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CLAY MINERALOGY OF SUGARCANE SOILS FORMED ON GRANITE-GNEISS PARENT MATERIAL OF CHITTOOR DISTRICT, ANDHRA PRADESH

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ABSTRACT

Mineralogy of clay fractions using X-ray diffraction technique and characteristics of sugarcane growing soils developed from granite-gneiss parent material in Chittoor district of Andhra Pradesh under semi-arid climate were studied during 2012. The clay fraction of these soils exhibited the characteristic peaks of smectite, illite and kaolinite. Semi-quantification of clay fractions based on relative areas under corresponding peaks indicated that the pedon 1 was dominated by kaolinite followed by illite, feldspars and smectite. Pedons 2 and 6 were dominated by smectite followed by illite, kaolinite and feldspars. Pedons 3 and 4 were dominated by smectite followed by kaolinte, feldspars and illite whereas pedon 5 was dominated by smectite followed by kaolinite, illite and quartz and pedon 7 dominated by illite followed by kaolinite, smectite and feldspars. The formation of smectite suggests that these soils were formed through a progressive landscape reduction process and appears to be under basic environment. Chemical composition showed that soils were neutral to strongly alkaline in reaction, non-saline with CEC ranging from 1.30 to 28.80 cmol (p+) kg^{-1} soil.

Key words: *Clay mineralogy, illite, kaolinite, smectite, sugarcane soils*

INTRODUCTION

Clay is an important soil constituent that controls its properties and also influences its management and productivity (Davies *et al.,* 1972). Clay with cementing agents contributes structural stability that helps in resisting the destructive effects of rain and wind. Moreover, clays have a large specific surface area that is mostly negatively charged and these sites retain nutrients like K^+ and NH^+ ions and also adsorb many toxic elements. The mineralogy of soil clays is the result of several factors interacting with the parent material. In certain combination of circumstances soil forming processes exhibit their effects on the clay mineralogy viz., Oxisols, Vertisols and Andisols (Newman, 1984). Soil mineralogy, which is closely linked to soil texture, is a major determinant of physical and chemical properties of soils (Sumner, 2000). Soil mineralogy defines the capacity of soil minerals to adsorb and protect organic carbon, which depends on the specific surface area and surface charge characteristics of the mineral (Krull *et al.,* 2001, Zinn, 2005). Knowledge of clay minerals in soils is thus critical to our understanding and use of soil. However, there is no information available on the clay mineralogy of sugarcane growing soils of Chittoor district. Hence, the present investigation was carried out to identify the clay minerals in these soils for their sustainable management.

MATERIALS AND METHODS

Study Area

The study area lies in between 12^o 37" and 14^o 80" N latitude and 78^o 33" and 79^o 55" E longitude. The climate of the area is semi-arid monsoonic with distinct summer, winter and rainy seasons. The annual precipitation was 893.63 mm of which 94.31 per cent was received during May to December. The mean annual soil temperature was 27.70^{o}C with a mean summer and winter temperatures of 31.77^{o}C and 26.99^{o}C, respectively. The area qualifies for isohyperthermic temperature regime. The soil moisture control section remains dry for more than 90 cumulative days or 45 consecutive days in four months following summer solistice and qualifies for ustic soil moisture regime. The soils of the study area are developed from granite-gneiss parent material. The natural vegetation of the study area was *Parthenium hysterophorus, Calotropis gigantia, Tridax procumbens, Pongamia pinnata, Azardirachta*

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indica, Lantana camera, Cyperus rotundus and *Cynodon dactylon*.

Seven representative pedons (P1 to P7) in sugarcane growing soils of Chittoor district in Andhra Pradesh were selected after surveying the area in the year 2011. The horizon-wise soil samples were collected for analysis of chemical parameters whereas the samples collected from control section (25-100cm) of the pedons were analysed for clay minerals. The samples were air-dried at room temperature and stored in polyethylene bags. The air-dried samples were crushed, passed through a 2 mm sieve, mixed and stored for analysis. The chemical parameters were determined by following standard procedures. The clay fractions were separated by sedimentation technique (Jackson, 1979). The clays (< 2μm) were isolated by removing organic matter, sesquioxides and allophones. Basically oriented clay samples (Mg-25^{O}C, Mg-glycerol, K-25^{O}C and K-550^{O}C heated) were subjected to X-ray diffraction studies. The X-ray diffractograms were recorded in Philips diffractometer (Model 1140) using Ni-filtered Cu-Kα radiation at a scanning speed of 2^{O} 2θ per min. Identification and semi-quantitative estimation of clay minerals was also carried out based on peak intensities (Gjems, 1967).

RESULTS AND DISCUSSION

The general characteristics of the study area have been represented in Table 1. The soils were developed on granite-gneiss parent material. P1, P2 and P5 were located on plains while P3, P4, P6 and P7 were developed on uplands. Moderate erosion was observed in pedons 3, 4, 6 and 7 while others did not show any erosion. The drainage was moderately well drained.

Table 1: Salient site characteristics of the profiles in the study area

Features	Pedon 1 (Neruvoi*)	Pedon 2 (Palamangalam*)	Pedon 3 (Gollapalle*)	Pedon 4 (Vonaruvaripalli*)	Pedon 5 (Digavapokalavaripalli*)	Pedon 6 (Gattivaripalli*)	Pedon 7 (KMV Palli*)
Physiography	Plain	Plain	Upland	Upland	Plain	Upland	Upland
Slope (%)	0-1	0-1	3-8	3-8	0-1	3-8	3-8
Elevation (msl)	120m	120m	120m	120m	120m	120m	120m
Drainage	Moderately well drained	Moderately well drained	Moderately well drained	Moderately well drained	Moderately well drained	Moderately well drained	Moderately well drained
Parent material	Weathered gneiss	Weathered gneiss	Weathered gneiss	Weathered gneiss	Weathered gneiss	Weathered gneiss	Weathered gneiss
Erosion	Very slight	Very slight	Moderate	Moderate	Very slight	Moderate	Moderate
Land use	Sugarcane crop	Sugarcane crop	Sugarcane crop	Sugarcane crop	Sugarcane crop	Sugarcane crop	Sugarcane crop

**Name of the village*

Chemical composition

The data on chemical composition (Table 2) revealed that, the pH of the soils ranged from 7.35 (neutral) to 8.21 (strongly alkaline). Cation exchange capacity of the soils varied between 1.30 and 28.80 cmol (p^{+}) kg^{-1} in different horizons and was positively and significantly correlated with clay (r = +0.756**) and negatively and significantly with sand (r = -0.669**). The base saturation ranged from 53.19 to 94.05 per cent. The higher base saturation in some pedons might be due to higher amount of Ca^{+2} occupying exchange sites on the colloidal complex and also may be due to recycling of basic cations through vegetation. Higher values (8.21) of loss on ignition (LOI) may be due to the presence of expanding type of clay minerals. The values of SiO_2 and Al_2O_3 indicated the occurrence of appreciable amounts of 2:1 type of clay minerals. The Fe_2O_3 content of clays in these soils suggested the presence of iron-bearing minerals. Values of MgO and CaO indicate the presence of minerals rich in magnesium and calcium. The K_2O content in all the pedons indicates the presence of K-bearing clay minerals (Raina *et al.,* 2006). Relatively higher values of P_2O_5 in the soil might be due to the presence of P-bearing minerals such as calcium apatite and also due to use of higher doses of phosphatic fertilizers (Table 2).

Table 2: Chemical composition of the sugarcane growing soils

Pedon no. & horizon	Depth (m)	pH (1:2.5)	EC (dS m^{-1})	CEC [cmol (p^+) kg^{-1}]	SiO_2 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	P_2O_5 (%)	K_2O (%)	Na_2O (%)	CaO (%)	MgO (%)	LOI (%)
Pedon 1	Neruvoi (Fine -loamy, kaolinitic, isohyperthermic Ultic Haplustalfs)												
Ap	0.00-0.20	7.64	0.01	8.52	79.60	3.16	8.52	0.13	0.15	1.22	2.73	2.09	4.80
Bw	0.20-0.47	7.63	0.03	8.05	82.04	3.68	6.68	0.08	0.27	1.45	2.45	1.39	4.60
Bt	0.47-0.65	7.37	0.08	9.50	74.80	5.22	12.10	0.10	0.38	1.88	2.03	1.29	6.62
BC1	0.65-0.87	7.39	0.24	4.54	80.75	4.03	7.64	0.09	0.23	1.27	2.66	1.08	4.84
BC2	0.87-1.06	7.43	0.06	4.67	81.40	4.78	5.12	0.09	0.28	1.42	3.36	0.95	5.24
BC3	1.06-1.30	7.40	0.06	5.60	77.20	4.83	9.11	0.08	0.29	1.58	3.36	0.75	5.35
BC4	1.30-1.60 +	8.21	0.05	5.38	75.20	5.96	7.98	0.11	0.28	1.43	3.92	2.32	7.11
Pedon 2	Palamangalam (Sandy, smectitic, isohyperthermic Typic Dystrustepts)												
Ap	0.00-0.22	8.19	0.14	10.41	86.75	2.55	5.15	0.14	0.15	1.17	2.24	0.60	3.85
Bw	0.22-0.40	8.12	0.17	15.52	82.70	3.22	7.26	0.09	0.22	1.10	3.01	0.10	3.69
BC	0.40-0.52	8.12	0.03	11.82	85.85	3.26	4.95	0.10	0.20	0.98	2.31	0.20	3.69
2C1	0.52-0.71	8.04	0.13	1.36	90.04	1.22	2.46	0.12	0.07	1.16	2.52	0.45	1.14
2C2	0.71-1.00	7.92	0.08	1.30	89.24	1.19	4.88	0.09	0.05	1.10	1.54	0.15	0.99
3C3	1.00-1.30 +	8.03	0.13	14.10	80.58	4.45	8.19	0.09	0.25	1.31	1.96	0.75	4.05
Pedon 3	Gollapalle (Fine-loamy, smectitic, isohyperthermic Typic Ustorthents)												
Ap	0.00-0.23	8.05	0.06	28.12	77.35	4.70	11.92	0.09	0.34	1.17	1.68	1.10	5.81
2A1	0.23-0.38	7.80	0.10	6.52	88.15	2.20	3.91	0.12	0.14	1.27	1.22	1.14	2.29
3A2	0.38-0.59	7.64	0.07	28.80	84.28	4.22	7.14	0.13	0.19	1.16	0.91	0.25	3.80
Pedon 4	Vonaruvaripalle (Fine-loamy, smectitic, isohyperthermic Typic Ustorthents)												
Ap	0.00-0.15	7.51	0.14	6.95	90.31	1.80	3.02	0.09	0.09	1.27	0.98	0.25	2.75
A1	0.15-0.28	7.58	0.02	3.04	87.26	1.82	6.04	0.09	0.18	1.23	0.91	0.73	0.65
A2	0.28-0.48	7.55	0.13	17.46	85.70	3.09	5.16	0.10	0.20	1.25	1.61	1.59	6.69
Cr	0.48	Weathered gneiss											
Pedon 5	Digavapokalavaripalli (Fine-loamy, smectitic, isohyperthermic Typic Haplustepts)												
Ap	0.00-0.20	7.88	0.08	31.71	83.48	3.50	7.54	0.15	0.20	1.25	1.61	0.65	8.21
Bw1	0.20-0.41	8.08	0.10	14.32	85.64	3.45	5.55	0.11	0.20	1.23	1.96	0.10	4.30
Bw2	0.41-0.60	7.91	0.03	16.64	85.20	3.53	5.64	0.09	0.15	1.12	1.47	0.20	3.85
Bw3	0.60-0.83	7.94	0.16	6.25	87.28	2.45	5.29	0.08	0.11	1.19	1.33	0.25	5.15
Bw4	0.83-1.10	7.81	0.20	19.65	87.01	2.69	5.80	0.07	0.11	1.11	1.47	0.15	3.20
Cr	1.10	Weathered gneiss											
Pedon 6	Gattivaripalli (Fine-loamy, smectitic, isohyperthermic Typic Haplustepts)												
Ap	0.00-0.22	7.67	0.03	16.83	84.86	3.36	7.57	0.14	0.16	1.23	1.19	0.15	3.45
Bw1	0.22-0.48	7.43	0.24	13.75	83.26	3.68	7.53	0.12	0.15	1.09	1.54	0.79	2.84
Bw2	0.48-0.73	7.35	0.02	11.62	85.20	4.90	6.45	0.14	0.21	1.26	0.84	0.20	4.00
Bw3	0.73-1.00	7.42	0.18	12.38	80.65	5.75	8.58	0.12	0.16	1.23	1.26	0.30	4.20
Cr	1.00	Weathered gneiss											
Pedon 7	KMV Palli (Sandy, mixed, isohyperthermic Typic Ustorthents)												
Ap	0.00-0.23	7.80	0.03	13.35	87.15	2.36	4.76	0.14	0.18	1.22	1.19	0.25	3.90
A2	0.23-0.52	7.98	0.41	5.71	90.75	1.52	3.42	0.14	0.12	1.10	0.70	0.20	2.60
Cr	0.52	Weathered gneiss											

X-ray Diffraction

The X-ray diffraction pattern of clay fraction indicated that pedon 1 contained kaolinite (67%) (dominant), illite, feldspars and smectite (Fig. 1). The intense dominant peak at 0.724 nm and 0.358 nm d-spacing in Mg-saturated ethylene glycol solvated treatment indicated the presence of kaolinite. A sharp large peak was observed at 1.008 nm d-spacing followed by higher order peaks at 0.506 and 0.333 nm d-spacings in Mg-saturated ethylene glycol solvation treatment and in K-25^{o}C treatment and persistence of these peaks at K-550^{o}C treatment indicated the presence of illite clay mineral. The peak position at 1.342 nm d-spacing in Mg-saturated sample shifted to 1.685nm upon ethylene glycol solvation suggested the presence of smectite. Feldspars were identified by a small peak at 0.304 nm in Mg-saturated ethylene glycol solvation and Mg-saturated at room temperature treatments, respectively.

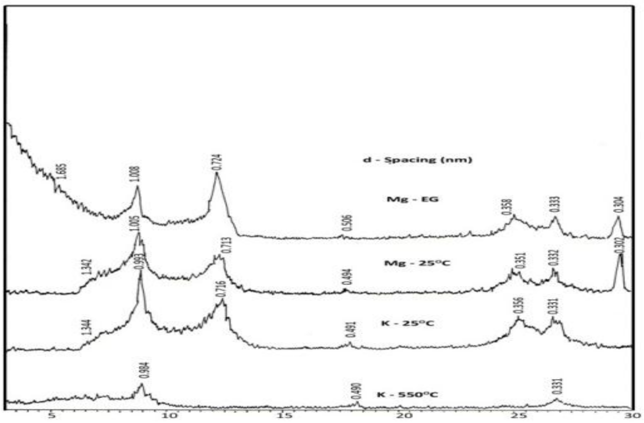

Fig. 1: Representative XRD diagrams of fine -loamy, kaolinitic, isohyperthermic Ultic Haplustalfs (0.2µm) of Pedon 1

In clay fraction of pedon 2, smectite (45%) was the dominant mineral followed by illite, kaolinite and feldspars (Fig. 2). A strong peak at 1.234 nm d-spacing in Mg-saturated sample which expanded to 1.701 nm d-spacing with Mg-saturated ethylene glycol solvated treatment indicated the presence of smectite. The presence of weak peaks at 1.003 nm, 0.500 nm and 0.335 nm is indicative of illite. Small peaks at 0.711nm and 0.355 nm d-spacings and their persistence in all the treatments except at K-550^{O}C confirmed the presence of kaolinte. A characteristic peak at 0.304 nm d-spacing indicated the presence of feldspars.

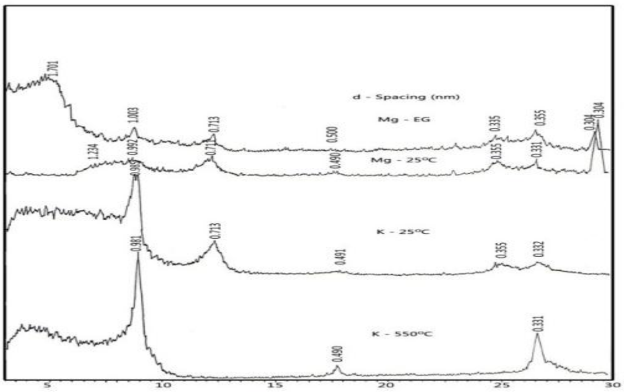

Fig. 2: Representative XRD diagrams of Sandy, smectitic, isohyperthermic Typic Dystrustepts (0.2µm) of Pedon 2

Smectite was the dominant clay mineral followed by kaolinite and illite (Fig. 3). The Mg-saturated sample in pedon 3 showed a peak at 1.228 nm d-spacing and its shift to 1.654 nm indicated the presence of smectite. The peaks at 0.717 nm d-spacing and 0.355nm in all the treatments except in K-550^{O}C treatment confirmed the presence of kaolinite. Feldspars and illite were recognized by the presence of small peaks at 0.303 nm and 1.013 nm, 0.495 nm and 0.334 nm respectively.

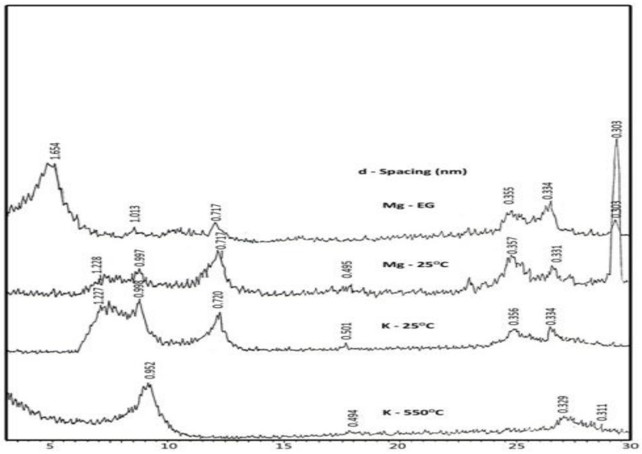

Fig. 3: Representative XRD diagrams of Fine-loamy, smectitic, isohyperthermic Typic Ustorthents (0.2µm) of Pedon 3

A peak at 1.221 nm and the other at 1.652 nm in pedon 4 on glycolation, confirmed the presence of smectite (Fig.4). The sharp peak at 0.724 nm followed by a high angle diffraction maxima at 0.355 nm in different treatments confirmed the presence of kaolinite as explained earlier. Further, a small peak at 0.301 nm d-spacing confirmed the presence of feldspars. The peaks at 1.013 nm, 0.491 nm and 0.335 nm d-spacings showed the presence of illite.

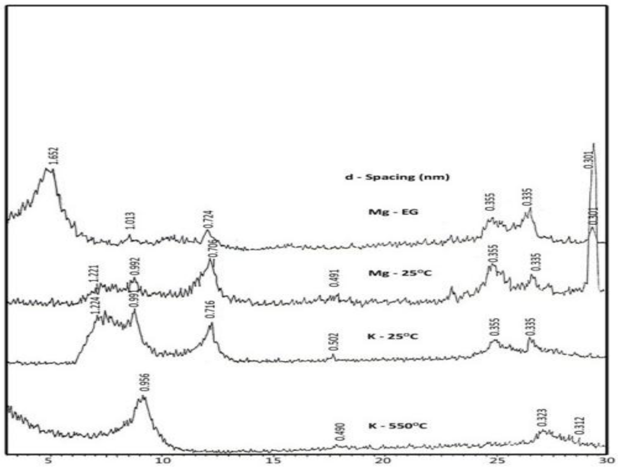

Fig. 4: Representative XRD diagrams of Fine-loamy, smectitic, isohyperthermic Typic Ustorthents (0.2µm) of Pedon 4

The Mg-saturated sample in pedon 5 showed a peak at 1.682 nm d-spacing which indicated the confirmation of smectite (Fig.5). The peaks at 0.722 nm and 0.358 nm d-spacing in all the treatments except in K-550^{O}C treatment confirmed the presence of kaolinite. Presence of a sharp peak at 0.995 nm, 0.498 nm and 0.332 nm in all the treatments suggests the presence of mica. The peaks were not affected by glycerol treatment or by heating up to 550^{O}C, thereby confirmed that the degree of hydration of mica was not much. Very small peak at 0.415 nm confirmed the presence of quartz.

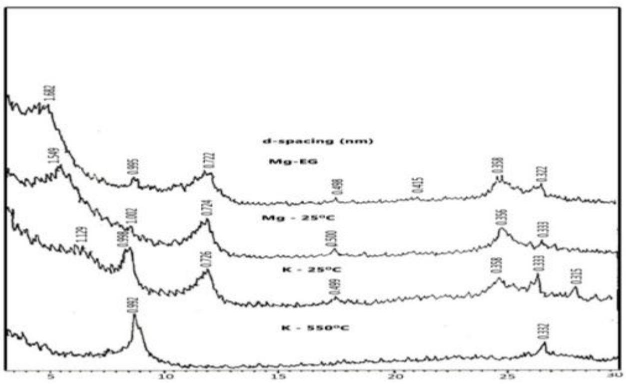

Fig. 5: Representative XRD diagrams of Fine-loamy, smectitic, isohyperthermic Typic Haplustepts (0.2μm) of Pedon 5

An intense large peak in pedon 6 at 1.232 nm in Mg-saturated sample which expanded to 1.703 nm on ethylene glycolation confirmed the presence of smectite (Fig.6). Presence of large peaks at 1.003 nm, 0.504 nm and 0.332 nm d-spacing in all the treatments suggests the presence of mica. Kaolinite was recognised by a large intense peak at 0.715 nm

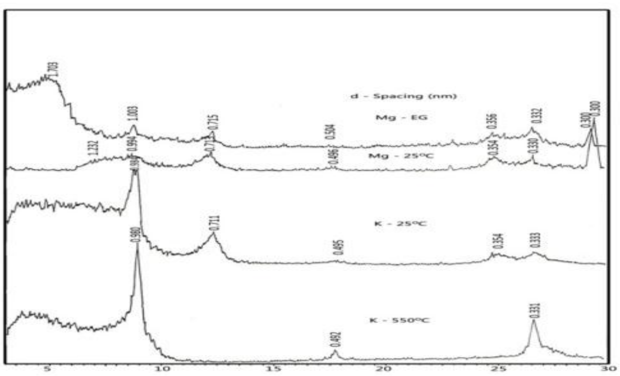

Fig. 6: Representative XRD diagrams of Fine-loamy, smectitic, isohyperthermic Typic Haplustepts (0.2μm) of Pedon 6

in all the treatments, but it disappeared in K-saturated sample heated to 550^{O}C. A characteristic peak at 0.300 nm d-spacing confirmed the presence of feldspars.

Pedon 7 showed a mixed mineralogy with no dominance of any specific mineral (Fig.7). The abundant quantity of illite in pedon 7 was detected by the presence of a sharp peak at 0.996 nm, 0.499 nm and 0.334 nm which persisted in all the treatments. The small peak at about 0.716 nm and 0.355 nm d-spacing in all the treatments except in K-saturation and heating at 550^{o}C is indicative of kaolinite. A high intensity peak at 1.415 nm in Mg-saturated sample which shifted to 1.711 nm on ethylene glycol solvation indicated the presence of smectite. Small quantities of feldspars were recognized by the presence of a sharp and low intensity peak at 0.304 nm.

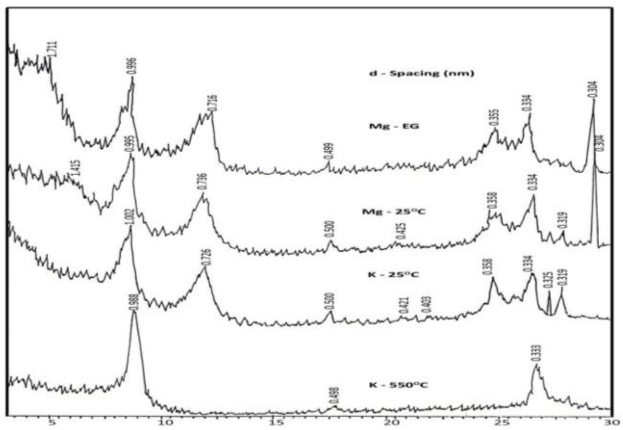

Fig. 7: Representative XRD diagrams of Sandy, mixed, isohyperthermic Typic Ustorthents (0.2μm) of Pedon 7

Genesis of clay minerals

The clay fraction of soils in the present study was found to be a mixture of three clay minerals *viz.,* smectite, illite and kaolinite. Smectite was the single most dominant mineral in pedons 2, 3, 4, 5, 6, whereas kaolinite was the dominant mineral in pedon 1. In pedon 7 no dominance of any specific mineral was observed. It is quite unlikely that such a high amount of smectite in these soils could be produced during the low rainfall period of the present semi-arid conditions (Bhattacharyya *et al.,* 1993). Smectite was also formed possibly from plagioclase during earlier geologic period and was an ephemeral in humid environment (Tardy *et al.,* 1973 and Bhattacharyya *et al.,* 1993), however its retention was possible because of climate change from humid to semi-arid during pleistocene transition period (Pal *et al.,* 1989).

Kaolinite was the dominant mineral in pedon 1. Kaolinite present in this pedon might had been formed from smectite (Bhattacharyya *et al.,* 1993). Kaolinite minerals could be formed by neosynthesis from the products of hydrolytic decomposition of feldspars and other primary minerals (Geetha Sireesha *et al.,* 2015) and by conversion of smectite or vermiculite to kaolinite following hydroxy interlayering in the expandable mineral or mixed layering between 2:1 and 1:1 layers (Pal *et al.,* 1989 and Bhattacharyya *et al.,* 2000). Further, the kaolinite was formed in an earlier geological period with more rainfall and greater fluctuations in temperature (Pal and Deshpande, 1987). The study area had also experienced the above conditions, which lead to synthesis of kaolinite mineral in pedon 1.

Table 3: semiquantitative estimats of clay minerals (%)

Pedon No.	Tentative soil series	Smectite	Kaolinite	Illite	Feldspars	Quartz
1	Neruvoi	3	67	18	12	-
2	Palamangalam	45	20	20	15	-
3	Gollapalle	54	22	10	14	-
4	Vonaruvaripalli	51	29	7	13	-
5	Digavapokalavaripalli	65	15	15	Tr	5
6	Gattivaripalli	50	15	22	13	-
7	KMV Palli	24	30	33	13	-

Illite was present in small quantities in all the pedons. Illite present in the clay might have been derived by alteration of micas from the parent material. Potassium bearing minerals of rocks under the prevailing conditions of the soil formation had led to formation of illitic type of minerals (Satyanarayana and Biswas, 1970). Quartz was present in small quantities in these soils.

Clay mineralogy investigation by X-ray diffraction technique indicated that smectite was the dominant clay mineral in almost all the pedons except pedons 1 and 7. Kaolinite was dominant mineral in pedon 1 and pedon 7 showed mixed mineralogy. The relative similarities in the mineralogy of these granite-gneiss derived soils irrespective of the degree of pedogenesis suggested that all the clay minerals were inherited from the parent material with very little *in- situ* transformation under prevailing conditions. The information regarding the relative proportion of various minerals is vital for effective management of soils.

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GAMMA RAYS AND EMS INDUCED VIABLE MUTANTS AND MUTAGENIC FREQUENCY IN ADT (R) 47 RICE

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ABSTRACT

The present study was carried out to induce viable mutants in ADT (R) 47 rice. Seeds were subjected to different treatment levels of gamma rays and Ethyl Methane Sulphonate (EMS). The treated and untreated plants were self-fertilized in M_1 generation to observe different morphological characters in M_2 generation. A wide spectrum of unique macro mutants was isolated in this investigation. These independent mutants exhibited varied phenotypes from wild type. The mutagenic frequency was highest at 300Gy (0.88%) of gamma irradiation and gamma rays were found to be most effective in inducing viable mutations compared to EMS. Four broad types of viable mutants could be witnessed. The most distinct mutants isolated were different leaf characters, plant stature, duration and altered grain characters.

Key words: Rice, Gamma rays, EMS, Viable mutants

INTRODUCTION

Rice (*Oryza sativa* L.) is an ideal system for studying plant architecture and is the staple food source among cereals consumed by more than half of the world's population. India has the largest area under rice in the world and ranks second in production (Anonymous, 2013). The induction of mutations as a technique for crop improvement occupies a significant place among modern methods of plant breeding. Nilan *et al.* (1977) have suggested induced mutations as a best supplement to natural genetic variability. In plants, ionizing radiations and chemicals have proved to be most efficient in inducing new genetic variability. A striking example of their role has been in rice breeding, where induced mutants have not only been released directly as improved cultivars but more importantly have been used as donor parents in standard hybridization programs. Mutation breeding is also envisaged to enlarge the frequency and spectrum of mutations and to increase the incidence of viable mutations as an approach towards directed mutagenesis (Singh *et al.,* 1998). Plants showing morphological deviations and survival up to maturity were scored as viable mutants. The occurrences of morphological mutations after treatments with physical and chemical mutagens have been reported in rice crop (Chakravarti *et al.* (2012; Vasline and Sabesan, 2011). In general any mutational event may bring large or small changes in the phenotype of the plant. The changes in macro mutants have highest significance in plant breeding because they may sometimes give a desired phenotype. The present study has been made to assess the frequency and spectrum of viable mutants in M_2 generation of the Rice cultivar ADT (R) 47.

MATERIALS AND METHODS

In the current investigation, the seeds of rice cultivar ADT (R) 47 were selected to induce viable mutations. The genetically pure seeds of ADT (R) 47 rice (*Oryza sativa* L.) variety were obtained from Tamil Nadu Rice Research Institute, Aduthurai of Tamil Nadu Agricultural University. The seeds were irradiated with different doses (200, 250 and 300Gy) of gamma rays from ^{60}CO at Centre for Plant Breeding and Genetics, Coimbatore. For EMS treatment, healthy seeds were treated with varied concentrations of (100, 120 and 140mM). The treated seeds were carefully removed from the solution and they were thoroughly washed in running tap water for two to three times to eliminate the residual effect of the chemical. The field experiment was carried out in the south farm, Tamil Nadu Rice Research Institute, Aduthurai without replication. Thirty days after sowing, the seedlings were transplanted to the main field with the single

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seedling per hill. Normal agronomic practices were followed to raise a good crop. The spacing was maintained at 20 cm (between the rows) and 10 cm (between plant to plant) in the field. The M_1 plants were harvested separately and the plant progenies were raised in M_2 generation. From each treatment of gamma irradiation and EMS, 100 M_1 plants individually, totalling to 600 plants were forwarded to M_2 generation based on M_1 seed fertility. The primary panicle of individual M_1 plant was forwarded to M_2 as per plant to progeny method. The control and treated progenies were screened several times for viable mutations throughout the M_2 crop duration. The frequency and spectrum of different types of viable mutants were scored at various developmental stages of M_2 plants particularly from flowering to maturity period. All visible changes in comparison to the control were classified for deviation from the normal and the most conspicuous characters taken into consideration were leaf characters, plant stature, crop duration and grain characters. The frequency and spectrum of viable mutants were calculated in M_2 population on seedling basis. The frequency of viable mutations was calculated on the basis of total number of M_2 plants in the respective mutagen. The frequency of each mutant type was also calculated on the basis of the total number of M_2 plants screened in all the treatments. Finally, the overall frequency of viable macro mutations isolated in each mutagen was calculated on the basis of the total number of M_2 plants screened.

The formula proposed by Konzak *et al.* (1965) was followed for the calculations of mutagenic effectiveness and efficiency by incorporating the mutation frequency values recorded for each mutagenic treatment.
Mutagenic effectiveness = Mutagenic Frequency / Dose or (concentration (c) x time (t))
Mutagenic efficiency = Mutagenic Frequency / Biological damage

RESULTS AND DISCUSSION

Economic potentialities of identified viable mutants in the M_2 generation

Swaminathan (1965) classified mutations into two major groups: (1) those which can be detected in a group of plants requiring testing by biometrical analysis as micro mutations, (2) others which can be recognized by a study of individual plants involving gross changes in the phenotype as macro mutations. Induced macro mutations in many cases may not be suitable for being released directly for cultivation, but they may prove excellent initial breeding materials (Gustafsson and Tedin, 1954). The great merit of such mutants is that the variability would be available in well adapted variety. Gaul (1965) defined macro mutations as those involving gross changes in the phenotype which could be recognized with certainty in a single plant. In the present investigation various types of viable mutants such as Tall, Dwarf, Narrow leaf, Early maturity plants, Late maturity plants, Bold seed and Small seed could be detected at seedling stage in M_2 generation. The data pertaining to the mutation spectrum and frequency of viable mutants was recorded in all the treatments. In the current study, some of the morphological (viable) mutants were observed in M_2 generation with different dose/concentration of mutagens. An increase in the number of viable mutants was realized with the increase in the dose/concentration of gamma rays and EMS treatments in the present study.

Spectrum of viable mutants

In the present study, four broad types of viable mutants could be witnessed in the M_2 populations of ADT (R) 47 treated with physical and chemical mutagens. They consisted of 22 leaf mutants - short leaf (1), narrow leaf (14) and broad leaf (7); 44 stature mutants – tall (24), dwarf (20); 31 duration mutants – early (9), late (22) and 59 grain type mutants - long slender grains (28), medium slender grains (12), grain with beaks (14) and awned type (5) (Fig.1). The mutagenic frequency was highest at 300Gy (0.88%) of gamma irradiation and gamma rays were found to most effective in inducing morphological and viable mutations compared to EMS. Vasline and Sabesan (2011) also concluded that 0.8% EMS was the most effective dose in inducing a wide range of viable mutants in rice varieties ADT 43 and ADT (R) 45.

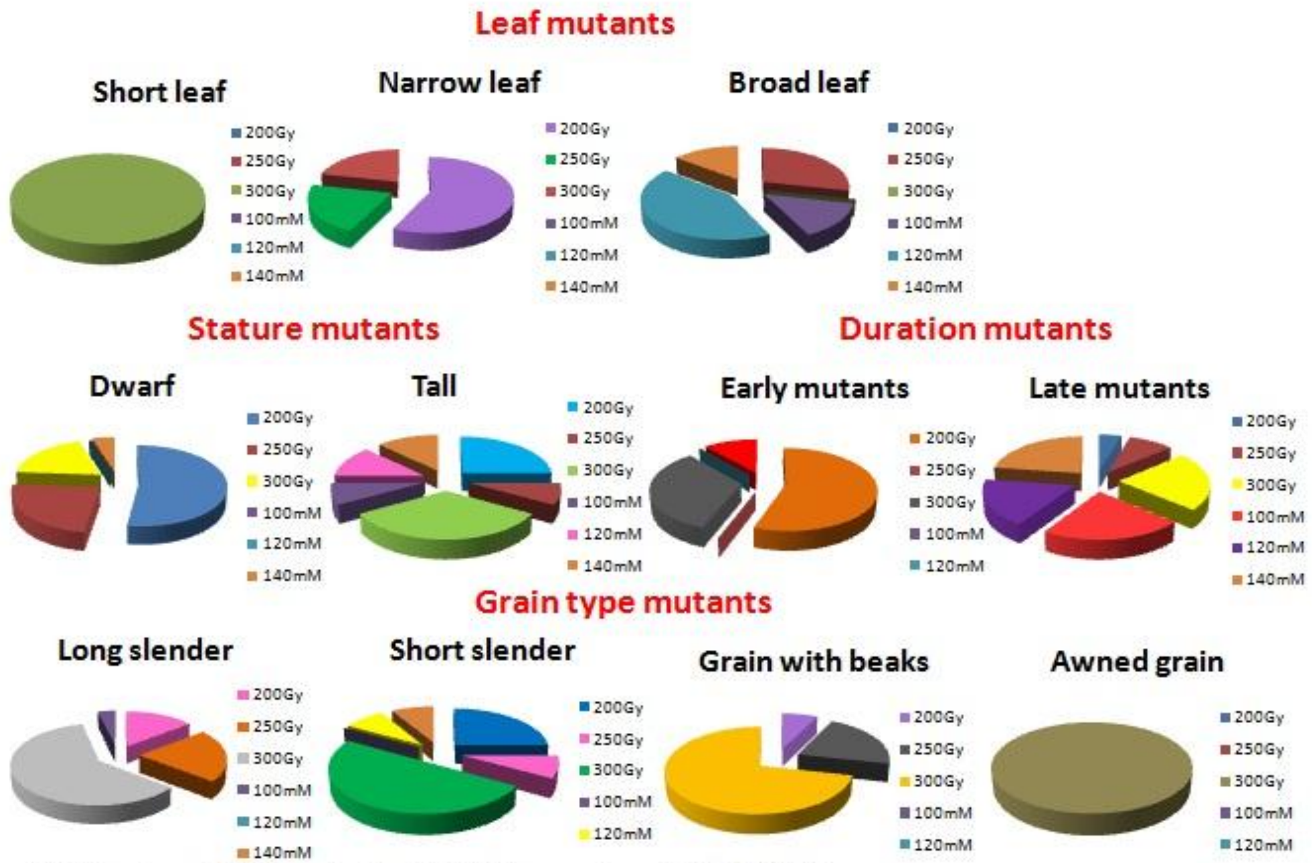

Fig 1. Spectrum of viable mutants isolated in M_2 generation of ADT (R) 47 Rice

Leaf mutants

Among the 22 leaf mutants, three categories *viz.,* short leaf, narrow leaf and broad leaf could be seen in this study. One short leaf mutant was observed at 300Gy dose of gamma rays. Out of 14 narrow leaf mutants, eight mutants were noticed in 200Gy, three in 250Gy and three in 300Gy gamma treatments. Broad leaf mutants were observed both in gamma and EMS treatments *viz*., two at 250Gy dose, one each at 100mM and 140mM, three at 120mM concentrations. Broad leaf mutants had more number of productive tillers and grains per panicle; medium in duration with increased panicle length. Maximum narrow leaf mutants were observed at 0.8 % EMS in IR 64 by Singh *et al.* (1998) Singh and Singh (2003) and Vennila (2005).

