y = a+ab^x$

Where,

Y= Predicted cumulative rainfall

X= Standard week from 1 to 52

a,b,c= Constants

The cumulative rainfall values were chronologically divided into three equal segments. The subtotal of reciprocals of individual observation in each of these segments was obtained. The subtotals were represented in chronological order by S_1,S_2 and S_3. The difference between the subtotals i.e. S_1-S_2

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and S_3-S_2 were represented by D_1 and D_2 respectively. Number of observations in each segment was denoted by n.

The values of constants a,b and c of this model were computed by the relationship given by Mills (1955) as given below.

$$a = \frac{1}{n} S_1 - \left(\frac{d_1}{C^n - 1}\right)$$

$$b = \frac{d1\,(C-1)}{(Cn-1)2}$$

$$c = \left(\frac{d_2}{d_1}\right)^{1/n}$$

The mathematical expression for prediction of cumulative rainfall was developed using the values of constants. The suitability of model was studied by computing coefficient of determination and per cent average absolute deviation between the actual cumulative rainfall and its predicted values at different probability levels.

RESULTS AND DISCUSSION

Average weekly precipitation corresponding to each standard week at probability levels at 25%, 50% and 75% worked out using Weibull's method are given in table 1. From the table, it is clear that the precipitation values are sufficiently good.

Crop planning :

For Pusad at 50% and 75% probability level rainfall values are very small, hence it is difficult to have crop planning at 50% and 75% probaility level. Hence, crop planning will have to be done based on 25 per cent probability level with some risk. Considering the 25 per cent probability level the sowing operation can be carried out after 25^{th} met week i.e. after receiving 77 mm rainfall for the crop like jowar, cotton and soybean.

At 25% probability level, 66 per cent of total rainfall of these season took place from 22nd to 33rd met week.

These average weekly precipitation values given in table 1 are then converted into weekly cumulative precipitation values and are given in table 2 at different probability levels. From the table, it is very clear that as the average weekly cumulative precipitation of Pusad taluka is 829.65 mm and the weekly cumulative precipitation is showing somewhat closer fit with the predicted weekly cumulative precipitation by logistic model at 25% probability which appears reliable. The cumulative precipitation at 50% and 75% probability level is showing prediction at much lower level than the average precipitation of the centre and hence, prediction at 75% and 50% probability levels do not provide reliable prediction.

The values of constant for Logistic model were developed using the method suggested by Mills (1955) from the previous 31 years precipitation data, which was collected from IMD, Pune for Pusad taluka at different probability levels and are given in the table 3.

Using the Logistic model developed for Pusad taluka the cumulative rainfall values were predicted for all the weeks and at different probability levels of 25%, 50% and 75% and are presented in table 4. From the table 4, it is very clear that when prediction at 25%, 50% and 75% are estimated and observed critically, the prediction at 50% and 75% are at much lower side than the average precipitation of Pusad taluka and the precipitation at 25% probability was showing some what closer fit with the observed values of precipitation of the same station (Gadgil and Shrinivasan, 2011).

The suitability of the logistic model developed for Pusad taluka was tested statistically by computing two statistical parameters namely coefficient of determination and per cent average absolute deviation between the observed values and their predicted values.

Form the table 5, it is observed that the Logistic model gave the reliable prediction at 25% probability level and hence it can be suitably used for prediction of precipitation in these areas while planning irrigation water management by developing the logistic model with prediction at 25% probability (Singh and Vidya, 1990).

The comparison of predicted values of precipitation at 25% probability level was made with weekly cumulative precipitation at 25% probability level are presented graphically in Fig.1. Careful

Table 1. Average weekly precipitation at different probability levels for Pusad Station

Met. Week	Dates	Weekly average precipitation at different probabilities in mm		
		25%	**50%**	**75%**
22	28-03, June	22.50	2.16	1.68
23	04-10, June	23.18	3.58	2.18
24	12-18, June	1.00	0.79	0.68
25	19-24 June	31.87	1.12	0.78
26	25-01, July	20.12	2.89	2.15
27	02-08, July	32.48	31.72	26.12
28	09-15, July	11.77	1.08	0.89
29	16-22, July	16.50	14.17	0.00
30	23-29. July	62.78	20.18	1.29
31	30-05, August	21.12	0.79	0.69
32	06-12 August	18.21	0.83	0.51
33	13-19 August	39.27	4.24	2.31
34	20-26, August	14.20	0.38	0.18
35	27-02, September	17.89	0.00	0.00
36	03-09, September	37.26	5.27	4.12
37	10-16, September	7.18	1.02	3.18
38	17-23, September	43.78	7.19	0.15
39	24-30, September	30.12	1.07	7.18
40	01-07, October	42.48	11.68	3.12
41	08-14, October	10.21	1.07	0.89
42	15-21, October	9.57	0.00	0.00
43	22-28, October	48.12	1.18	0.69

Table 2. Weekly cumulative precipitation at different probability levels for Pusad Station

Met. Week	Dates	Weekly average precipitation at different probabilities in mm		
		25%	50%	75%
22	28-03, June	22.50	2.16	1.68
23	04-10, June	45.68	5.74	3.86
24	12-18, June	46.68	6.53	4.54
25	19-24 June	78.55	7.65	5.32
26	25-01, July	98.67	10.54	7.47
27	02-08, July	131.15	42.26	33.59
28	09-15, July	142.92	43.34	34.48
29	16-22, July	159.42	44.51	34.48
30	23-29. July	222.20	64.79	35.77
31	30-05, August	243.32	65.48	36.46
32	06-12 August	261.53	66.31	37.07
33	13-19 August	300.80	70.58	39.38
34	20-26, August	315.02	70.96	39.56
35	27-02, September	332.91	70.96	39.56
36	03-09, September	370.17	76.23	43.68
37	10-16, September	377.35	77.25	46.86
38	17-23, September	421.13	84.44	47.01
39	24-30, September	451.25	85.51	54.19
40	01-07, October	493.73	97.19	57.31
41	08-14, October	503.94	98.26	58.20
42	15-21, October	516.51	98.26	58.20
43	22-28, October	561.63	99.44	58.89

Table 3. Values of constants for logistic model at different probability levels for Pusad taluka

Model	Constants	Values of constants at different probability levels		
		25%	50%	75%
Logistic model	a	0.0023	0.0129	0.0229
	b	0.0341	0.4358	0.5732
	c	0.7259	0.5735	0.5732

Table 4. Predicted Weekly cumulative precipitation using Logistic Model for Pusad Station at different probability levels compared with mean observed values

Met. Week	Dates	Predicted Weekly cumulative precipitation at different probabilities in mm			Mean observed values
		25%	50%	75%	
22	04-10, June	36.81	3.80	2.72	0.00
23	12-18, June	49.10	6.39	4.35	1.20
24	19-24, June	64.81	10.50	6.79	71.76
25	25-01, June	84.41	16.63	10.25	163.05
26	02-08, July	108.16	24.99	14.76	219.76
27	09-15, July	135.92	35.12	20.06	246.48
28	16-22, July	167.06	45.76	25.57	355.92
29	23-29, July	200.38	55.37	30.64	368.08
30	30-05 August	234.30	62.96	34.77	420.48
31	06-12, August	267.14	68.33	37.84	505.36
32	13-19, August	297.40	71.85	39.96	546.90
33	20-26, August	324.04	74.03	41.35	631.32
34	27-02, September	346.58	75.35	42.23	664.25
35	03-09, September	365.02	76.12	42.78	754.77
36	10-16, September	379.68	76.57	43.11	767.25
37	17-23, September	391.08	76.83	43.32	779.55
38	24-30, September	399.79	76.98	43.44	780.15
39	01-07, October	406.37	77.07	43.52	788.31
40	08-14, October	411.28	77.12	63.56	794.11
41	15-21, October	414.92	77.15	43.59	812.45
42	22-28, October	417.60	77.17	43.60	824.13
43	29-04, November	419.58	77.18	43.62	824.13

Table 5. Values of Coefficient of determination and per cent average absolute deviation between predicted cumulative precipitation and their observed values using Logistic Model for Pusad Station

Model	Coefficient of determination and per cent average absolute deviation at different probability level					
	25%		50%		75%	
	Coefficient determination	Per cent average absolute deviation	Coefficient of determination	per cent average absolute deviation	Coefficient of determination	per cent average absolute deviation
Logistic Model	0.9384	10.14	0.9112	9.89	0.8828	12.74

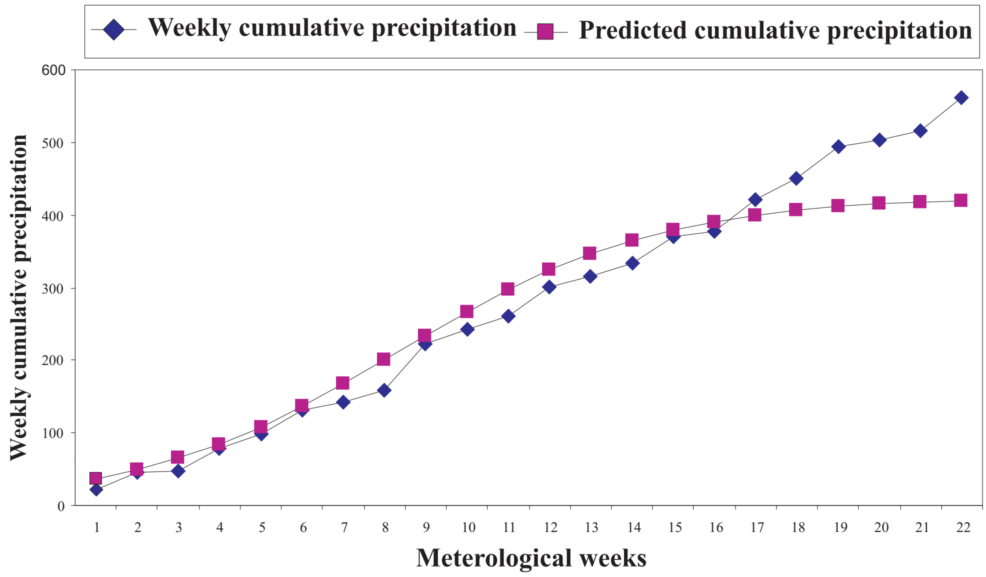

Fig. 1: Graph between cumulative precipitation and and predicted weekly cumulative precipitation at 25% probability level