Stature mutants

The mutants with short stature (less than 75cm in height) and tall stature (those having more than 110cm plant height) in comparison to ADT (R) 47 variety were encountered. Twenty dwarf mutants *viz.*, 11 under 200Gy, five under 250Gy and four under 300Gy were found in gamma irradiated populations and only one was observed at 140mM of EMS. Out of 24 tall mutants, 16 mutants *viz.*, six in 200Gy, two in 250Gy, and eight in 300Gy and eight mutants *viz.,* three each at 120mM and 140mM and two at 100mM were recovered in gamma and EMS induced mutated populations. Mutagenesis has proved very effective in reducing plant height (Baloch *et al.,* 2003; Chakravarty, 2010). The induction of dwarf mutants by radiation is considered to be one of the most promising applications of mutations in plant breeding. In some of the crops, erectoides mutants characterized by shorter height with dense ears would be of a progressive value not only because of their improved lodging resistance but also due to their concomitant high yielding ability under high nitrogen response. Such modifications in plant height could be developed with short culm without impairing their yield with considerably high efficiency (Kawai *et al.,* 1961).

Among the plant stature mutants, the frequency of dwarfs was the maximum in gamma ray treated population. The dwarf mutants were early with less number of grains per panicle and low yield. Dwarf mutants in ADT (R) 47 were obtained to an extent of 10-15cm reduction in height. However, single plant yield was low and hence these mutants could be utilized in the hybridization programme to transfer the desirable character. Dwarf mutants were developed through utilization of the induced mutation method in rice breeding by Alionte and Alionte (1995), Singh *et al.* (1998), Shadakshari *et al.* (2001), Singh and Singh (2003) and Qin *et al.* (2008). Tall mutants were of higher proportion in EMS treatments in this study. The tall mutants showed an increased height of 25-30cm and had longer maturity period but with increase in panicle length and single plant yield compared to the control. In M_3 generation of Akshaya rice variety, Krishnaveni and Niveditha (2014) isolated eight different types of morphological mutants, of which dwarf plant type occupied the top position (21.0%) followed by tall types (18.8%).

Duration mutants

There were two classes *viz.*, early (110-119 days) and late (>140 days) mutants in comparison with the control. Early mutants were less in number *viz*., five at 200Gy, three at 300Gy of gamma rays and one at 140mM of EMS treatments compared to 22 late mutants. These late mutants comprised of five each at 300Gy, 100mM and 140mM, four at 120mM, two at 250Gy and one at 200Gy. Several mutants affecting the maturity period were obtained which ranged from early (110-119 days) to late (>140 days) in duration. As early as in 1968, Tanaka reported a large number of early flowering and early maturity mutants which have been selected in rice after using different physical mutagens. The degree of earliness varied considerably in the different genotypes. In exceptional cases, an extra ordinary high shift of the flowering was realized. For instance, a Japonica rice mutant was about 60 days earlier than that of parent variety. More early mutants were isolated in gamma treatments than EMS in the present study.

A reduction of vegetative growth duration offers several advantages such as diminution of the damage caused due to natural disaster and advancing the harvesting time. In the present study, the magnitude of late mutants was of higher proportion than early mutants in gamma rays and EMS treatments. Frequent occurrence of lateness than earliness was evidenced from the studies conducted by Gopinathan Nair (1971), Rao and Reddi (1986) and Singh *et al.* (1998) and Singh and Singh (2003).

Table 1: Mutagenic frequency of viable mutants in M_2 generation of ADT (R) 47 Rice

Viable mutants	Gamma rays (Gy)			EMS (mM)		
	200	250	300	100	120	140
Total of no. of plants isolated	39	24	62	9	11	12
Seedlings examined	7333	7357	7014	6728	7135	7631
Mutagenic frequency (%)	0.53	0.33	0.88	0.13	0.15	0.16

Grain type mutants

Seed size and seed shape mutants were found in both gamma and EMS treated populations of the genotype ADT (R) 47. Among the different categories, 28 mutants had long slender grains, 12 had medium slender grains, 14 had beaks in the grain, five were of awned type. The mutants were classified based on changes in size. Long, medium, bold, grain with beaks as well as awned grain mutants were also noticed in different treatments. Of the 59 mutants, only three were observed in EMS treatments and the rest were isolated in gamma irradiation. Grain type mutants were in greater proportion in gamma ray treatments than in EMS treatments. This might be due to the genotypic effect which showed greater sensitivity to irradiation treatments. Mutants with alterations in grain size were also reported by Kaul *et al.* (1980); Shobharani *et al.* (2004); Patnaik *et al.* (2006); Bhat *et al.* (2007) and Chakravarti *et al.* (2012). A wide range (15 types) of viable macro-mutations was observed by Chakravarti *et al.* (2012) *i.e.,* 10 types in Kala Namak and 12 types in Badshah Bhog. Among these, semi-dwarf, early maturing, increased tillering and grain yield mutant were more frequent. The frequency of different mutants over genotypes were 135 (semi-dwarf), 29 (early maturing), 24 (increased tillering), 9 (bushy and stiff stem), 12 (broad and narrow leaf), 4 (pigmented node), 13 (short slender grain), 38 (straw colour grain), 11 (change in grain size) and 29 (high yielding). The differences observed in the spectra of morphological mutations were more of quantitative nature rather than qualitative. Mutability was found to be high (43.1%) for plant height followed by grain mutants (19.80%), early maturity (9.3%) and increased tillering (7.7%). The more frequent induction of certain mutations might be attributed to the fact that the genes for these traits were probably relatively more vulnerable to mutagenic treatments.

Table 2: Mutagenic effectiveness and efficiency based on viable mutations in M_2 generation of ADT (R) 47 rice

Mutagen	% seedling height in M_1(I)	% survival reduction in M_1 (L)	% pollen sterility in M_1 (S)	Mutation frequency (M)	Effectiveness	Efficiency		
					(M x100) / Gy or cxt	(M x 100) / I	(M x100) / L	(M x 100)/ S
Gamma rays (Dosage)								
200Gy	89.00	41.94	18.07	0.53	0.27	0.60	1.27	2.94
250Gy	79.73	56.77	22.16	0.33	0.13	0.41	0.57	1.47
300Gy	73.54	73.76	28.58	0.88	0.29	1.20	1.20	3.09
				1.74	0.69	2.21	3.04	7.51
EMS (Concentration)								
100 mM	86.67	35.76	13.45	0.13	0.022	0.15	0.37	1.00
120 mM	81.67	52.89	16.03	0.15	0.021	0.19	0.29	0.96
140 mM	78.33	62.10	22.23	0.16	0.019	0.20	0.25	0.71
				0.45	0.062	0.54	0.92	2.66

Mutagenic frequency, effectiveness and efficiency based on viable mutations

The mutagenic frequency of gamma rays to induce viable mutants was highest at 300Gy (0.88%) followed by 0.53% and 0.33% at 200Gy and 250Gy doses (Table 1 & 2). The chemical mutagen EMS exhibited highest mutagenic frequency of 0.16% at 140mM concentration. The lower concentrations of 120mM and 100mM recorded 0.15% and 0.13% mutagenic frequency. The effectiveness of gamma rays in inducing morphological and viable mutations ranged between 0.13 % (250Gy) and 0.29 % (300Gy). The effectiveness of EMS in inducing viable mutations was in the range of 0.019 % (140mM) to 0.022 % (100mM). The physical mutagen *viz.,* gamma irradiation displayed higher effectiveness (0.69) when compared to EMS (0.062). In gamma irradiated populations, based on injury, the mutagenic efficiency ranged between 0.41 % (250Gy) and 1.20 % (300Gy). In terms of lethality, efficiency of gamma rays in inducing viable mutations was in the range of 0.57 % (250Gy) to 1.27 % (200Gy). Its efficiency to induce viable mutations based on sterility ranged from 1.47 % (250Gy) to 3.09 % (300Gy). Highest efficiency of gamma rays in inducing viable mutants on the basis of injury and sterility was observed at 300Gy and lethality was noticed at 200Gy. The efficiency of EMS in inducing viable mutations based on injury, ranged between 0.15 % (120mM) and 0.20 % (140mM). Based on lethality, the values ranged from 0.25 % (140mM) to 0.37 % (100mM). On the basis of sterility, efficiency values ranged from 0.71 % (140mM) to 1.00 % (100mM). Maximum efficiency of EMS in inducing viable mutants on the basis of lethality and sterility was observed at 100mM concentration. Highest efficiency of gamma rays in inducing viable mutants on the basis of injury (1.20%) and sterility (3.09%) was observed at 300Gy and lethality (1.27%) was noticed at 200Gy. Likewise in EMS, at 100mM concentration, viable mutants were induced on the basis of lethality (0.37) and sterility (1.00%).

The induction of early flowering, dwarf and semi-dwarf mutants could be useful in recombination breeding program indirectly for developing high yielding lines, while high yielding mutants could be of immediate use directly as varieties. Further, these mutants can also be used to identify genes responsible for different developmental stages of plants.

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PHOSPHATE SOLUBILISING ACTIVITY OF *SYNCEPHALASTRUM* SP. ISOLATED FROM IRON MINE WASTE SOIL OF BARBIL, KEONJHAR

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ABSTRACT

Phosphate solubilising efficacy of microorganisms is influenced greatly by medium composition especially the N and C sources and pH of the medium used. The test organism Syncephalastrum was isolated from the iron mine waste soil of Barbil in Keonjhar district of Odisha during February 2013-July 2015. In the present investigation, phosphatase activity of the isolate Syncephalastrum sp., having phylogenetic relationship between zygomycetes and ascomycetes varied greatly when Pikovskaya's medium was supplemented with carbon sources(sucrose, dextrose, starch, manitol, sorbitol and fructose) at varied concentration(0.5,1, 1.5 and 2%) separately. Optimal activity for both acid and alkaline phosphatase was observed at 2% dextrose followed by sucrose and maltose in the medium, at 29^{0}C after 7 days of incubation. While different nitrogen sources (ammonium nitrate, sodium nitrate, calcium nitrate, Yeast-extract, potassium nitrate and peptone) at varied concentration (0.1, 0.3, 0.5 and 0.7%) were used separately to study their effect on phosphatase activity, it was observed that the isolate showed optimum solubilising activity at 0.7% ammonium sulphate followed by 0.1% sodium nitrate and 0.1% Yeast-extract at 29^{0}C after 7 days of incubation. The study underscores the importance of Syncephalastrum sp. as a potential biofertilizer and could be exploited as bio-inoculants in reclamation of mine waste soil.

Key words: S*yncephalastrum* sp, mine waste soil, phosphatase activity, RSM

INTRODUCTION

Soil microbes have a big impact on plant productivity. In soil, special group of microorganisms are known as plant growth promoting rhizobacteria (PGPR) that colonize in plant roots and promote growth of plants (Lucy *et al.* 2004). These organisms enhance crop productivity by increasing soil fertility in different ways such as nitrogen fixation, increasing supply of nutrients (phosphorus, sulphur, iron, copper etc.), producing plant hormones, controlling various fungal and bacterial diseases. Next to nitrogen, phosphorus plays an important role in nutrition of plants such as, photosynthesis, energy transfer, signal transduction, macromolecular biosynthesis and respiration (Khan *et al.* 2010). Phosphate is present in soil in insoluble forms and it can be made available by different biogeochemical cycles through various group of bacteria and fungi (Harris *et al.* 2006; Perez *et al.* 2007). The concentration of bioavailable phosphate in soil is very low reaching the level of 1.0g - 1kg soil (Ezawa *et al.* 2002) in comparison, in case of mining soil available phosphate is also much lower than the standard value. This low level of phosphate in mining soil could be attributable to low microbial interaction in these environments, due to low availability of inorganic carbon and other nutrients. High temperature, low pH and presence of heavy amount of iron pyrite regulate not only microbial diversity also microbial activity (Arumanayagam and Arunmani 2014). In view of the above, the fungal isolate *Syncephalstrum* sp. isolated from mining soil of Barbil, Keonjhar, Odisha, India was subjected for studying its phosphate solubilising activities in order to explore its use as a phosphate solubiliser in these mine soil.

MATERIALS AND METHODS

Study site and sample collection

Barbil a municipal township in the Keonjhar district of the state of Odisha, India, lies between 22^0.10' N latitude, 85^0.37' E longitude and 477 metre altitude. The surrounding region of Barbil has the fifth largest deposit of iron ore and manganese ore in the world. A total of 10 soil samples were collected

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from different sites of Barbil from explored and unexplored mining area (Forest area) following the method adopted by Baruah and Barthakur (1998) during Feb 2013 – July 2015. All the soil samples were subjected to physico-chemical analysis (Parida *et al.* 2014).

Isolation and identification of source organism

The fungus (Isolate DB34) was isolated from mining soil of Barbil Keonjhar, Odisha through standard viable culture technique on Potato dextrose agar medium. Based on colony morphology, growth characters and microscopic features the isolate was identified as *Syncephalstrum* sp. [National Centre for Fungal Taxonomy (NCFT), New Delhi]. Molecular identification of the isolate was carried out through 18s rDNA sequencing. Evolutionary analyses were conducted by MEGA5 (Tamura *et al.* 2011). Total 22 sp of Zygomycotina and Ascomycotina with *Syncephalstrum* sp. (DB-34) were taken into account for preparation of the phylogenetic tree following the method of maximum parsimony. The assembled sequence of ITS region of 18S RNA of the isolate was submitted to NCBI, having accession number, KU 343134.

Screening for phosphate solubilizing activities

Phosphate solubilization activity of the isolates was tested on Pikovskaya's agar (PA) plate containing tricalcium phosphate as insoluble phosphate source. Pikovskaya's agar plates were prepared as per manufacturer's (Yeast extract 0.500 gm/L, Dextrose 10 gm/L, Calcium phosphate 5 gm/L, Ammonium sulphate 0.5 gm/L, Potassium chloride 0.2 gm/L, Magnesium sulphate 0.1 gm/L, Manganese sulphate 0.0001 gm/L, Ferrous sulphate 0.0001 gm/L, agar 15gm/L) instructions. Freshly grown culture of the isolate was spot inoculated on PA plates by the help of a sterile needle. Inoculated plates were incubated at 30^0 C for 72 hrs. Formation of a halo zone around the colony is indicative of positive phosphatase activity. Solubilizing index (SI) of the isolate was determined by using the formula of Arun and Sridhar (2005) as follows:

$$SI = \frac{\text{Halo zone + Colony diameter}}{\text{Colony diameter}}$$

Assay for phosphatase activity of the isolate

The isolate was cultured in Pikovskaya's broth, at 28 ± 2^0C, for 7 days. After the incubation period, the culture was filtered by Whatman filter paper. The filtrate was centrifuged at 1000 rpm for 10min and the supernatant was used for phosphatase assay, spectrophotometrically using p-nitrophenyl phosphate (p-NPP) as substrate. The p-nitrophenol was used to make standard curve for determination of phosphatase activity. Enzyme activity was indicated by an increase in the absorbance of light at λ = 410 nm. Phosphatase activity was transformed to absolute units using a standard curve based on increasing concentrations of p-nitrophenol (Berman *et al.,* 1990). The presence of acid phosphatase and alkaline phosphatase were determined as: 0.4 ml filtrate was incubated for 20 min with 0.8 ml of p-NPP at 70^0C for alkaline phosphatase, adding 0.4 ml of 0.05M tris-HCl buffer (pH 9.5) and at 65^0C for acid phosphatase in 0.25M sodium acetate buffer (pH 6.0). Reaction was terminated by adding 2 ml of 1N of NaOH to measure the freely dissolved phosphatase activity (acid and alkaline). The activity was expressed in n mol p-NP released/ml/ 20 min. (Lo pez *et al.* 2006).

Condition optimization for phosphatase activity of the Isolate

Incubation period: The phosphatase activity by the isolate was studied at different incubation period. Isolate was cultured at 29^0C in the medium as described above. The phosphate solubilizing activity was assayed at different time intervals i.e. 3, 4, 5, 6, 7, 8, 9,10,11,12 and 13 days, following the procedure described earlier.

Temperature: The isolate was cultured on Pikovskaya's medium at different temperatures (15^0C, 22^0C, 29^0C, 36^0C, 43^0C and 50^0C). The phosphatase activity was assayed after 7 days of incubation following the procedure as described earlier.

pH: The phosphatase activity was determined at different pH by following the method as described earlier, after 7 days of incubation at 29^0C by growing the isolate in Pikovskaya's medium at different pH (4, 5, 6, 7, 8, 9, 10, 11 and 12) separately.

*Carbon sources***:** An experiment was designed to study the effect of different carbon sources on phosphatase activity of the isolate. Briefly, Pikovskaya's medium was supplemented with different carbon sources (sucrose, dextrose, starch, manitol, sorbitol and fructose) at varied concentration (1, 1.5 and 2%) separately. The isolate was incubated in the carbon supplemented medium at 29^{0}C for 7 days and the phosphatase activity was studied as described previously.

***Nitrogen sources*:** The Pikovskaya's medium was supplemented with different nitrogen sources (ammonium nitrate, ammonium sulphate, sodium nitrate, calcium nitrate, Yeast, potassium nitrate and peptone) with varied concentrations (0.1, 0.3, 0.5 and 0.7%) separately. The isolate was incubated at 29^{0}C for 7 days and the phosphatase activity was studied.

Optimization of incubation period, temperature and pH using Response Surface Methodology (RSM):

RSM is a statistical tool by which effect of different factors on microbial production can be summarized. Here, the effect of different factors (Incubation period, pH and Temperature) on phosphate solubilising activity of the isolate was optimized by statistical modelling and it was carried out by using Central Composite Design (CCD) (Stat-Ease, version 8 of Design-Expert).

Phosphatase (Y, n mol p-NP released/ml/ 20 min) was used as the dependent output variable. The three independent factors were investigated at five different coded levels (-1.682, -1, 0, +1,+1.682) (Table 2). A 2^3 factorial Central Composite Experimental Design, with six axial points and six replications at the centre points leading to a total number of 20 experiments was employed. Equation-1: Y=b0+b1X1+b2X2 +b3X3 +b11X21 +b22 X22 +b33 X23 +b12 X1 X2 +b23 X2X3 +b13 X1X3. Whereas, Y is the predicted response (Phosphatase) of X1, X2 and X3 are the coded levels of the independent variables, b0 intercept, b1, b2 and b3 the linear coefficients, b11, b22 and b33 are the squared coefficient and b12, b13 and b23 are the interaction coefficients. Statistical significance of the model equation was determined by Fisher's test value and the production of variance explained by the model was given by the multiple coefficient of determination, R squared (R^2) (Manikandan and Viruthagiri, 2010; Jena and Rath, 2013).

Statistical analysis

One way ANOVA was performed using SPSS (version 16) software, to test whether the mean sensory scores of the effect of carbon and nitrogen sources on phosphatase activity differed significantly from each other or not.

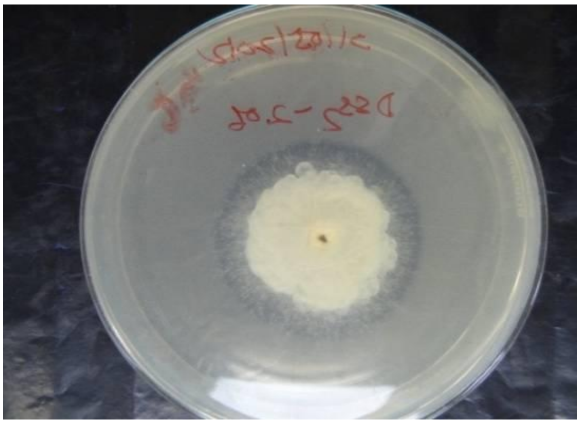
RESULTS AND DISCUSSION

Identification of the isolate

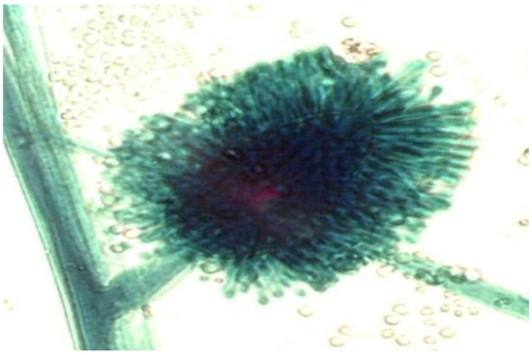
Primarily, the isolate was identified by studying their colony morphology on Potato Dextrose Agar medium and microscopic analysis of reproductive structure. The growth was very fast; initially the colony appeared whitish and later on light grey, cottony to fluffy, finally becoming dark grey with the development of sporangia. Sporangiophores are erect, stolon-like, often producing adventitious rhizoids, and show sympodial branching (racemose branching) producing curved lateral branches. The main stalk and branches form terminal, globose to ovoid vesicles which bear finger-like merosporangia directly over their entire surface (Fig. 1). The phylogentic relation of the isolate with zygomycotina and ascomycotina was evaluated by using the Maximum Parsimony method. The consistency index was observed to be 0.839437 (0.648148), with retention index 0.831858 (0.831858), and composite index 0.698292 (0.539167) for all sites and parsimony-informative sites. The MP tree was obtained using the Close-Neighbour-Interchange algorithm (Nei and Kumar, 2000). The analysis involved 26 nucleotide sequences (Fig. 2).

Table 1: Range of the values for the Response Surface Methodology of phosphatase activity

Independent variables	Coded levels				
	-1.682(-α)	-1	0	+1	+1.682 (+α)
Incubation Period (day)	1.9	5	7	10	12.04
Incubation Temperature (^{o}C)	5.5	15	29	43	52.5
pH	3.6	5	7	9	10.36



(a)



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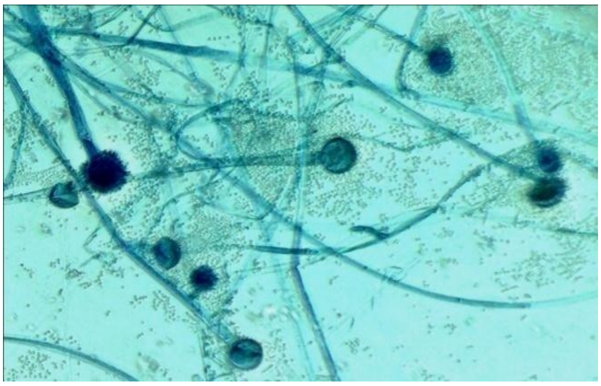


(c)

Fig. 1: Morphological identification of the isolates: (a) colony morphology and phosphate solubilisation (presence of halozone around the colony) on Pikovaskya's agar plate, (b) & (c) reproductive structure: sporangiophore with meroporangia [cover glass mount with lactophenol cotton blue staining (10X40x Magnification)

Effect of physical parameters (incubation period, temperature, pH) on phosphatase activity

The phosphatise activity of the isolate was assayed using P-NPP as the substrate following the method of Berman *et al.* (1990) and Lo pez *et al.* (2006). While studying the effect of incubation period on phosphate solubilising activity of the isolate, it was observed that the isolate showed maximum phosphatase activity after 7 days of incubation at 29^{0}C (12.4±0.3 and 9.22±0.5 n mol p-nitrophenol/mi/20 min of acid and alkaline phosphatase respectively). Surprisingly, while comparing the dry biomass with respect to phosphatase activity, it was found that the isolate did not grow after 7 days of incubation. Hence, all experiments were further conducted after 7days of incubation. On the other hand, the production of acid phosphatase was found to be more than alkaline phosphatase. The pH was reduced with the days of incubation from 4.18 to 3.4 (Fig. 3).

The effect of temperature on phosphatase activity was studied on Pikovskaya's medium by incubating the culture flasks at different temperatures (15^{0}C, 22^{0}C, 29^{0}C, 36^{0}C, 43^{0}C, 50^{0}C) after 7 days of incubation. The maximum phosphatase activity was observed to be 10.68±0.9 and 8.5±0.4 n mol p-nitrophenol/ml/20min for both acid and alkaline phosphatase respectively, at 29^{0}C. A decrease in both alkaline and acid phosphatase was reported at higher temperatures. The pH and dry biomass was found to be 4.26 and 0.43 g respectively at 29^{0}C (Table 2 and Fig. 3).

When the phosphate solubilizing activity of the isolate was studied at different pH (pH 4-12), maximum activity was observed at pH 7 (10.07±0.4 and 8.62±1 n mol p-nitrophenol/ml/20min of acid and alkaline phosphatase respectively) and a degree in reduction in activity was recorded at alkaline pH range. The pH was changed 4.26 from pH 7 after incubation and the dry biomass was observed to be 0.47 g.

Optimization of incubation period, temperature and pH by using RSM

The results of Central Composite Design (CCD) experiments were taken to study the effect of three independent variables (incubation period, temperature and pH). The actual phosphate solubilising activity of the isolate obtained in the experiments and the yields predicted by the model equation (1) in Table 2. The ANOVA result of quadratic regression model for Y of phosphate solubilizing activity is described in Table 3, where, Y is the phosphate

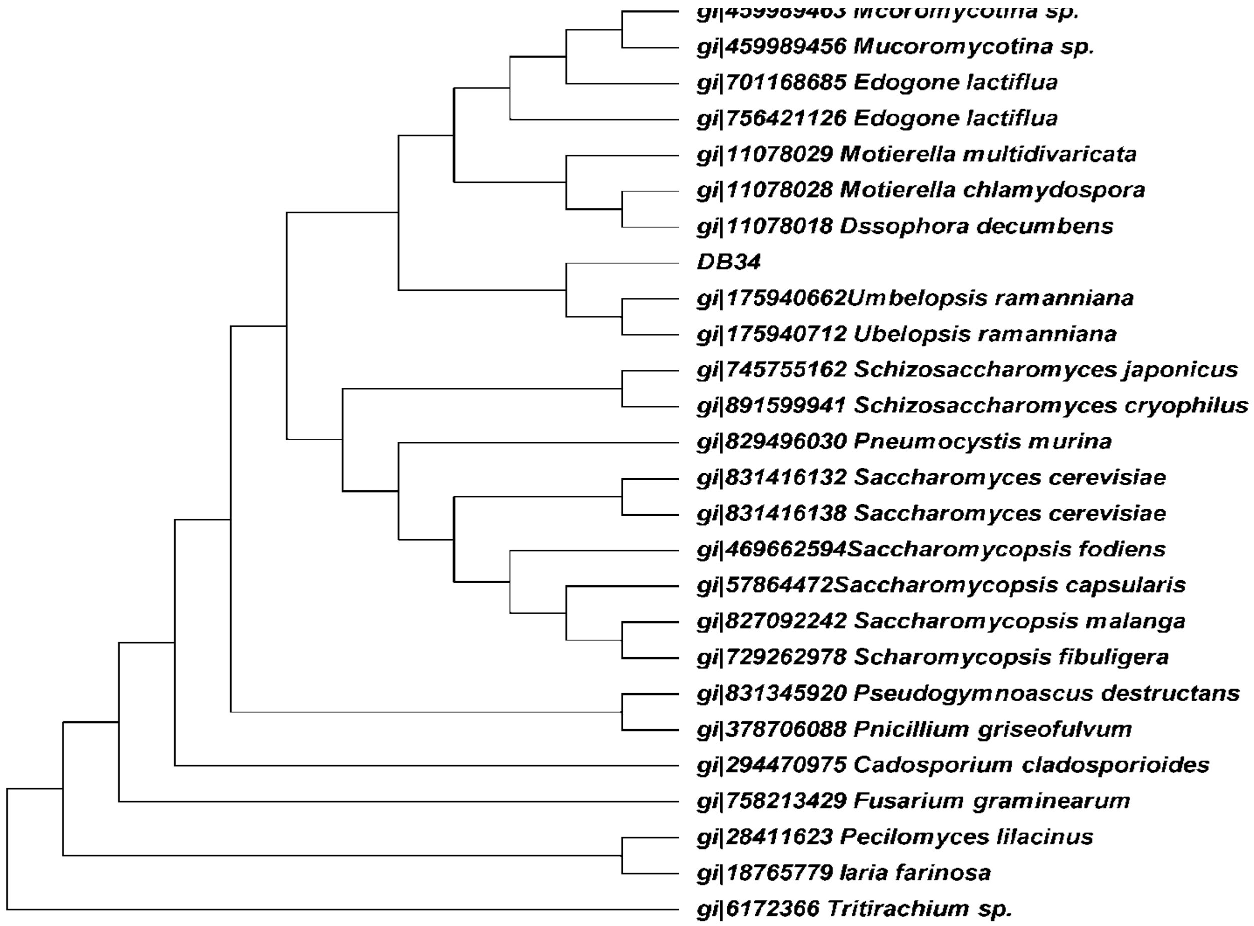
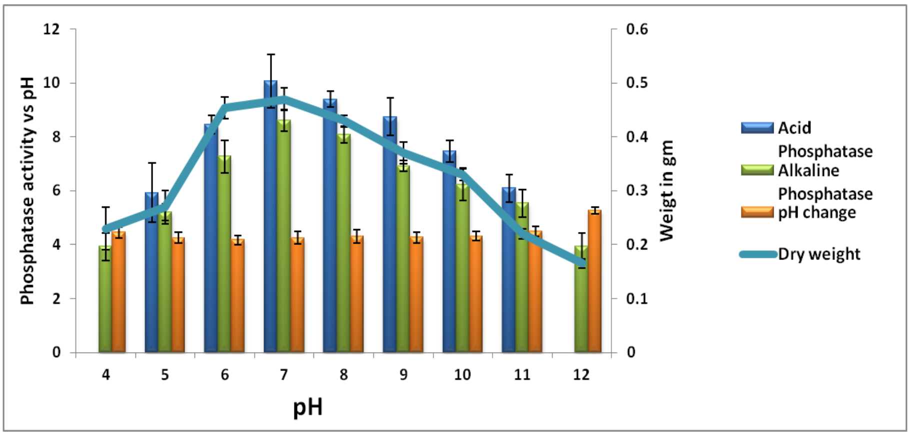


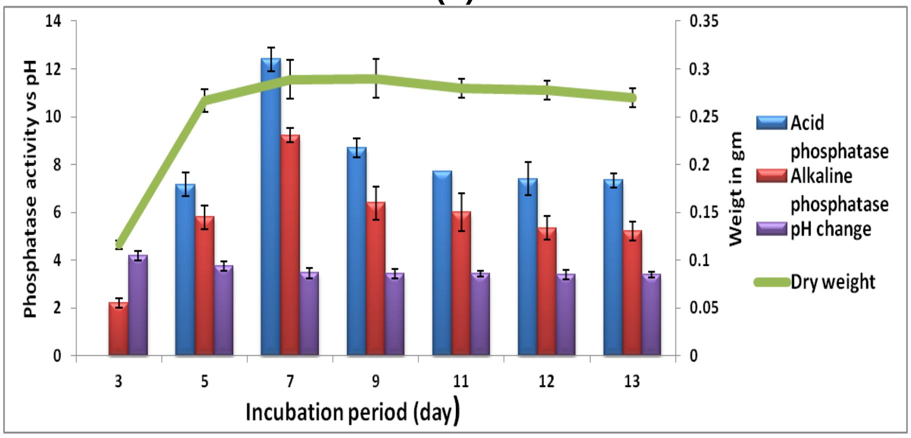
Fig. 2: Phylogenetic tree generated by maximum Parsimony showing evolutionary relationship of *Syncephalastrum* (DB34) along with 25 closely related species of of Zygomycotina and Ascomycotina sp.

Table 2: Experimental design and result of CCD of response methodology of phosphatase activity (n mol p-nitrophenol/ml/20mm)

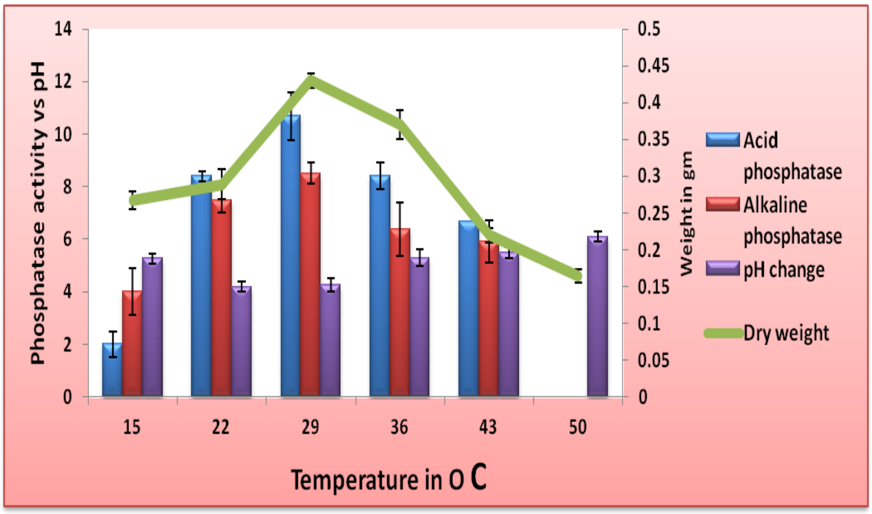
Standard order	A: Incubation period (day)	B: Temperature (^{0}C)	C: pH	Phosphatase activity	
				Experimental value	Predicted value
1	7	29	3.65	2	0.58
2	7	5.4	7	4	3.19
3	10	15	5	3	4.19
4	4	15	9	4	6.8
5	7	29	7	5	1.43
6	4	43	9	6	4.03
7	7	29	7	8	8.04
8	1.9	29	7	10	10.64
9	7	29	7	4	5.86
10	10	43	5	11	10.24
11	7	29	7	0	4.25
12	10	15	9	16	12.85
13	7	29	7	0	-1.42
14	4	43	5	0	2.52
15	7	29	7	20	19.8
16	7	52.5	7	20	19.8
17	7	29	10.3	20	19.8
18	12.04	29	7	20	19.8
19	4	15	5	20	19.8
20	10	43	9	19	19.8



(A)



(B)



(C)

Fig. 3: Effect of different environmental conditions on phosphatase activity (n mol p-nitrophenol/ml/20min) of the isolate *Syncephalastrum*: (A) pH; (B) Incubation period; (C) Temperature

solubilizing activity. The coefficient of determination (R2) for phosphate solubilizing activity was found to be 0.94, indicating that the statistical model can explain 94% of variability in the response.