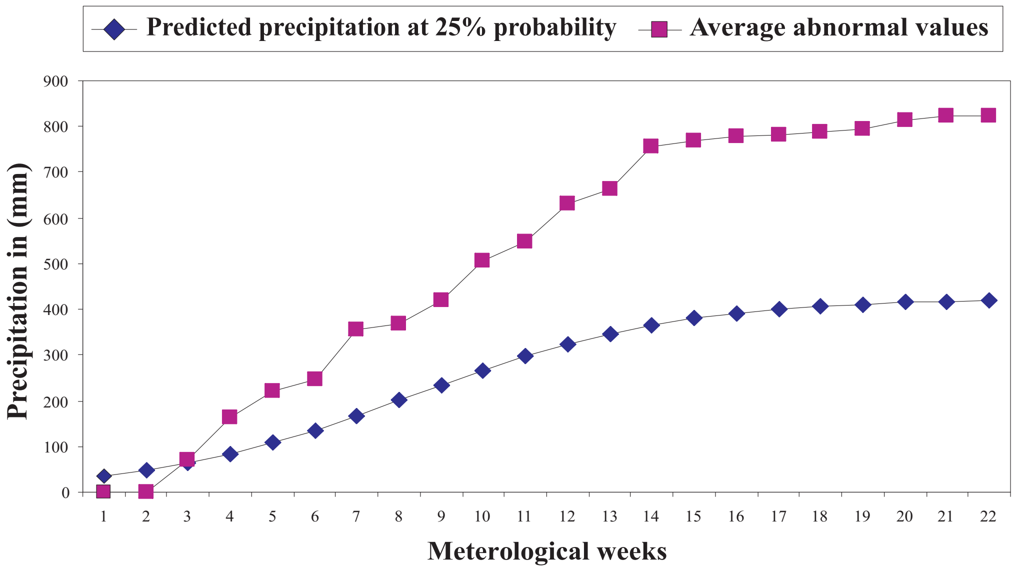

Fig. 2. Comparison of predicted and observed values at 25% probability level by logistic model for Pusad station

observation of figure shows closer fitting between weekly cumulative precipitation and predictedcumulative precipitation at 25% probability level.

The predicted values were compared with actual observed values at 25% (2002-2006) probability level for more accurate comparison (Fig.2). The careful observation of the Fig.2 shows the almost similar trend between predicted value of 25% probability level and average observed value but the predicted values at 25% probability level are at lower side than the average observed values. Therefore, logistic model gives reliable prediction of precipitation at 25% probability level and hence, it can be suitably used for prediction of precipitation in these areas while planning irrigation water management, crop planning and designing the soil and water conservation structures.

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Rec. on 17.08.2011 & Acc. on 20.11.2011

J. Soils and Crops 22 (2) 404-409, Dec., 2012 ISSN 0971-2836

EFFECT OF MOISTURE CONTENT ON SOME PROPERTIES OF MUCUNA BEAN

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ABSTRACT

The study was carried out in the Department of Agricultural Process Engineering, Dr. PDKV, Akola during the year 2010 on effect of moisture content on physical properties. In this study, the physical parameters of mucuna bean are expressed in the form of regression equations, as a function of moisture content. Once the moisture content is known, the physical parameters can be calculated from these equations. As moisture content depends on weather conditions, these equations can be used for other environmental conditions than those of India. These data can also be used for designing machines and storage facilities in India as well as in other countries. The average length, width, thickness and thousand grain mass of white seeded mucuna bean were 15.12 to 15.68 mm, 13.17 to 13.86 mm, 8.83 to 9.74 mm and 1216.2 to 1293.6 g respectively in the range of 5.62 to 17.37% (db). The geometric mean diameter, sphericity, surface area and volume were increased from 12.21 to 13.65 mm, 0.68 to 0.73, 38.34 to 42.86 mm^2 and 590 to 713 mm^3 and bulk density, true density and bulk porosity were decreased from 773 to 714 kg m^{-3}, 1412.5 to 1216 kg m^{-3} and 45.27 to 43.33% respectively with increase in moisture of seeds 5.62 to 7.37% (db). Terminal velocity and angle of repose were increased from 13.27 to 16.93 m s^{-1} and 29.23 to 35.23^o in the moisture range of 5.62 to 17.3% (db). The static coefficient of friction increased with increase in moisture content.

(Key words: Moisture content, mucuna bean, physical properties)

INTRODUCTION

Mucuna bean (M*ucuna pruriens* L.) is known as velvet bean and it is found in Tropical Africa, India and Caribbean. Mucuna bean contains higher amount of Levodopa which helps to maintain healthy cholesterol and blood sugar level. The seed powder has long been used in Ayurvedic medicine on Parknison's disease. The whole plant is fed to animal as silage that contains 11-23% crude protein, 35-40% crude fiber and dried beans contain 20-35% crude protein (Anonymous, 2011).

Physical and engineering properties are important in many problems associated with the design of machines and the analysis of the behavior of the product during agricultural process operations such as handling, planting, harvesting, threshing, cleaning, sorting and drying. Solutions to problems in these processes involve knowledge of their physical and engineering properties (Irtawange, 2000). The physical properties of agricultural product are needed in designing and constructing equipment and structures for handling, transportation, processing and storing and also for assessing the product quality (Sirisomboon *et al*., 2007 and Kashaninejad *et al.*, 2006). Physical properties of Mucuna beans are important to design thresher, nut shelling and drying and also in other processes like, transportation and storage. However, these properties have not been reported in the literature.

Grain dimensions are important in designing the dehulling or nut shelling machine, and data on them can be used to determine the lower size limit of the conveyors such as belt conveyor, bucket elevator and screw conveyor. Porosity (calculated from solid density and bulk density) and surface area affect the resistance to airflow through the bulk material bed and data on them are necessary in designing the drying process. Bulk density is used in determining the size of the storage bin.

Moisture content is useful information in the drying process. Static friction coefficient of various surfaces affects the maximum inclination angle of conveyor and storage bin. The magnitude of frictional force affects the amount of power required to convey the materials. Angle of repose is a useful parameter for calculation of belt conveyor width and for designing the shape of storage. The coefficient of friction between seed and wall is an important parameter in the prediction of seed pressure on walls. Several investigators determined the physical properties of pulses and oilseed at various moisture contents such as Chowdhury *et al.* (2001) for gram and Hossain *et al*. (1998) for groundnut kernel. The sizes of these grains are small compared to mucuna bean. Therefore, shelling and dehulling of mucuna bean done traditionally by beating with hammer. This job is laborious and ineffective. The suitable type of sheller on moisture dependent properties for mucuna bean is not available commercially as per literature. Hence, the study was taken with an objective to

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provide the data of moisture dependent physical properties for designing nut sheller, dehuller, grinder, storage bin etc.

MATERIALS AND METHODS

Sample preparation :

The white seeded mucuna beans were manually cleaned to remove all foreign materials such as dust, dirt, broken and immature beans. The initial moisture content of the samples was determined by oven drying method at 103º C for 48 h as suggested by ASAE, (Anonymous, 1993). The initial moisture contents of grains were 5.62% (db).

The MC was determined by using following expression

$$MC\ (\%\ wb) = \frac{W_1 - W_2}{W_2 - W_3} \times 100$$

Where,
W_1 = Initial weight of the test sample (g)
W_2 = Final weight of the test sample (g)
W_3 = Weight of petridish (g)

The moisture content (m.c.) obtained in %, wet basis(wb) was converted into %, dry basis(db) by using following formula

$$MC\ (\%\ db) = \frac{MC\ (\%\ wb)}{100 - MC\ (\%\ wb)} \times 100$$

In samples moisture content was raised by adding a calculated amount of water to get optimum moisture difference by using following equation (Cookun *et al.*, 2005).

$$Q = \frac{W_i (M_f - M_i)}{100 - M_f}$$

Where,

Q Quantity of water added, kg
Wi The initial weight of the sample, kg
Mi The initial moisture content of the sample, % db
Mf The final moisture content of the sample, % db

The calculated amount of water (60 ml kg^{-1}) was added to get optimum difference of 5% moisture content and kept it for eight hours in refrigerator for moistening. The similar procedures were adopted for increasing moisture content from 5.62 to 17.37% (db). After making grain sample at three levels of moisture content, those were sealed in separate polythene bags and stored in a refrigerator at 5 °C for a week. Before each experiment, the required sample was taken out from the refrigerator and kept sealed in an ambient environment to equilibrate the water and temperature throughout the sample. All the physical properties of the beans were determined at moisture levels of 5.62, 11.23 and 17.37% (dry basis). Four replications of each test were made at each moisture content level.

Determination of physical properties :

The length, width, thickness and thousand grain mass of mucuna beans were measured in randomly selected 100 beans using vernier caliper to an accuracy of 0.02 mm (Mohsenin, 1980).

Geometric mean diameter (D_g) is the cube root of product of three axis of seed. Three major principle axis were measured with the help of vernier caliper having a least count of 0.02 mm.

$$D_g = (L \times W \times T)^{1/3}$$

Where,
L Length (mm), W Width (mm), T Thickness (mm)

The sphericity (ø) in per cent was defined as the ratio of the surface area of the sphere having the same volume as that of the grain to the surface area of the grain and was determined by using following equation (Mohsenin, 1980).

$$Ø = (D_g / L) \times 100$$

The surface area (S) in mm^2, were obtained from the following equation

$$S = \pi D_g^2$$

Grain volume (V) was determined by toluene displacement method. Grain sample of about 4 to 5 g was dipped into the toluene. The volume displaced by the grains was noted. The true volume of grain was divided by the number of seeds used to find the volume of individual seed.