The R square value ranged between 0 and 1, the closer the R^2 to 1.0, the stronger is the model and the better it predicts the response (Ray *et al.* 2010). In adequate precision of 11.324 for phosphate solubilizing activity was calculated. The lack of fit F-value of 83.3 means that lack of fit is significant. The model F-value is 17.56, prob >F (< 0.05 indicated that the model terms are significant) indicating that the model is significant for phosphate solubilizing activity. The predicted R^2 0.5518 are in reasonable concurrences with the adjusted R-Squared 0.8870 respectively. This indicated a good accord between the experimental and predicted value for phosphate solubilizing activity of the isolate *Syncephalastrum*. Response surface was generated by plotting the response of phosphate solubilizing activity on the Z axis against any two independent variables while keeping other independent variable at zero level. The response surface 3D curves and counter plots (Fig. 4) explained the interactions of independent variables and determine the optimum phosphate solubilizing activity of dependent variable. The maximum orientation of the principal axes of the response surface plot between incubation period and temperature, pH and temperature, temperature and incubation period, indicated that the mutual interactions between independent variables had a significant effect on dependent variable. In the present study the three response surface plots for phosphate solubilizing activity proved to be significant i.e. incubation period with temperature, incubation period with pH and temperature with pH for phosphate solubilizing activity in the medium by the isolate. A linear increase of phosphate solubilizing activity was found with the increase of incubation period up to 7days thereafter, it was declined. A similar result was found in case of pH and temperature for phosphate solubilizing activity. Thus, temperature at 29^{0}C and pH (7.0) were adequate for attaining maximum phosphate solubilizing activity (Fan *et al.* 2011). The experimental values were found to be very close to the predicted values and hence, the model was successfully validated and also reflected the accuracy and applicability of RSM to optimize the process for enzyme production in submerged fermentation (Table 2 and 3) Validation of the statistical model and regression equation was performed by taking [X1(7 days), X2 (29^{0}C), X3 (pH 7)] in the experiments.

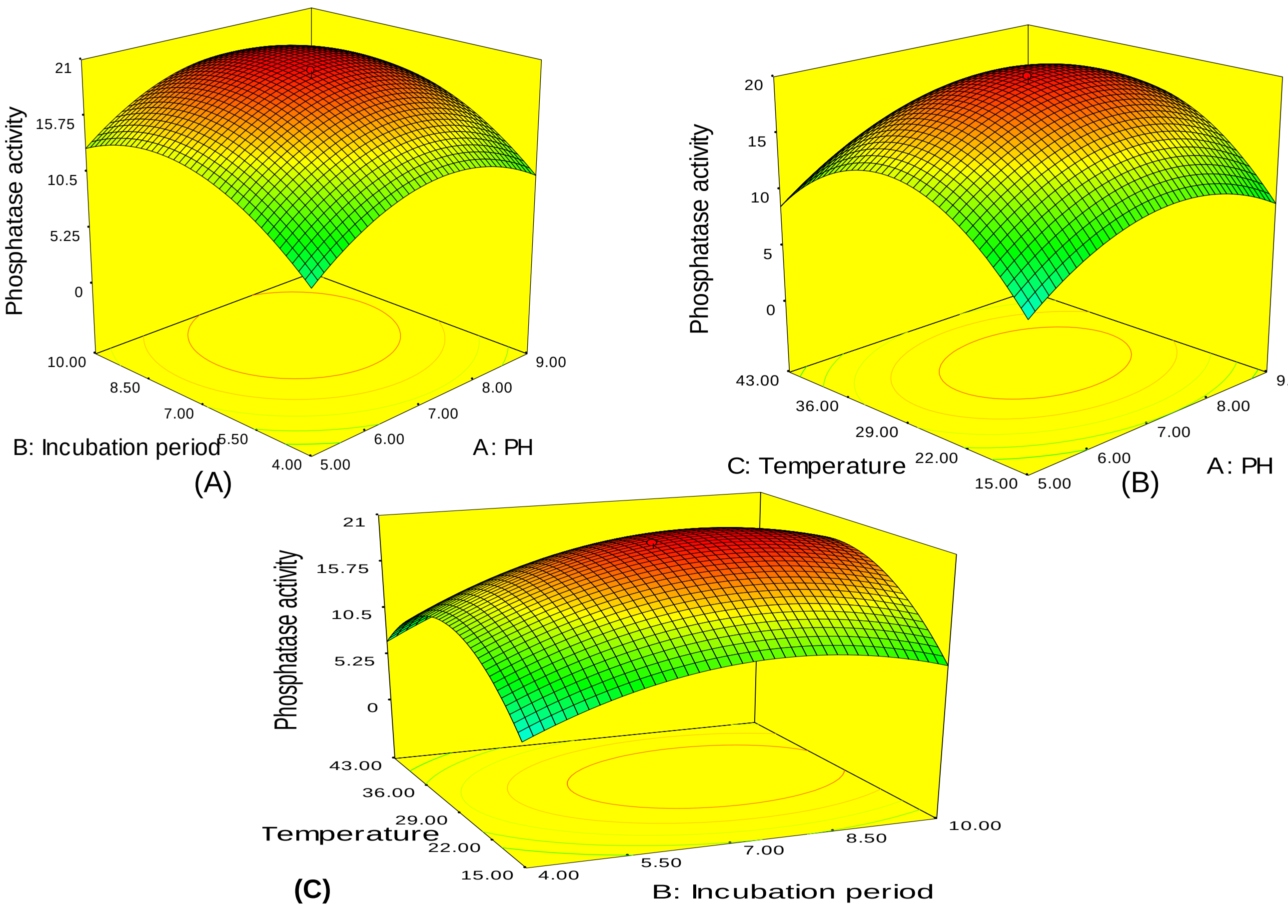


Fig. 4: Statistical optimization of Phosphatase activity (n mol p-nitrophenol/ml/20min) of the isolate *Syncephalastrum* using RSM: (A) pH and Incubation period; (B) pH and Temperature; (C) Temperature and Incubation period

Table 3: ANOVA for phosphates activity (n mol p-nitrophenol/ml/20mm) in batch culture of the isolate

Sources	Sum of squares	Degree of freedom	Mean square	F- value	p- value
Model	1110.548	9	123.3942	17.56447	< 0.0001
Lack of Fit	69.41885	5	13.88377	83.30262	< 0.0001
Pure Error	0.833333	5	0.166667		
Total	1.234401	19			

R-Squared 0.9405; Adj R-Squared 0.8870; Pred R-Squared 0.5518; Adeq Precision 11.324

Effect of carbon and nitrogen on phosphatase activity of the isolate

The phosphatase activity of the test isolate varied greatly with respect to carbon sources used in the experiment. The isolate showed optimum solubilizing activity at 2% dextrose followed by sucrose 2% and maltose 2% at 29^{0}C after 7 days of incubation. The activity at 2% dextrose was reported to be 23.65±0.32 and11.33±0.08 n mol p-nitrophenol/ml/20 min of acid and alkaline phosphate respectively. The pH changed from neutral to 4.51 after 7 days of incubation and the dry mass was 1.8 g (Fig. 5).

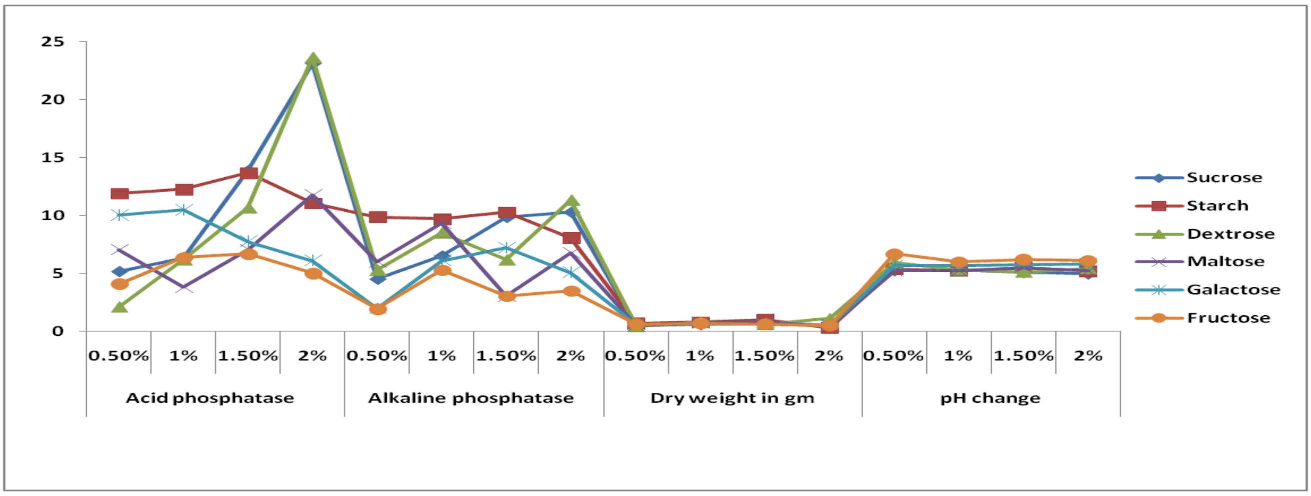


Fig. 5: Effect of different carbon sources on phosphatase activity (n mol p-nitrophenol /ml /20min) of the isoalte

It was observed that the isolate showed optimum solubilizing activity at 0.7% ammonium sulphate. It was found to be followed by 0.1% sodium nitrate and 0.1% yeast extract at 29^{0}C after 7 days of incubation. The activity at 0.7% ammonium sulphate was reported as 23.28±2 and 4.78±0.7 n mol p-nitrophenol/ml/20 min of acid and alkaline phosphatise, respectively. However, the pH changed from neutral to acidic 5.45 after 7 days of incubation with a dry mass was 0.33 g (Fig. 6).

Statistical modeling of different carbon and nitrogen sources on phosphatase activity in flask culture

The analysis of ANOVA showed that all the six carbon sources differed significantly from each other. Post-hoc analysis revealed that 2% dextrose followed by sucrose, and maltose have significant effect on phosphate solubilizing activity production ($P< 0.05$; Tukey's LSD). Further, all other carbon sources were less significantly differred from each other. While, the mean scores of six nitrogen sources were subjected to One-way ANOVA, the Post-hoc analysis revealed that, only three nitrogen sources i.e ammonium nitrate at 0.7% followed by peptone (0.1%), yeast (0.5) have highly significant effect on phosphate solubilizing activity ($P<0.05$; Tukey's LSD) of the test fungus.

In the present investigation, an attempt was made to study the effect of incubation period, incubation temperature, pH, carbon and nitrogen sources on phosphate solubilizing

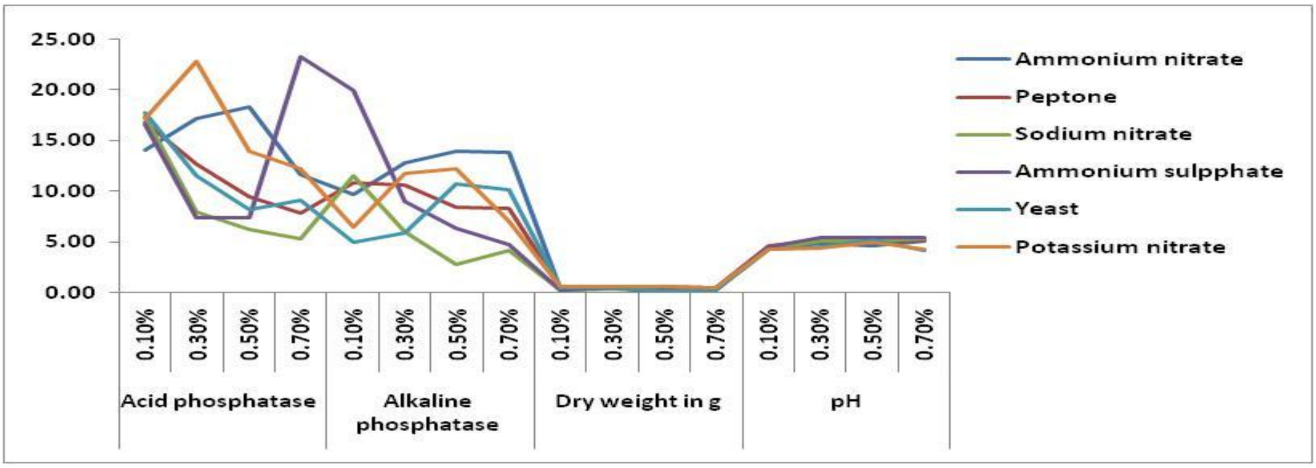


Fig. 6: Effect of various nitrogen sources on phosphatase activity (n mol p-nitrophenol /ml /20min)

activity of the isolate *Syncephalastrum* sp isolated from mining soil of Barbil, Keonjhar. Barbil is an industrialized area with mining activities throughout the year. Parida *et al.* (2014) reported that moisture content of explored mining soil was comparatively lower and it varied from 5.8 to 8.6. But, highest percentage of moisture (13.4%) was recorded from unexplored area or vegetation area. Soil temperature of the studied area varied from 34 – 44^0C. The percentage of organic carbon varied from 0.14 – 1.18 among the sites. Salinity of the soil samples was found to be even. Phosphorus content of the soil was observed to be very less, varied from 2.4 to 4.4 kg ha^{-1}. In contrast potassium content was found to be highest in unexplored area (351 kg ha^{-1}), lowest (50 kg ha^{-1}) of the explored area (Parida *et al.* 2014). Observation of above soil properties idicated that, the isolate have the ability to tolerate different adverse condition during their life process.

The phosphatase activity of the isolate, *Syncephalastrum* sp. was in a wide range of pH (4-12). But maximum phosphatase activity was reported at neutral pH. Our findings are in agreement with Oyeleke and Oduwole (2009) who stated that the most microbial enzymes function between a pH range of 6 and 8. Further, the retention of phosphatase activity by *Syncephalastrum* at a wide range of pH, suggested that it is a potential isolate that could be exploited for biofertilizer in mining soil environment. At all the stages, the isolate produced more acidic phosphatase in comparison to alkaline phosphatase. Jena and Rath (2013) reported that decrease of the pH in growth medium was due to the production of different titrable acid and could be attributable to the acidic phosphatase activity by the species as observed here. Further, it could be due to the production of different organic acids in the medium, as organic acids play a key role to solubilizing both inorganic and organic insoluble phosphates (Henri *et al.* 2008).

The phosphatase activity of the isolate was within 3 to 13 days of incubation. The isolate also showed phosphatase activity at a wide range of temperature (15-50^0C). It could be attributable to the variation of soil temperature 10-50^0C of the study site, and the viability of the isolate at this wide temperature variation. However, the optimal activity was reported on 7^{th} day of incubation at 29^0 C. Phosphate solubilizing efficacy of microorganisms is influenced greatly by medium composition, especially the N and C sources, and the pH of the medium used (Mehta and Nautiyal, 2001, Pradhan and Sukla, 2005). Maximum phosphatase activity of the isolate was observed while the medium was supplemented with dextrose, as dextrose is the simplest carbon source and used by fungi for growth and development. The isolate, *Syncephalastrum* sp. showed maximum phosphate solubilizing activity with ammonium sulphate and dextrose in the medium as N and C sources respectively. Furthermore, it could be due to the production of inorganic acid by proton exchange mechanism in presence of NH_4^+ in the medium that accelerated phosphate solubilization (Sridevi *et al.* 2007) as NH_4^+ and NO_3^- are absorbed by heterotrophic organisms as the nitrogen sources.

It is indicated that, our isolate *Syncephalastrum* sp., is a rarely isolated soil fungus and this species is phylogeneticaly linked Zygomycetes and Ascomycetes. Interestingly, it was isolated from a mining soil rich with iron and showed phosphatase activity during the investigation. The isolate could retain its phosphate solubilizing activity even at high temperature and low pH hence; it could be exploited biotechnologically for their possible development as a biofertilizer for use in agriculture of mining soil. However, studies are essential to examine the toxicity of the strain towards plants and animals and their crop specificity (if any) before its use in agriculture.

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EFFECT OF AZOLLA AS GREEN MANURE ON SOIL PROPERTIES AND GRAIN YIELD OF RICE IN ACID SOIL OF JHARKHAND

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ABSTRACT

Rice (Oryza sativa) was grown during Kharif season as a test crop to study the effect of Azolla sp. Azolla caroliniana on the grain yield, nutrient uptake and some soil properties at experimental plot of Birsa Agricultural University, Ranchi having nine treatments namely control, Azolla as green manure, Azolla green manure (GM) + intercrops of Azolla (I), Azolla (GM)+50% NPK, Azolla (GM)+75% NPK, Azolla (GM) +100% NPK; 50% NPK; 75% NPK and 100% NPK. Initial soil pH was 5.7 where as OC was 3.8 g kg^{-1} with sandyloam textured soil. The results revealed that incorporation of Azolla into the soil increased grain yield of rice (7-31%) when either alone or with fertilizer. By the conjunctive use of Azolla as green manuring before transplanting and as intercrop increased grain yield of rice up to 16.3 per cent. The maximum grain yield (50.6 q ha^{-1}) was obtained with Azilla + 100% NPK that was statistically significantly superior to all the treaments. Bulk density and water holding capacity significantly improved by the application of Azolla eithe as green manuring or intercropping. Organic carbon, available N, P_2O_5, K_2O and NPK uptake were increased significantly by control. Incorporation of Azolla as green manure or as intercropping saved 50% inorganic fetilizer N in rice cultivation.

Key words: *Rice, Azolla caroliniana, green manure and intercropping.*

INTRODUCTION

Intensive crop production is the demand of time to feed the vast growing population of the country. This has created a pressure to use more chemical fertilizer. Use of chemical fertilizer injudiciously without organic manure create many soil health problems like low fertilizer use efficiency, poor soil physical condition, reduced water holding capacity, degraded rhizospharic properties, and low fertility as reported by (Awodun, 2008). Many other environmental problems are also being created. Farmers are using no or insufficient organic manures with the chemical fertilizers because they are habituated to use chemical fertilizers alone becuse they were getting higher yield. But by the continuous use of fertilizers they are not getting increasing trend of yield because of low fertilizer use efficiency. Imbalanced fertilizer use is also a problem as majority of farmers of the state use only urea or DAP without potassic fertilizer. All these factor resulting in the gradual declining in yield, multi-nutritional deficiency, deggradation of soil health and properties. The use of quality organic compost along with chemical fertilizer is must for the sustainability of soil productivity, fertility, health and quality of the natural resources as well as environment. The nutrient content however is low in compost but it help in may ways as acts like sponge to hold nutrients, water and air for the growth of plants (Swarup, 2010). It also works as an ameliorating agent for the soils chemical problems (Swarup and Gaunt 1998). Organic matter also affects the allelopathy of the soil and so controls the thermal effect also. Better aeration and proliferation of the roots are the other advantages. Now the question is how quality compost can be achieved in a sufficient quantity in time to meet the requirement. Use of fast growing and easily compostable organic substrates are needed in addition to the other organic sources of composts. Phytoplankton like Azolla might be useful to meet the need to some extent, because, it takes very less time for its growth and multiplication and it is easily compostable too. Azolla takes 2 to 3 days for doubling its mass trough multiplication and growth. There is a huge mass of surface water in the form of lake, ponds, ditches, dams, sewage, etc which can be utilize to grow it from where it can be harvested and utilized in crop production as the source of plant nutrients. Azolla grow and survive on the surface without disturbing flow of the water. It also kills the weeds by checking their growth by preventing penetration of sun light below. It contains macro, secondary and micronutrients that is important for quality rice production. The present investigation was, therefore conducted to study the response of rice to Azolla as green manure in acid soil.

MATERIALS AND METHODS

The experiment was conducted in *Kharif* season at the Research farm of Birsa Agricultural University, Ranchi. The test crop was medium land rice and variety - *Lalat*. There were nine treatments namely : T_1-Control; T_2- 20 t Azolla ha^{-1} as green manure (GM); T_3-Azolla (GM) + Intercrops of Azolla (I); T_4-50% NPK+ Azolla (GM); T_5-75% NPK + Azolla (GM); T_6-100% NPK+ Azolla (GM); T_7-50% NPK; T_8-75% NPK and T_9-100% NPK :: 80:40:20. Fertilizer N was applied in three splits, 50% at the time of transplanting as basal with full dose of phosphorus and potassium whereas the rest 50% nitrogen was applied at two different crop growth stages (25 and 50 days after transplanting of rice crop). Experiment was conducted with three replications in ranomised block design. Azolla containing 3.2% N, 0.9% P, 2.2% K, 0.4% Ca, 0.7% Mg, 0.1% Mn and 0.2% Fe was incorporated in the plot as green manure as per treatment. Collected post harvest soils were analyzed for bulk density, water holding capacity, pH (1:2.5 soil and water ratio) and organic carbon by adopting standard procedures (Jackson, 1973). Soil samples were analyzed for vailable nitrogen (Subbiah and Asija, 1956), phosphorus (Watanable and Olsen, 1965) and available K in 1N NH_4 OAc using flame photometer, Nitrogen in grain was analyzed by Kjeldahl method, potassium by flame photometer and phosphorus using vanado molybdate (Jackson, 1973) in diacid extracts.Initial soil sample of the experimental plot was analyzed properly after well processing, using standard methods. The soil of the experimental plot was sandy clay loam (sand 42.0 %, silt 26.0 % and clay 30.0 %), having pH 5.7, organic carbon 3.6 g kg^{-1} and bulk density 1.53 g/cc, available nitroge 218.5 kg ha^{-1}, phosphorus 19.1 kg ha^{-1} and potash 295.4 kg ha^{-1}.

RESULTS AND DISCUSSION

Grain yield

The maximum grain yield (50.6 q ha^{-1}) was observed with 100% NPK + Azolla (GM) which increased by 31.6% over control. Application of 75% NPK + Azolla (GM) also contributed significant increase in grain yield (47.0 q ha^{-1}) compared to 100% NPK alone (46.0 q ha^{-1}). It is observed that the 75% NPK+ Azolla (GM) gave the at par result with 100% NPK whereas, 50% NPK alone gave at par rasults with Azolla green manure + intercrop.

Table 1: Effect of Azolla as green manure on grain yield and nutrient uptake in rice

Treatments	Grain yield (q ha^{-1})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
T_1 - Control	38.5	36.9	11.7	14.33
T_2 – Azolla (GM)	41.2	40.5	13.2	16.9
	(7.0)	(9.7)	(12.6)	(12.7)
T_3 – Azolla (GM) + Azolla (I)	44.7	43.3	13.6	17.2
	(16.3)	(17.3)	(15.9)	(15.0)
T_4 - Azolla (GM) + 50% NPK	44.8	43.8	13.9	17.3
	(16.4)	(18.8)	(18.9)	(15.4)
T_5 - Azolla (GM) + 75% NPK	47.0	44.2	14.9	18.6
	(22.2)	(19.7)	(27.8)	(23.7)
T_6 - Azolla (GM) + 100% NPK	50.6	47.8	15.4	19.4
	(31.6)	(29.6)	(31.7)	(29.6)
T_7 - 50% NPK	43.5	42.1	13.5	17.3
	(13.1)	(14.0)	(15.7)	(15.3)
T_8 - 75% NPK	45.4	44.5	14.5	17.7
	(18.1)	(20.6)	(24.3)	(17.8)
T_9 - 100% NPK	46.0	45.3	15.0	17.8
	(19.6)	(22.9)	(27.9)	(18.4)
CD (5%)	3.5	5.6	2.1	2.6
CV	10.1	7.5	8.7	8.6

* *Green manuring (GM), Intercropping (I)*
* *Value in parenthesis indicates percent over control*

Application of 50% NPK + Azolla was more beneficial in terms of grain yield copared to 50% NPK alone. The increase in grain yield might be due to build up of soil organic carbon and more nitrogen through the integrated use of NPK and green manuring with Azolla. Brian *et al.* (2013) also reported similar result on integrated plant nutrient management in rice - rice cropping system.

Nutrient uptake

All the treatments except Azolla alone as well as 50% NPK application showed significant increase in nitrogen uptake compared to the control. This may be due to continuous application of Azolla in rice field (Ram *et al.,* 1994). Application of Azolla proved beneficial for P upteke as compared to the control but there were no significant difference between the treatments T_5 and T_6 of different combination of NPK either alone or along with the Azolla green manuring whereas, 100% NPK showed the higher uptake (15.4 kg ha^{-1}) of P (Table 1). Increase in nutrient uptake might be due to the better supply of nutrient to the crop during the growth period through the integrated use of Azolla with chemical fertilizer. Lakshaminarayana and Patiram (2006) also reported similar effects of integrated plant nutrients management.

Table 2: Effect of Azolla as green manure on post-harvest nutrient status and physical properties of the soil

Treatments	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	OC (g kg^{-1})	WHC (%)	Bulk density (g /cc)
T_1 - Control	218.5	18.1	291.2	3.9	1.53	1.53
T_2 – Azolla (GM)	239.4	19.5	309.1	5.1	1.43	1.43
	(9.6)	(7.7)	(6.2)	(30.8)	(7.0)	(7.0)
T_3 – Azolla (GM) + Azolla (I)	253.0	21.5	313.6	6.3	1.39	1.39
	(15.8)	(19.0)	(7.7)	(61.2)	(8.7)	(8.7)
T_4 - Azolla (GM) + 50% NPK	248.8	23.2	318.1	5.5	1.41	1.41
	(13.9)	(28.5)	(9.2)	(41.0)	(7.2)	(7.9)
T_5 - Azolla (GM) + 75% N PK	253.0	27.6	340.5	5.5	1.42	1.42
	(15.8)	(52.5)	(16.9)	(41.0)	(7.9)	(7.2)
T_6 - Azolla (GM) + 100% N PK	274.0	29.6	358.2	5.6	1.42	1.42
	(25.4)	(64.0)	(23.0)	(43.6)	(6.8)	(6.8)
T_7 - 50% NPK	239.4	22.1	309.1	4.2	1.51	1.51
	(9.6)	(22.2)	6.2)	(7.7)	(0.9)	(0.9)
T_8 - 75% NPK	246.7	25.2	336.0	4.2	1.50	1.50
	(12.9)	(39.7)	(15.4)	(7.7)	(1.7)	(1.7)
T_9 - 100% NPK	255.1	27.4	345.0	4.4	1.50	1.50
	(16.7)	(51.6)	(18.5)	(12.8)	(1.7)	(1.7)
CD (5%)	34.6	3.8	NS	1.5	5.3	NS
CV %	8.1	9.1	9.9	16..9	12.0	9.0

Status of available nutrients in soil

Available nitrogen in the post harvest soil ranged from 218.5 to 274.0 kg ha^{-1}. The highest available nitrogen (274.0 kg ha^{-1}) was recorded with 100% NPK along with Azolla green manuring (T_6). Azolla application through the combination of two methods in rice as green manuring, before transplanting and intercrop within a week of transplanting (T_3) in the same plot was found similar to the treatment 100% NPK (T_9) in restoring post harvest available nitrogen into the soil (Table 2). However, Azolla application before rice transplanting only did not contributed better to the post harvest available nitrogen in the soil but in conjunction with intercropping of Azolla found significantly superior in increasing available nitrogen compared to the control plot, It might be due to the fixation of atmospharic nitrogen by azolla in addition to the fertilizer N (Awodun, 2008 and Ram *et al.,* 1994).Use of two methods as green manuring and as intercrop of using Azolla (T_3) proved beneficial and significant result over control in respect of P content (Table 2). The highest available phosphorus (29.6 kg ha^{-1}) was recorded with 100% NPK + green manuring of

Azolla. Treatment T_6 increased 42 percent of available P content compared to the control. Application of 75% NPK with Azolla was at par with 100% NPK alone. Available p increased may be due to the biochemical changes to release different forms of P present in the soil (Sudadi and Sumarno, 2014). Available K content was not affected significant by various treatments.

Physical properties of soil

The build up of organic carbon in the soil was significant with Azolla applied either alone or in combination with chemical fertilizers over control. Fertilizer application without Azolla was not beneficial. Significantly highest value (6.6 g kg^{-1}) of organic carbon was recorded with the Azolla as green manure and Azolla as intercropping (T_3). This may be due to the better growth and easy decomposition of the green biomass of the tinny fern of Azolla (Awodun, 2008). Azolla as green manure markedly affected the water holding capacity in both the situation either with fertilizer or without fertilizer. The treatment Azolla (GM) + Azolla (I) was found highly significant in increasing the water holding capacity of the soil (29.7%). Green manuring of Azolla along with fertilizer also found beneficial. It may be due to the increased organic carbon content in soil and better root biomass of crop. Bulk density was also improved by the incorporation of Azolla as green manuring. The bulk density increased by 8.7% with T_3 over control. Fertilizer application alone did not show any change in the bulk density as compared to the control. Change in physical properties was due to the contribution of organic carbon built into the soil by the decomposed mass of Azolla that was applied during the rice cultivation. The result corroborates with the earlier findings of Ram *et al.* (1994).

From the results it may be concluded that incorporation of Azolla increased the yield of paddy in an acid Alfisol up to 16% without addition of any fertilizer. For better and sustainable yield, addition of chemical fertilizer along with Azolla was also very beneficial. Addition of Azolla in any form in rice field not only increased the paddy yield but also maintained the soil health in terms of soil physical and chemical properties for sustainable yield.

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PRODUCTIVITY, NUTRIENT UPTAKE AND ECONOMICS OF WHEAT AS AFFECTED BY NUTRIENT OMISSIONS IN ALLUVIAL SOIL

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ABSTRACT

Field experiments were conducted with wheat (Triticum aestivum L. emend Fiorid & Paol) at four locations (Artoni, Panwari, Nanpur and Sahara) in Agra characterized by semi-arid climate in South-western plain zone of Agra region, (Uttar Pradesh) during rabi season of 2010-11 to investigate the effect of nutrient omissions on yield, uptake of nutrients and economics of the wheat crop. The results revealed that the maximum grain and straw yields of wheat were recorded with application of balanced use of fertilizers (NPKS) at all the sites. Significantly lower grain and straw yields were recorded in nitrogen omission plots as compared to other treatments. Nitrogen was the first nutrient limiting factor for yield followed by P, K and S and the reductions in grain yield due to N, P, K and S were 42, 10, 25 and 8%, respectively over balanced use of fertilizers (T_1). The N, P, K and S concentrations in grain and straw were significantly reduced in the respective nutrient in the reduction of P and K concentration in both grain and straw. The quality of produce in terms of protein content and yield improved with balanced fertilization and reduced with omission of nutrients, maximum being with N omission. The uptake of N, P, K and S significantly reduced in the respective omission treatments and reductions were higher in the N omission. The balanced use of nutrients led to maximum profit to the farmers and minimum in N omission.

Keywords: Balanced use of nutrients, uptake of nutrients, crop productivity wheat.

INTRODUCTION

Wheat is one of the most important staple food grain crops cultivated next to rice both in area and production, but it stands first in productivity amongst the cereals. Wheat accounts for 28% of the fertilizer consumption in the country and ranks second to rice. Stagnation in wheat production, lower productivity and inferior quality of the produce is due to various constraints including inadequate and imbalanced nutrient application. Fertilizer constitutes one of the costliest inputs in present day agriculture. Greater economy in fertilizer can be made, if fertilizers are applied on the basis of soil test. This practice ensures balanced fertilization, higher yield and more profitability. Besides, balanced nutrition of growing crop the approach gives due consideration in soil fertility and strikes a real balance between the nutrients already available in the soil and those required by the crops to achieve a pre determined yield target. This helps to maintain soil fertility. Crop production in this area is confined primarily to the application of nitrogen and phosphorus fertilizers. Very little or no potassium is being applied by the farmers and thus most of it comes from K reserves of the soil and continuous cropping without K application has been reported to cause considerable drain of K fertilization. After N, K has been reported to be absorbed in large amount than any other element. Sulphur application is almost neglected by the farmers. Increasing S deficiency in soil as one of the major cause for declining yield seems to be true as a result of excess withdrawals than its replenishment. Farmers are experiencing declining responses to N and P due to omission of other essential nutrients in their fertilizer schedules. So adoption of balanced and judicious use of all needed nutrients can help improving the productivity of wheat crop. Efficient management of plant nutrients through fertilizer best management practices ensures that fertilizers are used in the most environmentally acceptable and sustainable way and crops are supplied with all essential plant nutrients at the appropriate time and in the required quantity. In quest to enhance food production, the plant nutrition system must operate to be socially acceptable, environmentally benign and economically viable. The yields of crop can even be increased by means of balanced nutrients to crop and improved NPK inputs under similar conditions. Initiatives are made in recent years through nutrient omission approaches to estimate the soil and fertilizer contributions in the crop performance and finally arrive at site specific nutrient management recommendations for targeted and sustainable yield. The yield in the plot balanced fertilization with relatively good crop management can be used to estimate an attainavle yield target. Nutrient limited yields are determined from plots in which the nutrient of interest is not added. Therefore, it was desirable to assess the effect of nutrient omissions on productivity, content and uptake of nutrients and economics of wheat.

MATERIALS AND METHODS

The field experiments were conducted at four different locations viz. Artoni, Panwari, Nanpur and Sahara villages of Agra district of Uttar Pradesh during rabi season of 2010-11. The area is characterized by a semi arid climate hot summer with mean maximum temperature of 45°± 2° C, mean minimum temperature of around 3° ± 2° C in December-January. The average annual rainfall in the study area is 650mm of which about 90% is received during kharif seasons from July to September and rest during the rabi season. The important physico-chemical characteristics of soils (0-15 cm) of four locations are presented in Table 1. The experiments were laid out in randomized block design with five treatments. Fertilizer treatments were based on soil test fertilizer recommendation of 180 kg N, 90 kg P_2O_5 and 100 kg K_2O and 30 kg S ha^{-1} and was considered as optimum treatment (OPT). Four deletion plots individually omitted N, P, K and S based on the rates in the OPT. Urea, di-ammonium phosphate, muriate of potash and elemental sulphur were used as sources for NPK and S, respectively. In OPT-N treatment, phosphorus was applied as single superphosphate. The treatments at different locations were replicated in plots of varying size with 500 m² except for nitrogen omission treatment (100 m²). Individual farmer was treated as replication for statistical analysis of the results. Wheat crop (var. PBW 343) was sown in first week of November 2010. The crop was harvested in second week of April, 2011. At harvest, yield data of the crop (grain and straw) were recorded. The nitrogen content in grain and straw of the crop was analysed by micro Kjeldahl method (Jakson, 1973). Phosphorus, potassium and sulphur in di-acid (HNO_3 and $HClO_4$) digest was determined by vanadomolybdate yellow colour method, flame photometer and turbidimetric method (Chesnin and yien 1951), respectively. Uptake of nutrients was calculated by multiplying nutrient content in grain and straw with their respective yields. The economic analysis of different nutrient management options are in terms of net returns and B:C ratio. The economic efficiency (EE) of fertilizer application was calculated from the average net returns on unit area basis and average crop duration. The crop productivity of fertilizer application was worked out by diving crop yield on unit area basis by average crop duration.

RESULTS AND DISCUSSION

Yield

The grain yield of wheat varied from 3449 to 5615, 3085 to 5358, 3227 to 5408 and 2912 to 5388 kg ha^{-1} and Artoni, Panwari, Nanpur and Sahara, respectively. The corresponding ranges for straw yield were from 5243 to 8523, 4592 to 8070, 4833 to 8159 and 4327 to 8094 ha^{-1}. Wheat productivity was influenced significantly by fertilizer management and the highest grain (5358 to 5615) and straw (8070 to 8523) yields were achieved under T_1 (NPKS) treatment. The increase in grain yield of wheat due to balanced fertilization is attributed to improvement in growth and yield attributes, which in turn resulted in higher production and translocation of photosynthates and nutrients, ultimately reflected into higher grain and straw yield. These results corporate the findings of Chandel *et al.* (2014). Omission of N, P, K and S from the fertilizer schedule resulted in a marked yield loss, indicating the significance of replenishment of these nutrients for achieving high yield targets. These data confirm that N deficiency is a general feature of wheat in Agra district. The mean yield reductions due to N, P, K and S omissions were 42, 10, 25 and 8 %, respectively. These results confirm the finding of long term experiments conducted at various locations in India, wherein application of N alone depleted the native P, K, S and micronutrients reserves of soil, thus causing significant yield loss (Sainy *et al.* 2012, Das *et al.* 2015).