A method suggested in IS: 4333 (Part IV) – (Anonymous, 1968) was used to determine the thousand grain mass. One thousand randomly selected sound mucuna bean at various moisture levels were selected and weighed on a digital electronic top pan balance having an accuracy of 0.01 g.

The bulk density (B_d) was determined by filling a 500 ml beaker with seeds by dropping them from a height of 150 mm and weighing the seeds, Kaleemullah (1992). Dropping the seeds from a height of 150 mm produces a tapping effect in the container to reproduce the settling effect during storage.

The true density (T_d) was determined by using the toluene (C_7H_8) displacement method. Toluene was used instead of water because it has less surface tension and degeneration (Mohsenin, 1980). The volume of toluene displaced was found by immersing a weighted quantity of mucuna beans in the measured toluene.

The porosity (ρ) was calculated from bulk and true densities were derived using the relationship (Mohsenin, 1980, Fathollahzadeh *et al.*, 2009) as follows:

$$\rho = \left(1 - \frac{B_d}{T_d}\right) \times 100 \quad (5)$$

The angle of repose (V) was determined by using a hollow cylindrical mould of 100 mm diameter and 150 mm height. The cylinder was placed on a wooden table, filled with mucuna bean and raised slowly until it forms a cone of beans. The diameter (d) and height (h) of the cone were recorded. The angle of repose (Θ) was calculated by using the formula as suggested by Kaleemullah (1992).

$\Theta = \tan^{-1}(2h/d)$

Terminal velocity :

The terminal velocity (□) of mucuna bean sample at different moisture contents were measured using air column. For each test 15 to 20 g sample was dropped into the air stream from the top of the air column. Air was blown by using in column till the material is in the suspended condition in the air stream. Air velocity near the location of the grain suspension was measured by an electronic anemometer having a least count of 0.1 m s^{-1}.

Static coefficient of friction :

The static coefficient of friction (μ) of mucuna bean was determined on four different materials namely stainless steel, wood, glass and galvanized iron. The tilting platform of 350 x 120 mm was fabricated and used for experimentation. A topless and bottomless plastic cylinder of 65 mm and height of 40 mm was filled with the seeds and placed on the tilting surface. The cylinder was raised slightly so as not to touch the surface. The structural surface with the box resting on it was inclined gradually with a screw device until cylinder just started to slide down and the angle of tilt (fl) was read from a graduated scale.

μ = tan fl

RESULTS AND DISCUSSION

Grain Dimensions :

Average values of the physical properties of Mucuna bean at different moisture contents are presented in table 1. It is observed that, the bean expands in length, width and thickness within the moisture range of 5.62 to 17.37% (db). The average length, width and thickness of the 100 grains increased from 15.12 to 15.68 mm, 13.17 to 13.89 mm and 8.83 to 9.74 mm, respectively.

$L = 0.0475MC + 14.878$ $R^2 = 0.9779$
$W = 0.0589MC + 12.815$ $R^2 = 0.9868$
$T = 0.0778MC + 8.3424$ $R^2 = 0.9678$
Where MC is moisture content (%)

The coefficient of determination (R^2) value for all variables are high (>0.95) indicating high proportion of variability. The reason of this increase was probably the presence of some tiny voids on the pits. The dimensions increased with increase in moisture content. The similar results were reported for Almond nut and kernel (Aydin, 2003) and Chick pea splits (Ghadge *et al.,* 2008).

Size, Spericity and Surface area

The geometric mean diameter, sphericity and surface area at different moisture contents are shown in table 2. It is observed that, the geometric mean diameter, sphericity and surface area of mucuna bean increased linearly with increasing moisture contents from 5.62 to 17.37% (dry basis). Fathollahzadeh *et al.* (2009) have reported similar trends in Apricot pit.

Volume:

The grain volume of mucuna bean varied

between 590.00 to 713.00 mm^3. Volume of mucuna bean increased with increase in moisture content. The similar trends were found for Pistachio nut and kernel (Razavi *et al.,* 2007) and Apricot pit (Fathollahzadeh *et al.,* 2009).

The linear regression equations were developed for geometric mean diameter, sphericity surface area and volume of mucuna bean with moisture content (MC %, db) as shown in following equation. Hossain *et al.* (1998) found similar results for groundnut kernel, respectively.

$D_g = 0.1222MC + 11.566$ $R^2 = 0.9904$
$Ø = 0.0044MC + 0.6594$ $R^2 = 0.9820$
$S = 0.3838MC + 36.316$ $R^2 = 0.9904$
$V = 10.508MC + 525.47$ $R^2 = 0.9789$
Where MC is moisture content (%)

The coefficient of determination (R^2) value for all variables are high (>0.97) indicating high proportion of variability.

Thousand grain mass :

Thousand grain mass (1216.2 to 1293.6 g) of mucuna bean appeared to be dependent on moisture content and increased linearly with increase in moisture contents as shown in table 2. The regression equation was developed for thousand grain mass of mucuna bean for the moisture range 5.62 to 17.23% (db). Hossain *et al.* (1998) reported the similar results for groundnut kernel. The coefficient of determination (R^2) value for all variables are high (>0.99) indicating high proportion of variability.

$M_{1000} = 6.5771MC + 1180.6$ $R^2 = 0.9965$
Where MC is moisture content (%)

Bulk density and true density :

Table 3, shows the bulk density, true density and porosity of mucuna bean which decreased from 773 to 714 kg m^{-3}, 1412.5 to 1216 kg m^{-3} and 45.27 to 43.33% respectively, in moisture contents from 5.62 to 17.37% (db). At the same moisture content, the bulk density was found to be lower than true density. The linear regression equations were developed for bulk density and true density as shown in following equations.

$B_d = -5.0243MC + 801.64$ $R^2 = 0.9995$
$T_d = -16.761MC + 1511.9$ $R^2 = 0.9925$
$\rho = -0.1645MC + 46.113$ $R^2 = 0.9809$
Where MC is moisture content (%)

The coefficient of determination (R^2) value for all variables are high (>0.98) indicating high proportion of variability. The negative linear relationship of bulk density and true density with moisture content was also observed by Aydin (2003) for Almond nut and kernel.

Angle of repose :

The angle of repose increase from 29.23 to 35.20° with increase of moisture content from 5.62 to 17.37% (db) as shown in table 3. The linear regression equation was developed for the angle of repose of mucuna bean with moisture content. This finding agree with the findings of Hossain *et al.* (1998) for groundnut kernels who reported that the coefficient of determination (R^2) value for all variables are high (>0.96) indicating high proportion of variability.

$\Theta = 0.5089MC + 26.735$ $R^2 = 0.9627$
Where MC is moisture content (%)

Terminal velocity :

Table 3 shows that, the increase in terminal velocity of mucuna bean was 27.58% with increase in moisture content from 5.62 to 17.37% (db). The linear regression equation was developed for the terminal velocity of mucuna bean with varied moisture contents. The coefficient of determination (R^2) value for all variables are high (>0.99) indicating high proportion of variability.

$v = 0.3113MC + 11.542$ $R^2 = 0.9996$

Static coefficient of friction:

The static coefficient of friction of mucuna bean on various surfaces at different moisture levels are shown in table 4. From Fig. 1, it is observed that, with increase in moisture content the static coefficient of friction increased for all surfaces but with different levels. The highest values of coefficient of static friction were obtained on plywood. At all moisture contents, the least static coefficient of friction were found on glass. The coefficient of determination (R^2) value for all variables are high (>0.98) indicating high proportion of variability.

The reason for increasing friction coefficient at higher moisture content may be the extant water in bean offering a cohesive force on the surface of contact. Water tends to adhere to surface and the water

Table 1. Principle dimension of mucuna bean at different moisture content

Properties	N	Moisture Content (db), %		
		5.62	11.23	17.37
Length, mm	100	15.12±1.5 0(9.92)	15.46±1.03 (6.66)	15.68±0.54 (3.44)
Equatorial width perpendicular to the length, mm	100	13.17±1.08 (8.20)	13.43±0.28 (2.08)	13.86±0.33 (2.39)
Breadth perpendicular to the length and width, mm	100	8.83±0.6 7(9.85)	9.12±0.30 (3.29)	9.74±0.36 (3.70)

Table 2. Physical properties of white seeded mucuna bean

Properties	N	Moisture Content (db), %		
		5.62	11.23	17.37
Geometric mean diameter, mm	100	12.21±0.246(2.013)	13.02±0.005(0.038)	13.65± 0.006(0.047)
Sphericity, %	100	0.678±0.005(0.745)	0.720±0.002(0.282)	0.730±0.001(0.096)
Surface Area, mm^2	100	482.87±31.736 (6.572)	468.39±27.326(5.834)	586.78±47.167(8.038)
Grain Volume, mm^3	100	590±21.349(3.617)	633±36.552(5.766)	713±39.020(5.470)
1000- unit mass, g	100	1216.2±82.333(6.767)	1257.4±40.481(3.221)	1293.6±35.761(2.765)

n is the number of samples. Data are mean value ± standard deviation.
Figure in parenthesis are CV.

Table 3. Properties depend on moisture content

Properties	N	Moisture Content (db), %		
		5.62	11.23	17.37
Bulk density, g cm^{-3}	3	773±55.362(7.165)	746±50.714(6.797)	714±44.395(6.215)
True density, g cm^{-3}	20	1412.5±56.497(4.000)	1335±100.05(7.492)	1216±72.26(5.943)
Porosity, %	NA	45.27±0.158(0.349)	44.11±0.693(1.577)	43.33±0.203(0.492)
Terminal velocity, m s^{-1}	3	13.27±0.304(2.131)	15.08± 1.130(7.496)	16.93±0.701(4.141)
Angle of repose, degree	3	29.23±1.995(6.612)	32.35±2.000(6.182)	35.2±2.135(6.063)

n is the number of samples. Data are mean value ± standard deviation.
NA is not applicable. Figures in parenthesis ar CV.

Table 4. Static coefficient of friction depend on moisture content

Moisture content, %	Static coefficient of friction			
(db)	Stainless Steel	Wood	Glass	Galvanized Iron
5.62	0.381	0.416	0.313	0.392
11.23	0.394	0.434	0.332	0.421
17.37	0.412	0.456	0.364	0.443

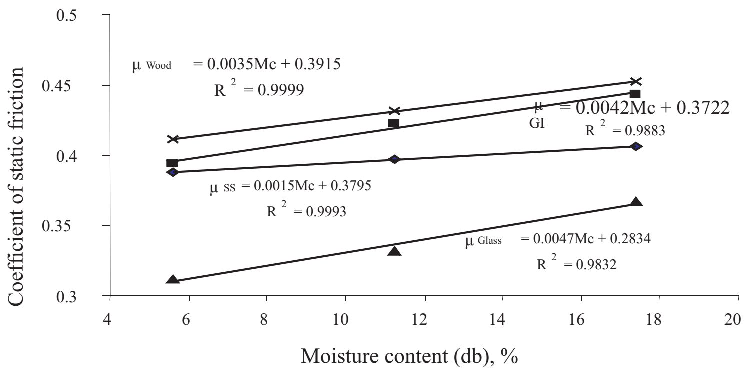

Fig. 1 Effect of moisture content on coefficient of static friction

on the moist bean surface would be absorbed to the across surface on which the sample is being moved. Aydin (2003) reported that, at all investigated moisture contents, both static and dynamic coefficients of friction were the greatest against plywood and least for galvanized sheet metal with rubber in between. As the moisture content of the nut increased, the static and dynamic coefficients increased significantly. Kashaninejad *et al.* (2006) reported that, the static coefficient of friction was the highest on rough concrete and the least for galvanized iron. As the moisture content increased, the static coefficient of friction increased linearly.

As a general rule, the coefficients of variance should be less than 10% (Snedecor and Cochran, 1967). In this study, the coefficient of variance for moisture dependent properties is less than 10%.

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Rec. on 08.09.2011 & Acc. on 10.12.2011

J. Soils and Crops 22 (2) 410-414, Dec., 2012 ISSN 0971-2836

PERFORMANCE OF EMBANK TYPE WATER HARVESTING STRUCTURE IN *KHARIF* RICE PRODUCTION IN EASTERN VIDARBHA

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ABSTRACT

An experiment was conducted during June 2004 to December 2006 for evaluation of Embankment type farm pond at Ranwadi Micro watershed, Zonal Agricultural Research Station, Sindewahi, Dist. Chandrapur (M.S.),with a view to providing protective irrigation to the paddy crop. The excess runoff water particularly in the month of July and August was harvested and stored in the farm pond and it was recycled to provide protective irrigation to *kharif* paddy during water stress period. Embankment type farm pond as a water harvesting structure-having capacity of 1417 m^3 was constructed in Ranwadi Micro watershed. Water harvesting structure of size 60 m X 25 m X 1 m, costing to Rs.51000/-provide one protective irrigation of 8 cm depth for 1.77 ha area during water stress period to save the yield of *kharif* paddy crop upto 30 per cent.

(Key Words: Harvesting of runoff, embankment type farm pond, protective irrigation, rice, recycling)

INTRODUCTION

Normal average rainfall of Eastern Vidarbha Zone(E.V.Z.) of Maharashtra is 1410 mm with paddy cropping system. Water requirement of paddy crop in the field from transplanting to harvest is between 800 and 1200 mm, with a daily consumption of 6-10 mm (Kung and Atthayyodhin, 1968). During *kharif* cropping season this Zone faces an erratic and uncertain distribution of monsoon rainfall which is thus a main constraint for getting optimum yield level.

Generally, it is observed that during the month of July and August, there is an excess rainfall received than the water requirement of paddy crop. Thereafter, long dry spell occurs during the month of September and October and creates water stress condition. This period coincides with critical plant growth stages including panicle initiation, flowering and milky stage of grain. Ultimately, it affects the grain yield upto 52.7 per cent as compared to irrigated paddy (Sahu, 1999).

It is an strategic attempt to fulfill the need of farmers of E.V.Z. of Maharashtra by harvesting excess rainfall received during July, August and storing it in the embankment type farm pond for recycling it during water stress period. This storage of water in farm pond serves as a protective irrigation to critical growth stages *of kharif* paddy crop during September and October months. Evaluation study was carried out to have an idea of size and capacity of water harvesting structure, for the benefit of small land holding farmers, who regularly face the problem of loss of paddy crop due to water stress condition.

MATERIALS AND METHODS

Evaluation study was carried out during June 2004 to December 2006 on an evaluation of Embankment type farm pond at Ranwadi Micro watershed, Zonal Agricultural Research Station, Sindewahi, Distt. Chandrapur (M.S.). The catchment area of Micro watershed area is 4.60 ha. Topographic features of catchment area are 250 m in length, 200 m wide, 2.5 per cent average slope, sand-clay-loam soil type having 45 cm depth, infiltration rate 12 mm day^{-1}, average evaporation 5 mm day^{-1} and planted with Horticulture garden of Mango, Sapota, Cashew nut and paddy crop with teak plantation on the bunds of paddy bundies.

To undertake the study, one Embankment type farm pond of size 60 m x 25 m x 1 m having capacity 1417 m^3 was constructed during 1997. The design dimensions of ponds are 60 m top length, 25 m top width, 58 m bottom length and 23 m bottom width with slide slope 1:1. The waste weir was constructed having length of crest 1 m, height of weir 0.50 m and side slope 1:1. The elevation of the inlet from bottom of the pond was 1.10 m. The elevation of the outlet from bottom of the pond was 1 m and depth of pond was 1 m. Storage capacity of pond was 1417 m^3 with four out flow.

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Runoff water from this watershed area of 4.60 ha was harvested during excess of rainfall occurred during the month of July and August from 2004 to 2006. Availability of the stored water in the farm pond was measured from 27^{th} met. week to 3^{rd} met. week. *Kalinga* variety of paddy crop was cultivated as a non-replicated trial with two treatments i.e. T_1- No protective irrigation applied and T_2 - one or two protective irrigations were applied during water stress period as per need. With a view to measuring the volume of stored water in the farm pond, the depth of water (in cm), and the area of top surface water (A_1) in m^2, was measured at the end of each met. week. The area of the bottom (A_2) in m^2 was constant and was taken into account.

RESULTS AND DISSCUSION

During monsoon season from June to September, the availability of stored water in the farm pond was measured on standard meteorological week basis. The mean availability of the water stored over three years from June 2004 to December 2006 is presented in table.1. The maximum water stored in farm pond was recorded 100.0 cm in 33^{rd} MW and depth of water in the pond was zero in the 1^{st} MW. In the year 2004, two irrigations were given on 17^{th} September (38^{th} MW) and 26^{th} October (43^{rd} MW). Similarly in next year 2005, two irrigations were given on 26^{th} September (39^{th} MW) and 8^{th} October (41^{st} MW) and during the year 2006, two protective irrigations were given on 23^{rd} September (38^{th} MW) and 8^{th} October (41^{st} MW). During the year 2004 and 2006 seventeen overflows were recorded. This indicates that the depth of the pond can be increased to increase the water storage capacity. Data clearly indicated that the protective irrigation from this tank was given generally in the month of September and in the month of September and October.

Data regarding capacity of pond in relation to the depth of water in pond are presented in table 2. When the depth of water in pond was full i.e.100 cm, the capacity of pond was 1417 M^3 . The quantity of water utilized for providing protective irrigation has been calculated from the initial water level and final water level after supplying irrigation from the pond. It was observed that during three crop seasons i.e.2004,2005 and 2006, an average 366.63 m^3 quantity of water was applied as a protective irrigation with average 8.76 cm depth and area of paddy crop irrigated with this quantity of water was 4167 m^2.

There was decreasing trend of depth of water in the pond from the beginning of September during which the water stress condition occurs and coincides with the critical growth stage of paddy crop i.e. panicle initiation and flowering stage, due to which the paddy crop yield reduces upto 50 per cent. As summarized in table 4,the mean yield (kg $plot^{-1}$) for control treatment was 15.36 and for the treatment with protective irrigation was 18.93. Similarly mean yield (q ha^{-1}) for the control treatment was 19.48 and for treatment with protective irrigation was 24.00 (q ha^{-1}) with an average increase over the control by 26.8 per cent during 2004 - 2006. The average yield of paddy crop is 40-45 q ha^{-1} during good monsoon season in Eastern Vidarbha Zone of Maharashtra (Anonymous, 2002). Water stress at 31 to 60 days after transplanting is more severe so far the productivity of the paddy crop is concerned (Sarkar, 2001). The results suggest that water stress increased remobilization and grain-filling rate which attributed to enhanced sink strength by regulating sucrose syntheses and starch branching enzyme activities in rice grains when subjected to water stress during the grain-filling period (Jiang Chang Yang *et al*.,2003). It was reported that substantial quantities of carbohydrates are accumulated in different parts of rice, which are of paramount importance when plant experiences water deficit at flowering (Perez *et al.,* 1971) .

Harvested water during monsoon 2004 was utilized for providing two irrigations of 9.19 cm and 8.93 cm depth respectively to the paddy crop with 27.4 per cent increase in paddy yield over control plot with no irrigation. Similar results were recorded in the year 2005 and 2006 with increase over the control by 24.3 and 28.70 per cent respectively. The mean yield saved for three consecutive seasons was found to be 26.80 per cent as compared to the treatment with no irrigation (Table 4.) Moisture stress at reproductive and ripening stage is crucial for growth and productivity of rice.

366.63 m^3 quantity of water is applied with a depth of 8.76 cm over 4167 m^2 area of paddy as a protective irrigation, due to which there was saving of 26.8 per cent yield over no irrigation (control treatment) during water stress period. If the full capacity of harvested water in the structure i.e. 1417 m^3 , as evaluated in table 2, is utilized for providing an one protective irrigation of 8 cm depth during water stress condition then it will cover the area of 1.77 ha and will save the grain yield loss upto 30 per cent over control treatment with no protective irrigation in Eastern Vidarbha Zone of Maharashtra (Mhaske *et al.*, 2010).