Table 1: Soil characteristics of the experimental fields (mean of 5 farmer's field)

Soil characteristics	Artoni	Panwari	Nanpur	Sahara
pH (1:2.5)	7.7	7.6	8.0	8.1
EC (dSm^{-1})	0.21	0.30	0.27	0.33
Organic carbon (g kg^{-1})	3.9	3.7	3.8	3.9
Available N (kg ha^{-1})	177.5	161.0	161.2	164.0
Available P (kg ha^{-1})	12.1	10.7	12.7	11.3
Available K (kg ha^{-1})	132.2	123.7	129.7	129.2
Available S (kg ha^{-1})	16.8	12.2	15.7	14.7

Economics

Economic analysis closely followed the wheat yield with respect to the treatment used in the study. The OPT (T1) gave higher mean gross return of `. 80393.5 $ha^{-1}$ than other treatments. Wheat crop profitability responded to fertilizer treatments with highest mean net return of `.53741.2 ha^{-1} realized in the balanced fertilization plots. Highest B: C ratio of 2.02 was also realized in the optimum nutrient plots. It is obvious that realization of higher net returns and benefit: cost ratio was the result of higher productivity. Hussain *et al.* (2013) also reported higher net returns and benefit: cost ratio with higher dose of fertilizers. Cost of cultivation differed marginally on an account of nutrient omissions but resulted in large decrease in net profit. Nitrogen omission reduced the net returns drastically and P proved to be the second most limiting nutrient in wheat production. Potassium omission also reduced the net returns. The effect of S omission on net profit was only marginal at all the sites. Omission of N, P, K and S from the OPT reduced the mean profit by ` 29977.4, ` 6809.1, ` 18994.2 and ` 5658.4 ha^{-1}, respectively. Similar results reported by Dwivedi *et al.* (2011).

Table 2: Effect of nutrients on yield and economics of wheat

Treatment	Yield (kg ha^{-1})		Δ Yield (kg ha^{-1})	Gross return (` ha^{-1})	Net return (` ha^{-1})	B:C ratio
	Grain	Straw				
			Artoni			
T_1 NPKS	5615	8523	-	83072.5	53741.2	2.12
T_2 -N	3449	5243	2166 (39)	51046.5	23763.8	1.22
T_3 -P	5192	7849	423 (8)	76734.5	46932.1	2.03
T_4 -K	4407	6669	1208 (22)	65149.5	34797.0	1.51
T_5 -S	5142	7800	473 (9)	76062	48082.8	1.95
CD (P=0.05)	64.0	72.5	-	-	-	-
			Panwari			
T_1 NPKS	5358	8070	-	79113.0	52460.7	1.97
T_2 -N	3085	4592	2273 (43)	45415.0	22456.3	0.98
T_3 -P	4799	7200	559 (11)	70789.0	45480.4	1.79
T_4 -K	3968	5912	1390 (26)	58428.0	32515.7	1.25
T_5 -S	4913	7379	445 (9)	72490.5	46713.2	1.81
CD (P=0.05)	69.2	78.1	-	-	-	-
			Nanpur			
T_1 NPKS	5408	8159	-	79885.5	53233.2	2.00
T_2 -N	3227	4833	2181 (41)	47579.0	24620.3	1.07
T_3 -P	4788	7231	620 (12)	70745.5	45436.9	1.79
T_4 -K	4180	6290	1228 (23)	61705.0	35792.7	1.38
T_5 -S	5038	7490	370 (7)	74143.0	48365.7	1.87
CD (P=0.05)	68.5	76.7	-	-	-	-
			Sahara			
T_1 NPKS	5388	8094	-	79503.0	52850.7	1.98
T_2 -N	2912	4327	2476 (46)	42849.5	19890.8	0.87
T_3 -P	4794	7184	594 (11)	70694.0	45385.4	1.79
T_4 -K	3912	5809	1476 (28)	57554.5	31642.2	1.22
T_5 -S	4935	7384	453 (9)	72745.0	46967.7	1.82
CD (P=0.05)	62.2	71.4	-	-	-	-

- *ΔYield = Yield of OPT – Yield of omitted nutrient treatment.*
- *Data in parentheses are % yield loss*
- *n= number of farmers at each site*

Nutrient Content

Nitrogen content in wheat grain ranged from 1.95 to 2.24% and in straw from 0.56 to 0.74% irrespective to different sites, maximum values being under OPT(180 kg N + 90 kg P_2O_5 + 100 kg K_2O + 30 kg S ha^{-1}) and minimum at no nitrogen. This may be attributed to increased availability of nutrients to the crop as a result of improved soil fertility. Nitrogen content in grain and straw was significantly affected by various nutrient omission treatments. Nitrogen omission had significantly lower N content in grain and straw at all the sites. Nitrogen content in the crop was also significantly lower in the treatment where P and K were omitted. Omission of other nutrients also reduced the absorption of N because of imbalance in the nutrient supply and the role of other nutrients particularly P and K in efficient N accumulation. Similar results were reported by Hussain and Kumar (2013). Optimum fertilization treated crop had higher P content in grain and straw over P omission at all the sites. Omission of N reduced the P content but omission of K and S had a non-significant effect on P content in grain and straw. Potassium content in straw was nearly double than that of grain. The K content in wheat was significantly affected by nutrient omission treatments and significantly lower K content in grain and straw was recorded in K omission treatment. Omission of P and S had non-significant effect on K content in grain and straw. It might be due to inactivation of root system under imbalanced nutrition of the crop.

Table 3: Effect of nutrients on the content of nutrients (%) in grain and straw of wheat

Treatments	Nitrogen		Phosphorus		Potassium		Sulphur	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Artoni								
T_1 NPKS	2.21	0.71	0.25	0.15	0.49	2.03	0.32	0.16
T_2 -N	1.95	0.57	0.22	0.12	0.47	1.98	0.29	0.14
T_3 -P	2.11	0.60	0.19	0.09	0.46	0.98	0.30	0.14
T_4 -K	2.13	0.62	0.22	0.12	0.40	1.84	0.30	0.11
T_5 -S	2.11	0.64	0.23	0.12	0.48	2.01	0.25	0.11
CD (P=0.05)	0.04	0.03	0.02	0.01	0.03	0.10	0.02	0.01
Panwari								
T_1 NPKS	2.24	0.74	0.24	0.14	0.49	2.07	0.32	0.16
T_2 -N	2.00	0.59	0.22	0.12	0.47	2.04	0.29	0.14
T_3 -P	2.13	0.64	0.20	0.10	0.46	2.02	0.30	0.14
T_4 -K	2.15	0.65	0.22	0.10	0.39	1.85	0.31	0.15
T_5 -S	2.17	0.66	0.27	0.13	0.46	2.04	0.26	0.10
CD (P=0.05)	0.05	0.02	0.03	0.01	0.04	0.09	0.01	0.01
Nanpur								
T_1 NPKS	2.23	0.72	0.24	0.14	0.50	2.01	0.31	0.16
T_2 -N	1.99	0.56	0.21	0.11	0.47	1.97	0.29	0.14
T_3 -P	2.12	0.60	0.18	0.09	0.48	1.97	0.30	0.14
T_4 -K	2.14	0.62	0.20	0.11	0.39	1.80	0.30	0.15
T_5 -S	2.14	0.64	0.21	0.12	0.48	1.98	0.26	0.10
CD (P=0.05)	0.04	0.02	0.03	0.02	0.03	0.08	0.01	0.01
Sahara								
T_1 NPKS	2.24	0.72	0.24	0.14	0.50	2.04	0.32	0.17
T_2 -N	2.00	0.58	0.22	0.12	0.47	2.01	0.29	0.14
T_3 -P	2.14	0.63	0.19	0.10	0.46	1.97	0.30	0.15
T_4 -K	2.15	0.64	0.22	0.12	0.39	1.85	0.30	0.15
T_5 -S	2.17	0.66	0.22	0.13	0.47	2.02	0.25	0.12
CD (P=0.05)	0.06	0.03	0.02	0.02	0.02	0.010	0.02	0.01

Quality

The protein content in grain and straw varied from 12.1 to 14.0% and 3.5 to 4.6%, respectively. The optimum fertilization had significantly higher protein content in grain and straw at all the sites. The increase in protein content with balanced fertilization might be due to improved nutritional environment in the rhizosphere as well as in plant system leading to enhanced translocation of N and P to reproductive parts (Dhaka and Pathan 2013). The nitrogen and phosphorus omissions had significantly lower protein content than the optimum fertilization treatment. The reductions in protein content in grain and straw were higher due to N omission followed by P omission. Omissionof K and S also reduce the protein percentage in wheat grain and straw over OPT treatment. Mean protein yield was 756 kg ha^{-1} under balanced fertilization (T_1) compared 391.7 kg ha-^{1} under N omission. Among the omission treatments, mean higher protein yield (673.2 kg ha-^{1}) was under S omission and minimum (391.7 kg ha^{-1}) in N omission. This may be attributed to lower grain yield and protein content as a result of nutrient omission.

Uptake of nutrients

The uptake of nutrients in grain and straw was significantly influenced by the application of nutrients in balanced form. The maximum uptake of N, P, K and S in grain and straw was recorded with T_1 (NPKS) treatment. It was due to the fact that added nutrients increased the N, P, K and S content in grain and straw of the crop by providing balanced nutritional environment inside the plant, higher photosynthetic efficiency, which favoured higher yields, resulted in more uptakes of nutrients (Gupta *et al.* 2009). These results again emphasize the importance of balanced fertilization in providing adequate nutrition to the plants. By comparison, total uptake of nutrients under nutrient omission treatments appeared to decrease. In general, the lowest uptake of N, P, K and S were recorded under OPT – N, OPT – P OPT – K and OPT – S treatments, respectively. Among these omission treatments, N omission had far greater impact on the uptake of nutrients by wheat crop. This was because the N omission strongly depressed the grain and straw production of wheat (Hussain and Kumar, 2013).

Table 4: Effect of nutrients on the uptake of nutrients (kg ha^{-1}) in grain and straw of wheat

Treatments	Nitrogen		Phosphorus		Potassium		Sulphur	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Artoni								
T_1 NPKS	124.0	60.5	14.0	12.7	27.5	173.0	17.9	13.6
T_2 -N	67.2	29.8	7.5	6.2	16.2	103.8	10.0	7.3
T_3 -P	109.5	40.6	8.3	6.0	20.2	132.0	13.2	9.3
T_4 -K	110.5	48.7	11.4	9.4	20.7	144.4	15.5	11.7
T_5 -S	108.4	49.9	12.8	9.3	24.6	156.7	13.3	8.6
CD (P=0.05)	6.2	2.7	1.2	1.7	1.2	9.8	1.8	1.1
Panwari								
T_1 NPKS	120.0	59.7	12.9	11.2	26.2	167.0	17.1	12.9
T_2 -N	61.7	27.0	6.7	5.5	14.4	93.6	8.9	6.4
T_3 -P	84.5	37.8	7.9	5.9	18.2	119.4	11.9	8.2
T_4 -K	103.1	46.8	10.5	8.6	18.7	133.2	14.8	10.8
T_5 -S	106.8	48.7	13.2	9.5	22.5	150.5	12.7	7.3
CD (P=0.05)	4.7	2.1	0.97	1.9	1.4	10.2	2.0	1.0
Nanpur								
T_1 NPKS	120.5	58.7	12.9	11.4	27.0	163.9	16.7	13.0
T_2 -N	64.2	27.0	6.7	5.3	15.1	95.2	9.3	6.7
T_3 -P	88.6	37.7	7.5	5.6	20.0	123.9	12.5	8.8
T_4 -K	102.4	44.8	9.5	7.9	18.6	130.1	14.3	10.8
T_5 -S	107.8	47.9	10.5	8.9	24.1	148.3	13.0	7.4
CD (P=0.05)	7.5	2.4	1.1	1.4	1.1	8.8	1.7	1.2
Sahara								
T_1 NPKS	120.7	58.2	12.9	11.3	26.9	165.1	17.2	13.7
T_2 -N	58.2	25.0	6.7	5.1	13.6	86.9	8.4	6.0
T_3 -P	83.7	36.5	7.4	5.8	17.9	114.4	11.7	8.7
T_4 -K	103.0	45.9	10.5	8.6	18.6	132.9	14.3	10.7
T_5 -S	107.0	48.7	10.8	9.5	23.1	149.1	12.3	8.8
CD (P=0.05)	5.8	1.9	1.3	1.6	1.4	11.1	1.9	1.5

Crop efficiency parameters

The performance of wheat with various rates of fertilizer application was quantified through different crop efficiency parameters viz. EE, CP and PFP. The economic efficiency of wheat under different treatments varied from `. 157.30 to `. 389.10, ` 154.87 to `. 361.79, `. 169.10 to `. 387.12 and `. 137.18 to `. 364.48 ha^{-1} day^{-1}, respectively at Artoni, Panwari, Nanpur and Sahara (Table 5). The omission of N, P, K and S from the OPT (T_1) reduced the mean economic efficiency by `. 221.0, `. 47.4, `. 135.6 and `. 119.3 ha^{-1} day^{-1}, respectively. Thus, the EE in omission plots was relatively lower than that of T_1 treatment at all the sites emphasizing the need of all the nutrients for higher crop production. Among the treatments, the lower values of EE at all the sites were noted under nitrogen omission. The crop productivity of wheat was 38.7, 37.0, 37.3 and 37.1;/ kg ha^{-1} day^{-1} under T_1 treatment at Artoni, Panwari, Nanpur and Sahara, respectively. On the other hand, the lowest values of crop productivity were noted under nitrogen omission. The crop productivity of wheat under S omission was relatively higher than those under P,K and N omissions. These results substantiate the positive influence of balanced use of nutrients in wheat crop. The influence of the combined effect of all nutrients on grain yield is quantified through partial factor productivity. The results revealed that PFP for wheat grown with ample amounts of fertilizers (N, P, K, S) varied from 13.4 to 14.0 kg/kg at different locations and was markedly higher under K and S omissions. The PFP decreased due to balanced levels of NPKS (T_1) indicating poor rate of utilization of nutrients by the crop at higher level. The behavior of these characters due to fertilizer treatments may be explained on the basis of their effect on the economic yield.

Table 5: Effect of different treatment on crop efficiency (mean of 2 years)

Treatments	Protein Content in grain (%)	Protein content in straw (%)	Protein yield (kg ha^{-1})	Economic efficiency (`. ha^{-1} day^{-1})	Crop productivity (kg ha^{-1} day^{-1})	Partial factor productivity (kg/kg)
			Artoni			
T_1 NPKS	13.8	4.4	774.8	389.10	38.7	14.0
T_2 -N	12.1	3.6	417.3	157.30	23.8	15.7
T_3 -P	13.2	3.7	685.3	354.66	35.8	16.7
T_4 -K	13.8	3.9	608.2	270.60	30.4	14.7
T_5 -S	13.2	4.0	678.7	346.79	35.5	13.9
CD (P=0.05)	0.3	0.09	29.5	-	-	-
			Panwari			
T_1 NPKS	14.0	4.6	750.1	361.79	37.0	13.4
T_2 -N	12.5	3.7	385.6	154.87	21.3	14.0
T_3 -P	13.3	4.0	638.2	313.66	33.1	15.5
T_4 -K	13.4	4.1	531.7	224.24	27.4	13.2
T_5 -S	13.6	4.1	668.2	322.16	33.9	13.3
CD (P=0.05)	0.4	0.11	28.7	-	-	-
			Nanpur			
T_1 NPKS	13.9	4.5	751.7	367.12	37.3	13.5
T_2 -N	12.4	3.5	400.1	169.10	22.2	14.6
T_3 -P	13.2	3.7	632.0	331.36	33.0	15.4
T_4 -K	13.4	3.8	560.1	246.85	28.8	13.9
T_5 -S	13.4	4.0	675.0	322.44	34.7	13.6
CD (P=0.05)	0.2	0.12	26.5	-	-	-
			Sahara			
T_1 NPKS	14.0	4.5	747.3	364.48	37.1	13.5
T_2 -N	12.5	3.6	364.0	137.18	20.0	13.2
T_3 -P	13.4	3.9	642.2	313.00	33.1	15.5
T_4 -K	13.4	4.0	524.2	218.22	27.0	13.0
T_5 -S	13.6	4.1	671.1	323.91	34.0	13.3

CD (P=0.05)	0.5	0.08	28.0	-	-	-

It may be concluded from the results that there was significant improvement in crop yield with highest gross and net returns and improved uptake of nutrients by crops with balanced use of fertilizers. The highest EE and crop productivity of wheat achieved with ample use of fertilizers emphasized the need of balanced use of fertilizers. Thus, the balanced fertilizer use in wheat crop results in achieving economically viable crop yield in Agra region of Uttar Pradesh. Nitrogen is the most limiting nutrient and its omission resulted in drastic reduction in yield and profitability of wheat.

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SOIL FERTILITY STATUS OF PUNJAB AGRICULTURAL UNIVERSITY SEED FARM, CHAK RULDU SINGH WALA, SANGAT, BATHINDA, PUNJAB

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ABSTRACT

Fertility status of soil and their correlation study was carried out for PAU seed farm located at Chak Ruldu Singh Wala, Sangat, Bathinda. In surface (0-15cm) soils, the value of pH ranged from 8.3 to 8.5 with a mean value of 8.3. The pH value increased in sub surface soil (15-30 cm) across the sites and varied from 8.2 to 8.6 with a mean value of 8.5. The EC varied from 0.16 to 0.26 and 0.11 to 0.25 dSm^{-1} with mean values of 0.19 and 0.17 dSm^{-1} in surface and sub-surface soils, respectively. Organic carbon content in surface soils ranged form 3.2 to 8.7 g kg^{-1} with an average value of 4.9 g kg^{-1} and decreased with increase in soil depth. Available P content varied from 17.5 to 21.5 kg ha^{-1} in surface and 12.5 to 14.5 kg ha^{-1} in sub-surface soils with average values of 19.9 and 13.9 kg ha^{-1}, respectively. Status of available K in the soils ranged from 220 to 610 kg ha^{-1} with an average of 404 kg ha^{-1} in upper layer; however, it varies from 195 to 510 kg ha^{-1} with an average of 326 kg ha^{-1} in lower layers. The DTPA –extractable Fe, Cu, Zn and Mn concentration varied from 10.55 to 13.02, 0.58 to 1.34, 2.44 to 3.45 and 6.42 to 8.75 mg kg^{-1} with mean values of 11.9, 0.99, 3.10 and 7.78 mg kg^{-1} in upper layer. DTPA-extractable Fe, Cu, Zn and Mn showed decreasing trends with increase in soil depth and ranged from 5.25 to 6.25, 0.25 to 0.95, 1.11 to 1.88 and 3.56 to 4.66 mg kg^{-1} with mean value of 5.8, 0.44, 1.51 and 4.09 mg kg^{-1} in lower layers. The available P had significantly negative correlation (r = -0. 466, P< 0.05), (r = -0.461, P< 0.05) with pH and EC respectively. A significantly and positive correlation (r = 0.468, P< 0.05) of available P was recorded with organic carbon. A significant and positive correlation of available K was reported between organic carbon (r = 0. 573, P< 0.05) and EC (r = 0. 487, P< 0.05). The available K showed negative and non-significant correlation with pH (r = -0. 218, P< 0.05). The DTPA – extractable Fe, Cu, Zn and Mn did not reveal any significant relationship with soil pH and electrical conductivity (EC), however significantly positive correlation (r= 0.487, P< 0.05), (r= 0.545, P< 0.05), (r=0.578, P< 0.05) and (r= 0.593, P< 0.05) was recorded with organic carbon for Fe, Cu, Zn and Mn respectively.

Key Words: Soil fertility, phosphorus, potassium, iron, copper, zinc, manganese.

INTRODUCTION

Role of balanced plant nutrition is well-established for sustainable agricultural production. Present agricultural systems are exploitive of nutrients through intensive tillage, mono-cropping year after year, use of high yielding varieties, imbalanced use of nutrients coupled with limited use of organic manures, less recycling and burning of crop residues, soil erosion, undulating topography and indiscriminate use of irrigation water. Balanced use of organics, fertilizers and bio-fertilizers plays an important role to maintain soil fertility in long run. The availability of macro and micronutrients to plants is influenced by several soil characteristics. Similarly, different cropping systems are suitable for different soil groups as regards to production and productivity. For understanding the reasons of deficiency of available nutrients in soils, correlation of physic-chemical properties with available macro and micronutrients were needed. Also, detailed study on status of macro and micronutrients of Chak Ruldu Singh Wala Seed Farm of Punjab Agricultural University, Regional Station, Bathinda had not been undertaken so far. Hence, present investigation was undertaken to study the status of macro, micronutrients and their relationship with important soil characteristics.

MATERIALS AND METHODS

General characteristics of the study area

The Bathinda district is situated at 30.2° North latitude and 74.95° East longitude and 202 m elevation above the mean sea level. The study area is located at 30.0° North latitude and74.78° East longitude in Sangat block (Latitude 30.2 ° North and Longitude 74.94 ° East). The farm is mainly used to seed

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production in both the cropping seasons. Cotton, moong and guar is grown in *Kharif* whereas wheat, barley and raya are produced during *Rabi* season since last ten years. Recommended doses of fertilizers were applied for each crop according to recommendations made in package of practices for crops of Punjab (*Kharif* and *Rabi*) with respect of the year.

Soil sampling and analysis

Geo-referenced twenty eight soil samples of the farm were collected at 0-15 cm and 15-30 cm depth with the help of an augur during *Kharif* 2015, and latitude and longitude of the sampling sites were recorded using global positioning system (GPS).The samples were air-dried, ground ,passed through 2-mm sieve and stored in properly labelled plastic bags for analysis. The pH and EC of the soils were determined in 1:2 soil-water suspensions using a glass electrode pH meter and conductivity meter respectively (Jackson, 1973). The organic carbon was determined by wet digestion method (Walkley and Black, 1934). The available P in the soil was extracted by employing Olsen extractant (0.5M $NaHCO_3$, pH 8.5) as described by Olsen *et al.* (1954) and the available K was extracted by using neutral ammonium acetate and the content was determined by aspirating the extract into flame photometer (Jackson, 1973). The plant available Fe, Cu, Zn and mn in soil samples were extracted with DTPA (0.005 M DTPA + 0.01 M $CaCl_2$ + 0.1 M triethanolamine, pH 7.3) as per method described by Lindsay and Norvell (1978) and concentration of Fe, Cu, Zn and Mn in the DTPA extract was determined using atomic absorption spectrophotometer (AAS). The correlation analysis of data was computed in relation to available nutrient with different properties of soils as suggested by Panse and Sukhatme (1961).

RESULTS AND DISCUSSION

The soil properties of the sites exhibited variation with respect to different sampling sites and soil depths. In surface (0-15cm) soil layers, the value of pH ranged from 8.27 to 8.52 with mean value of 8.31. However pH value increased with increase in soil depth across the sites and varies from 8.24 to 8.57 with mean value of 8.46 (Figure 1). The higher pH in lower layers could be due to increase in accumulation of exchangeable of cations. Electrical conductivity values of the soil layers indicated that non salinity character of the soil profiles. The EC varies from 0.16 to 0.26 dSm^{-1} in surface (0-15 cm) with mean value of 0.19 dSm^{-1} and 0.11 to 0.25 dSm^{-1} in sub-surface layer (15-30 cm) with mean value of 0.17 dSm^{-1} (Figure 1). Similar findings were also reported by Behera and Shukla (2013)

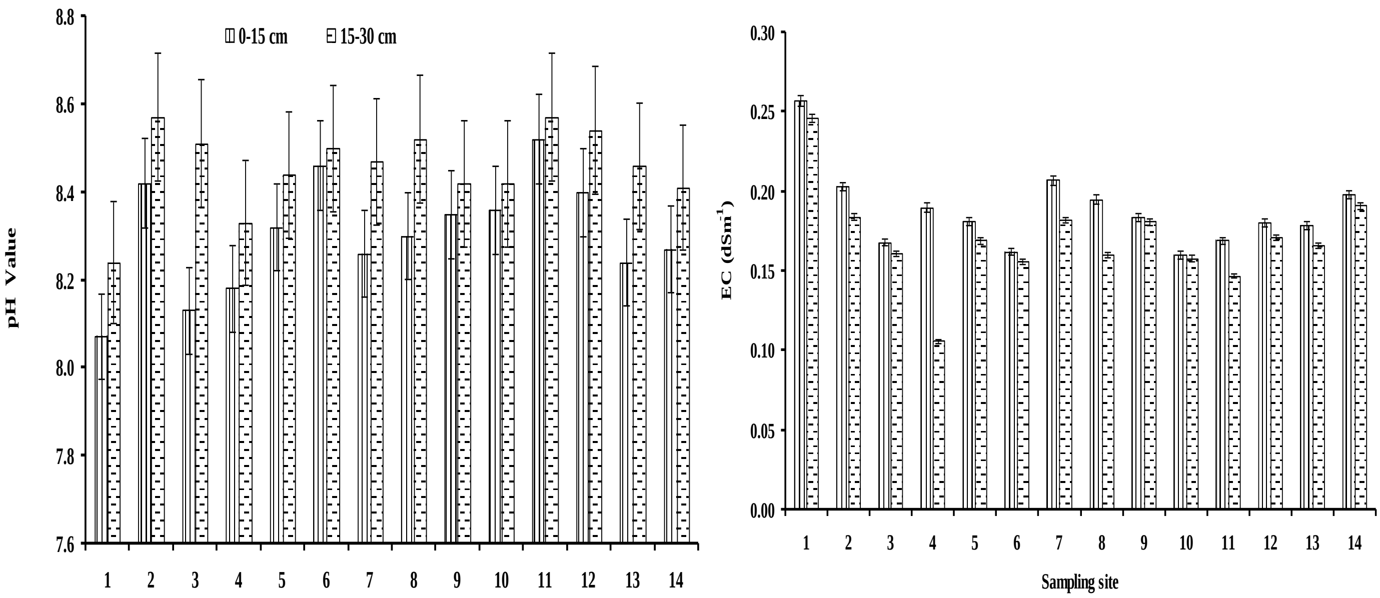

Fig.1: Soil reaction (pH) and electrical conductivity (EC) of the different soil profile

Organic carbon (OC) content in surface soil layer (0-15 cm) ranged form 3.2 to 8.7 g kg^{-1} with an average value of 4.9 g kg^{-1}. The value of organic carbon content in soil decreased with increase in soil depth across the sites. According to soil testing manual (2011) rating limit, on an average the surface soil contain low to medium organic carbon (<0.5 - 0.5%) and sub-surface soil layers contain low organic carbon (<0.5%) (Figure 2). The distribution of soil samples with respect to organic carbon content indicates that 21%, 71% and 8% soil samples had low, medium and high organic carbon in surface soils; however 92% and 8% samples were reported low and medium respectively, in sub-surface soils (Srivastava *et al.* 2016). The medium organic carbon content in surface soils may be attributed to the proper vegetation, growing of leguminous crops and incorporation of crop residues in soil.

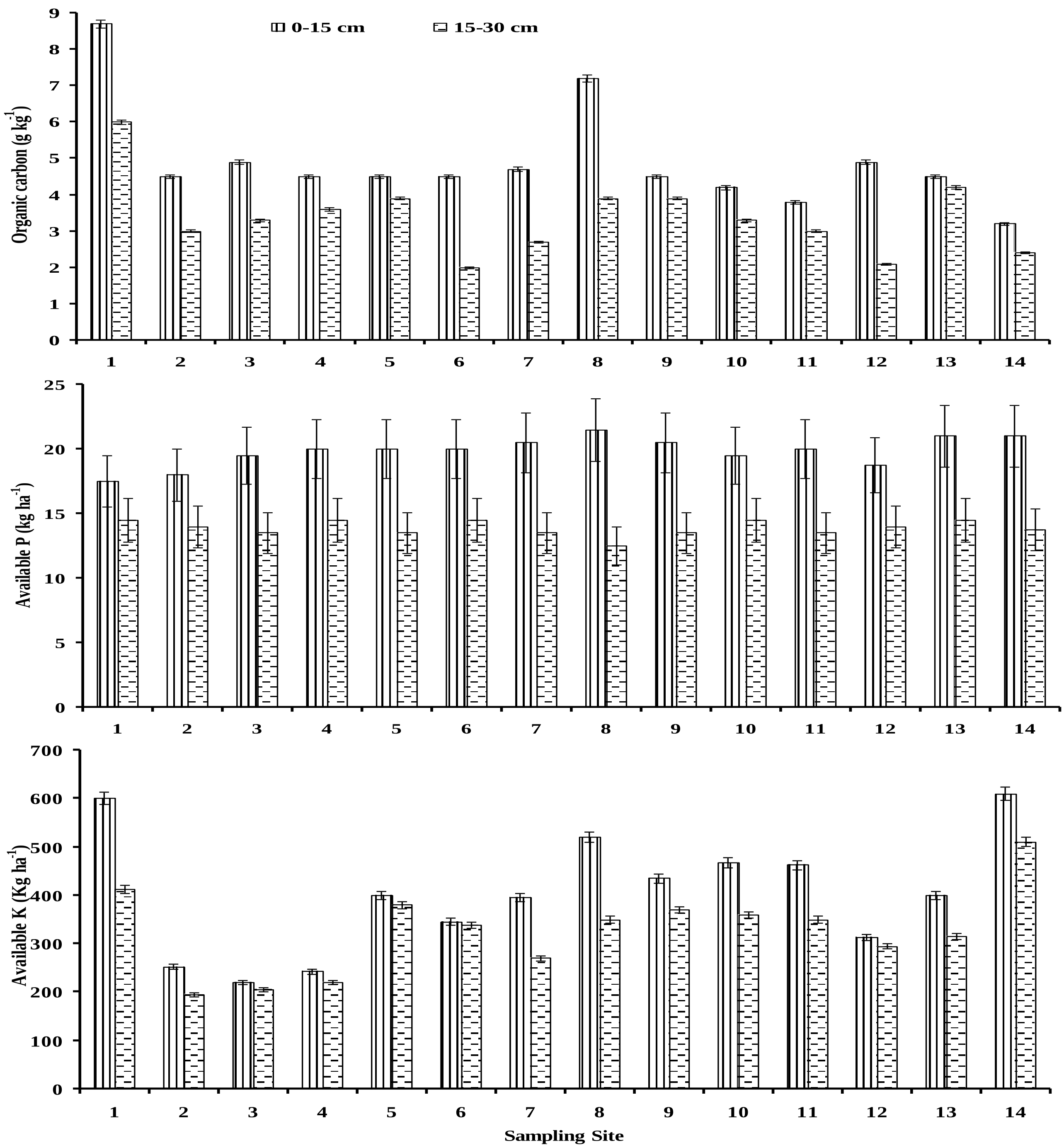

Fig. 2: Organic carbon, phosphorus and potassium content of the samples

Available P content varied from 17.5 to .21.5 kg ha^{-1} in surface layer (0-15cm) and 12.5 to 14.5 kg ha^{-1} in sub-surface layer (15-30cm) with an average value of 19.9 and 13.9 Kg ha^{-1} respectively (Figure 2). On the basis of the limits suggested by Govt. of India in soil testing manual (2011) all the soils samples (100%) of seed farm contain medium P (10-24.6 kg ha^{-1}). The high available P content is attributed to the regular application of phosphatic fertilizers and the immobile nature of phosphate ions in soils which must have resulted in accumulation of P in soils. Medium to high P content in soils of arid tract of Punjab has also been reported by Verma *et al.* (2005). Status of available K in the soils ranged from 220 to 610 kg ha^{-1} with an average of 404 kg ha^{-1} in upper layer (0-15 cm), whereas it varied from 195 to 510 kg ha^{-1} with an average of 326 kg ha^{-1} in lower layers (15-30 cm). According soil testing manual (2011) rating limit, all the samples (100%) showed high K content (Figure 2). The higher content of available K is attributed to the prevalence of Illite - a potassium rich mineral in these soils. Moreover, as the ground waters of south-western district have considerable amount of dissolved potassium, irrigation with such waters also results in higher amounts of available K in these soils (Patel *et al.,* 2000). These finding are also in line as reported by Verma *et al.* (2005).

Distribution of Fe, Cu, Zn and Mn in soil profile

Data regarding distribution of DTPA-extractable Fe, Cu, Zn and Mn in soil profiles of different sites have been given in Figure 3. The DTPA –Fe concentration varied from 10.55 to 13.02 (with mean value of 11.9 mg kg^{-1}) and 5.25 to 6.25 (with mean value of 5.8 mg kg^{-1}) in 0-15 and 15-30 cm depth, respectively. DTPA-Fe showed decreasing trends with increase in soil depth, which is in line of the findings of Shrama *et al.* (2000), Pati and Mukhopadhyay (2011) and Behera and Shukla (2013). It is also observed that the soil contains higher level of Fe as compared to critical level in soil as suggested by methods manual soil testing in India (2011).

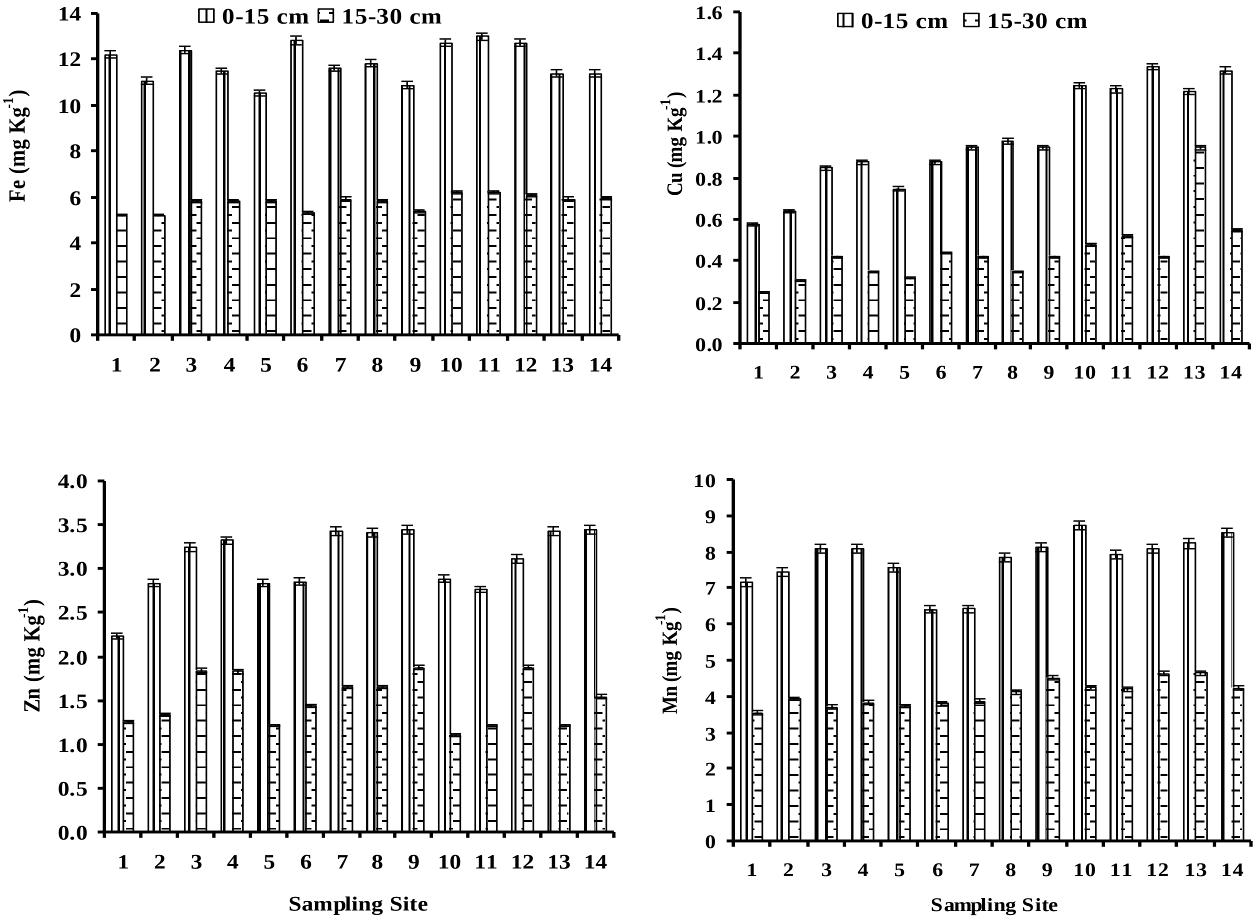

Fig. 3: Distribution of Fe, Cu, Zn and Mn in soil profile

Available Cu concentrations in different soil depth are given in figure 3. Copper concentration ranged from 0.58 to 1.34 (with mean value of 0.99 mg kg^{-1}) and 0.25 to 0.95 (with mean value of 0.44 mg kg^{-1}) in 0-15 and 15-30 cm soil depths, respectively across the sites. The lower depth (15-30 cm) had less mean DTPA extractable-Cu, which corroborates the observations made by Behera *et al.* (2009) in an Inceptisol. These results reveal that availability of Cu to the plants is more in surface soil layer (0-15 cm) than in sub soil layer (15-30 cm). The data also showed that the soils of the farm had higher Cu content compared to critical limit suggested by Govt. of India in soil testing manual (2011).The concentration of DTPA –Zn in surface soil layers spanned from 2.44 to 3.45 with an average of 3.10 mg kg^{-1} in upper layer (0-15 cm). However, it ranged from 1.11 to 1.88 with an average of 1.51 mg kg^{-1} in sub-surface layer (15-30 cm). The mean value of DTPA-Zn decreased with increase in soil depth across the sites. Similar results were also reported by Sharma *et al.* (2000). The decaline in DTPA-extractable Zn may be ascribed to decaline in soil organic C content down the soil profile as organic carbon content significantly correlated with DTPA-extractable Zn in surface soil as reported by Behera *et al.* (2011). Considering the critical limits for Zn (0.4-1.2 mg kg^{-1}) by Govt. of India as suggested in soil testing manual (2011), both the soil profile of all sites had sufficient available Zn concentration. The concentration of DTPA extractable- Mn ranged from 6.42 to 8.75 (with mean value of 7.78 mg kg^{-1}), 3.56 to 4.66 (with mean value of 4.09 mg kg^{-1}) in 0-15 cm and 15-30 cm respectively in soil profiles across the sampling sites. All the soil samples showed Higher Mn content in both the layers when we considered the limits as suggested in soil testing manual (2011).