Due to climate change, behavior of the rain fall has became erratic and uncertain and hence the intensity of rainfall has increased and number of rainy days were reduced (Madsen, 2009) causing excess rainfall than the water requirement of paddy crop particularly in the month of July and August. During this period there is a scope of water harvesting. On the other hand there is a water stress particularly in the month of September and October during critical growth stages of the paddy crop where the harvested water in the month July and August can be recycled for providing protective irrigation. On the basis of this experiment, it is concluded that with a view to conserving the excess rainfall of early monsoon in the EVZ(which otherwise is going waste as a runoff) a farm pond of minimum size 60 m x 25 m x 1 m (i.e. 10 per cent area of paddy field) be constructed to harvest runoff water . This will provide one net protective irrigation of 8 cm depth for 1.77 ha area during water stress period to save up to 30 per cent yield of *kharif* paddy crop or two irrigations to half of the above area.

Table 1. Stored water available in Embankment type farm ponds at Ranwadi watershed

Month	MW	Stored water in farm ponds (cm)						Average stored water in farm ponds (cm)
		2004-2005	Rainfall 2004	2005-2006	Rainfall 2005	2006-2007	Rainfall 2006	
July	27	25.0	11.6	58.0	61.4	128.0*	99.2	20.64
	28	38.0	69.2	60.0	56.2	115.0*	90.2	32.67
	29	42.0	38.4	65.0	51.4	115.0*	89.0	48.00
	30	55.0	65.2	110*	158.8	96.0	34.0	85.00
Aug	31	75.0	87.6	130.0*	92.2	95.0	65.80	91.67
	32		113.8	130.0*	104.2	98.0	293.60	100.00
	33		35.2	130.0*	103.2	130.0*	39.2	100.00
	34		105.6	130.0*	32.4	120.0*	23.2	100.00
	35		0.0	100.0	5.8	98.0	20.2	100.00
Sept	36	100.0	36.0	95.0	27.0	95.0	151.2	98.33
	37	95.0	21.6	100.0*	160.8	100*	55	96.70
	38	-	49.0	100.0*	39.2	95.0IR	133.0	88.33
	39	I	55.6	75.0IR-	6.2	75.0	50.2	75.00
		75.0 .		1				
Oct	40	75.0	39.6	0.70	0.0	70.0	36.6	71.67
	41	73.0	0	45.0IR-	0.0	68.0	0	62.00
	42	70.0	0	II	101.6	65.0	0	58.33
	43	-II	0	0.40	0.0	40.0	IR-II	39.00
				0.32				
Nov	44		0	0.26	0.0	27.0	0	35.67
	45		1.4	0.18	0.0	20.0	0	30.00
	46		0	.010	0.0	12.0	0	24.33
	47		0	0.4	0.0	7.0	0	32.00
Dec	48	25.0	0	--		0.0		16.33
	49	20.0	0	--		0.0		12.67
	50	15.0 .	0	--		0.0		9.67
	51	10.0	0	--		0.0		7.00
	52	5.0	0	--		0.0		5.5
Jan	1	0.0	0	--				1
	2	0.0	0	--				.
	3	0.0	0	--				0
								-

* indicates overflowing of ponds and 100 cm was considered on the depth of water

Table 2. Capacity of Embankment type farm pond in relation to depth of water in the pond

Depth of water in the Pond (m)	Area of top surface A_1 (m^2)	Area of b ottomA2 (m^2)	Mean area $\frac{A_1 + A_2}{2}$ (m^2)	capacity of pond(m^3)
1.00	1500.00	1334.00	1417.00	1417.00
0.95	1491.00	1334.00	1412.76	1342.00,
0.90	1483.00	1334.00	1408.50	1267.00
0.85	1474.50	1334.00	1404.20	1193.50
0.80	1466.20	1334.00	1400.10	1120.00
0.75	1457.70	1334.00	1395.50	1046.60
0.70	1449.30	1334.00	1391.60	974.10
0.65	1440.90	1334.00	1387.40	901.80
0.60	1432.60	1334.00	1383.30	829.90
0.55	1424.30	1334.00	1379.10	758.50
0.50	1416.00	1334.00	1375.00	687.50
0.45	1407.70	1334.00	1370.90	616.90
0.40	1399.40	1334.00	1366.70	546.60
0.35	1391.20	1334.00	1362.70	476.90
0.30	1382.90	1334.00	1358.40	407.50
0.25	1374.70	1334.00	1354.30	338.60
0.20	1366.40	1334.00	1350.20	*270.00*
0.15	1358.30	1334.00	1346.10	201.90
0.10	1350.20	1334.00	1342.10	134.20
0.05	1342.10	1334.00	1338.0	66.90
0.00	1334.10	1334.00	1334.00	0.0

Table 3. Utilization of harvested water in Embankment type farm Pond for protective irrigation

Year	Date of irrigation	Initial water level		Final water level		Quantity of water utilized (m^3)	Area irrigated (m^2)	Depth of irrigation (cm)
		Depth (m)	Volume (m^3)	Depth (m)	Volume (m^3)			
2004-2005	17.9.2004	0.95	1342.00	0.70	971.80	367.90	4000	9.19
	26.10.2004	0.70	974.10	0.45	616.90	357.20	4000	8.93
2005-2006	26.9.2005	1.00	1417.00	0.75	1046.60	370.40	4000	9.26
	8.10.2005	0.70	974.10	0.45	616.90	357.20	4000	8.93
2006-2007	23.9.2006	0.95	1342.0	0.70	974.10	367.90	4000	9.19
	8.10.2006	0.65	901.80	0.40	546.00	355.20	5000	7.10
Average		0.825	1158.50	0.575	795.38	366.63	4167	8.76

Table 4. Effect of protective irrigation on the yield of paddy crop.

Year	Treatment	Mean yield (kg $plot^{-1}$)	Yield (q ha^{-1})	Increase in yield over control %
2001-	T_1- No irrigation (control)	17.10	21.10	--
2002	T_2- protective irrigation (one)	21.80	26.90	27.4
2002-	T_1- No irrigation (control)	15.20	18.70	--
2003	T_2- protective irrigation (one)	18.89	23.24	24.3
2003-	T_1 No irrigation (control)	13.80	17.00	--
2004	T_2 - protective irrigation (two)	17.76	21.88	28.7
Average	**T_1 - No irrigation (control)**	**15.36**	**18.93**	**--**
	T_2 - Protective irrigation	**19.48**	**24.00**	**26.8**

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Rec. on 20.07.2011 & Acc. on 15.10.2011

J. Soils and Crops 22 (2) 415-419, Dec., 2012 ISSN 0971-2836

EFFECT OF DIFFERENT LEVELS OF SULPHUR ON CONTENT AND UPTAKE OF MAJOR NUTRIENTS OF DIFFERENT GENOTYPES OF LINSEED

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ABSTRACT

The experiment was laid out in Factorial Randomized Block Design with 12 treatment combinations of four levels of sulphur i. e. 0, 10, 15 and 20 kg ha^{-1} with RDF (60:30:0) and three genotypes of linseed i.e. NL-97,NL-260 and Padmini in the year 2011-12 in *rabi* season. The application of sulphur @ 20 kg ha^{-1} significantly increased the content of N (2.63%), P (0.6291%), K (1.2597%) and S (0.3411%) in seed and N (0.8167%), P (0.1816%), K (0.3270%), and S (0.1833%) in straw. Where as in case of genotypes NL-260 showed the higher content of N (2.72%), P (0.6515%), K (1.3046%) and S (0.3532%) in seed and N (0.8458%), P (0.1881%), K (0.3387%) and S (0.1898%) in straw followed by NL-97 and Padmini. The application of sulphur @ 20 kg ha^{-1} significantly increased the uptake of N, P, K and S (31.87 N kg ha^{-1}, 7.63 P kg ha^{-1}, 15.26 K kg ha^{-1} and 4.12 S kg ha^{-1} in seed and 16.61 N kg ha^{-1}, 3.65 P kg ha^{-1}, 6.59 K kg ha^{-1} and 3.73 S kg ha^{-1} in straw respectively) of linseed. Where in case of genotypes of linseed, NL-260 recorded highest nutrients uptake (35.57 N kg ha^{-1},8.49 P kg ha^{-1}, 16.98 K kg ha^{-1} and 4.57 S kg ha^{-1} in seed and 17.67 N kg ha^{-1}, 3.89 P kg ha^{-1}, 7.03 K kg ha^{-1} and 3.96 S kg ha^{-1} in straw respectively) followed by Padmini and NL-97. The application of sulphur @ 20 kg ha^{-1} significantly increased the total uptake of N, P, K and S (48.37 N kg ha^{-1}, 11.28 P kg ha^{-1}, 17. 25 K kg ha^{-1} and 7.85 S kg ha^{-1} respectively) of linseed. Where in case of genotypes of linseed, NL-260 recorded highest total uptake (53.72 N kg ha^{-1}, 12.38 P kg ha^{-1}, 19.18 K kg ha^{-1} and 8.54 S kg ha^{-1}) of linseed. From the above results it is stated that sulphur @ 20 kg ha^{-1} gave higher content and uptake of NPK and S while genotype NL-260 performed better and recorded higher content and uptake of NPK and S .

(Key words : Genotype, linssed, sulphur, nutrients)

INTRODUCTION

The importance of sulphur in Indian agriculture has been realized only in recent years with the appearance of its deficiency in many parts of the country. Sulphur deficiency is known to affect nitrogen metabolism in plant. When sulphur is limiting, protein synthesis decreases where by nitrogen is not fully utilized resulting in accumulation of non-protein N in the plant. The critical N:S ratio varies with the crop and variety and there is a strong relationship between total-N, total-S and protein N, protein S ratios (Dev *et al.,* 1981).

In the plant, sulphate (SO_4^{-2}) ions reduced and accumulated in to organic compounds. The available sulphate (SO_4^{-2}) ion remains in soil solution, much like the nitrate ion (NO_3^-), until it is taken up by the plant, in this form, it is subject to leaching as well as microbial immobilization.

In water logged soils, it may be reduced to elemental sulphur (S) or other unavailable form. Nitrogen is associated with S in soil organic matter in a ratio of about 8:1, although the extreme ratios may vary from 5:1 to 13:1.

MATERIALS AND METHODS

The experiment was conducted on field of AICRP (All India Co-ordinated Research Project) on linseed, College of Agriculture, Nagpur, (M.S.) during *rabi* season of 2011-12 with three genotypes i.e. NL-97, NL-260 and Padmini and four sulphur levels i.e. 0, 10, 15 and 20 kg ha^{-1} with 12 treatments combination with three replications. The experiment was laid out in Factorial Randomized Block Design (FRBD). Standard procedure for analysis of total N (Kjeldahl method as described by Piper, 1966), P (vanadomolybdate yellow colour method using spectrophotometer), K (flame photometer, as described by Piper, 1966) and S (by using spectrophotometer as described by Chesnin and Yein, 1951) were followed.

RESULTS AND DISCUSSION

Effect of sulphur application on N, P, K, S content in seed of linseed :

Data regarding nitrogen, phosphorus , potassium and sulphur content in seed, are presented in table 1. Data revealed that, nitrogen, phosphorus , potassium and sulphur content in seed increased significantly with the increasing sulphur levels. The maximum nitrogen(2.63 %), phosphorus (0.629%), potassium(1.259%) and sulphur (0.341%) content in seed were found at sulphur level @ 20 kg ha^{-1} which was at par with sulphur level @ 15 kg ha^{-1} (2.62%N, 0.627%P, 1.256%K and 0.339%S), when compared

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with sulphur level @ 10 kg ha^{-1} and control. Similar results were reported by Bhorase *et al*. (2011). They reported that increasing sulphur levels increased the content of nitrogen, phosphorus, potassium and sulphur in seeds of toria.

In case of genotypes, NL-260 had highest content of N (2.72%),, P (0.651%), K (1.304%) and S (0.353%) in seed as compared to NL-97 (2.52% N, 0.604 % P, 1.209% K and 0.327% S) and Padmini (2.47% N, 0.591% P, 1.184% K and 0.320% S) which might be due to genetic makeup of genotypes.

Interaction effects of different levels of sulphur and genotypes were found to be non-significant for nitrogen, phosphorus, potassium and sulphur content in seeds of linseed.

Effect of sulphur application on N, P, K, S content in straw of linseed :

Data presented in table 2 revealed that, the maximum nitrogen (0.816%), phosphorus (0.181%), potassium (0.327%) and sulphur (0.1833%) content in straw was noted at sulphur @ 20 kg ha^{-1} which was at par with sulphur level @15 kg ha^{-1} (0.814%) N, (0.181%) P, (0.326%) K and (0.1827%) S, respectively. Similar results were reported by Giri *et al.* (2003). They reported that the application 30 kg ha^{-1} gypsum recorded significantly the higher content of 'S' and 'N' in straw of mustard.

In case of genotypes, NL-260 gave highest content of nitrogen, phosphorus, potassium and sulphur content in straw i.e. 0.845%, 0.188%, 0.3387% and 0.1898% respectively when compared with NL-97 and Padmini.

Interaction effects of different levels of sulphur and genotypes were found to be non-significant for nitrogen, phosphorus, potassium and sulphur content in straw of linseed.

Effect of sulphur application on N, P, K, S uptake by seed of linseed :

Data regarding the N,P,K and S uptake in seed (Table 3) revealed that, application of sulphur @ 20 kg ha^{-1} gave highest N (31.87 kg ha^{-1}) ,P (7.63 kg ha^{-1}), K (15.26 kg ha^{-1}) and S (4.12 kg ha^{-1}) uptake in seed which was found to be at par with sulphur level @15 kg ha^{-1} i.e. N 31.23 kg ha^{-1}, P 7.45 kg ha^{-1}, K 14.8 kg $ha^{-1}$and S 4.01 kg ha^{-1}. Similar findings were reported by Wasmatkar *et al.* (2002). They reported that the application of 'S' significantly increased the uptake of N,P,K, and S at harvest stage in seeds of soybean.

In case of genotypes NL-260 gave the highest nitrogen (35.57 kg ha^{-1}) , phosphorus (8.49 kg ha^{-1}), potassium (16.98 kg ha^{-1}) and sulphur (4.57 kg ha^{-1}) uptake by seed followed by Padmini (27.31 N,6.51 P, 13.03 K and S 3.52 kg ha^{-1}) and NL-97 (24.55N, 5.90 P, 11.80 K and 3.19 kg ha^{-1}S respectively). As NL-260 gave highest uptake which might be due to highest seed yield and content of N,P, K and S.

Interaction effects of different levels of sulphur and genotypes for N,P,K and S uptake in linseed were statistically non-significant.

Effect of sulphur application on N, P, K, S uptake by straw of linseed :

Results regarding the N, P, K and S uptake in straw, (Table 4) showed that, N, P, K and S uptake in straw significantly increased due to increase in sulphur levels. The highest N (16.61 kg ha^{-1}), P (3.65 kg ha^{-1}), K (6.59 kg ha^{-1}) and S (3.73 kg ha^{-1}), uptake in straw was recorded at sulphur level @ 20 kg ha^{-1}, which was found to be at par with sulphur level @ 15 kg ha^{-1} i.e. N 16.36 kg ha^{-1}, P 3.58% kg ha^{-1} , K 6.47 kg ha^{-1} and S 3.68 kg ha^{-1} respectively. Similar results were reported by Singh and Singh (2007). They reported that, each successive increase in the level of sulphur upto 60 kg ha^{-1} significantly increased content of 'N, P, K and S' ' by the linseed crop straw . Also Raut *et al*. (2000) reported that increase in application of levels of sulphur increased the N,P,K and S uptake of straw of mustard.

From the data it was also found that NL-260 gave the highest nitrogen (17.67kg ha^{-1}) , phosphorus (3.89 kg ha^{-1}), potassium (7.03 kg ha^{-1}) and sulphur (3.96 kg ha^{-1}) uptake by straw followed by Padmini and NL-97 .

Interaction effects of different levels of sulphur and genotypes were statistically non-significant.

Table 1. Effect of different levels of sulphur on nutrients content in seed

Treatments	N %	P %	K %	S %
Sulphur levels				
S_0 (0 kg ha^{-1})	2.47	0.590	1.182	0.319
S_1 (10 kg ha^{-1})	2.57	0.615	1.232	0.333
S_2 (15 kg ha^{-1})	2.62	0.627	1.256	0.339
S_3 (20 kg ha^{-1})	2.63	0.629	1.259	0.341
SEm	0.02	0.005	0.01	0.003
CDat 5%	0.06	0.014	0.03	0.009
Varieties				
V_1 (NL -97)	2.52	0.604	1.209	0.327
V_2 (NL -260)	2.72	0.651	1.304	0.353
V_3 (Padmini)	2.47	0.591	1.184	0.32 0
SEm	0.02	0.004	0.008	0.002
CDat 5%	0.05	0.012	0.025	0.007
Interaction				
SEm	0.03	0.005	0.017	0.005
CD at 5%	-	-	-	-
CV %	4.23	4.37	4.41	4.62

Table 2. Effect of sulphur application on N, P, K, S content in straw of linseed

Treatments	N %	P %	K %	S %
Sulphur levels				
S_0 (0 kg ha^{-1})	0.766	0.170	0.3070	0.1719
S_1 (10 kg ha^{-1})	0.799	0.177	0.3199	0.1795
S_2 (15 kg ha^{-1})	0.814	0.181	0.3260	0.1827
S_3 (20 kg ha^{-1})	0.816	0.181	0.3270	0.1833
SEm	0.006	0.0016	0.0027	0.0016
CD at 5%	0.018	0.0045	0.0078	0.0045
Varieties				
V_1 (NL -97)	0.783	0.174	0.3139	0.1756
V_2 (NL -260)	0.845	0.188	0.3387	0.1898
V_3 (Padmini)	0.768	0.170	0.3074	0.1725
SEm	0.006	0.001 3	0.0023	0.0014
CD at 5%	0.016	0.0039	0.0068	0.004
Interaction				
SEm	0.011	0.0027	0.0046	0.0027
CD at 5%	-	-	-	-
CV %	4.41	5.59	4.49	4.63

Table 3. Effect of sulphur application on N, P, K, S uptake (kg ha^{-1}) by seed of linseed

Treatments	N	P	K	S
Sulphur levels				
S_0 (0 kg ha^{-1})	25.53	6.11	12.24	3.32
S_1 (10 kg ha^{-1})	27.93	6.67	13.36	3.61
S_2 (15 kg ha^{-1})	31.23	7.45	14.89	4.01
S_3 (20 kg ha^{-1})	31.87	7.63	15.26	4.12
SEm	1.02	0.23	0.44	0.11
CD at 5%	2.99	0.67	1.29	0.32
Varieties				
V_1 (NL -97)	24.55	5.90	11.80	3.19
V_2 (NL -260)	35.57	8.49	16.98	4.57
V_3 (Padmini)	27.31	6.51	13.03	3.52
SEm	0.88	0.2	0.38	0.09
CD at 5%	2.59	0.58	1.12	0.27
Interaction				
SEm	1.76	0.39	0.77	0.19
CD at 5%	-	-	-	-
CV %	10.49	9.78	9.52	8.71

Table 4. Effect of sulphur application on N, P, K, S uptake (kg ha^{-1}) by straw of linseed

Treatments	N	P	K	S
Sulphur levels				
S_0 (0 kg ha^{-1})	13.57	3.00	5.41	3.04
S_1 (10 kg ha^{-1})	15.07	3.34	6.01	3.38
S_2 (15 kg ha^{-1})	16.36	3.58	6.47	3.68
S_3 (20 kg ha^{-1})	16.61	3.65	6.59	3.73
SEm	0.46	0.1	0.17	0.11
CD at 5%	1.36	0.28	0.51	0.32
Varieties				
V_1 (NL -97)	14.01	3.09	5.58	3.14
V_2 (NL -260)	17.67	3.89	7.03	3.96
V_3 (Padmini)	14.52	3.19	5.76	3.27
SEm	0.4	0.08	0.15	0.09
CD at 5%	1.18	0.24	0.44	0.28
Interaction				
SEm	0.8	0.17	0.3	0.19
CD at 5%	-	-	-	-
CV %	9.04	8.55	8.59	9.51