Relationship between soil properties and available nutrients

Relationship between soil properties (0-30 cm) and available nutrients (0-30 cm) showed that the available P had significantly negative correlation (r = -0. 466*, P< 0.05), (r = -0.461*, P< 0.05) with pH and EC, respectively. This is because at higher pH, calcium precipitates with P as Ca-phosphate and reduced P availability A significant and positive correlation (r = 0.468*, P< 0.05) of available P was recorded with organic carbon. This relationship might be due to the presence of more P in organic forms and after the decomposition of organic matter as humus is formed which forms complex with Fe and Al and that is a protective cover for P fixation with Fe and Al, thus reduce P adsorption or fixation in soil. Similar results were also reported by Meena *et al.* (2006) and Singh *et al.* (2014). A significant and positive correlation of available K was reported between OC(r = 0. 573*, P< 0.05) and EC (r = 0. 487*, P< 0.05). This might be due to creation of favourable soil environment with presence of high organic matter. The available K showed negative and non-significant correlation with pH (r = -0. 218*, P< 0.05). Similar results were reported by Meena *et al.* (2006) and Singh *et al.* (2014). The DTPA – extractable Fe, Cu, Zn and Mn did not reveal any significant relationship with soil pH and electrical conductivity (EC). This indicates that distribution of available cationic micronutrients in the soil is not influenced by above soil properties. Bhera and Shukla (2013) studied the depth-wise distribution of zinc, copper, manganese and iron in acid soils of India and their relationship with some soil properties and observed no relationship between DTPA – extractable Fe, Cu, Zn and Mn with soil pH and EC. Pati and Mukhopadhyay (2011) also recorded no relationship of soil pH with DTPA – extractable Fe, Cu and Zn. The DTPA-extractable Fe, Cu, Zn and Mn increase significantly with increase in OC (r= 0.487*, P< 0.05, for Fe), (r= 0.545*, P< 0.05, for Cu), (r= 0.578*, P< 0.05 for Zn) and (r=0.593*, P< 0.05 for Mn). The results confirm the observations of Sharma *et al.* (2006), Bhanwaria *et al.* (2011) and Singh *et al.* (2014).

The soils of the farm are non-saline and alkaline in reaction with medium to high organic carbon. The availability of P in soil was medium, whereas high in K content. Sufficient availability of micronutrients such as Fe, Cu, Zn and Mn were found in the soil. All the macro and micro-nutrients analysed decreased with increase in soil depth, however, no deficiency were observed in sub-surface layer. The soils of the farm has sufficient amount of nutrients for sustainable crop production.

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CORRELATION AND PATH COEFFICIENT ANALYSIS IN MAIZE GENOTYPES

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ABSTRACT

A study was conducted to assess the genetic variability, characters association for the direct and indirect effects of 16 morpho-physiological traits in 24 maize inbred lines. A trial was conducted during kharif, 2012 following a randomized block design with three replications. Analysis of variance revealed that there were a significant differences among the genotypes for all the traits studied. Highest PCV and GCV were observed for leaf area/plant, preceded by cobs/plant and kernels/row. Correlation coefficient revealed that cob length (0.54, 0.55), leaf area/plant (0.52, 0.53), grain rows/cob (0.38, 0.40), 100 seed weight (0.38, 0.39), cobs/plant (0.36, 0.37) and leaf relative water content (0.32, 0.35) had significant positive correlation with grain yield/plant at the phenotypic (r_p) and genotypic levels (r_g), respectively. However, days to maturity and plant height showed negative correlation with grain yield/plant at the genotypic level.Path coefficient analysis reflected that days to 50 % silking (0.153), cob height (0.003), cobs/plant (0.087), cob length (0.213), number of grain rows/cob (0.354), kernels/row (1.282), 100 seed weight (1.165), plant height (0.024), cob girth (0.074) and chlorophyll content (0.034) showed positive direct effect on grain yield at the genotypic levels. While, days to 50% tasselling (-0.132), anthesis-silking interval (-0.036) and days to maturity (-0.096) showed negative direct effect on grain yield at the genotypic level. Positive but indirect effects were shown by days to 50% tasselling (0.109), days to 50% silking (0.066), cob length (0.555), cob girth (0.366), grain rows/cob (0.404), kernels/row (0.232), 100 seed weight (0.394), chlorophyll content (0.120), leaf area/plant (0.532) and leaf relative water content (0.358) at the genotypic level. Thus, the selection of such characters would help to improve the grain yield of maize in further breeding program.

Key words: Maize, physiological traits, correlation coefficients, path analysis

INTRODUCTION

Maize (*Zea mays* L.; 2n=20) is the third most widely distributed crop of the world, being grown in diverse seasons and ecologies with highest production and productivity among food cereals. Among the cereals, maize is rich in starch, oil, sucrose and carotene. Maize serves as a source of basic raw material for a number of industries *viz*., starch, protein, oil, alcoholic beverages, food, sweeteners, cosmetics and bio-fuels (Khan and Dubey 2015). Globally 67 percent of maize is used for livestock feed, 25% human consumption, industrial purposes and balance is used as seed and the demand for grain is increasing worldwide (Reddy *et al.* 2013). Yield of corn (*Zea mays* L.) is considered as a complex inherited character therefore, direct selection for yield *per se* may not be the most efficient method for its improvement, but indirect selection for other yield related characters, which are closely associated with yield and high heritability estimates will be more effective. Genetic correlation analysis is a handy technique which elaborates the degree of association among important quantitative traits. In order to develop promising genotypes with high yielding potential, it is essential to know the associations among different traits, especially with grain yield, which is the most important and ultimate objective in any breeding programme (Rafiq *et al.* 2010). Association studies could lead plant breeders in the selection of traits contributing towards the character(s) of concern, and ultimately their improvement through hybridization. With increased industrial demand, it is necessary to maximize maize production at a much faster pace than at current. Knowing the correlations between traits is of great importance for success of selections in breeding programmes (Alake *et al.* 2008). The analysis of correlation coefficient is one of the most widely used tool among numerous methods that can be used. A path coefficient analysis permits the separation of correlation coefficient into direct and indirect effects (effects exerted through other variables) and effectively measuring the relative importance of causal factors. The study of characters association along with the path coefficient analysis has been applied in many

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crops like, rice (Allam *et al.* 2015), wheat (Singh *et al.* 2014), barley (Singh *et al.* 2014), sorghum (Kumar 2013). It is therefore, necessary to analyze the cause and effect relationship between dependent and independent variables to untangle nature of relationship between variables. Keeping these points in view, an effort was made to measure genetic variability among the characters in maize and to study the relationship between yield and its component characters in maize.

MATERIALS AND METHODS

The experimental materials consisted of 24 diverse maize genotypes, obtained from the Department of Genetics and Plant Breeding, Sam Higginbottom Institute of Agriculture, Technology and Sciences, Allahabad (U.P.). Field trials were laids out in a randomized block design with three replications with a spacing of 60 cm x 20 cm (3.0 m row length for each entry) The recommended cultural practices were followed to raise healthy plants. Five plants from the middle row of each entry in each replication were randomly taken for recording observations on days to 50% silking, days to 50 % tasselling, anthesis-silking interval, days to maturity, plant height, cob height, number of cobs/plant, ear length, ear girth, grain rows/ cob, kernels/row, 100 grains weight, chlorophyll content, leaf area/plant, leaf relative water content and grain yield/plant. The data were analyzed by using analysis of variance suggested by Panse and Sukhatme (1964), and genetic parameters such as PCV and GCV were calculated by the formula given by Burton (1952), heritability in broad sense (h^2) by Lush (1949), genetic advance in percent of mean (genetic gain) were work out as suggested by Johnson *et al.* (1955), correlation coefficient by Al-jibouri *et al.* (1958) and path coefficient analysis by Dewey and Lu (1959).

RESULTS AND DISCUSSIONS

Analysis of variance

The analysis of variance (Table 1) revealed that there were significant differences among the characters which indicated that sufficient genetic variability were present among the different genotypes. These results are in accordance with findings of Alake *et al.* (2008), Krupakar *et al.* (2013) and Agrawal *et al.* (2014) who observed significant variability for yield and its contributing traits in maize inbred lines.

Table 1: Analysis of variance for yield and yield related characters in 24 inbred lines

Source of Variations	Replication (df=2)	Treatment (df=23)	Error (df=46)
Days to 50 % tasselling	0.01	4.60**	0.09
Days to 50 % silking	0.00	4.52**	0.05
Anthesis-silking interval	0.00	0.51**	0.00
Days to maturity	0.00	31.65**	0.13
Plant height	15.79	1287.57**	8.51
Cob height	29.32	175.94**	45.72
Cobs/plant	0.00	0.51**	0.00
Cob length	0.00	11.13**	0.00
Cob girth	0.61	2.74**	0.91
Grain rows/cob	0.14	2.47**	0.16
Kernels/row	0.14	82.51**	0.57
Grain yield/plant	0.48	275.75**	2.61
100 seed weight	0.55	30.44**	0.36
Chlorophyll content (SPAD)	0.85	128.53**	1.94
Leaf area/plant	9286.92	6751197.00**	16344.39
Leaf relative water content	7.61	150.46**	6.06

*** Significant at 0.01 level of significance; * Significant at 0.05 level of significance*

Genetic variability

The highest GCV and PCV values (Table 2) were recorded for leaf area/plant (36.21, 36.29) followed by cobs/plant (32.97, 33.06), kernel/row (23.67, 23.84) and anthesis-silking interval (20.02, 20.03), respectively. The differences between PCV and GCV values were low for most of the characters studied indicating low environmental influence in the characters expression. However, cob height (3.27) and cob girth (3.92) showed high difference in the PCV and GCV values reflecting considerably high environmental influence. These characters also had medium heritability (between 0.50 and 0.59) coupled with low genetic gain. These results were well supported by Langade *et al.* (2013) and Reddy *et al.* (2013). Except cob height and cob girth, all other characters studied have high heritability's indicating that the selection is effective for the improvement of grain yield and associated characters. These results were well supported by Sharma *et al.* (2014). Hepziba *et al.* (2013) revealed high broad-sense heritability for cobs/plant and 100 grains weight in maize. Direct selection can be done for enhancing grain yield since it has high heritability (0.98) and genetic gain (23.85). Agrawal *et al.* (2014) reported moderate heritability and genetic advance for grain yield, ear height, plant height and ear length. Ali *et al.* (2013) and Mustafa *et al.* (2014) recorded higher magnitude of heritability and genetic advance for most of the characters.

Table 2: Estimates of genetic components for maize inbred lines

Characters	GCV	PCV	Genotypic variance	Phenotypic variance	h^2 (broad sense)	Genetic gain	Genetic advance as % of mean
Days to 50 % tasselling	3.01	3.07	2.26	2.35	0.96	3.03	6.07
Days to 50 % silking	2.85	2.88	2.23	2.29	0.98	3.04	5.80
Anthesis-silking interval	20.02	20.03	0.26	0.26	1.00	1.05	41.21
Days to maturity	4.05	4.07	15.76	15.90	0.99	8.14	8.31
Plant height	16.34	16.45	639.53	648.04	0.99	51.75	33.43
Cob height	10.72	13.99	65.11	110.84	0.59	12.74	16.93
Cobs/plant	32.97	33.06	0.26	0.26	0.99	1.04	67.71
Cob length	18.89	18.90	5.56	5.57	1.00	4.86	38.90
Cob girth	9.44	13.36	0.91	1.83	0.50	1.39	13.74
Grain rows/cob	8.79	9.38	1.16	1.32	0.88	2.08	16.97
Kernels/row	23.67	23.84	40.97	41.55	0.99	13.09	48.42
Grain yield/plant	17.91	18.08	136.57	139.18	0.98	23.85	36.54
100 seed weight	19.00	19.23	15.04	15.40	0.98	7.89	38.67
Chlorophyll (SPAD)	18.91	19.20	63.30	65.24	0.97	16.14	38.38
Leaf area/plant	36.21	36.29	3367426.25	3383770.75	1.00	3771.07	74.40
Leaf relative water content	14.83	15.44	72.20	78.27	0.92	16.81	29.34

Correlation coefficient analysis

The genotypic (r_g) and phenotypic (r_p) correlation coefficients for all the traits (Table 3) revealed that genotypic correlation was at a higher magnitude than phenotypic correlation in most of the cases indicating a high degree of association among the characters. Therefore, selection based on phenotypic traits would be effective in achieving genetic gain. Results revealed that the cob length (0.54**, 0.55**), leaf area/plant (0.52**, 0.53**), grain rows/cob (0.38**, 0.40**), 100 seed weight (0.38**, 0.39**), cobs/plant (0.36*, 0.37*) and leaf relative water content (0.32*, 0.35*) showed significant positive correlation with grain yield/plant at the phenotypic(r_p) and genotypic levels (r_g),respectively. As the genotypic relationship among traits affecting grain yield elucidate true association as they exclude environmental influences. This was well supported by Malik *et al.* (2005), Saleem *et al.* (2007) and Kanagarasu *et al.* (2012) where cob height and leaf area were positively significantly correlated with grain yield. Days to maturity (-0.33*), however, showed negative but significant correlation with grain yield/plant. Nzuve *et al.* (2014) and Nataraj *et al.* (2014) found that several characters showed positive significant correlation with grain yield at the genotypic and phenotypic levels. Kote *et al.* (2014) also reported significant association in desirable direction with seed yield/plant at both genotypic and phenotypic levels.

Days to 50 % tasselling showed significant and positive correlation with days to 50 % silking (0.92**). Anthesis-silking interval showed significant negative correlation with plant height (-0.45**) and cob height (-0.29*). Days to maturity had significant negative correlation with cob length (-0.33*), grain rows/cob (-0.36*) and chlorophyll content (-0.55**). There was a significant positive correlation between plant

Table 3: Genotypic (r_g) and phenotypic (r_p) correlation coefficients for quantitative and physiological characters in maize (*Zea mays* L.)

Characters		Days to 50 % silking	Anthesis silking Interval	Days to maturity	Plant height (cm)	Cob height (cm)	Cobs/ plant	Cob length (cm)	Cob girth (cm)	Grain rows/ Cob	Kernels per row	100 seed wt (g)	Chlorophyll content (Spad)	Leaf area per plant (cm²)	LRWC (%)	Grain yield/ plant (g)
Days to 50 % tasselling	r_p	0.92**	-0.19	-0.11	0.07	0.12	-0.08	-0.13	-0.11	0.20	0.15	-0.15	0.08	-0.19	-0.21	0.10
	r_g	0.95	-0.19	-0.11	0.06	0.09	-0.08	-0.13	-0.16	0.22	0.15	-0.16	0.09	-0.19	-0.23	0.10
Days to 50 % silking	r_p		0.14	-0.15	-0.08	-0.001	-0.08	-0.18	-0.19	0.15	0.14	-0.14	0.11	-0.16	-0.21	0.06
	r_g		0.14	-0.16	-0.08	0.005	-0.08	-0.18	-0.30	0.15	0.14	-0.14	0.11	-0.16	-0.23	0.06
Anthesis-silkinginterval	r_p			-0.12	-0.45**	-0.29*	-0.006	-0.13	-0.24	-0.16	-0.04	0.04	0.06	0.09	0.00	-0.12
	r_g			-0.12	-0.46	-0.38	-0.007	-0.13	-0.34	-0.17	-0.04	0.04	0.06	0.09	-0.002	-0.12
Days to maturity	r_p				0.10	0.16	0.17	-0.33*	-0.004	-0.36*	0.03	-0.07	-0.55**	-0.11	-0.10	-0.33*
	r_g				0.11	0.26	0.17	-0.33	0.02	-0.40	0.03	-0.07	-0.56	-0.11	-0.10	-0.33*
Plant height	r_p					0.75**	0.21	0.10	0.41**	0.20	-0.13	-0.11	0.20	0.03	0.18	-0.14
	r_g					0.96	0.21	0.10	0.61	0.22	-0.13	-0.12	0.21	0.03	0.19	-0.14
Cob height	r_p						0.23	0.16	0.27	0.04	-0.13	-0.12	0.21	-0.10	0.08	-0.17
	r_g						0.30	0.21	0.48	0.10	-0.19	-0.14	0.32	-0.13	0.06	-0.24
Cobs/plant	r_p							-0.22	0.14	0.06	-0.35*	-0.02	0.10	-0.26	-0.04	0.36 *
	r_g							-0.22	0.20	0.05	-0.35	-0.02	0.10	-0.26	-0.04	0.37*
Cob length	r_p								0.22	0.35*	-0.11	0.31*	0.38 **	0.37 **	0.24	0.54 **
	r_g								0.32	0.38	-0.11	0.31	0.39	0.37	0.24	0.55**
Cob girth	r_p									0.24	-0.16	0.31 *	0.04	0.44 **	0.40 **	0.26
	r_g									0.35	-0.28	0.47	0.05	0.64	0.59	0.36
Grain rows/cob	r_p										-0.37 **	0.33 *	0.28	0.26	0.44 **	0.38 **
	r_g										-0.39	0.37	0.31	0.28	0.51	0.40**
Kernels/row	r_p											-0.70 **	-0.29 *	-0.09	-0.35 *	0.22
	r_g											-0.72	-0.30	-0.09	-0.37	0.23
100 seed weight	r_p												0.17	0.51 **	0.54 **	0.38 **
	r_g												0.17	0.51	0.58	0.39**
Chlorophyll content (SPAD)	r_p													-0.07	0.07	0.11
	r_g													-0.06	0.06	0.12
Leaf area/plant	r_p														0.65 **	0.52 **
	r_g														0.68	0.53**
Leaf relative water content	r_p															0.32 *
	r_g															0.35*

Table 4: Direct (diagonal) and indirect (off diagonal) effect of quantitative and physiological characters to yield in maize (*Zea mays* L.) at phenotypic level

Characters	Level	Days to 50% tasseling	Days to 50% silking	Anthesis-silking interval	Days to maturity	Plant height	Cob height	Cobs/plant	Cob length	Cob girth	Grain rows/ cob	Kernels /row	100 seed weight	Chlorophyll content (SPAD)	Leaf area /plant	Leaf relative water content
Days to 50% tasseling	r_p	-0.2431	-0.2260	0.0468	0.0290	-0.0173	-0.0304	0.0199	0.0329	0.0286	-0.0496	-0.0383	0.0386	-0.0213	0.0477	0.0524
Days to 50% silking	r_p	0.2436	0.2620	0.0371	-0.0416	-0.0221	-0.0003	-0.0221	-0.0482	-0.0499	0.0414	0.0372	-0.0389	0.0301	-0.0432	-0.0575
Anthesis-silking interval	r_p	0.0231	-0.0170	-0.1202	0.0155	0.0550	0.0350	0.0008	0.0168	0.0298	0.0201	0.0056	-0.0057	-0.0079	-0.0114	0.0000
Days to maturity	r_p	0.0159	0.0212	0.0172	-0.1336	-0.0145	-0.0217	-0.0229	0.0446	0.0006	0.0489	-0.0047	0.0101	0.0743	0.0152	0.0140
Plant height	r_p	-0.0006	0.0007	0.0039	-0.0009	-0.0084	-0.0063	-0.0018	-0.0009	-0.0035	-0.0017	0.0011	0.0010	-0.0017	-0.0003	-0.0015
Cob height	r_p	0.0088	-0.0001	-0.0205	0.0115	0.0530	0.0705	0.0166	0.0119	0.0194	0.0034	-0.0094	-0.0091	0.0154	-0.0076	0.0062
Cobs/plant	r_p	-0.0081	-0.0083	-0.0007	0.0169	0.0207	0.0232	0.0985	-0.0217	0.0147	0.0059	-0.0347	-0.0023	0.0105	-0.0259	-0.0044
Cob length	r_p	-0.0298	-0.0406	-0.0308	-0.0736	0.0237	0.0373	-0.0487	0.2206	0.0507	0.0777	-0.0255	0.0696	0.0852	0.0826	0.0531
Cob girth	r_p	0.0036	0.0058	0.0075	0.0001	-0.0127	-0.0083	-0.0045	-0.0070	-0.0303	-0.0076	0.0050	-0.0096	-0.0015	-0.0136	-0.0121
Grain rows/cob	r_p	0.0710	0.0550	-0.0583	-0.1275	0.0699	0.0168	0.0210	0.1227	0.0868	0.3483	-0.1309	0.1165	0.0984	0.0938	0.1547
Kernels/row	r_p	0.1817	0.1635	-0.0536	0.0404	-0.1553	-0.1535	-0.4061	-0.1331	-0.1917	-0.4335	1.1529	-0.8144	-0.3380	-0.1063	-0.4077
100 seed weight	r_p	-0.1675	-0.1568	0.0504	-0.0801	-0.1254	-0.1359	-0.0245	0.3332	0.3339	0.3532	-0.7457	1.0556	0.1820	0.5403	0.5780
Chlorophyll content	r_p	-0.0013	-0.0017	-0.0009	0.0080	-0.0029	-0.0032	-0.0015	-0.0056	-0.0007	-0.0041	0.0042	-0.0025	-0.0144	0.0010	-0.0010
Leaf area/plant	r_p	0.0058	0.0049	-0.0028	0.0034	-0.0010	0.0032	0.0078	-0.0111	-0.0134	-0.0080	0.0027	-0.0152	0.0021	-0.0297	-0.0195
LRWC	r_p	0.0053	0.0054	0.0000	0.0026	-0.0045	-0.0022	0.0011	-0.0060	-0.0099	-0.0110	0.0088	-0.0136	-0.0017	-0.0163	-0.0248
Grain yield/plant	r_p	0.1086	0.0681	-0.1251	-0.3300	-0.1417	-0.1758	-0.3662	0.5490	0.2651	0.3836	0.2284	0.3802	0.1114	0.5262	0.3297
Partial R^2	r_p	-0.0264	0.0178	0.0150	0.0441	0.0012	-0.0124	-0.0361	0.1211	-0.0080	0.1336	0.2634	0.4014	-0.0016	-0.0156	-0.0082

Table 5: Direct (diagonal) and indirect (off diagonal) effect of quantitative and physiological characters to yield in maize at genotypic level

Characters	Level	Days to 50% tasseling	Days to 50% silking	Anthesis-silking interval	Days to maturity	Plant height	Cob height	Cobs/plant	Cob length	Cob girth	Grain rows/ cob	Kernels /row	100 seed weight	Chlorophyll content (SPAD)	Leaf area/plant	Leaf relative water content
Days to 50% tasselling	r_g	-0.1321	-0.1265	0.0260	0.0147	-0.0089	-0.0127	0.0109	0.0183	0.0218	-0.0293	-0.0205	0.0217	-0.0131	0.0260	0.0306
Days to 50% silking	r_g	0.1463	0.1528	0.0218	-0.0246	-0.0133	0.0008	-0.0132	-0.0285	-0.0461	0.0235	0.0217	-0.0221	0.0180	-0.0256	-0.0355
Anthesis silking interval	r_g	0.0070	-0.0051	-0.0355	0.0046	0.0164	0.0137	0.0003	0.0050	0.0123	0.0063	0.0017	-0.0017	-0.0023	-0.0034	0.0001
Days to maturity	r_g	0.0107	0.0155	0.0124	-0.0961	-0.0109	-0.0255	-0.0166	0.0322	-0.0027	0.0386	-0.0038	0.0075	0.0548	0.0111	0.0105
Plant height	r_g	0.0016	-0.0021	-0.0110	0.0027	0.0237	0.0228	0.0050	0.0025	0.0146	0.0052	-0.0032	-0.0030	0.0052	0.0008	0.0045
Cob height	r_g	0.0003	0.0000	-0.0011	0.0008	0.0027	0.0028	0.0009	0.0006	0.0014	0.0003	-0.0005	-0.0004	0.0009	-0.0004	0.0002
Cobs/plant	r_g	-0.0071	-0.0075	-0.0006	0.0149	0.0184	0.0262	0.0867	-0.0191	0.0182	0.0047	-0.0307	-0.0019	0.0095	-0.0230	-0.0038
Cob length	r_g	-0.0294	-0.0397	-0.0298	-0.0713	0.0228	0.0464	-0.0470	0.2130	0.0692	0.0812	-0.0248	0.0678	0.0835	0.0801	0.0528
Cob girth	r_g	-0.0123	-0.0224	-0.0258	0.0021	0.0456	0.0361	0.0156	0.0242	0.0744	0.0261	-0.0212	0.0352	0.0040	0.0477	0.0441
Grain rows/cob	r_g	0.0784	0.0544	-0.0632	-0.1420	0.0782	0.0364	0.0193	0.1349	0.1241	0.3539	-0.1395	0.1341	0.1121	0.1011	0.1813
Kernels/row	r_g	0.1987	0.1818	-0.0612	0.0511	-0.1739	-0.2475	-0.4535	-0.1495	-0.3647	-0.5054	1.2821	-0.9240	-0.3957	-0.1157	-0.4821
100 seed weight	r_g	-0.1912	-0.1687	0.0554	-0.0914	-0.1450	-0.1715	-0.0257	0.3708	0.5514	0.4414	-0.8397	1.1651	0.2002	0.6024	0.6763
Chlorophyll content	r_g	0.0033	0.0039	0.0022	-0.0191	0.0073	0.0109	0.0037	0.0132	0.0018	0.0106	-0.0104	0.0058	0.0335	-0.0023	0.0021
Leaf area/plant	r_g	0.0306	0.0260	-0.0148	0.0180	-0.0053	0.0212	0.0412	-0.0584	-0.0996	-0.0444	0.0140	-0.0803	0.0108	-0.1554	-0.1065
LRWC	r_g	0.0039	0.0039	0.0000	0.0018	-0.0032	-0.0011	0.0007	-0.0042	-0.0100	-0.0087	0.0064	-0.0098	-0.0011	-0.0116	-0.0169
Grain yield/plant	r_g	0.1087	0.0664	-0.1249	-0.3338	-0.1452	-0.2410	-0.3717	0.5548	0.3660	0.4041	0.2315	0.3939	0.1202	0.5319	0.3577
Partial R^2	r_g	-0.0144	0.0102	0.0044	0.0321	-0.0034	-0.0007	-0.0322	0.1182	0.0272	0.1430	0.2967	0.4589	0.0040	-0.0826	-0.0061

Where, r_p = Phenotypic level and r_g= Genotypic level ,Genotypic path (R^2 =0.9554 , Residual effect =0.2113) and Phenotypic path (R^2 = 0.8893, Residual effect =0.3327 height and cob height (0.75**), cob girth (0.41**). Cobs/plant showed significant negative correlation with kernels/row (-0.35*). Cob length had significant and positive correlation with grain rows/cob (0.35*), 100 seed weight (0.31*), chlorophyll content (0.38**) and leaf area/plant (0.37**). Cob girth showed significant and positive correlation with 100 seed weight (0.31*), leaf area/plant (0.44**) and leaf relative water content (0.40**). Similar results were reported by Niyokwizigirwa *et al.* (2014). Grain row/cob showed significant and positive correlation with 100 seed weight (0.40**) and leaf relative water content (0.44**), but it showed negative but significant correlation with kernels/row (-0.37**). Kernels/row showed negative significant correlation with 100 seed weight (-0.70**), chlorophyll content (-0.29*) and leaf relative water content (-0.35*). 100 seed weight showed significant and positive correlation with leaf area/plant (0.51**) and leaf relative water content (0.54**). Leaf area/plant showed significant and positive correlation with leaf relative water content (0.65**). Such results could help the breeder to select high grain yield through selection for one or more of these characters. The findings indicates that selection for long cob, more number of grain rows/cob, high 100 seed weight and more number of cobs/plant may be given company to increase grain yield of maize. Langade *et al.* (2013) and Dhutmal *et al.* (2015) reported similar results.

Path analysis

Path analysis reveals the direct and indirect effects of characters on grain yield (Table 4 and 5) The characters days to 50 % silking (r_p=0.262, r_g=0.153), cob height (r_p=0.071, r_g=0.003), cobs/plant (r_p=0.099, r_g=0.087), cob length (r_p=0.221, r_g=0.213), number of grain rows/cob (r_p=0.348, r_g=0.354), kernels/row (r_p=1.153, r_g=1.282), and 100 seed weight (r_p=1.056,r_g=1.165), showed positive direct effect on grain yield at both the phenotypic (r_p) and genotypic (r_g) levels. However, plant height (0.024), cob girth (0.074) and chlorophyll content (0.034) showed positive direct effect on grain yieldonly at the genotypic (r_g) level. These showed that selection is effective for increasing grain yield/plant through selecting the traits having direct effect on grain yield/plant. The experimental results were in accordance with earlier findings of Muhammad *et al.* (2008), Bello *et al.* (2010) and Kumar *et al.* (2014). While, days to 50% tasselling (-0.132), anthesis-silking interval (-0.036) and days to maturity (-0.096) showed negative direct effect on grain yield at the genotypic level. Positive but indirect effect was shown by days to 50% tasseling (0.109), days to 50% silking (0.066), cob length (0.555), cob girth (0.366), grain rows/cob (0.404), kernels/row (0.232), 100 seed weight (0.394), chlorophyll content (0.120), leaf area/plant (0.532) and leaf relative water content (0.358) at the genotypic level. Similar findings were reported by Zarei *et al.* (2012) and Kumar *et al.* (2013).

Thus, the present study indicated the characters namelydays to 50 % silking, cob height, cobs per plant, cob length, number of grain rows/cob, kernels/row, and 100 seed weight would help to improvemaize yield since these characters recorded significant genotypic and phenotypic correlation with high direct effect on grain yield.

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RESPONSE OF ONION TO IRON AND ZINC NUTRITION IN AN ALLUVIAL SOIL

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ABSTRACT

A field experiment was conducted at R. B. S. College Research farm Bichpuri, Agra (U.P.) during rabi season to study the effect of graded levels of iron (0,5,10,20 kg Fe ha^{-1}) and Zn (0, 2.5, 5.0 and 10.0 kg Zn ha^{-1}) on yield attributes, yield, quality and uptake of nutrients in onion (Allium cepa L). The experiment was laid out in randomized block design with three replications. Results revealed that the weight of a bulb, bulb yield and bulb dry matter yield increased linearly up to 10 kg Fe ha^{-1} and 5 kg Zn ha^{-1}. The bulb yield (23.81 t ha^{-1}) at 10 kg Fe ha^{-1} was 14.1% higher than that obtained in the control. Similarly, application of 5 kg Zn ha^{-1} gave the highest yield of bulb (24.85 t ha^{-1}), which was 23.0% more in comparison with that of the control. Similarly dry matter yield of onion bulbs increased significantly with 10 kg Fe ha^{-1} and 5 kg Zn ha^{-1} over their respective controls. The content and yield of protein in onion bulbs increased significantly with an increase in level of iron. Similarly, application of zinc increased the content (3.87%) and yield (14.63 q ha^{-1}) of protein up to 10 and 5 kg Zn ha^{-1}, respectively. The uptake of Fe and Zn by bulbs significantly increased up to 20 kg Fe ha^{-1} and 5 kg Zn ha^{-1}, respectively. An increase in Fe uptake was noted up to 5 kg Zn where as Zn uptake decreased up to 20 kg Fe ha^{-1} addition. The minimum value of Zn uptake by onion bulbs was recorded at 20 kg Fe ha^{-1}. Iron application up to 10 kg ha^{-1} significantly increased the uptake of N, P, K and S by the onion bulb over control followed by a reduction at 20 kg Fe ha^{-1}. A phenomenal increase in uptake of nutrients was recorded in onion bulbs due to increasing levels of Zn up to 5 kg ha^{-1}, thereafter a reduction was noted at 10 kg Zn ha^{-1}.

Key words: Iron, zinc, yield, quality, nutrient uptake onion.

INTRODUCTION

Onion (Allium cepa L) is one of the most important commercial vegetable crops grown in India. Onion requires substantial amount of plant nutrients and responds very well to the added nutrients. Iron and zinc deficiencies and neglect to give equal importance to these nutrients in fertilization programme has resulted in low productivity of onion. Intensive cropping along with lower use of organic manures and very low rates of application or practically no use of iron and zinc in soils have led to depletion of the reserves of Fe and Zn in soils, limiting the crop productivity. The low yields of bulb crops and poor quality of the produce are due to various constraints including micronutrient management. Iron is a structural component of porphyrin molecules cytochromes, haemes, hematin, ferrichrome and leg-haemoglobin involved in oxidation-reduction reactions in respiration. It is an important part of the enzyme nitrogenase which is essential for nitrogen fixation through nitrogen fixing bacteria. The ferrodoxins are Fe-S proteins and are the first stable redox compound of the photosynthetic electron transport chain (Havlin *et al.* 2014). Zinc plays a significant role in various enzymatic and physiological activities of the plant body. Zinc catalyses. The process of oxidation in plant cells and plays a vital role in transformation of carbohydrates, regulates the consumption of sugar, increases, the source of energy for the production of chlorophyll, adds in the formation of auxins and promotes absorption of water. Zinc is also important micronutrient reported deficient in Indian soils and plays a significant role in various enzymatic and physiological activities of plant bodies. Response to applied zinc for better growth and yield of vegetable crops has also been reported from almost all corners of country (Solanki *et al.* 2010).Iron shows interaction with Zn and affects the Zn nutrition of crops like mustard (Kumar *et al.* 2006), wheat (Mohammed and Mohammad 2009) and other crops. However, such information is not available for onion under agro-climatic conditions of Agra region. Therefore, a field experiment was

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conducted to study the effect of Fe and Zn application on yield, quality and nutrient uptake by onion in alluvial soil.