Table 5. Effect of sulphur application on total uptake of N, P, K, S of linseed

Treatments	N	P	K	S
Sulphur levels				
S_0 (0 kg ha^{-1})	39.16	9.11	13.93	6.35
S_1 (10 kg ha^{-1})	42.89	10.01	15.15	6.99
S_2 (15 kg ha^{-1})	48.31	11.03	16.89	7.68
S_3 (20 kg ha^{-1})	48.37	11.28	17.25	7.85
SEm.	1.08	0.26	0.54	0.16
CD at 5%	3.19	0.76	1.61	0.47
Varieties				
V_1 (NL -97)	38.75	8.99	13.51	6.34
V_2 (NL -260)	53.72	12.38	19.18	8.54
V_3 (Padmini)	42.06	9.70	14.73	6.79
SEm	0.94	0.22	0.48	0.14
CD at 5%	2.77	0.66	1.40	0.41
Interaction				
SEm	1.88	0.45	0.95	0.27
CD at 5%	-	-	-	-
CV %	7.28	7.85	10.42	6.70

Effect of sulphur application on total uptake of N, P, K, S of linseed :

Data regarding total N, P, K and S uptake are presented in table 5. Data revealed that, total N (48.37 kg ha^{-1}), P (11.28 kg ha^{-1}), K (17.25 kg ha^{-1}) and S (7.85 kg ha^{-1}) uptake were highest at sulphur level @ 20 kg ha^{-1} which was found to be at par with sulphur level @ 15 kg ha^{-1} (48.31 N, 11.03 P, 16..89 K and 7.68 kg ha^{-1} S, respectively). Similar findings were reported by Ravi *et al*. (2008). They reported that increasing levels of sulphur increased total uptake of nitrogen, phosphorus, potassium and sulphur of safflower . Similar findings were also reported by Girish and Reddy (2005). They reported that sulphur uptake by the crop increased with the increasing levels of sulphur due to higher biomass and seed yield.

Genotype NL-260 gave the highest total N (53.72 kg ha^{-1}) , P (12.38 kg ha^{-1}) , K (19.18 kg ha^{-1}) and S (8.54 kg ha^{-1}) uptake followed by Padmini (42.06 N, 9.70 P, 14.73 K and 6.79 S kg ha^{-1}), and NL-97 (38.75 N, 8.99 P, 13.51 K and 6.34 S kg ha^{-1}). Increase in total uptake might be due to highest seed and straw yield and content of N, P, K and S by NL-260.

Interaction effects of different levels of sulphur and genotypes were found non-significant.

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Rec. on 16.04.2012 & Acc. on 20.05.2012

J. Soils and Crops 22 (2) 420-423, Dec., 2012 ISSN 0971-2836

MANAGEMENT OF GROUNDNUT RUST (*Puccinia arachidis* Speg.) BY FUNGICIDES, PLANT EXTRACT AND BIOAGENTS

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ABSTRACT

The present investigation was undertaken during the year 2010 – 2011 at Plant Pathology Section, College of Agriculture, Nagpur for Management of groundnut rust (*Puccinia arachidis* Speg.) by integrating fungicides, plant extract and bioagents. All the treatments significantly lowered the incidence and intensity of rust disease and increased the 100 seed weight, pod yield and haulm yield over unsprayed control. Among fungicides, Difenconazole @ 0.1% showed maximum reduction in Per cent Disease Incidence (9.39) at 60 DAS and Mancozeb @ 0.2% (13.37%) at 90 DAS. Difenconazole @ 0.1% showed lowest Per cent Disease Intensity (5.61 and 7.21) both at 60 DAS and 90 DAS. Among plant extract and bioagents, Neem Seed Kernel Extract @ 5% was superior followed by *Trichoderma harzianum* @ 0.5%. Whereas in case of effect of various treatments Difenconazole 0.1% recorded maximum 100 seed weight, dry pod and haulm yield over all other treatments.

(Key words: *Puccinia arachidis*, fungicides, plant extract, *Trichoderma harzianum, Pseudomonas fluorescens*)

INTRODUCTION

Groundnut (*Arachis hypogoea* L.) is a most important oil seed crop grown in more than 100 countries in world. India occupies first rank amongst the groundnut growing countries of world, both in respect of area and production. Groundnut is 13th most important food crop and 3rd most important source of vegetable protein of world hence, recognized as “Poor Man's Nut” such a most economically important crop is infected by many diseases like rust, early and late leaf spot, crown rot, stem rot, bud necrosis etc. Among the important diseases of groundnut, rust caused by *Puccinia arachidis* (Speg.) is serious disease causing yield losses up to 50% (Ghuge *et al*.,1981).

Yield losses are usually greater as disease appears early in the growing season of groundnut and it progresses rapidly. Therefore, initiation of fungicidal spray schedule early in the season either before onset of first appearance of symptom in crucial stage to substantial crop losses.

Losses in pod yield (up to 29 %) due to rust at Dharwad were reported by Siddaramiah *et al*.(1977). The effective fungicides and botanicals will have good impact for management of diseases.

Hence, an attempt was made to study on management of groundnut rust by fungicides, plant extract and bioagents were successfully used in farm of Plant Pathology Section, College of Agriculture, Nagpur during *kharif* season 2010-2011.

MATERIALS AND METHODS

Fungicides viz., Propiconazole (25% EC), Hexaconazole (5% EC), Penconazole (10% EC), Difenconazole (25% EC), Mancozeb (75% WP) and pure cultures of bioagents, *Trichoderma harzianum* and *Pseudomonas fluorescens* were obtained from Plant Pathology Section, College of Agriculture, Nagpur. Powder of Neem Seed Kernel Extract (NSKE) was procured from Neem foundation Nagpur. Pure culture of *T. harzianum* and *P. fluorescens* were multiplied on Potato Dextrose Broth and King's B Broth medium respectively.

Preparation of aqueous extract:

500 gm powders of Neem Seed Kernel was mixed in 3 liters of water and 10 g adjuvant like soap and kept for overnight, filtered the solution by muslin cloth at morning and made volume of 10 litres that gave 5% concentration of NSKE solution for spraying.

Preparation of bioagents for spraying :

Trichoderma harzianum was multiplied on Potato Dextrose Broth and *Pseudomonas fluorescens* was multiplied on King's B Medium broth. Organisms were separated from culture filtrates through filtration and centrifugation. Thereafter, supernatant of individual organism was further diluted to get 0.5 per cent concentration in sterilized water (Nirmalkar and Lakpale, 2007).

All standard and recommended package of practices such as tillage, manuring, sowing, fertilizer

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application and weeding were followed for cultivation of crop as and when required.

Per cent Disease Incidence and Intensity of rust :

Ten plants from each treatment were selected randomly and each plant was tagged. Then observations were recorded from the same ten plants each time. The leaves of each plant were graded for rust disease as per shown in plate 1 (Mayee and Datar, 1986).

Per cent Disease Incidence and Per cent Disease Intensity were recorded at 30 DAS, 60 DAS and 90 DAS whereas, 100 seed weight, pod and haulm yield were recorded at harvesting. Spraying was done at the initiation of disease and thereafter two spraying were undertaken at 15 days interval. Per cent Disease Incidence and Per cent Disease Intensity were calculated by following formula-

$$\text{Per cent Disease Incidence} = \frac{\text{Number of infected leaves}}{\text{Total number of leaves}} \times 100$$

$$\text{Per cent Disease Intensity} = \frac{\text{Sum of all numerical rating}}{\text{Total number of leaves examined} \times \text{Maximum grade (9)}} \times 100$$

RESULTS AND DISCUSSION

Results from table 1 (Fig.1 and Fig. 2) revealed that all the treatments significantly minimized Per cent Disease Incidence and Per cent Disease Intensity over unsprayed control. However, among all treatments, application of Difenconazole @ 0.1% was found most effective, recording lowest Per cent Disease Incidence (9.39) at 60 DAS and lowest Per cent Disease Intensity (5.61 and 7.21) both at 60 DAS and 90 DAS. Mancozeb @ 0.2% recorded lowest incidence of disease (13.37%) at 90 DAS. Next best treatment was Propiconazole @ 0.1% recorded disease incidence (10.19% and 15.63%) at 60 DAS and 90 DAS and disease intensity (6.23% and 7.89%) at 60 DAS and 90 DAS respectively. Among plant extract and bioagents, NSKE (5%) was found effective, recording Per cent Disease Incidence (16.31% at 60 DAS and 20.97% at 90 DAS) and disease intensity (6.84% and 9.56%) both at 60 DAS and 90 DAS, respectively, followed by *Trichoderma harzianum* recorded (6.97% at 60 DAS and 9.87% at 90 DAS) disease incidence and (18.23% and 21.87%) disease intensity at 60 DAS and 90 DAS respectively. The similar results have been observed by Jadeja *et al*. (1999). They were carried out experiment on groundnut rust and recorded that Difenconazole , Propiconazole , Mancozeb and Hexaconazole were found most effective in reducing disease severity. Same lines were written by Tiwari *et al*. (2004) and Kalappanavar *et al*. (2008). Whereas, in case of plant extract and bioagents, Sunkad and Kulkarni (2005) reported that NSKE showed highest rust control in groundnut. Mathivanan *et al.* (2000) as well as Burmeister and Hau (2009) revealed that *T. viridae* was equally effective as that of controlling rust in groundnut and bean respectively.

Data presented in table 2 revealed that among fungicides Difenconazole (0.1%) treatment recorded highest hundred seed weight (48.80 g), dry pod yield of 1744 kg ha^{-1} and dry haulm yield of 5386 kg ha^{-1} followed by Propiconazole @ 0.1% (47.53 g) 1692 kg ha^{-1} and 5129 kg ha^{-1} pod and haulm yield respectively. Among plant extract and bioagents, NSKE 5% gave highest hundred seed weight, pod and haulm yield (41.43g, 1161 kg ha^{-1} and 3833 kg ha^{-1} respectively) followed by *T. harzianum* @ 0.5% (40.06 g, 1075 kg ha^{-1} and 3515 kg ha^{-1}) hundred seed weight, pod and haulm yield respectively. The present results are in conformity with those findings reported earlier by several workers viz., Johnson and Subramanyam (2003) tested Hexaconazole, which showed highest pod yield and haulm yield .Tiwari *et al*. (2004) recorded higher pod yield and 100 seed weight from Hexaconazole treated plot. In case of plant extract and bioagents, Usman *et al*. (1991) conducted an experiment for plant disease management on groundnut with naturally occurring plant products and indicated that NSKE sprayed plot registered significantly the highest pod yield. Burmeister and Hau (2009) evaluated several species of *T. harzianum* against bean rust and observed its efficacy to reduce number of uredial pustules, ranging from 1 to 50 %.

The details of field experiment was as given below –

1. Location	:	Farm of Plant Pathology Section, College of Agriculture, Nagpur.
2. Name of Crop	:	Groundnut
3. Variety	:	TAG -24
4. Season	:	*kharif* 2010 -2011
5. Spacing	:	30 x 22.5 cm
6. Gross Plot Size	:	2.4 x 1.8 m^2
7. Net Plot Size	:	2.1 X 1.57 m^2
8. Experimental Design	:	Randomized Block Design (RBD)
9. Number of Treatments	:	09 (Nine)
10. Number of Replications	:	03 (Three)
11. Method of Sowing	:	Dibbling
12. Date of Sowing	:	2nd July, 2010
13. Date of harvesting	:	12th October, 2010

Score for grade (Plate 1)

0	-	No pustule on leaf.
1	-	Small rust pustules covering 1% or less of the leaf area.
3	-	Typical rust pustules scattered covering 1-5 % of leaf area.
5	-	Typical rust pustules, coalescing and covering 6-20 % leaf area.
7	-	Rust pustules coalesce to form irregular necrotic patches covering 21-50% of leaf area
9	-	Rust pustules coalesce to form irregular necrotic patches covering 51 % or more leaf area. Yellowing and withering of l eaves followed by shedding.

Table 1. Effect of fungicides, plant extract and bioagents on Per cent Disease Incidence and Per cent Disease Intensity of groundnut rust

	Treatments	Per cent Disease Incidence		Per cent Disease Intensity	
		60 DAS	90 DAS	60 DAS	90 DAS
T_1	Propiconazole 25% EC @ 0.1%	10.19 (3.29)	15.63 (3.94)	6.23 (2.49)	7.89 (2.80)
T_2	Hexaconazole 5% EC @ 0.1%	12.08 (3.57)	17.62 (4.15)	6.29 (2.50)	8.32 (2.87)
T_3	Penconazole 10 % EC @ 0.1%	16.07 (4.00)	20.53 (4.52)	6.66 (2.57)	8.94 (2.98)
T_4	Difenco nazole 25% EC @ 0.1%	9.39 (3.05)	14.64 (3.82)	5.61 (2.36)	7.21 (2.68)
T_5	Mancozeb 75 % WP @ 0.2%	15.52 (3.93)	13.37 (3.64)	6.41 (2.53)	8.63 (2.93)
T_6	Neem Seed Kernel Extract @ 5%	16.31 (4.07)	20.97 (4.57)	6.84 (2.61)	9.56 (3.09)
T_7	*Trichoderma harzianum* @ 0.5 %	18.23 (4.26)	21.87 (4.66)	6.97 (2.63)	9.87 (3.14)
T_8	*Pseudomonas fluorescens* @ 0.5 %	21.13 (4.59)	24.49 (4.94)	7.21 (2.68)	10.11 (3.17)
T_9	Control	25.59 (5.05)	29.09 (5.38)	8.28 (2.87)	12.22 (3.49)
	SE (m) ±	0.10	0.11	0.036	0.077
	CD (P = 0. 05)	0.32	0.34	0.12	0.19

(figures in parentheses are square root transformed value)

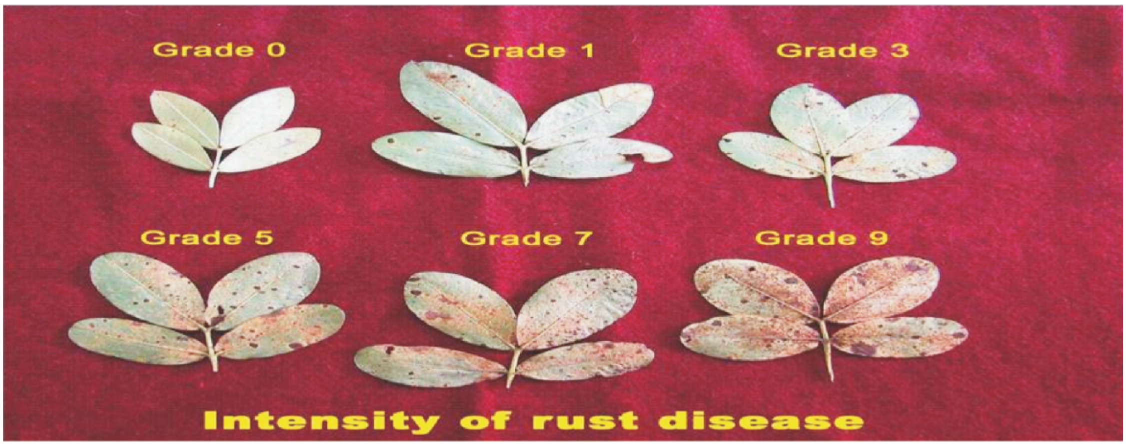

Plate 1. Photograph showing 0-9 grade scale for intensity of rust disease on groundnut

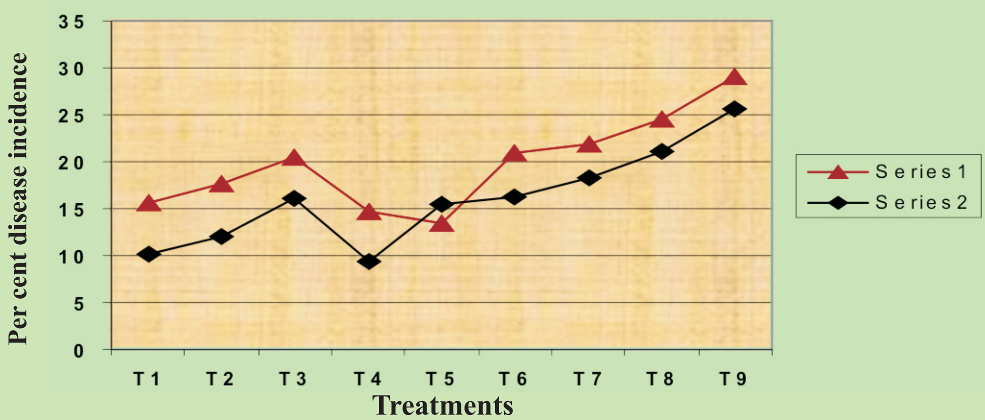

Fig 1. **Effect of fungicides, plant extract and bioagents on per cent disease incidence of groundnut rust**

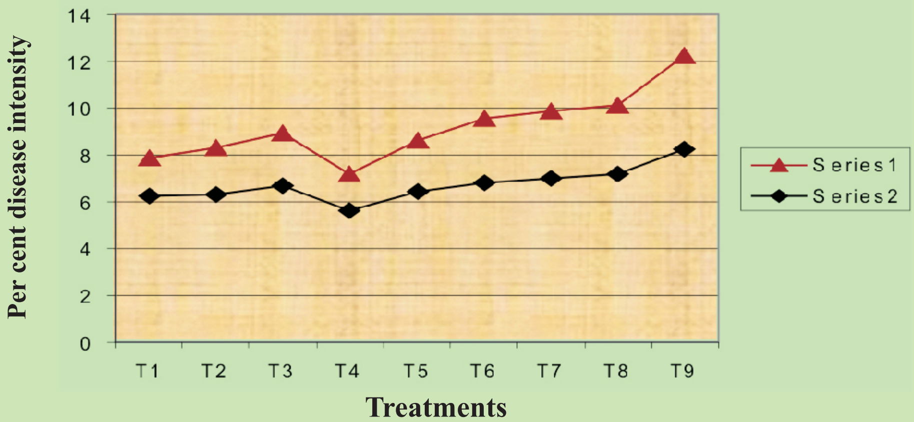

Fig 2. **Effect of fungicides, plant extract and bioagents on per cent disease intensity of groundnut rust**

Table 2. Effect of various treatments on hundred seed weight. dry pod yield and dry haulm yield of groundnut

	Treatments	100 seed weight (g)	Dry pod yield (kg ha^{-1})	Dry haulm yield (kg ha^{-1})
T_1	Propiconazole 25% EC @ 0.1%	47.53	1692	5129
T_2	Hexaconazole 5 % EC @ 0.1%	45.69	1530	4813
T_3	Penconazole 10 % EC @ 0.1%	44.20	1407	4356
T_4	Difenconazole 25 % EC @ 0.1%	48.80	1744	5386
T_5	Mancozeb 75 % WP @ 0.2%	43.00	1292	4121
T_6	Neem Seed Kernel Extract @ 5 %	41.43	1161	3833
T_7	*Trichoderma harzianum* @ 0.5 %	40.06	1075	3515
T_8	*Pseudomonas fluorescens* @ 0.5 %	38.40	977	3027
T_9	Control	35.70	891	2066
	SE (m) ±	0.86	17.04	69.73
	C.D. (P = 0.05)	2.60	51.10	209.06

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Rec. on 25.09.2011 & Acc. on 28.12.2011

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