MATERIALS AND METHODS

Field experiments were conducted at R. B. S. College Research farm Bichpuri (Agra). The climate of the study area is semi-arid with an average rain fall of about 650 mm per annum, about 80% of which is received during June to September. The soil of the experimental field was sandy loam in texture, having pH 8.1, organic carbon 3.9 g kg^{-1} and available N, P, K, Fe and Zn 145, 9.2, 115 kg ha^{-1}, 4.2 and 0.55 mg kg^{-1}, respectively. The experiment was laid out in randomized block design with three replications. The treatments included four levels each of iron (0.5, 10 and 20 kg Fe ha^{-1} and Zn (0, 2.5, 2.0 and 10 kg Zn ha^{-1}). Recommended dose of N, P and K(150,kg N, 100 kg P_2O_5 and 50 kg K_2O ha^{-1}) were applied as urea, di-ammonium phosphate and muriate of potash, respectively. Potassium and phosphorus were applied at planting but the crop received nitrogen in two splits, half as basal and half at 60 days after planting. Iron and zinc were applied as ferrous oxide and zinc chloride at the time of planting. The seedlings of onion cv Nasik Red N-53 were planted in mid December during both the years. The spacing adopted was 20x10 cm. Onion crop was irrigated after planting and later as and when required. The crop was harvested at physiological maturity and yield data were recorded. The yield attributes of onion crop were recorded at harvest. Processed bulb samples were analyzed for their nutrients by digesting the samples using di-acid mixture (HNO_3 : $HClO_4$:10 : 4) followed by estimation of Fe and Zn on an AAS. Phosphorus, K and S were determined by vanado molybdo phosphoric yellow colour method, flame photometer (Jackson 1973) and turbidi metric method (Chesnin and Yien 1951), respectively. Nitrogen content was determined following micro Kjeldahl method. The proteln content was computed from the nitrogen content multiplied by a factor 6.25. The uptake of nutrients was then computed from their concentrations in bulb samples and bulb yield.

RESULTS AND DISCUSSION

Yield attribute and yield

A perusal of data (Table 1) revealed that the application of graded doses of Fe to onion significantly enhanced the weight of a bulb over control. The maximum weight (61.7 g) of a bulb was recorded with the application of 10 kg Fe ha^{-1} over rest of the levels of iron. The increase in weight of bulb may be due to low available Fe status of the soil. There was a reduction in weight of bulb with 20 kg Fe ha^{-1} over 10 kg Fe ha^{-1}. Choudhary *et al.* (2015) reported similar results. With increasing levels of zinc, successive increase was observed in weight of onion bulb up to 5 kg Zn ha^{-1} application. Thereafter, weight of a bub reduced with 10 kg Zn ha^{-1}. The weight of bulb increased from 61.0 g at control to 62.2 g with 5 kg Zn ha^{-1}. This increase in weight of bulb with Zn application may be attributed to low level of Zn in experimental soil. Similar results were reported by Singh *et al.*(2015).Application of 10 kg Fe ha^{-1} and 5 kg Zn ha^{-1} produced significantly higher bulb yield and bulb dry matter yield in comparison to control (Table 1). The highest mean bulb yield and dry matter yields of bulbs were recorded with the application of 10 kg Fe ha^{-1}, which were respectively, 14.0 and 13.8% higher than that of the control. Application of 5 kg Zn ha^{-1} recorded the highest bulb yield and bulb dry matter yield, which were respectively 23.0 and 23.5% higher than in the control. This increase might be attributed to the deficiency of these nutrients in soil. Choudhary *et al.* (2015) and Solanki *et al.* (2010) reported similar results in fennel and onion for Fe and Zn, respectively. The higher magnitude of Zn response may be due to quite low initial available Zn status of the soil. In addition, the favourable influence of Zn application on the yield of onion may be attributed to its role in various enzymic reactions, growth processes, hormone production and protein synthesis and also the transformation of photosynthates to reproductive parts thereby leading to higher yield of the crop. Solanki *et al.* (2010) and Choudhary *et al.* (2015) reported similar results in onion and fennel, respectively.

Table 1: Effect of iron and zinc levels on yield and quality of onion (mean of two years)

Treatments	Yield (t ha^{-1})			Protein content (%)	Protein yield (q ha^{-1})
	Weight of bulb (g)	Fresh bulb	Dry matter		
Iron (kg ha^{-1})					
0	61.4	20.95	3.23	3.68	11.88
5	61.5	21.90	3.38	3.75	12.67
10	61.7	23.81	3.68	3.81	14.02
20	60.9	22.46	3.47	3.81	13.22
SEm±	0.01	0.38	0.06	0.05	0.31
CD (p= 0.05)	0.02	0.77	0.13	0.11	0.63
Zinc (kg ha^{-1})					
0	61.0	20.17	3.11	3.62	11.29
2.5	61.5	22.10	3.41	3.75	12.79
5.0	62.2	24.85	3.84	3.81	14.63
10.0	60.8	22.00	3.39	3.87	13.12
SEm±	0.01	0.38	0.06	0.05	0.31
CD (p= 0.05)	0.02	0.77	0.13	0.11	0.63

Quality

Application of iron increased the protein content in onion bulb and this increase was significant over control. The maximum value of protein content (3.81%) was noted at 10 kg Fe ha^{-1}. Protein content increased significantly with the application of zinc, which was lowest in control (3.62%) and highest (3.87%) at 10 kg Zn ha^{-1}. This increase in protein content with iron application may be attributed to its involvement in nitrogen metabolism. Similar results were reported by Chandel *et al.* (2013).This increase in protein content may be attributed to its involvement in nitrogen metabolism.The protein production increased from 11.88 q ha^{-1} at control to 14.02 q ha^{-1} with 10 kg Fe ha^{-1}. Application of zinc increased the protein production significantly over control. The maximum protein yield (14.63 q ha_{-1}) was observed in the treatment where 5 kg Zn ha^{-1} was applied. Since, protein yield is the resultant of bulb yield and protein content, it also increased due to Fe and Zn because of increase in bulb yield. Solanki *et al.* (2010) and Choudhary *et al.* (2015) reported similar results in onion and fennel respectively.

Table 2: Effect of iron and zinc levels on uptake of N, P, K, S (kg ha^{-1}) and Fe and Zn (g ha^{-1}) by onion bulbs (mean of two years)..

Treatment	N	P	K	S	Fe	Zn
Iron (kg ha^{-1})						
0	19.0	4.5	16.1	9.6	161.5	109.8
5	20.3	5.1	17.2	11.8	184.2	106.8
10	22.4	4.8	17.3	13.6	220.8	105.7
20	21.2	3.5	15.6	12.1	225.5	93.3
SEm+	0.58	0.02	0.48	0.59	9.8	5.1
Cd (p_2 0.05)	1.17	0.04	0.97	1.19	19.7	10.3
Zinc (kg ha^{-1})						
0	18.1	4.1	15.3	9.0	192.8	82.7
2.5	20.5	5.1	17.0	11.6	199.8	99.0
5.0	23.4	4.4	18.4	14.6	215.0	121.7
10.0	21.0	3.4	15.6	12.2	179.0	115.3
SEm+	0.58	0.02	.48	0.59	9.8	5.1
Cd (p_2 0.05)	1.17	0.04	0.97	1.19	19.7	10.3

Nutrient uptake

The uptake of nitrogen by onion bulbs increased significantly with lower levels of iron addition followed by a reduction at 20 kg Fe ha^{-1}. The maximum value of N uptake (220.4 kg ha^{-1}) was recorded at 10 kg Fe ha^{-1}. The increase in N uptake with lower levels of iron may be due to higher bulb production. Mohammad and Mohammad (2009) also reported similar results. Nitrogen uptake by onion bulb increased significantly with increasing levels of zinc and the highest N uptake was observed with 5 kg Zn ha^{-1} i.e 23.4 kg $ha^{-1}$and lowest in the control (18.1kg ha^{-1}). Thus the beneficial effect of Zn on photosynthesis and metabolic processes augments the production of photosynthates and their translocation to different plant parts including bulb. These results are in accordance with the findings of Singh *et al.* (2015).

The utilization of P by onion bulbs increased significantly with lower levels of Fe over control. The higher level (20 kg Fe ha^{-1}) caused a significant reduction in P uptake by onion crop over 5 kg Fe ha^{-1}. This reduction may be due to reduction in dry matter yield of onion bulbs. Similar results were reported by Chandel et al (2013). Phosphorus uptake first increased due to increase in yield but at the higher dose of zinc, it increased due to decrease in P content in bulb. The decrease in P uptake with higher level of zinc might be due to antagonistic effect between P and Zn. Similar results were reported by Singh and Pandey (2006) and Singh *et al.* (2015). The K uptake by onion bulbs increased significantly and consistently up to 10 kg Fe ha^{-1}. Thereafter, a reduction in potassium uptake by onion bulbs was noted at 20 kg Fe ha^{-1}. Kumar *et al.* (2006) reported similar results.The uptake of K by onion bulb was significantly increased with increasing levels of Zn up to 5 kg Zn ha^{-1}. The magnitude of increase in K uptake with 5 kg Zn ha^{-1} was 20.2 % in onion bulbs over control. This increase in K uptake may be ascribed to greater dry matter production with zinc application (Singh *et al.* 2015).

The S uptake by onion bulbs increased significantly with increasing levels of Fe over control (Table 2) which may be due to increased availability of S in soil. In onion bulbs, S uptake ranged from 9.6 kg ha^{-1} (control) to 13.6 g ha^{-1} (10 kg Fe ha^{-1}). There was a significant increase in S uptake by onion bulb with the application of Zn up to 5 kg Zn ha^{-1} over the control. Thereafter, a reduction in S uptake was noted at higher level of zinc (10 kg ha^{-1}) over 5 kg Zn ha^{-1} (Singh *et al.* 2015). Application of Fe progressively increased its uptake by onion bulb, i.e. at 5,10 and 20 kg Fe ha^{-1}, it was 14.0,36.7and 39.6% higher over control, respectively. This increase may be due to increased availability of iron in soil (Chandel *et al.,* 2013). The Fe application had significant adverse effect on Zn uptake by the onion bulb. The highest level of Fe (20 kg ha^{-1}) reduced the Zn uptake compared with its lower levels as a result of lower content of Zn in bulbs. The Zn uptake by onion bulbs increased with its addition and the highest value of Zn uptake 121.7 g ha^{-1} was recorded at 5 kg Zn ha^{-1}. It was due to combined effect of higher yield along with higher Zn content. Zinc application increased the Fe uptake by onion bulb significantly over the control. However, higher level of Zn slightly reduced the Fe uptake in onion bulbs over control.

From the results, it can be concluded that application of iron and zinc was found to be effective for sustainable production, quality and uptake of nutrients in onion bulbs. Application of 10 kg Fe ha^{-1} and 5 kg Zn ha^{-1} had significant effect on yield, quality and uptake of nutrients by inion bulbs under the agro-climatic conditions of Agra.

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EFFECT OF FYM, POTASSIUM AND ZINC ON YIELD, QUALITY AND UPTAKE OF NUTRIENTS IN FORAGE CLUSTERBEAN IN ALLUVIAL SOIL

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ABSTRACT

A field experiment was carried out at the research farm, R.B.S. College, Bichpuri, Agra (U.P.) during kharif season to study the effect of FYM (0 and 5t ha^{-1}), potassium (0,30,60 and 90 kg K_2O ha^{-1}) and zinc (0,1,2 and 4 kg ha^{-1}) levels on the yield, quality and uptake of nutrients in forage cluster bean (Cyamopsis tetragonoloba L.). The experiment was laid out in split plot design with three replications. Data revealed that the plant height, green foliage and dry matter yields and protein content and yield increased significantly with the application of 5t FYM, 90 kg K_2O and 4 kg Zn ha^{-1} over their respective controls. Application of 5t FYM ha^{-1} gave 14.6 and 24.1 per cent higher green foliage and dry matter yield of fodder cluster bean over control respectively. It also increased the uptake of nutrients by the forage crop over control. Application of 90 kg K_2O ha^{-1} was more effective in increasing plant height green foliage and dry matter yields than those of 30 and 60 kg K_2O ha^{-1}. The higher green foliage (304.2 t ha^{-1}) and dry matter yield (43.94 t ha^{-1}) were recorded with 90 kg K_2O ha^{-1}, which was 14.8 and 23.6% higher than that of control. The uptake of nutrients by the crop increased significantly up to 90 kg K_2O ha^{-1} over control. Potassium application tended to increase the content and yield of protein in cluster bean. Application of zinc proved superior to control in terms of protein content and yield in cluster bean. The uptake of nutrients by the crop increased significantly with Zn addition up to 4 kg Zn ha^{-1} over control. Green foliage (309.87 t ha^{-1}) and dry matter yield (43.64 t ha^{-1}) of cluster bean were the highest with 4 kg zinc ha^{-1}.

Keywords: FYM, potassium, zinc, yield, uptake of nutrients, quality, cluster bean.

INTRODUCTION

Cluster bean (Cyamopsis tetragonoloba L.) is an important legume crop mainly grown under rain fed condition during kharif season. It is hardy and drought tolerant crop. It is grown for different purposes viz. vegetable, green fodder, green manure and production of seeds. The ever-rising demand for fodder and feed for sustaining livestock production can be met through increasing productivity of fodder. The various factors are responsible for low productivity such as poor fertilization and improper soil management of which poor fertilization is main factor for poor productivity of cluster bean. Farmyard manure improves physical, chemical and biological properties of soil and sustains fertility and productivity of cultivated land. FYM has shown considerable increase in crop yield and helps in enhancing nutrient availability both from applied and native sources. Potassum is the most important essential nutrient after nitrogen and phosphorus and plays a vital role in plant cell sap, support enzymatic activity, photosynthesis and transportation of sugar, synthesis of protein and starch but does not bounds with carbon or oxygen. It also develops tolerance to drought condition and enhances plant ability to resist attacks of pest and diseases. Zinc plays an important role as a metal component of enzymes (alcohol dehydrogenase, super oxide dismutase, carbonic anhydrase and RNA polymerase) or as a functional, structural or regulator cofactor of a large number of enzymes (Marschner, 1986). It is considered to be the most yield limiting micronutrient in crop production in various parts of the world. Integration of K and Zn with FYM will not only sustain the crop production but also will be effective in improving soil fertility. As information is lacking on the effect of FYM, K and Zn on cluster bean production in Agra region of Uttar Pradesh, the present study was therefore, planned to assess the effect of FYM, potassium and zinc on productivity of cluster bean.

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MATERIALS AND METHODS

The field experimental was conducted during kharif season at R.B.S.College Research farm Bichpuri, Agra (U.P.). The soil was sandy loam in texture having pH 7.8, EC 0.29 dSm^{-1}, organic carbon 3.6 g kg^{-1}, available N 165 kg ha^{-1}, P 8.5 kg ha^{-1}, K 110 kg ha^{-1} and Zn 0.51 mg kg^{-1}. The experiment was laid out in split plot design with two levels of FYM (0 and 5t ha^{-1}), four levels each of K (0, 30, 60 and 90 kg K_2O ha^{-1}) and Zn (0, 1, 2 and 4 kg Zn ha^{-1}) with three replications. A uniform dose of N and P @ 20 and 60 kg P_2O_5 ha^{-1} was applied through diammonium phosphate at the time of sowing. Well decomposed FYM was applied before sowing of the crop. Potassium and Zn were applied through mutriate of potash and zinc sulphate, respectively at the time of sowing. Cluster bean (cv RGC-986) was sown as fodder crop in last week of June in both the years. Other agronomic management practices were followed as per standard recommendation. The crop was harvested after 90 days of sowing.The plant samples were digested with di acid mixture of HNO_3 and HCl O_4 in 9:1 ratio. Phosphorus was determined by vanadomolybdate yellow colour method (Jackson, 1973), S by turbidi metric method (Chesnin and Yien 1951), K by flame photometer, Zn by atomic absorption spectrophotometer. Nitrogen in plants was determined by modified micro Kjeldahl method. The nutrient uptake was calculated by multiplying the nutrient concentration values with the dry matter yield. The data were statistically analysed using standard procedures of ANOVA at 5% level of significance.

RESULTS AND DISCUSSION

Effect of FYM

The plant height, green foliage and dry matter yields and protein content in cluster bean fodder increased significantly with FYM application over control (no FYM). The mean maximum plant height (144.1 cm) green foliage (312.29 t ha^{-1}), dry matter (45.41 t ha^{-1}) yields, protein content (15.2 %) were obtained at 5 t FYM ha^{-1}. The mean increases in green foliage and dry matter yield due to 5 t FYM ha^{-1} over control were 14.6 and 24.1 per cent, respectively. The increase in yield might be due to steady decomposition of FYM and release of nutrients throughout the crop growth period coupled with better assimilation of nutrients (Saket *et al.* 2014). The beneficial effect of FYM on yield was also reported by Singh *et al.* (2013a). The protein yield also significantly increased with FYM application from 51.6 q ha^{-1}at control to 69.0 q ha^{-1} at 5 t FYM ha^{-1}. Saket *et al.* (2014) also reported similar results.

Application of 5 t FYM ha^{-1} significantly increased the uptake of N (111.0 kg ha^{-1}), P (17.2 kg ha^{-1}), K (146.9 kg ha^{-1}), S (7.7 kg ha^{-1}) and Zn (84.0 g ha^{-1}) by cluster bean crop over control. The increase in nutrient uptake may be due to increase in nutrient content and dry matter yield. Higher uptake of N with FYM may be due to mineralization of N from FYM which sufficiently meet the nutritional requirement of the crop (Singh *et al.,* 2013b). The effect of FYM in increasing P uptake may be associated with improvement of the soil environment which encouraged proliferation of roots resulting in more absorption of water and nutrients from larger area and depth, The higher nutrient uptake with FYM might be attributed to solubilization of nutrients, chelation of complex intermediate organic molecules, produced during the decomposition of added FYM, their mobilization and accumulation of different nutrients in different plant parts. Similar results were reported by Saket *et al.* (2014).

Effect of potassium

Data (Table 1) show that application of potassium significantly increased the plant height in cluster bean up to 90 kg K_2O ha^{-1}. This may be due to function of K in most of the physiological and metabolic processes resulting in increased growth and development of plants. Similar results were reported by Singh and Singh (1994).Application of 30, 60 and 90 kg K_2O ha^{-1} increased the green foliage yield by 3.0, 8.1 and 14.8 per cent over contro l, respectively. As potassium is essential for growth, the favorable effect of high doses of K on growth and yields of cluster bean was mainly responsible for green foliage and dry matter yields. The results are in close conformity with those of Tomar *et al.* (2002).

Table 1: Effect of FYM, potassium and zinc on growth, yield and quality of fodder clusterbean

Treatment	Plant height (cm)	Yield ($t\ ha^{-1}$)		Protein content (%)	Protein yield ($q\ ha^{-1}$)
		Green foliage	Dry matter		
FYM ($t\ ha^{-1}$)					
0	127.0	272.50	36.60	14.1	51.6
5	144.1	312.29	45.41	15.2	69.0
SEm±	1.35	2.47	2.17	0.31	3.04
CD (P=0.5)	3.87	7.06	6.21	1.00	8.69
Potassium ($kg\ ha^{-1}$)					
0	128.0	265.02	35.54	14.1	50.1
30	131.4	273.02	38.41	14.4	55.3
60	133.2	286.60	41.40	14.6	60.4
90	135.5	304.20	43.94	14.8	65.0
SEm±	0.34	1.26	0.70	0.11	0.98
CD (P=0.5)	0.98	3.61	2.00	0.31	2.80
Zinc ($kg\ ha^{-1}$)					
0	126.0	268.30	34.29	14.0	48.0
1	128.5	273.53	36.25	14.2	51.5
2	130.0	206.51	39.40	14.5	57.1
4	132.8	309.87	43.64	14.8	64.6
SEm±	0.36	0.99	0.54	0.04	0.76
CD (P=0.5)	1.04	2.85	1.55	0.11	2.17

Each successive increase in K levels from 0 to 90 kg $K_2O\ ha^{-1}$ increased the protein content and yield. The maximum value of protein yield (65.0 q ha^{-1}) was obtained with 90 kg $K_2O\ ha^{-1}$. Since, protein yield is the resultant of dry matter yield and protein content, it also increased due to potassium application because of an increase in dry matter yield. Similar results were reported by Tomar *et al.* (2002).A marked increase in N uptake (104.8 kg ha^{-1}), P (15.6 kg ha^{-1}), K (142.0 kg ha^{-1}), S (8.1 kg ha^{-1}) and Zn (78.1g ha^{-1}) was recorded with the application of 90 kg $K_2O\ ha^{-1}$ (Table 2). Since, the nutrient uptake is a function of their content in crop plant and yield of plant, increases in nutrients uptake by the crop are expected. These results are in conformity with those of Tomar *et al.* (2002) and Brar *et al.* (2004) who reported increased uptake of N, P, K, S and Zn by Chickpea and Pea, respectively.

Table 2: Effect of FYM, potassium and zinc on uptake of N, P, K, S ($kg\ ha^{-1}$) and Zn ($g\ ha^{-1}$) by cluster bean crop

Treatment	Nitrogen	Phosphorus	Potassium	Sulphur	Zinc
FYM ($t\ ha^{-1}$)					
0	82.7	9.7	114.6	3.8	58.0
5	111.0	17.2	146.9	7.7	81.0
SEm±	1.26	1.71	2.22	0.63	7.7
CD (P=0.5)	3.62	4.88	6.35	1.82	22.0
Potassium ($kg\ ha^{-1}$)					
0	80.5	9.1	111.6	4.4	51.0
30	88.7	11.0	121.8	5.6	60.0
60	97.1	13.5	132.5	6.6	69.0
90	104.8	15.6	142.0	8.1	78.1
SEm±	0.74	0.99	1.29	0.37	2.4
CD (P=0.5)	2.11	2.83	3.69	1.05	6.9
Zinc ($kg\ ha^{-1}$)					
0	77.2	9.1	106.6	4.2	49.0
1	82.8	10.7	114.0	5.1	57.0
2	91.6	13.0	125.3	6.8	66.2
4	103.6	15.9	140.3	8.9	78.1
SEm±	0.63	0.54	1.18	0.21	2.2
CD (P=0.5)	1.80	1.54	3.38	0.61	6.2

Effect of zinc

Application of zinc increased the plant height over control. The maximum value of this character was noted at 4 kg Zn ha^{-1} followed 2, 1 kg Zn ha^{-1} and control. Similar findings were reported by Meena *et al.* (2006) and Ali *et al.* (20013). Application of Zn also increased the green foliage and dry matter yield significantly up to 4 kg Zn ha^{-1} (Table 1). The magnitude of increase was 15.5 and 27.3 per cent in green foliage and dry matter yield, respectively over control. The increase in plant height and yields might be due to role of Zn in biosynthesis of indole acetic acid (IAA) and especially due to its role in initiation of primordial for partitioning of photosynthates towards them which resulted in better yield (Ali *et al.* 2013). Increasing levels of Zn from 0 to4 Zn ha^{-1} increased the content and yield of protein from 14.0 to 14.8 % and from 48.0 to 64.6 q kg ha^{-1}, respectively in cluster bean crop. This was mainly owing to higher dry matter yield and protein per centage in ciuster bean plants. The results corroborate with the findings of Meena *et al.* (2006) and Ali *et al.* (2013). A perusal of data (Table 2) revealed that N, P, K, S, and Zn uptake increased significantly with Zn application over control. The highest uptake of N (103.6kg ha^{-1}) was associated with 4 kg Zn ha^{-1}. Significant increase in P uptake by plants (15.9kg ha^{-1}) was also found with 4 kg Zn ha^{-1} as observed by Singh and Singh (2012). The maximum uptake of K by the crop (140.3 kg ha^{-1}) was recorded with 4 kg Zn ha^{-1}. Plant uptake of S and increased along with rise in levels of Zn up to 4 kg ha^{-1}. The increase in nutrient uptake may be due to increase in nutrient content and dry matter yield. Zinc plays structural and regulatory roles in large numbers of enzymes and protein synthesis, which directly affects the nutrients absorption from the soil (Behera *et al.* 2009 and Sharma *et al.* 2014). Zinc uptake by cluster bean crop increased significantly with increasing levels of applied Zn. Highest Zn uptake was found with 4 kg Zn ha^{-1} and lowest in control. The higher Zn uptake due to its application could be attributed to the priming effect caused by higher crop growth and consequently higher removal of zinc due to its application. Ali *et al.* (2013) reported similar results.

From the present investigation, it may be concluded that the application of FYM, K and Zn increased the green foliage and dry matter yields and protein content in fodder cluster bean, Application of 5 t FYM, 90 kg K_2O and 4 kg Zn ha^{-1} gave the maximum values of yields and protein content in cluster bean under agroclimate condition of Agra region.

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GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE IN EARLY MATURING CAULIFLOWER

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ABSTRACT

A field experiment was conducted at Pantnagar (Uttarakhand) during 2013-14 to study the genetic variability in thirty five diverse genotypes of early maturing cauliflower for various quantitative and qualitative characters. Analysis of variance revealed significant differences among the genotypes for all the characters except for number of leaves per plant, days to curd initiation and days to curd maturity. The genotypes, viz. Inb-21-2, PES-2, PG-6, and PG-3 were found promising in terms of desirable quantitative and qualitative traits. Inb-21-2 had maximum curd yield (308.53 q ha^{-1}) while PG-3 exhibited earliest harvestable curd maturity (114.6 days). Moderate ranges of phenotypic and genotypic coefficients of variation (PCV and GCV) were observed for characters net curd weight, marketable curd weight, curd yield per hectare, harvest index, curd index and gross plant weight. High heritability along with moderate genetic advance were observed for gross plant weight, net curd weight, marketable curd weight and curd yield. From the study it could be concluded that net curd weight, marketable curd weight, curd yield and gross plant weight are the most important traits for applying selection in early cauliflower for crop improvement.

Keywords: Early cauliflower, genetic variability, heritability and genetic advance

INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis* L.) is one of the most widely grown vegetable crops in many parts of the world. India is the second largest producer of cauliflower in the world after China (Anonymous, 2014). It is one of the important winter vegetables grown under varying agro-climatic conditions in India. The word cauliflower comes from Latin term caulis and floris, meaning stem or stalk and flower, respectively. It is grown for its white tender curd which has been described as a pre-floral structure. Replacement of open-pollinated cultivars with narrow genetic based F_1 hybrids has resulted in the genetic erosion of cauliflower and other cole crops. So, sincere efforts are needed to preserve the germplasm (Singh *et al.,* 2013). The development of an effective improvement programme depends upon the existence of genetic variability in the crop. The nature and magnitude of variability present in the gene pool for different characters and relationship with each other determine the success of genetic improvement of a character. Most of the important characters including marketable yield are highly influenced by environment, since they are polygenically controlled. This makes the selection process difficult. Therefore, knowledge of heritability for different component traits were essential for any crop improvement programme, because the heritable component is the consequence of genotype and is inherited from generation to generation (Wright, 1921). Genetic coefficient of variation together with heritability and genetic advance estimates give reliable indication of the amounts of the extent of improvement accepted from selection and further remarked that accepted genetic gain under particular system, which provides true practical information needed by a breeder (Atter *et al.,* 2011). Hence, an investigation was carried out for estimating genetic variability, heritability and genetic advance among various economic traits in thirty five lines of early maturing cauliflower.

MATERIALS AND METHODS

The present investigation was conducted at the Vegetable Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (Uttarakhand) during summer season of 2013-2014. Pantnagar is geographically

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situated at an altitude of 243.84 m above mean sea level and at 29^0N latitude and 79.3^0 E longitudes. This falls in the humid subtropical zone and situated in the Tarai belt in the foothills of Shivalik range of the great Himalayas. The experimental material comprised of 35 diverse genotypes of early cauliflower. The seeds of all diverse lines were sown on 15 cm raised seedbeds in nursery and the seedlings were transplanted in the main field after one month at the spacing of 50 cm × 50 cm. The experiment was laid out in randomized block design with three replications. Uniform cultural operations were followed as per the recommended package of practices. Observations were recorded on five randomly selected competitive plants per replication for each entry on quantitative *viz*., plant height, plant diameter, number of leaves per plant, leaf length, days to curd initiation, days to curd maturity, gross plant weight, marketable curd weight, net curd weight, curd diameter, curd depth, harvest index, curd index and curd yield and five qualitative characters *viz.*, curd colour, curd compactness, tolerance to diseases, tolerance to insect pests and tolerance to disorders. The data regarding above mentioned quantitative characters were averaged and subjected to analysis of variance (Panse and Sukhatme, 1984). Phenotypic and genotypic coefficients of variations were estimated according to Burton and DeVane (1953). Heritability in broad sense was calculated as per formula given by Burton and DeVane (1953) and Allard (1960). Genetic advance expressed as per cent of population mean was calculated by the method given by Johnson *et al.* (1955).

RESULTS AND DISCUSSION

The study revealed that twenty one genotypes had white coloured curd, ten genotypes creamy white curd and four yellowish curd. Seventeen genotypes had compact curd while remaining eighteen genotypes possessed loose curd. Eighteen genotypes were reported to be tolerant to major diseases; twelve moderately tolerant and remaining five genotypes were susceptible to diseases (Table 1). According to tolerance to major insect pests, eighteen genotypes were classified as tolerant, thirteen as moderately tolerant and remaining four genotypes as susceptible. Twenty one genotypes were observed with none physiological disorder, eight with more occurrence of riceyness, two with more leafyness, three others with more buttoning and one was found with both Riceyness and leafiness.

Analysis of variance showed that the differences due to genotypes were significant for all the characters studied except for number of leaves /plant, days to curd initiation and days to curd maturity, indicating adequate scope for selection of superior and diverse genotypes (data not shown). The line Inb-21-2 was found to excel others in overall performance with respect to marketable curd weight, net curd weight, curd index, harvest index and curd yield. The highest curd yield was recorded in Inb-21-2 (308.53 q ha^{-1}) followed by PES-2 (290.80 q ha^{-1}). Curd maturity in terms of days after sowing was found earliest in PG-3 (114.6) followed by DC-98-4-2 (116.6), PG-6 (117), Inb-PCF-79 (117.3) and PES-2 (117.6). On the basis of different quantitative and qualitative characters observed, the genotypes *viz.* Inb-21-2, PES-2, PG-3 and PG-6 were found promising.

The genotypes showed considerable range for most of the characters under study. The phenotypic coefficient of variation (PCV) was greater than genotypic coefficient of variation (GCV) for all the traits indicating the predominant role of environment in the expression of the traits. Moderate ranges of PCV and GCV were found in net curd weight (PCV= 26.55 %, GCV= 24.99 %), marketable curd weight (PCV=22.70 %, GCV=21.34 %), curd yield (PCV=22.70 %, GCV=21.34 %), harvest index (PCV=20.59 %, GCV=20.17 %), curd index (PCV=20.17, GCV=15.04 %) and gross plant weight (PCV=16.47, GCV=15.56 %). Rest of the parameters exhibited low coefficients of variation. Moderate PCV and GCV for net curd weight and marketable curd weight have also been reported by Kanwar *et al.* (2010). Dubey *et al.* (2003) reported moderate PCV and GCV for curd index and harvest index while Sharma *et al.* (2006) observed moderate PCV and GCV for gross plant weight.

Table 1: Qualitative characters of different genotypes of early cauliflower

S. No.	Genotypes	Curd Colour	Curd Compactness	Tolerance to diseases	Tolerance to insect pests	Occurrence of disorders
1.	Inb-21-2	White	Compact	Tolerant	Tolerant	No
2.	Inb-23-2	White	Compact	Tolerant	Susceptible	No
3.	Inb-PCF-27	Creamy white	Loose	Susceptible	Susceptible	Riceyness
4.	Inb-PCF-65	Creamy white	Loose	Susceptible	Moderately tolerant	No
5.	Inb-PCF-79	White	Loose	Tolerant	Tolerant	Riceyness
6.	Inb-PCF-92	White	Compact	Tolerant	Tolerant	No
7.	Inb-PCF-104	White	Compact	Tolerant	Tolerant	No
8.	Inb-PCF-105	Yellowish	Loose	Tolerant	Moderately tolerant	No
9.	Inb-PCF-108	White	Compact	Tolerant	Tolerant	Riceyness and leafyness
10.	Inb-PCF-114	Creamy white	Compact	Tolerant	Tolerant	No
11.	Inb-PCF-117-1	White	Loose	Tolerant	Tolerant	Riceyness
12.	Inb-PCF-118	Creamy white	Compact	Moderately tolerant	Moderately tolerant	No
13.	Inb-PCF-120	Creamy white	Loose	Moderately tolerant	Moderately tolerant	No
14.	Inb-PCPGR-1614	White	Loose	Tolerant	Tolerant	No
15.	PCPGR-1614	Yellowish	Loose	Moderately tolerant	Moderately tolerant	No
16.	Inb-DC-94-4-3	White	Compact	Moderately tolerant	Tolerant	Buttoning
17.	Inb-DC-98-4-2	White	Loose	Moderately tolerant	Tolerant	Buttoning
18.	PCPGR-2004	Creamy white	Compact	Moderately tolerant	Tolerant	No
19.	PG-3	White	Compact	Tolerant	Tolerant	No
20.	PG-5	White	Loose	Tolerant	Tolerant	Riceyness
21.	PG-6	White	Compact	Tolerant	Tolerant	No
22.	Composite-2	White	Loose	Susceptible	Moderately tolerant	Leafyness
23.	Composite-3	White	Compact	Tolerant	Tolerant	No
24.	Composite-4	Yellowish	Loose	Moderately tolerant	Moderately tolerant	Riceyness
25.	DC-5-3	White	Compact	Moderately tolerant	Moderately tolerant	Buttoning
26.	DC-98-4-2	Creamy white	Loose	Moderately tolerant	Susceptible	No
27.	DC-98-4-3	Creamy white	Loose	Tolerant	Moderately tolerant	Riceyness
28.	DC-541-5	White	Compact	Moderately tolerant	Tolerant	No
29.	CFH-131	White	Loose	Susceptible	Moderately tolerant	Leafyness
30.	PS-1	White	Loose	Tolerant	Moderately tolerant	Riceyness
31.	PES-1	White	Compact	Tolerant	Tolerant	No
32.	PES-2	White	Loose	Moderately tolerant	Moderately tolerant	No
33.	PES-3	Yellowish	Compact	Susceptible	Susceptible	No
34.	C-1	Creamy white	Compact	Tolerant	Tolerant	No
35.	PF-2	Creamy white	Loose	Moderately tolerant	Moderately tolerant	Riceyness

A broad sense heritability estimate provides information on relative magnitude of genetic and environmental variation in germplasm pool. Estimates of broad sense heritability were high (more than 80 %) for characters *viz.,* gross plant weight (89.33 %), net curd weight (88.62 %), marketable curd weight (88.41 %) and curd yield (88.41 %). High heritability for net curd weight and marketable curd weight have also been reported by Singh *et al.* (2006) and Singh *et al.* (2013) while high heritability for gross plant weight and harvest index was noted by Dubey *et al.* (2003) and Sharma *et al.* (2006). However, moderate range of heritability was exhibited by harvest index, plant height, curd diameter, curd index, and leaf length. Highest genetic advance as per cent of mean was observed for net curd weight (48.47 %) followed by marketable curd weight (41.35 %) and curd yield (41.35 %), harvest index (32.71 %) and gross plant weight (30.31 %). Kanwar *et al.* (2010) also earlier recorded moderate range of genetic advance as per cent of mean for net curd weight and marketable curd weight while Sharma *et al.* (2006) noted moderate genetic advance as per cent of mean for harvest index and gross plant weight. However, in contrast to present findings, high

Table 2: Mean performance of various genotypes of early cauliflower for quantitative characters

Genotypes	Plant height (cm)	Leaves per plant	Leaf length (cm)	Days to curd initiation	Days to curd maturity	Gross plant weight (g)	Marketable curd weight (g)	Net curd weight (g)	Curd diameter (cm)	Curd depth (cm)	Harvest index (%)	Curd index (cm^2)	Yield (q/ha)
1.	69.80	29.7	50.4	109.3	119.3	2004.33	771.33	638.00	17.8	11.6	31.94	208.59	308.53
2.	71.20	26.6	47.9	120.3	129.3	1577.00	386.67	296.00	12.4	9.47	18.79	118.52	154.67
3.	69.00	28.7	46.7	119.6	128.6	1604.67	476.00	359.00	15.6	10.3	22.36	162.31	190.40
4.	65.67	28.6	45.6	113.3	122.6	1636.33	476.33	353.00	14.1	11.3	21.60	159.17	190.53
5.	62.53	25.4	46.1	108.6	117.3	1553.00	412.00	318.67	13.5	9.03	20.47	122.80	164.80
6.	60.07	23.6	41.9	111.3	120.6	1176.67	382.67	269.67	13.7	10.8	23.07	148.63	153.07
7.	63.80	26.4	48.8	112.0	121.3	1755.67	456.33	351.67	14.3	9.87	20.03	141.47	182.53
8.	59.93	24.8	46.5	112.3	122.0	1474.67	375.67	278.67	13.9	8.97	18.85	124.85	150.27
9.	66.20	25.8	46.8	112.3	121.3	1561.00	533.67	428.33	14.7	10.3	27.45	152.34	213.47
10.	72.73	27.6	55.9	120.0	129.6	2108.33	436.67	325.33	13.5	10.3	15.61	140.46	174.67
11.	69.80	27.0	48.0	119.3	128.6	1581.00	339.00	244.67	11.7	9.13	15.49	107.82	135.60
12.	60.47	24.8	49.8	116.6	125.3	1858.00	456.33	342.00	13.4	9.30	18.40	124.81	182.53
13.	64.20	24.4	47.8	111.6	120.3	1728.33	431.33	332.67	13.2	10.7	19.23	141.28	172.53
14.	62.87	23.7	47.3	111.3	120.0	1500.00	324.67	240.33	12.3	8.97	16.02	111.05	129.87
15.	66.27	25.5	48.5	113.0	122.3	1669.33	473.33	361.67	14.0	10.7	21.67	149.28	189.33
16.	62.60	23.9	47.8	110.0	119.0	1702.00	411.67	310.33	12.7	8.90	18.21	112.77	164.67
17.	68.40	29.0	51.1	116.0	125.3	2170.00	716.67	595.00	16.9	11.2	27.55	190.10	286.67
18.	61.07	23.4	44.4	117.0	127.0	1505.67	536.00	431.00	14.4	9.83	28.65	142.13	214.40
19.	75.20	28.6	50.4	109.0	114.6	2267.00	608.67	486.67	15.2	10.9	21.58	166.24	243.47
20.	60.80	25.4	47.6	110.6	119.3	1527.67	429.00	327.67	13.1	9.03	21.46	118.37	171.60
21.	64.00	29.9	50.4	108.6	117.0	2112.67	628.00	517.00	16.6	11.7	24.47	196.42	251.20
22.	62.60	27.6	46.9	111.3	119.3	1676.00	497.67	388.67	14.7	10.1	23.17	148.95	199.07
23.	63.67	27.2	48.8	110.3	119.0	1904.67	526.33	416.00	14.1	10.2	21.85	144.21	210.53
24.	66.87	27.5	48.2	109.6	118.0	1579.33	399.33	297.33	12.6	9.97	18.79	125.82	159.73
25.	80.27	31.4	54.3	112.0	121.3	2479.67	505.33	390.67	15.6	10.3	15.89	160.94	202.13
26.	67.53	25.8	48.3	110.6	116.6	1685.67	516.67	412.00	15.4	10.8	24.44	167.83	206.67
27.	73.87	29.5	49.6	116.0	125.0	2060.33	470.33	359.67	14.5	9.93	17.48	145.29	188.13
28.	63.13	26.0	45.6	117.0	125.3	1549.00	400.00	304.67	13.3	9.93	19.66	131.21	160.00
29.	74.27	29.6	55.8	110.0	119.6	2215.67	648.00	508.00	15.2	11.0	23.02	167.81	259.20
30.	72.80	29.1	51.6	109.6	119.0	2002.67	495.33	381.33	14.1	9.97	19.24	141.01	198.13
31.	62.67	26.9	48.7	109.3	118.0	1821.00	482.67	379.67	14.2	8.97	20.85	127.91	193.07
32.	70.40	28.0	51.4	108.6	117.6	2083.00	727.00	598.00	15.8	12.0	28.72	190.41	290.80
33.	67.93	26.0	47.8	109.6	118.3	1703.33	422.67	325.33	13.5	9.57	19.09	128.84	169.07
34.	66.87	30.6	53.0	110.6	119.3	2101.67	523.00	403.33	14.0	9.93	19.18	139.36	209.20
35.	69.87	28.4	49.9	111.3	120.0	2004.67	439.33	337.00	13.4	10.2	16.83	138.16	175.73
SEm±	1.80	1.73	1.47	2.92	3.17	55.86	21.81	19.66	0.57	0.58	1.20	11.30	8.73
CV	4.66	11.0	5.19	4.50	4.53	5.38	7.73	8.95	6.92	9.91	9.84	13.44	7.73
CD (1%)	6.74	6.47	5.49	10.9	11.8	209.36	81.76	73.69	2.13	2.18	4.52	42.34	32.71
CD (5%)	5.08	4.87	4.14	8.25	8.95	157.64	61.56	55.48	1.61	1.64	3.40	31.88	24.63
GM	66.83	27.07	48.87	112.54	121.37	1798.29	489.019	380.257	14.24	10.16	21.174	145.633	195.608

Table 3: Range, General Mean (GM) and Variability parameters for 18 quantitative characters in early cauliflower

Character	Range	GM±SEm	PCV (%)	GCV (%)	ECV (%)	Heritability (h^2)	Genetic Advance (GA)	GA as % of mean
Plant height (cm)	59.93-80.27	66.838±1.80	8.331	6.904	4.663	68.669	7.877	11.785
No. of leaves per plant	23.47-31.4	27.074±1.73	11.984	4.664	11.04	15.145	1.012	3.739
Leaf length (cm)	41.93-55.93	48.878±1.47	7.398	5.267	5.19	50.676	3.775	7.723
Days to curd initiation	108.67-120.33	112.543±2.92	4.853	1.821	4.50	14.084	1.585	1.408
Days to curd maturity	114.67-129.67	121.371±3.17	4.91	1.904	4.52	15.034	1.846	1.521
Gross plant weight (g)	1176.67-2479.67	1798.29±55.85	16.469	15.565	5.38	89.328	544.982	30.306
Marketable curd weight (g)	324.67-771.33	489.019±21.81	22.701	21.345	7.72	88.414	202.19	41.346
Net curd weight (g)	240.33-638.00	380.257±19.66	26.549	24.994	8.95	88.623	184.308	48.469
Curd diameter (cm)	11.77-17.87	14.245±0.57	10.936	8.464	6.92	59.904	1.922	13.495
Curd depth (cm)	8.90-12.03	10.162±0.58	11.718	6.246	9.91	28.41	0.697	6.858
Harvest index (%)	15.49-31.94	21.174±1.20	20.586	18.08	9.84	77.129	6.926	32.709
Curd index(cm^2)	107.82-208.59	145.633±11.30	20.175	15.049	13.44	55.641	33.676	23.124
Yield(q/ha)	129.87-308.53	195.608±8.73	22.701	21.345	7.73	88.414	80.876	41.346

heritability for days to curd maturity and number of leaves per plant was reported by Kanwar *et al.* (2010).Johnson *et al.* (1955) suggested that the estimates of heritability coupled with genetic advance provide better information rather than heritability alone. High heritability along with moderate genetic advance were observed for gross plant weight, net curd weight, marketable curd weight and curd yield. The results are in conformity with Kumar *et al.* (2011). Early group of cauliflower has wide range of variability for different economic traits. From above study it can be concluded that net curd weight, marketable curd weight, curd yield gross plant weight and harvest index are the most important traits for applying the selection in cauliflower genotypes for crop improvement programme.

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GENETIC VARIABILITY IN PARENTS AND CROSSES OF DUAL SORGHUM

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ABSTRACT

Significant variation were recorded among nine parents and 36 crosses of sorghum (Sorghum bicolor (L.) Moench) for various morphological and yield traits developed at Sorghum Research Station, S. D. Agricultural University, Deesa, Gujarat during Kharif 2015-16. The phenotypic coefficients of variation (PCV) were higher than the genotypic coefficients of variation (GCV) for all the traits under investigation. High magnitude of genotypic and phenotypic coefficient of variations was observed for dry fodder yield and grain yield per plant. Estimates of heritability varied from 7.76% (leaf width) to 95.25% (fodder yield / plant). The association of high heritability with high genetic advance and GCV was reported in case of dry fodder yield, plant height and grain yield / plant. Grain yield /plant was significantly and positively correlated with panicle length while fodder yield was positively correlated with days to 50 % flowering, days to maturity, plant height, number of leaves /plant, leaf length and leaf width. Path coefficient analysis revealed as high direct effects of panicle length on grain yield /plant. Whereas, number of leaves /plant, plant height, leaf length, days to maturity and days to 50% flowering exerted positive and high direct effects on dry fodder yield /plant. Studied characters should be balanced for selecting high seed and fodder yielding genotypes.

Keywords: Sorghum, heritability, genotypic coefficient of variation, phenotypic coefficient of variation, correlation, path analysis

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.). Moench) is an important food and fodder crop of dry land agriculture. It has wide range of adaptability to various agro ecological situations of the region. It is the fifth most important food crop after wheat, rice, maize, and barley and is widely grown in the semi-arid regions of India. India is the fifth largest sorghum producer with 5.82 million hectares of area under sorghum cultivation, and with a total production of 5.39 million tonnes (FAOSTAT, 2014). Sorghum is more tolerance to high temperature and better ability to stand during drought conditions. The estimate of genetic parameters for different traits and their association is important for successful breeding programme. The study of relationships among quantitative traits is important for assessing the feasibility of joint selection of two or more traits and hence for evaluating the effect of selection for secondary traits on genetic gain for the primary trait under consideration. A positive genetic correlation between two desirable traits makes the job of the plant breeder easy for improving both traits simultaneously. Path coefficient analysis is simply a standardized partial regression coefficient which splits the correlation coefficient into the measures of direct and indirect effects. It measures the direct and indirect contribution of independent variables on dependent variable. Therefore, the present study was undertaken to estimate the variability in newly generated sorghum breeding materials.

MATERIALS AND METHODS

Forty six sorghum genotypes including 9 parents and 36 newly developed F_1s were used for the present study. The trial was grown in randomized block design with 2 replication at Sorghum Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa (Gujarat) during Kharif 2015. Deesa is situated at latitude of 24.5° N and longitude 72° E and at an elevation of 136 M above the Mean Sea Level. The soil of the field was sandy in texture with pH value of 7.5 having good physical and chemical properties (organic carbon 2.3 g kg^{-1} EC 0.23 dSm^{-1} available K 259 and P_2O_5 46.2 kg

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ha^{-1}). The experimental unit was a single-row plot of 4.0 m long, spaced at 0.45 m apart. NPK 120:60:00 fertilizers was applied as half basal dose of nitrogen and full dose of phosphorus at the time of sowing and half nitrogen applied after one month of sowing. Plots were thinned down after two weeks of crop emergence and plant-to-plant distance of 0.10 m was maintained. The all other recommended agronomical practices were followed to raise a good crop during the season. Data were taken on days to 50 % flowering, plant height, number of leaves /plant, leaf length, leaf width, panicle length, dry fodder yield /plant and grain yield /plant. Statistical analysis was done according to the standard statistical procedures (Burton, 1952; Johnson et al., 1955; Al-Jibouri et al., 1958 and Dewey and Lu, 1959).

RESULTS AND DISCUSSION

The analysis of variance revealed highly significant ($p<0.01$) differences among all the parents and crosses for days to 50 % flowering, plant height, number of leaves /plant, leaf length, leaf width, panicle length, dry fodder yield per plant and grain yield per plant (Table 1) .

Table 1: Analysis of variance for nine characters in Sorghum

Parameters	DF	Days to 50% flowering	Days to maturity	Plant height	No. of leaves/ plant	Leaf length	leaf width	Panicle length	Seed yield/plant	Fodder yield/plant
Replications	1	5.38	16.04	2788.90	3.21	0.71	0.10	0.10	16.10	6987.21
Treatments	44	77.91**	87.78**	4034.85**	6.36**	39.58**	2.79**	24.22**	1208.92**	52787.54**
Error	44	3.79	3.23	597.83	0.53	3.98	0.33	2.33	96.95	1217.76

, significant at 5% and 1% respectively*

High magnitude of variation for the experimental material was also reflected by wider range for all the traits under study (Table 2). This suggested adequate amount of variability among the materials that may be helpful for trait improvement and selection. These results are in agreement with the findings of Gobharle et al. (2010), Jain and Patel (2014). The genetic constants for the characters revealed that the magnitude of phenotypic coefficient of variation (PCV) was higher than the corresponding genotypic coefficient of variation (GCV) for all the traits denoting environmental factors influencing their expression to some degree or other. Wide differences between PCV and GCV for number of leaves per plant, leaf width, days to maturity, leaf length and days to 50% flowering implied their susceptibility to environmental fluctuation, whereas narrow differences between PCV and GCV for fodder yield per plant, grain yield per plant, panicle length and plant height suggested their relative resistance to environmental alterations. High magnitude of genotypic and phenotypic coefficient of variations (%) was observed for fodder yield per plant (56.63, 58.02) and grain yield per plant (40.08, 43.71) where as moderate to lower variation was observed for remaining traits. High values of GCV and PCV suggested that there is a possibility of improvement

Table 2: Estimates of mean, range, coefficient of variability, heritability and genetic advance for different characters in Sorghum

Character	Mean	Standard Deviation	Range	CV	GCV	PCV	Heritability	Genetic advance	Genetic advance % Mean
Days to 50% flowering	73.06	7.35	64.0-84.5	2.64	6.79	10.11	45.12	6.86	9.39
Days to maturity	103.53	9.61	94.5-121.5	1.71	3.82	9.32	16.79	3.34	3.22
Plant height	262.00	53.75	209.2-412.5	9.25	16.65	20.59	65.39	72.67	27.74
Leaves/plant	12.77	3.17	9.8-18.0	5.54	12.01	24.72	23.62	1.54	12.03
Leaf length	85.53	6.96	76.6-98.3	2.40	4.45	8.16	29.71	4.27	4.99
leaf width	9.01	3.24	7.5-10.1	6.50	10.01	35.95	7.76	0.52	5.75
Panicle length	25.96	3.81	18.4-33.2	6.05	12.96	14.75	77.21	6.09	23.45
Seed yield/plant	58.60	25.48	16.0-161.0	16.61	40.08	43.71	84.07	44.37	75.71
Fodder yield/plant	285.87	165.25	110.0-775.0	12.14	56.63	58.02	95.25	325.47	113.86

through direct selection for the seed and fodder yields. While for days to 50% flowering and maturity, number of leaves per plant, leaf length, leaf width, plant height and panicle length, the estimate of both the genotypic and phenotypic coefficients of variation were moderate to low, indicated that improvement for these traits can be achieved up to some extent. These results are in accordance with the findings of Mahajan *et al.,* (2011).

The estimate of GCV and PCV alone is not much helpful in determining the heritable portion. The amount of advance to be expected from selection can be achieved by estimating heritability along with coefficient of variability. Burton (1952) also suggested that GCV and heritability estimate would give better information about the efficiency of selection. In this case, maximum heritability was recorded for fodder yield per plant (95.25 %), grain yield per plant (84.07%) and panicle length (77.21 %). Whereas, medium to minimum estimate for heritability was observed by plant height (65.39 %), days to 50% flowering (45.12 %), leaf length (29.71%), number of leaves per plant (23.62%), days to maturity (16.79%) and leaf width (7.76%). The high degree of heritability estimates for most of the traits suggested that the characters are under genotypic control. High heritability coupled with high genetic advance and GCV were noticed for dry fodder yield/plant, seed yield per plant and plant height. This indicated the importance of the considerable additive (heritable) gene effect in governing their inheritance and phenotypic selection for their improvement could be achieved by simple method like pure line or mass selection or pedigree and bulk method following hybridization and selection in early generations. These results are accordance with the findings of earlier workers (Sharma *et al.,* 2006 and Jain *et al.,* 2013 and Jain and Patel. 2014).

Table 3: Estimation of phenotypic and genotypic correlation between different characters in Sorghum

Characters		Days to 50% flowering	Days to maturity	Plant height	Number of leaves/plant	Leaf length	leaf width	Panicle length	Seed yield/plant
Days to maturity	G	0.701**							
	P	0.813**							
Plant height	G	0.069^{NS}	0.245*						
	P	0.297**	0.400**						
Leaves/plant	G	1.075**	1.405**	0.682**					
	P	-0.234*	-0.467**	-0.055^{NS}					
Leaf length	G	-0.167^{NS}	-0.371**	0.789**	0.977**				
	P	0.457**	0.626**	0.659**	-0.414**				
leaf width	G	1.298**	1.947**	-0.318**	-0.353**	0.721**			
	P	-0.408**	-0.623**	-0.433**	0.751**	-0.623**			
Panicle length	G	-0.363**	-0.397**	-0.288**	-0.660**	-0.328**	0.222*		
	P	-0.398**	-0.370**	-0.287**	-0.052^{NS}	-0.348**	0.298**		
Seed yield/plant	G	-0.229*	-0.230*	-0.146^{NS}	-0.457**	-0.408**	-0.036^{NS}	0.609**	
	P	-0.066^{NS}	0.025^{NS}	-0.069^{NS}	-0.298**	-0.116^{NS}	-0.114^{NS}	0.482**	
Fodder yield/plant	G	0.441**	0.650**	0.820**	0.751**	0.800**	-0.259*	-0.402**	-0.211*
	P	0.324**	0.314**	0.659**	0.302**	0.466**	-0.137^{NS}	-0.352**	-0.186^{NS}

, significant at 5% and 1% respectively*

The genotypic and phenotypic correlation coefficients among different characters including grain and dry fodder yield per plant revealed that phenotypic correlation coefficient was varied from genotypic correlation coefficient (Table 3). The correlation coefficients at genotypic level were generally of higher magnitude than the corresponding phenotypic level, indicating the inherent/heritable relationship where as phenotypic correlation was higher than the genotypic correlation coefficients, which may be a result of modifying effect of environments on the association of the characters. Grain yield per plant was strongly correlated with panicle length. Whereas, the dry fodder yield per plant was positively and significantly correlated with plant height, number of leaves per plant, leaf length, days to maturity and days to 50% flowering. These results are in agreement with the findings of Jain *et al.* (2010), Arunah *et al.* (2015) and Khandelwal *et al.* (2015).

Table 4: Estimation of direct and indirect effects of yield components on seed yield per plant based on path Coefficient analysis in Sorghum

Characters	Days to 50% flowering	Days to maturity	Plant height	Number of leaves/plant	Leaf length	leaf width	Panicle length	Fodder yield/plant
Days to 50% flowering	-0.021	0.135	0.033	0.067	-0.155	0.042	-0.199	0.033
Days to maturity	-0.017	0.166	0.044	0.134	-0.213	0.064	-0.185	0.032
Plant height	-0.006	0.066	0.111	0.016	-0.224	0.045	-0.144	0.068
Number of leaves/plant	0.005	-0.077	-0.006	-0.288	0.141	-0.077	-0.026	0.031
Leaf length	-0.010	0.104	0.073	0.119	-0.340	0.064	-0.174	0.048
Leaf width	0.009	-0.103	-0.048	-0.216	0.212	-0.103	0.149	-0.014
Panicle length	0.009	-0.061	-0.032	0.015	0.118	-0.031	0.500	-0.036
Fodder yield/plant	-0.007	0.052	0.073	-0.087	-0.158	0.014	-0.176	0.103

Residual effects: 0.64328

Correlation co-efficient indicates only the general associations between any two traits without tracing any possible causes of such associations. In such situations, the path coefficient analysis at phenotypic level (table 4 and Table 5) is done to partition the correlation coefficients in to direct and indirect effects. Seed yield and fodder yield per plant were taken as dependent variable while computing the path coefficient. The results on path coefficient analysis revealed positive correlation as well as high or moderate direct effects of panicle length on grain yield per plant. Negative correlation and low direct effects of plant height, and fodder yield per plant on grain yield was also observed in this study. The high residual effect (0.643) indicated that further study should be done with other yield component like 1000-grain weight, harvest index and panicle width (Table 4). The path coefficient analysis for dry fodder yield per plant revealed that the characters like number of leaves per plant, plant height, leaf length, days to maturity and days to 50% flowering which had positive significant association with green fodder yield also exerted positive and high direct effects on dry fodder yield per plant (Table 5). This confirms the role of these traits in determining the dry fodder yield and therefore, their values in constructing the selection criterion (Nayak *et al.* 2016).

Table 5: Estimation of direct and indirect effects of yield components on fodder yield per plant based on path Coefficient analysis in Sorghum

Characters	Days to 50% flowering	Days to maturity	Plant height	Number of leaves/plant	Leaf length	leaf width	Panicle length	Seed yield/plant
Days to 50% flowering	0.051	0.117	0.104	-0.162	0.128	0.086	0.003	-0.004
Days to maturity	0.041	0.144	0.140	-0.322	0.175	0.131	0.003	0.001
Plant height	0.015	0.058	0.351	-0.038	0.184	0.091	0.002	-0.004
Number of leaves/plant	-0.012	-0.067	-0.019	0.691	-0.116	-0.158	0.000	-0.017
Leaf length	0.023	0.090	0.231	-0.286	0.280	0.131	0.003	-0.006
leaf width	-0.021	-0.090	-0.152	0.518	-0.174	-0.211	-0.003	-0.006
Panicle length	-0.020	-0.053	-0.101	-0.036	-0.097	-0.063	-0.009	0.027
Seed yield/plant	-0.003	0.004	-0.024	-0.206	-0.032	0.024	-0.004	0.055

Residual effects: 0.34660

It may be concluded from the resuls that high emphasis should be given on dry fodder yield/plant, grain yield per plant, plant height and panicle length, as they posses high heritability coupled with genetic advance indicating more gain of selection in next generation. Apart from this, results from both correlation and path coefficient analysis indicated that panicle length should be balanced for selecting high grain yielding genotypes in sorghum While, different characters viz., plant height, number of leaves per plant, leaf length, days to maturity and days to 50% flowering should considered for selecting the high fodder yielding genotypes.

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EFECT OF PHOSPHORUS AND MOLYBDENUM ON YIELD AND NUTRIENT UPTAKE OF FABA BEAN IN ALLUVIAL SOIL

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ABSTRACT

An experiment was conducted at Bichpuri (Agra) during rabi seasons of 2008-09 and 2009-10 to study the impact of phosphorus and molybdenum on yield and nutrient uptake by faba bean (Vicia faba)in alluvial soil. The experiment was laid out in randomized block design with four levels of phosphorus (0,30,60 and 90 kg P_2O_5 ha^{-1}) and four levels of molybdenum (0,1, 2,and 3 kg ha^{-1}).The results revealed that the faba bean responded significantly upto 90 kg P_2O_5 ha^{-1} and increased the graim and straw yield by 13.4 and 15.7 percent, respectively, over control. Application of 3 kg M_0 ha^{-1} proved superior to the control with respect to grain and straw yields and increased the grain and straw yields by 9.0 and 8.4 percent, respectively. The phosphorus levels significantly increased the nitrogen, phosphorus, potassium and molybdenum uptake by faba bean over control. Molybdenum application also influenced the utilization of nitrogen, P, K and Mo and the more beneficial effect was observed with highest level of molybdenum (3 kg ha^{-1}).The status of nutrients in post harvest soil improved significantly with P and Mo levels over the control.

Key words: Phosphorus, molybdenum, yield, nutrient uptake, faba bean.

INTRODUCTION

Vicia faba, also known as the broad bean, fava bean or faba bean or field bean is a species of bean (Fabaceae). In addition to its use as food for human and livestock, faba bean plays a critical role in some agricultural systems due to the ability of the nitrogen-fixing bacteria, it harbors to fix the atmospheric nitrogen under a broad spectrum of environmental conditions. This facilitates diversification of the agro ecosystem in both time (via crop rotations) and in space (via intercrops), which also may indirectly enhance associated diversity of wild flora and fauna, as well as soil microbes, which may in turn impact the sustainability of agricultural systems. Molybdenum is required for growth of most biological organisms including plants and animals which play an important role in the process of *Rhizobium* symbiosis. Molybdenum is a constituent of the nitrogenase enzyme and every bacterium which fixes nitrogen needs molybdenum during the fixation process. Molybdenum has a positive effect on yield quantity, quality and nodule formating in legume crops (Singh *et al.* 2014). Phosphorus is one of the most important elements significantly affecting plant growth and metabolism. It is, along with N, a major yield limiting nutrient Phosphorus may be a critical constraint of legumes under low nutrient environments because there is a substantial need for P in the N_2 fixation process. However, in legumes, the high requirement for P is consistent with the involvement of P in high rates of energy transfer that take place in the nodule. Under P shortage conditions, legumes may lose the distinct advantage of an unlimited source of symbiotic N. In addition, phosphorus has also an enhancing impact on plant growth and biological yield through its importance as energy storage and transfer necessary for metabolic processes (Srivastava *et al.,* 1998 and Singh *et al.,* 2014). Phosphorus addition increased the efficiency of plants to photosynthesis, enhances the activity of rhizobia and increases the number of branches and pod /plants, consequently greater yield of pea, lupine, faba bean and groundnut. The present study was undertaken to evaluate the effect of phosphorus and molybdenum on faba bean crop in alluvial soil.

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MATERIALS AND METHODS

The field experiments were conducted at the Agriculture Research farm of R.B.S. College Bichpuri, Agra (located in semi arid or gray steppe arid region of South-Western Uttar Pradesh. the intersect of 27.2 ^{0} N attitude and 77.9 ^{0} E longitude), during two consecutive rabi seasons of 2008-09 and 2009-10 on sandy loam soil. The soil had EC 0.16 dSm^{-1}, pH 8.4, organic carbon 3.4 g kg^{-1}, available N 170, P 9.4, K 111 kg ha^{-1}, and molybdenum 0.05 mg kg^{-1}. The experiment was laid out in randomised block design with four levels of phosphorus (control, 30, 60 and 90 kg P_2O_5 ha^{-1}) and four levels of molybdenum (control, 1.0,2.0 and 3kg ha-^{1}) with three replications. The recommended doses of N and K @ 25 and 60 kg K_2O ha^{-1}, respectively were applied as urea and muriate of potash. Phosphorus and molybdenum were supplied through single super-phosphate and ammonium molybdate as per treatments. The faba bean was sown on October 25, 2008 and October 27, 2009 and irrigated at the proper time as judged by the appearance of soil and crop. The weeds were eradicated time to time from the crop. The crop was harvested on maturity. The grain and straw samples were analysed for N content by Kjeldahl method (Jackson 1973). Grain and straw samples were digested in di acid (HNO_3, $HClO_4$) and the digest were analysed for phosphorus by vanado molyblophosphoric acid yellow colour method, K by flame photometer and Mo by atomic absorption spectrophotometer (Jackson 1973). The uptake of nutrients was calculated using the yield data in conjunction with their respective contents. The soil samples collected after harvest were analysed for organic carbon, available N, P, K and Mo as per procedures suggested by Jackson (1973).

RESULTSTS AND DISCUSSION

Yield

The grain and straw yields of faba bean increased significantly by levels of phosphorus over control (Table 1). Application of 90 kg P_2O_5 ha^{-1} recorded significantly higher yields of grain and straw over control. The increases in grain and straw yields with 90 kg P_2O_5 ha^{-1} were 13.4 and 15.7%, respectively over control. The increase in yield may be attributed to the effective metabolic activities coupled with increased rate of photosynthesis leading to better translocation of nutrients to sink. Similar results were reported by Nusakho Nyekha *et al.* (2015) in green gram and Singh *et al.* (2016) in lentil. Pooled data showed 9.0 and 84% increase in grain and straw yield of faba bean (Table 1) with the application of 3 kg Mo ha^{-1} over the control which might be owing to better nutritional environment in term of increased nitrogen fixation and increased plant growth. Molybdenum is known to be essential for N_2-fixation by rhizobia in legumes, being a component of nitrate reductase enzyme which controls the reduction of inorganic NO_3 and helps in fixing nitrogen as NH_3, as a result occurs increased nodulation, growth, grain and straw yield. These results confirm the findings of Kumawat *et al.* (2009) and Singh *et al.* (2014).

Table 1: Effect of Phosphorus and molybdenum on yield and uptake of N, P, K (kg ha^{-1}) and Mo (g ha^{-1}) by faba bean (mean of two years)

Treatment	Yield (q ha^{-1})		Uptake of nutrients			
	Grain	Straw	N	P	K	Mo
Phosphorus (kg ha^{-1})						
0	35.76	30.33	139.1	27.0	87.9	201.9
30	37.24	31.93	150.4	30.5	94.6	231.8
60	39.53	33.83	164.1	34.2	103.5	259.0
90	40.57	35.10	172.5	38.2	108.7	294.7
SEm±	0.16	0.12	2.25	0.45	0.84	6.46
CD (P = 0.05)	0.44	0.35	6.54	1.26	2.43	18.10
Molybdenum(kg ha^{-1})						
0	36.71	31.43	145.0	27.3	91.7	177.1
1	37.65	32.31	152.7	30.4	96.5	218.5
2	38.73	33.07	160.1	34.8	100.4	270.6
3	40.01	34.38	168.3	37.3	106.1	321.3
SEm±	0.16	0.12	2.25	0.45	0.84	6.46
CD (P = 0.05)	0.44	0.35	6.54	1.26	2.43	18.10

Nutrients Uptake

The uptake of nitrogen by faba bean crop increased significantly with increase in the levels of phosphorus compared to control.Application of 90 kg P_2O_5 ha^{-1} resulted in significantly higher nitrogen uptake by the crop which may be attributed to increased N content coupled with higher yield (Singh *et al.* 2016). The uptake of nitrogen was significantly higher with increase in the levels of molybdenum over control and maximum value was recorded with 3 kg Mo ha^{-1}. This increase in N uptake may be attributed to the role of molybdenum in the process of *Rhizobium* symbiosis. Molybdenum, which is a constituent of nitrogenase enzyme, fixes nitrogen during the fixation process. Kushwaha (1999) and Singh *et al.* (2014) reported similar results. Increase in phosphorus levels significantly increased the phosphorus uptake by the crop over control and lower levels of phosphorus. The maximum enhancement in phosphorus uptake was recorded with 90 Kg P_2O_5 ha^{-1}. Similar findings were also recorded by Singh *et al.* (2016). The utilization of phosphorus by the crop significantly increased with increasing levels of molybdenum compared to control and the maximum value was recorded at 3 Kg ha^{-1}. Similar observations were also recorded by Kumawat *et al.* (2009).The uptake of potassium by the crop increased significantly with 60 and 90 kg ha^{-1} compared to control. The uptake of potassium did not show any significant change with 30 kg P_2O_5 ha^{-1}. Comparatively higher potassium utilization was recorded with 90 kg P_2O_5 ha^{-1}. The increase in potassium uptake might be due to increased potassium content and yield of faba bean with phosphorus levels. Our findings are in agreement with those of Singh *et al.* (2014). The uptake of potassium increased significantly with increase in the levels of molybdenum in comparison to control. The more beneficial effect on potassium uptake was noted with highest level of molybdenum (3 kg Mo ha^{-1}). Higher values of potassium uptake with molybdenum application are apparently the result of favourable effect on grain and straw production. Similar results were also noted by Srivastava and Ahlawat (1995) and Alben Awomi *et al.* (2012). The utilization of molybdenum increased with increase in levels of phosphorus over control and the maximum values were recorded with 90 kg P_2O_5 ha^{-1}. This increase is attributed to enhanced faba bean production and an increase in molybdenum content. A further study (Table 1), reveals that the molybdenum uptake by the crop increased significantly with increasing levels of molybdenum as compared to control. The maximum enhancement in molybdenum uptake was recorded with highest level of molybdenum (3 kg ha^{-1}). Similar findings were reported by Kushwaha, (1999).

Table 2: Effect of P and Mo levels on fertility status of post harvest soil (mean of 2 years)

Treatment	Org. C (g kg^{-1})	Avail. N (kg ha^{-1})	Avail. P (kg ha^{-1})	Avail. K (kg ha^{-1})	Avail. Mo (mg kg^{-1})
Phosphorus (kg ha^{-1})					
0	3.1	162.0	8.8	101.0	0.04
30	3.4	163.8	9.1	103.0	0.04
60	3.5	170.1	10.1	105.0	0.05
90	3.6	173.5	11.6	107.0	0.05
SEm±	0.011	0.63	0.32	0.93	0.006
CD (P = 0.05)	0.030	1.76	0.88	2.60	NS
Molybdenum(kg ha^{-1})					
0	3.3	163.3	9.1	102.5	0.03
1	3.4	164.5	9.4	103.5	0.04
2	3.4	169.0	10.0	104.4	0.05
3	3.5	171.0	10.3	105.1	0.06
SEm±	0.011	0.63	0.32	0.93	0.006
CD (P = 0.05)	0.030	1.76	0.88	NS	0.017

Soil fertility

Organic carbon content in post harvest soil increased from 3.1 g kg^{-1} at control to 3.6 g kg^{-1} with 90 kg P_2O_5 ha^{-1}. Similarly, Mo application also enhanced the organic carbon content in soil. The minimum value of available N content in soil was recorded in control, which may be ascribed to greater utilization of N by faba bean. Molybdenum application also improved the status of available N in soil as compared to control (Singh *et al.* 2014). There was a significant build-up of available P in soil with P application and maximum value was recorded with 90 kg P_2O_5 ha^{-1} (Singh *et al.* 2016). The amount of available P in soil was lowest in control, which increased with Mo application. Similar results were reported by Singh *et al.* (2014). At harvest, the amount of available K was depleted from the initiat value of 110 kg ha^{-1} to 101 kg ha^{-1}. Available K content increased with various levels of Mo and maximum value was recorded with 3 kg Mo ha^{-1}. Available Mo was the lowest in the control (Table 2). The concentration of available Mo increased significantly with 3 kg Mo ha^{-1}. This increase may be ascribed to increased concentration of Mo in soil solution as a result of its addition. Application of P also increased the amount of Mo in soil. Similar results were reported by Singh *et al.* (2014).

It could be concluded from the results that the application of 90 kg P_2O_5 ha^{-1} and 3 kg Mo ha^{-1} is beneficial in increasing the status of available N, P, K and Mo in soil besides crop yield and uptake of nutrients by the faba bean.

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YIELD AND UPTAKE OF NUTRIENTS IN RICE AS AFFECTED BY SILICON AND BORON NUTRITION

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ABSTRACT

A field experiment was conducted at College of Agriculture, Padannakkad, Kasaragod, Kerala, during the kharif season of 2013 to study the yield and uptake of nutrients in rice as affected by silicon and boron nutritionin on laterite soils. The experiment was laid out in randomised block design replicated thrice with nine treatments using Aishwarya as the test variety. The results revealed that the three folia sprays of potassium silicate @ 0.5% and borax 0.5% were more effective in improving the content and uptake of nutrients compared to soil application of silicon and boron. The Fe content in straw (136 mg kg^{-1}) and grain (137 mg kg^{-1}) decreased with application of silicon while Fe uptake in plant alone was significantly increased. Application of three sprays of silicon and boron proved significantly superior with respect to plant height (90 cm), number of productive tillers plant^{-1} (17.33), thousand grain weight (30.70g), grain (6.54 t ha^{-1}) and straw (4.95 t ha^{-1}) yield of rice. Application of Si and B significantly improved the uptake of nutrients by crop, grain and straw yield of rice over control. Available B and Si in post harvest soil increased with their application over control.

Key words: Silicon, boron, rice, nutrient uptake, iron, yield

INTRODUCTION

Rice (*Oryzasativa*L.) is the most important food grain in India contributing 41.5% to the total food grain production. Rice yields are decelerating / stagnating / declining in post green revolution era mainly due to imbalance in fertilizer use, soil degradation, lack of suitable rice genotypes for low moisture adaptability and disease resistance. Crop production in laterite soils has been found to be low due to several constraints. However, there is considerable scope for improving the productivity of these acid soils through proper land management.The prevailing form of silicon in soil solution is monosilicic acid (H_4SiO_4). Iron and aluminum oxides of soil have the capacity to adsorb a considerable amount of silicon (Si) on their surfaces.Aluminum oxides are more effective in binding silicon through adsorption mechanism than iron oxides. Silicon (Si) is the second most abundant element in soil. Si is assimilated by plant roots as monosilicic acid (H_4SiO_4) (Epstein, 1999). Rice is a high silicon accumulating plant. Silicon is a beneficial element for plant growth and is agronomically essential for improving and sustaining rice productivity. Besides rice yield increase, Si has many fold advantages of increasing nutrient availability (N, P, K, Ca and Zn) and minimizing biotic and abiotic stress in plants. Hence the application of Si to soil or plant is practically useful in laterite derived paddy soils. Ahmad *et al.* (2013) reported that application of Si fertilizers enhanced the growth parameters, increased yield, yield attributes and quality of rice crop.The boron requirement is much higher for reproductive growth than for vegetative growth in most plant species. Boron uptake correlated well with the concentration of H_3BO_3 in soil solution. Boron is immobile in plant, deficiency symptoms of B in rice begin with a whitish discoloration and twisting of new leaves. Barman *et al.* (2014) observed that application of boron significantly increased N, P, K, Ca, Mg, S and Zn content in soil due to application of boron. The application of boron through different sources either through soil or foliar spray was found to be beneficial in stimulating plant growth and in increasing yield of rice (Rao *et al.,* 2013). With this background, the present study on the yield and uptake of nutrients in rice as affected by silicon and boron nutritionin laterite soilswas carried out.

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MATERIALS AND METHODS

The field experiment was laid out in farmer's field at Padannakkad. It is geographically located at12.2°N latitude, 75.1°E longitude and at an altitude of 16 m above mean sea level, having a humid tropical climate. The experimental soil was sandy loam belonging to the taxonomical order Inceptisol, having pH 4.7, EC 0.12 dSm-1, CEC 7.25 c mol (p+) kg-1, organic carbon 3.3 g kg^{-1}, available nitrogen 220.8 kg ha-1, available P2O5 61.6 kg ha-1, available K_2O 58.5 kg ha^{-1}, available Ca 261.7 mg kg^{-1}, available Fe 144.2 mg kg^{-1}, available Cu 1.26 mg kg^{-1}, available Zn 2.65 mg kg^{-1}, available B 0.16 mg kg^{-1} and available Si 20.5 mg kg^{-1}. The experiment was laid out in randomized block design replicated thrice with the test crop of rice variety Aishwarya. There were 9 treatments *viz.,*T_1- control, T_2 - 100 kg calcium silicate ha^{-1},T_3 - potassium silicate @ 0.5% spray,T_4 - 10 kg borax ha^{-1}, T_5 - borax 0.5 % 3 foliar sprays,T_6 - 100 kg calcium silicate ha^{-1} + 10 kg borax ha^{-1}, T_7 - 100 kg calcium silicate ha^{-1} + borax 0.5% sprays , T_8 - Potassium silicate @ 0.5% sprays + borax 0.5% sprays, T_9 - potassium silicate @ 0.5% sprays + 10 kg borax ha^{-1}.Nitrogen, P and K fertilizers were applied as per package of practices recommendations.. Straw and grain samples were analysed for N by Kjeldahl method. (Jackson, 1973).Phosphorus was analysed in di acid digest by vanadomolybdate yellow colour method, K by flame photometer, and Ca (Issac and Kerber, 1971) Fe, Cu and Zn on atomic absorptions spectrophotometer. Boron was analysed by azomethine-H colorimetric method (Bingam, 1982) and Si by blue silicomolybdous acid method (Ma *et al.,* 2002). Biometric observations *viz.,* plant height, number of productive tillers $plant^{-1}$, thousand grains weight, grain and straw yields were recorded at maturity. The results obtained were statistically analysed using statistical analysis software (SAS).

RESULTS AND DISCUSSION

Growth and Yield

The three sprayings of 0.5 % silicon + 0.5 % boron (T_8) recorded maximum plant height (90 cm) and number of productive tillers $plant^{-1}$ (17.33). The test weight of 30.70 g and grain yield of 4.94 t ha^{-1} were obtained in the treatment receiving three sprayings of 0.5 % silicon + 0.5 % boron (Table 1). In case of straw yield (6.57 t ha^{-1}), the treatment receiving 100 kg calcium silicate ha^{-1} + 10 kg borax ha^{-1} was superior to other treatments. The tune of increase in grain yield due to T_8 treatment was 1.90 t ha^{-1}(Table 1). This can be attributed to the significant increase in available nutrients and positive influence on the availability and uptake of nutrients as reported by Gholami and Falah (2013); Ahmad *et al.* (2013); Nagula *et al.* (2015).

Table 1: Effect of silicon and boron on yield and yield attributes of rice

Treatment	Plant height (cm)	Productive tillers $plant^{-1}$	Thousand grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1	74.66	12.00	20.96	3.05	4.75
T_2	84.66	15.33	30.20	4.61	6.17
T_3	80.66	14.66	29.30	4.25	6.20
T_4	85.73	14.00	29.90	3.50	6.00
T_5	83.33	14.66	29.53	3.52	6.04
T_6	87.00	16.00	30.30	4.76	6.57
T_7	82.33	14.33	29.63	3.54	6.33
T_8	90.00	17.33	30.70	4.95	6.54
T_9	85.33	15.00	29.86	4.00	6.22
CD (P=0.05)	2.71	2.34	1.57	0.09	0.41

Available nutrients

Application of 100 kg calcium silicate ha^{-1} + 10 kg borax ha^{-1} (T_6) increased available Si content (27.08 mg kg^{-1}) in soil at harvest stage (Table 2) over control. Application of calcium silicate prevailed in soil as monosilicic acid (H_4SiO_4) and enhanced soil silicon availability (Singh *et al.,* 2006). Available boron (0.30mgkg^{-1})

in soil at harvest stage, increased with soil application of 10 kg borax ha^{-1}(T_4) over control (Table 2). Therefore after meeting the requirement of the crop, the added boron might have helped to increase the boron status of the soil from the deficiency to sufficiency level. These finding are in line with those reported by Nagula *et al.* (2015). The lowest amounts of available Si and B were recorded under control.

Table 2: Silicon and boron content in soil at harvest stage of rice

Treatment	Silicon (mg kg^{-1})	Boron (mg kg^{-1})
T_1	16.66	0.19
T_2	24.00	0.24
T_3	23.91	0.22
T_4	19.58	0.30
T_5	18.33	0.25
T_6	27.08	0.28
T_7	25.00	0.22
T_8	23.00	0.24
T_9	21.16	0.25
CD (P=0.05)	5.09	0.02

Uptake of nutrients

Total uptake (180.2 kg ha^{-1}) of N was maximum with, 100 kg calcium silicate ha^{-1} + 10kg borax ha^{-1}(T_6) (Table 3). This might have naturally resulted in enhanced absorption of N by the crop ultimately leading to higher N uptake. Similar results have also been reported by Singh *et al.* (2006) and Barman *et al.* (2014). The sprayings of potassium silicate @ 0.5 % + borax 0.5 % (T_8) resulted in significantly higher total uptake of P (37.1 kg ha^{-1}). The higher uptake of P under this treatment may be due to better absorption of P by plant and higher yield of rice grain and straw. Similar results were reported by Ma and Takahashi (1990). The sprayings of Si and B increased total uptake (258.7 kg ha^{-1}) of K over control. The sprays of potassium silicate @ 0.5 % + borax 0.5 % (T_8) was superior in terms of total uptake of Ca (18.7 kg ha^{-1}) This increase may be ascribed in enhanced absorption of calcium along with yields (Cachorro *et al.* 1994).The treatment receiving 100 kg calcium silicate ha^{-1}(T_3) produced significantly higher total uptake of iron (3.25 kg ha^{-1}) compared to the other treatments (Table 2). Similar results were reported by Qiang *et al.,* (2012).The results revealed a significant increase in and total uptake of Zn and Cu in crop (Table 2) with potassium silicate @ 0.5 % spray + borax 0.5 % spray.

Table 3.Effect of silicon and boron on total nutrient uptake by rice crop (kg ha^{-1})

Treatments	N	P	K	Ca	Fe	Zn	Cu	Si	B
T_1	69.4	10.6	138.1	11.6	2.76	0.19	0.37	125.6	0.018
T_2	146.9	21.5	229.9	15.8	3.25	0.43	0.41	377.4	0.032
T_3	147.0	21.1	211.3	16.7	3.16	0.30	0.45	448.4	0.032
T_4	123.9	18.0	193.2	15.6	3.24	0.27	0.38	253.5	0.044
T_5	120.8	18.5	186.5	16.0	3.24	0.28	0.38	259.9	0.042
T_6	180.2	23.5	248.1	16.5	2.96	0.38	0.46	352.5	0.044
T_7	153.3	20.7	216.0	15.3	2.74	0.33	0.41	310.1	0.039
T_8	175.8	37.1	258.7	18.7	2.94	0.45	0.49	362.5	0.047
T_9	151.9	22.1	228.0	16.9	2.80	0.42	0.44	298.0	0.041
CD (P=0.05)	6.8	5.5	13.0	1.0	0.19	NS	NS	44.1	0.005

This increase may be associated with the above treatments which contributed to the higher uptake of Zn and Cu in the crop. These results also corroborate with the findings of Bhutto *et al.* 2013).The silicon nutrition of rice evaluated in terms of uptake was influenced by silicon fertilization as calcium silicate (soil application) and potassium silicate (foliar spray). Application of potassium silicate @ 0.5 % spray was superior to soil application of calcium silicate in respect of silicon uptake by the crop. Hence it can be presumed that the foliar application of potassium silicate (0.5%) resulted in better absorption and translocation of silicon compared to soil application of calcium silicate. These finding are in line with those reported by Singh *et al.* (2006).Soil application of boron (10 kg borax ha^{-1}) and foliar sprays (borax 0.5 % spray) showed significant increase in boron uptake in straw and grain over control. Application of potassium silicate @ 0.5 % spray + borax 0.5 % spray (T_8) was superior in terms of B uptake

(0.047 kg ha^{-1}) over other treatments. This is because the available boron content of soil also was increased from sub optimal level to the sufficiency level for the addition of borax as soil and foliar spray. Similar results were reported by Rakshit *et al.* (2002).

It may be concluded that spray application of potassium silicate @ 0.5 % spray + borax 0.5 % at 15 days interval significantly improved uptake of nutrients, grain and straw yield of rice in laterite soils.

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PERFORMANCE OF POTATO VARIETIES FOR MORPHOLOGICAL AND YIELD CHARACTERS UNDER MALWA REGION OF MADHYA PRADESH

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ABSTRACT

A field experiment was conducted during rabi season of 2014 -15 at research farm, College of Agriculture, Indore (Madhya Pradesh) to study the morphological and yield characters of ten potato varieties in three replications. Results revealed that the variety Kufri Arun recorded maximum growth, yield attributes and yield over other cultivars. The variety Kufri Arun recorded maximum (63.92 cm) plant height followed by Kufri Chandramukhi (62.18 cm) While, the minimum plant height (43.50 cm) was recorded in variety Kufri Chipsona-2. Maximum diameter of stem was recorded in variety Kufri Arun (4.09cm) which was followed by Kufri Chandramukhi (4.03 cm) and minimum diameter of stem was observed in variety Kufri Chipsona- 4 (3.05 cm). Kufri Arun produced maximum 20.11 leaves per plant followed by Kufri Chandramukhi (19.13) While, minimum leaves were attained by variety Kufri Chipsona- 4 (15.06). Kufri Arun recorded maximum (497.23cm2) leaf area per plant followed by Kufri Chandramukhi (482.73 cm2) as compared to all other varieties and Kufri Chipsona- 4 (378.78 cm2) recorded the minimum value for leaf area per plant (cm2). Kufri Arun showed maximum dry weight (44.96 g) and minimum in variety Kufri Chipsona- 4(17.65 g). The variety Kufri Arun recorded maximum LAI (0.43), NAR (0.009), CGR (0.132) while Kufri Chipsona 4 recorded the least values LAI (0.29),NAR(0.002), CGR(0.032). The variety Kufri Arun obtained the maximum yield (292.55 q ha^{-1}) as well as maximum net income (Rs 192490/ha) with B:C ratio of 3.32 which was followed by K.Chandramukhi and K. Jyoti, while the minimum yield (223.44 q ha^{-1}) as well as net income (` 105160 r ha^{-1}) and cost benefit ratio (2.92) was recorded in Kufri Chipsona- 4.

Key words: Potato, varieties, growth, B:C ratio, yield

INTRODUCTION

Potato (*Solanum tuberosum* L.) is an annual, herbaceous, tuber crop of family Solanaceae that contains all the essential food ingredients required for maintaining proper health. Potato is a staple food in most of the countries and is a good and cheap source of food calories and its high starch content can meet the energy requirement of the people living in food deficit countries. Potato produces highest dry matter, carbohydrates, edible protein, minerals and vitamin C and B per unit area and time among the major food crops. It is a wholesome, nutritious and versatile food which can come to the rescue of the developing countries for alleviating hunger and malnutrition especially in shrinking land resources. The average composition of the potato is about 80% water, 2% protein and 18% starch. As a food, it is one of the cheapest and easily available sources of carbohydrates and proteins and contains appreciable amount of vitamin B and C as well as some minerals. Moreover, protein of potato is of high biological value (Qasim *et al.,* 2013).Crude protein content is 2.0% and the fat content is very low 0.1%. The ash consisting of minerals constitutes 1.0%. In addition potato tuber contains fiber, vitamins and glycoalkaloids in small quantities. Most European varieties, introduced earlier in India performed poorly because conditions in India are entirely different than those prevalent in temperate countries. A need was therefore, felt that potato cultivation in India cannot depend on exotic varieties and technologies and the country must have its own research and development programme for potato. Before recommendation of any variety / crop suitable for the region, it is pertinent to evaluate genotypes giving emphasis on the aspects of genotypic suitability and yield (Kanauyia and Manjai Phom 2016).Keeping this in view the present study was carried out to select the suitable and improved varieties of

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potato having superior growth, yield characters and better economics variability for commercial production in Malwa condition.

MATERIALS AND METHODS

A field experiment was laid out at Research Farm College of Agriculture Indore, during (Rabi) 2014-2015. Indore is situated at an altitude of 555.5 meters above mean sea level (MSL). It is located at latitude 22.43^o N and longitude of 75.66^o E. It has subtropical climate having a temperature range of 21^o C to 45^o C and 6^o C to 31^o C in summer and winter seasons, respectively. The total rainfall received during crop growth period was 75.3 mm. The minimum and maximum temperature during crop growth period varied 5.3^{0}C to 18.79^{0}C and from 17.2^{0}C to 31.79^{0}C, with season's average values of 8.66^{0}C and 25.63^0 C respectively. The soil of experimental site was predominantly clayey in texture. The organic carbon content (2.6gm/kg) and available nitrogen (216.0 kg ha^{-1}) were low. The available phosphorus (12.2 kg ha^{-1}) and potassium (420 kg ha^{-1}) were medium and high, respectively. The soil pH (7.6) and electrical conductivity (0.35 dS m^{-1}) of soil was found normal .The experiment was conducted in a randomized block design with ten varieties namely K.Chipsona 1, K.Chipsona 2, K.Chipsona 3, K.Chipsona 4, K.Chandramukhi, K. Arun, K.Lauvkar, K. Surya, K. Jawahar and K. Jyoti with 3 replications. Healthy, uniform, medium sized tubers (35 – 45 mm or 45 – 50 g) at the rate of 30 - 35q ha^{-1} were used for sowing. Shallow furrows were opened 6 cm apart and tubers were dibbled at a spacing of 60 cm row to row and 20 cm plant to plant. Observations were recorded on days to 50% germination, sprouts/plants, plant height (cm), leaves/plant, Leaf area (cm^2) the assimilatory surface area (A), Leaf area index (LAI), diameter of main stem, Net Assimilation rate, Crop growth rate, days to haulm cutting, days to maturity, tubers/plant, rotted tubers /wt/plant and total yield /marketable yield. Several economic indices are available to evaluate the profitability of cropping systems. The economics of different treatments was worked out on the basis of prevailing market price of inputs and produce.

RESULTS AND DISCUSSION

Morphological characters

The significant varietal differences in potato were noticed with respect to morphological characters (Table 1). The plant height of varieties differed significantly ranging from 63.92 cm (Kufri Arun) to 43.50 cm (Chipsona- 2). Variation in plant height was due to the inherent genetic makeup of the plant. Similar findings were reported by Kumar (2011). The diameter of the stem ranged from 4.09cm in Kufri Arun to 3.05 cm in Kufri Chipsona- 4. Maximum (20.11) leaves per plant were recorded in variety Kufri Arun followed by Kufri Chandramukhi (19.13), Kufri Jyoti (18.37) and Kufri chipsona-2 (18.82) as compared to other varieties. While, minimum leaves per plant were attained by variety Kufri Chipsona- 4 (15.06). Maximum leaf length (5.96 cm) was recorded in variety Kufri Arun followed by Kufri Chandramukhi (5.88 cm) and Kufri Jyoti (5.85 cm) as compared to other varieties, while minimum in variety Kufri Chipsona- 4 (5.06 cm). Similarly maximum leaf width of 4.70 cm was recorded in variety Kufri Arun which was followed by Kufri Chandramukhi (4.62 cm), Kufri Jyoti (4.52 cm) and at par with all other varieties over Chipsona varieties. While, the minimum leaf width (3.75 cm) was recorded in variety Kufri Chipsona- 4. Variety Kufri Arun recorded significantly maximum (497.23cm2) leaf area per plant followed by Kufri Chandramukhi (482.73 cm2). However, Kufri Chipsona- 4 (378.78 cm2) recorded the minimum value for leaf area per plant. Maximum dry weight per plant was recorded in variety Kufri Arun (44.96 g) over other varieties. However, the minimum dry weight per plant was recorded in Kufri Chipsona-4(17.65 g). Amongst the varieties, Kufri Arun resulted in higher values of all these characters followed by Kufri Chandramukhi, Kufri Jyoti and Kufri Lauvkar. The differential behavior of potato varieties with respect to morphological characters could be explained solely by the variation in their genetic makeup and adaptability to soil and climatic conditions i.e. (G×E) interaction. Kumar (2011) and Patel *et al.* (2013) also reported the significant differences in the morphological traits that were positively correlated with the genotypes.

Table 1: Morphological characters and Growth analysis parameters of different potato varieties

Varities	Plant height (cm) 75 DAP	Diameter of stem (cm) 75 DAP	Leaves per plant 75 DAP	Leaf length (cm) 75 DAP	Leaf width (cm) 75 DAP	Leaf area plant (cm2) 75 DAP	Dry weight per plant (g) 75 DAP	Leaf area index 60-75 DAP	NAR (g/cm2 /day) 60-75 DAP	CGR (g/plant/ day) 60-75 DAP
Kufri Chipsona-1	58.46	3.82	17.72	5.48	3.82	410.8	30.84	0.32	0.005	0.063
Kufri Chipsona- 2	43.50	3.90	18.82	5.42	3.93	397.9	21.33	0.34	0.004	0.042
Kufri Chipsona- 3	56.51	3.92	16.52	5.44	3.80	382.7	20.42	0.30	0.004	0.051
Kufri Chipsona-4	45.10	3.05	15.06	5.06	3.75	378.7	17.65	0.29	0.002	0.032
Kufri Chandramukhi	62.18	4.03	19.13	5.88	4.62	482.7	42.20	0.38	0.008	0.130
Kufri Arun	63.92	4.09	20.11	5.96	4.70	497.2	44.96	0.43	0.009	0.132
Kufri Lauvkar	59.12	3.96	17.99	5.47	4.45	430.1	33.78	0.35	0.006	0.099
Kufri Surya	58.91	3.86	16.82	5.37	4.48	386.8	27.67	0.34	0.006	0.084
Kufri Jawahar	53.53	3.78	17.41	5.39	4.21	394.3	31.52	0.34	0.005	0.091
Kufri Jyoti	61.45	4.01	18.37	5.85	4.52	430.4	40.36	0.36	0.007	0.113
SEm±	2.40	0.05	0.63	0.13	0.22	10.84	0.033	0.017	0.00062	0.006
C.D. (P=0.05)	7.15	0.16	1.89	0.40	0.68	32.23	0.099	0.052	0.0019	0.018

Growth analysis parameters

Variety Kufri Arun recorded significantly maximum leaf area index as compared to other varieties. However, minimum leaf area index was observed in (0.435) Kufri Chipsona- 4(0.289). The leaf area and leaf area index (LAI) increased up to 75 DAP and decreased thereafter due to senescence and ageing of leaves. In general, the varieties showed a profound effect over these parameters and significant differences were noticed among the varieties at all the growth stages. However, Kufri Arun recorded significantly higher leaf area and LAI as compared to other cultivars at all the growth stages. These results are confirmed with the findings of Ahmed *et al.* (2013). The highest NAR was found in Kufri Arun (0.0088 g/cm2/day) followed by Kufri Chandramukhi (0.0078 g/cm2/day) and Kufri Jyoti (0.0069 g/cm2/day). The lowest value of NAR was observed in Kufri Chipsona- 4 (0.002 g/cm2/day). Similarly the highest CGR was observed in Kufri Arun 0.132 g/plant/day followed by Kufri Chandramukhi (0.130 g/plant/day) and lowest value in Kufri Chipsona- 4 (0.0318 g/plant/day).The varietal differences amongst these growth analysis parameters attributed to the variability in the genetic inheritance among the varieties. This has been supported by Patel *et al.* (2000).

Yield attributing characters

Minimum days for maturity (75.0 days) were observed for Kufri Chandramukhi followed by Kufri Lauvkar (80 days) and Kufri Arun (90 days). However, the varieties Kufri Chipsona- 2 and Kufri Jyoti required maximum 120 days for maturity. Relation of days to maturity to yield is positive and significant. Variation in days to maturity was due to the inherent genetic makeup of the variety and due to difference in response to day length and temperature. These findings are in agreement with the findings reported by Ranjbar and Mirzakhan (2012). Significantly maximum number of tubers per plant was recorded in Kufri Arun (12.67) followed by Kufri Chandamukhi (12.60), Kufri Jyoti (12.40) and Kufri Lauvkar (11.86). While Kufri Chipsona-4 (8.69) recorded minimum number of tubers per plant. The probable reason of enhanced tubers per plant may be due to better germination, genetic makeup and environmental interactions. These findings are in agreement with Singh *et al.* (2007) and Kaushik *et al.* (2006).

Table 2: Yield attributing characters and Economics of different potato varieties

Varieties	Days to maturity	Tubers per plant	Total yield of tubers (kg/plot)	Marketable yield of tubers (q ha^{-1})	Net income (Rs ha)	B:C ratio
Kufri Chipsona-1	100.0	10.33	24.81	242.55	159710	1:2.92
Kufri Chipsona- 2	120.0	9.86	22.28	196.88	114040	1:2.37
Kufri Chipsona- 3	100.0	10.13	24.11	223.55	140710	1:2.69
Kufri Chipsona- 4	110.0	8.69	20.11	188	105160	1:2.26
Kufri Chandramukhi	75.0	12.60	25.92	266.66	183820	1:3.21
Kufri Arun	90.0	12.67	26.33	275.33	192490	1:3.32
Kufri Lauvkar	80.0	11.86	25.14	255.22	172380	1:3.08
Kufri Surya	100.0	9.88	23.79	217	134160	1:2.62
Kufri Jawahar	100.0	9.87	22.81	202.44	119600	1:2.44
Kufri Jyoti	120.0	12.40	25.62	261.44	178600	1:3.15
SEm±	2.00	0.41	0.38	4.24		
C.D. at 5% level	5.96	1.22	1.13	12.68		

Variety Kufri Arun recorded significantly maximum (26.33 kg) yield of tubers per plot followed by Kufri Chandramukhi (25.92kg), Kufri Jyoti (25.62kg), Kufri Lauvkar (25.14kg) and Kufri Chipsona-1(24.81kg). While, the lowest yield of tubers per plot was noted in variety Kufri Chipsona- 4 (20.11 kg). Significantly maximum (24.78, kg per plot and 2735.33, q ha^{-1}) marketable tuber yields were recorded in Kufri Arun followed by Kufri Chandramukhi (24.00 kg per plot, 266.66 q ha^{-1}). However, the lowest marketable tuber yield was observed in Kufri Chipsona- 4 (916.92 kg per plot and 188 q ha^{-1}). The higher yield attributes in Kufri Arun may be owing to maximum increase in growth parameters as well as growth analysis parameters. The present findings on varietal differences are in consequence with those of Alam *et al.* (2003), Ullah and Saikia (2008), Rashid *et al.* (2008), Ummyiah *et al.* (2010) and Ahmad *et al.* (2013).

Economics

Amongst the potato varieties, Kufri Arun brought about the maximum net income (`.1,92,490/ha) with B:C ratio (3.32). This was followed by Kufri Chandramukhi and Kufri Jyoti. The lowest net income (`. 1,05,160/ha and B:C ratio (2.26) were obtained from Kufri Chipsona- 4 variety. The net economical gain was secured in accordance with the per hectare yield of the varieties and thereby gross income. Similar findings were reported by Hosea *et al.* (2012).

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EFFECT OF PLANTING DENSITY AND NUTRIENT MANAGEMENT ON PERFORMANCE OF RABI HYBRID MAIZE

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ABSTRACT

A field experiment was conducted at Crop Research Station, Bahraich (Uttar Pradesh) during rabi seasons of 2012-13 and 2013-14 to study the effect of planting density and nutrient management on the performance of rabi hybrid maize. The two varieties of hybrid maize viz. Shreeram 9682, HM-7705 were located in main plot and two plant geometry viz. 60 x 20 cm, 50 x 20 cm as well as three levels of nutrients viz. RDF (200:60:60 kg NPK ha^{-1}) Soil Test Crop Response (STCR) (250:50:50 kg NPK ha^{-1}) and Site Specific Nutrient Management (SSNM) (225:60:85 kg NPK ha^{-1}) were located in sub-sub plot in split plot design with three replications. Results indicated that the higher yield attributing characters, yield (78.20 q ha^{-1}) and nutrients uptake and economics (` 81973 ha$^{-1}$) were recorded under maize variety HM-7705, The highest grain yield (75.65 q ha$^{-1}$) and net profit of ` 78335 ha^{-1} and uptake of nutrients were recorded under 60 x 20 cm plant geometry. The grain and straw yields of maize were the highest with the application of SSNM which was 19.3 % higher over state recommendation and 12.0 % over STCR practice, respectively. All the yield attributing characters as well as yield of the crop showed beneficial effects of site-specific nutrient management. Higher net return of ` 97481 ha^{-1} was obtained with SSNM treatment.

Keywords: Variety, planting density, nutrients management, economics, yield, rabi maize

INTRODUCTION

Maize is most versatile emerging crop having high yield potential wider adaptability to diverse ecologies and adverse environment. It caters the needs of both human and animals by providing food and feed to them. Amongst various agricultural inputs, selection of suitable hybrid maize variety and plant density have vital role in production of crop as well as economics of crop production. High potential variety and more adoptive nature produce higher yield in comparison to other genotypes. The plant geometry and optimum plant production has an important role in plant growth, yield attributing characters and yield of crop. Fertilizer plays a chief source in achieving the food production targets. For higher productivity, there is a need for the application of higher dose of fertilizers but the increased use of high analysis fertilizers and adaptation of high yielding cultivars demanding more primary, secondary and micro nutrients for enhancing food grain production The stagnation in crop production in India is basically due conventional fertilizer recommendation, low fertilizer use efficiency and imbalanced use of fertilizers. The quantitative evaluation of fertilizer doses may assist in improving yield with simultaneous increase in the nutrient use efficiency. At present, nutrient mining is a great threat to Indian agriculture as there is wide gap between nutrient addition and nutrient removal. One of the reasons for lower production is imbalanced use of fertilizers by the farmers without knowing soil fertility status and nutrient requirement of crop. There is a scope to increase. The production of maize by Soil Test Crop Response (STCR) correlation method, the fertilizer doses are recommended based on fertilizer adjustment equations which are developed after establishing significant relationship between soil test values and the added fertilizers. In Uttar Pradesh much work has not been done on the production technology of rabi maize specially on selection of suitable genotype for specific areas, plant density and NPK doses for rabi maize. Keeping this view in mind, an experiment was undertaken to study the effect of maize variety, plant geometry and levels of nutrients on growth and yield of rabi maize.

MATERIALS AND METHODS

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The experiment was conducted at the Crop Research Station, Bahraich Uttar Pradesh during rabi season of 2012-13 and 2013-14, with two maize genotypes viz. Shreeram-9682 and HM-7705, two plant geometry (50 cm x 20 cm and 60 cm x 20 cm) along with three levels of nutrients viz recommended dose (200:60:60 kg NPK ha^{-1}). Soil Test Crop Response (250:50:50 kg NPK ha^{-1}) and Site Specific Nutrient Management (SSNM) basis (225:60:80 kg NPK ha^{-1}). The experiment was laid out in split plot design and treatments were replicated thrice. The genotypes were located in main plot, plant geometry located in sub plot and nutrients level in sub-sub plots. The soil of experimental plot was sandy loam in texture having neutral reaction (pH 7.5) low in organic carbon (2.8g kg^{-1} %) and available nitrogen (200 kg ha^{-1}) and medium in phosphorus (11.5 kg ha^{-1}) and potash (240 kg ha^{-1}), respectively. The crop was sown on 15 November in both the years. 1/3 dose of N and full dose of P and K were applied as basal placement at the time of sowing as urea, single superphosphate and muriate of potash, respectively and remaining 2/3 dose of nitrogen was applied as top dressing in two equal splits, first at time the of knee height and second at tassling stage of the crop. The irrigations and weed control measures were adopted in crop according to need of crop from time to time. Intercultur operations were also done two times during the crop season. Biometric observations such as plant height, cobs/plot, length of cobs, grains row/cob, number of grains/row, test weight, grain and stover yield were recorded after harvesting of crop. Economics of each treatment was calculated on the basis of nearest market prices of inputs and outputs. Grain and stover samples were digested in diacid mixture and P and K contents were determined by adopting standard methods (Jackson, 1973). Nitrogen content in grain and stover of maize was determined by modified Kjeldahl method. The data relating to each character were pooled and analyzed as per procedure advocated by (Gomez & Gomez, 1984).

RESULTS AND DISCUSSION

Effect of maize hybrids

The data (Table 1) indicated that the significant differences were observed in growth and yield attributes in both the hybrids. Highest plant height (180.5 cm) was noted under the variety Shreeram-9682 which was significantly superior to Hybrid-HM-7705 (178.7 cm). Significantly higher plant population (158.2 /plot), number of cobs (174.5 /plot), length of cobs (19.26 cm), number of grains row/cob (18.4), number of grain/row (34.8), test weight (246.8 g) and selling percentage (82.5) were recorded with hybrid-HM-7705 over Shreeram-9682 might be due to genetic characters. The differences between maize hybrids in relation to growth and yield attributes were also reported by Singh *et al.,* (2014), Gozubenli *et al.* (2001), Ramchadrappa *et al.* (2007). Data on grain and stover yield (Table 1) revealed that the maximum grain (78.20 q ha^{-1}) and stover (89.93 q ha^{-1}) yields were recorded under the hybrid HM-7705 which was 10.3 percent higher in grain and 5.8 percent in stover yield over the Hybrid Shreeram-9682. The variation in yields between both the varieties might be due to genetical variation in the varieties. The lowest yields of grains (70.87 q ha^{-1}**)** and stover yield (85.0 q ha^{-1}**)** were noted under hybrid Shreeram-9682. The maximum harvest index (46.5 %) was noted under hybrid HM-7705 while lower (45.4%) in hybrid Shreeram-9682. The differences in harvest index between hybrid maize might be due to yield difference between the varieties. The higher nutrient uptake (175.9, 39.1 and 58.1 kg NPK ha^{-1}**)** was noted in the hybrid HM-7705 as compared hybrid Shreram-9682. The data revealed that higher net income of Rs. 81973 ha^{-1} was noted under hybrid HM-7705. The variation in net income between hybrids might be due to variation in grain and stover yield. The B:C ratio was also noted in similar manner under both hybrids. The Similar findings was also reported by Singh *et al.* (2014), Ramchandrappa *et al.* (2007).

Effect of plant density

The significantly taller plants height (181.8 cm) was noted under plant geometry 50 x 20 cm, while lower (179.6 cm) in geometry 60 x 20 cm (Table 1). Plant population178.7 plot/plot and 156.5/plot were noted under 50 x 20 cm and 60 x 20 cm plant geometry, respectively. The difference between plant population/ plot was due to difference in row spacing. The yield attributes significantly influenced by plant geometry. Highest value of cobs/plot (181.5) was

recorded under the plant geometry 50 x 20 cm which might be due to more plant population. Higher cob yield (17.5 kg), selling percentage (83), length of cobs (20.4 cm), grain/row (33.2) and row (18.6) and test weight (248.4g) was recorded under plant geometry 60 x 20 cm over the plant geometry 50 x 20 cm. The higher value of yield attributes under 60 x 20 cm might be due to more space for plant development over the plant geometry 50 x 20 cm. The finding are in conformity with the result of Sahoo and Mahapatra (2007) and Singh *et al.* (2013).

The data (Table 1) indicated that significantly higher grain yield (75.65 q ha^{-1}**)** and stover yield (89.25 q ha^{-1}**)** were noted under the plant geometry 60 x 20 while lower values of 70.87 q ha^{-1} and 85.0 q ha^{-1} grain and stover yield, respectively were noted under 50 x 20 cm. The yield of grain and stover under plant geometry 60 x 20 cm might be due to better yield attributing characters noted under some spacing over the 50 x 20 cm plant geometry. Similar finding were also reported by Singh *et al.* (2013), Farnhan *et al.* (2001) and Sahoo *et al.* (2007).

The data on nutrient uptake (Table 2) indicated that higher plant nutrient uptake (170.2, 37.8 and 56.73 kg NPK ha^{-1}**)** were noted under plant geometry 60 x 20 cm which might be due to better root development and plant growth.

The data on economics of treatments (Table 2) revealed that higher net income of `. 78335 $ha^{-1}$ were noted under 60 x 20 cm spacing while `. 70722 ha^{-1} were noted under 50 x 20 cm. The difference between net incomes of plant geometry might be due to yield variation between both plant geometry. The higher B:C ratio (3.14) was noted under plant geometry 60 x 20 cm which might be due to higher net income under same plant geometry but cost of cultivation was same under both plant geometry.

Table 1: Effect of planting density and nutrient management on growth and yield attributes of rabi maize (mean of 2 years

Treatments	Plant height (cm)	Silking 50 % in days	Cobs/ plot	Cobs yield (kg /plot)	Selling Percentage	Length of cobs (cm)	Grain row/cobs	Grain /row	Test weight (g)
Varieties									
Shreeram-9682	180.5	96.5	168.4	16.8	81.0	18.5	17.2	31.5	242.5
HM-7705	178.7	94.4	174.5	18.2	82.5	19.2	18.4	34.8	246.8
CD (P=0.05)	1.35	1.15	2.15	1.85	0.5	0.75	0.65	1.2	0.85
Planting density									
60 x 20 (cm)	197.6	97.2	165.6	17.5	83.0	20.4	18.6	33.2	248.4
50 x 20 (cm)	181.8	95.3	181.5	16.8	81.0	18.2	17.4	30.8	240.2
CD (P=0.05)	1.25	1.14	3.65	1.64	0.45	0.45	0.48	1.14	0.75
Nutrients levels (NPK kg ha^{-1})									
RDF (200:60:60)	181.4	97.6	172.5	17.5	81.0	18.5	16.5	30.5	242.6
STCR (250:50:50)	182.5	95.4	176.8	18.4	82.0	20.4	18.4	33.4	247.8
SSNM (225:60:80)	184.6	94.3	182.4	20.5	82.5	21.2	19.5	33.8	248.2
CD (P=0.05)	0.75	0.65	3.25	1.75	0.3	0.65	0.38	1.27	0.82

Effect of nutrient levels on growth, yield attribute and yield:

The growth and yield attributes were recorded and presented in Table 1. Data indicated that significant variations were recorded under different fertilizer practices to the crop. The highest plant height (184 cm) was recorded with SSNM (225:60:80 kg ha^{-1}**)** which was higher over the RDF (200:60:60 kg NPK) and soil test crop response (250:50:50 kg ha^{-1}**)**. The yield attributes such as plant population/plot, cobs/plot, selling percentage, length of cobs, grains row/cobs, grains/row, test weight were significantly higher with SSNM treatment over state recommendation. The higher plant population (170/plot), cobs (182.4/plot), cobs yield (20.5 kg/plot), selling percentage (82.5), length of cobs (21.2 cm), grains row (19.5), grain/row (33.8) and test weight (248.2 g) were noted under SSNM (225:60:80 kg NPK ha^{-1}). This might be due to availability of more nutrients to the crop ultimately plant yield

attributes increased in comparison to rest of nutrient levels. The similar findings were also reported by Singh *et al.* (2013), Singh *et al.* (2014), Kumar *et al.* (2014). The lowest value of plant height and yield attributes were recorded under state of recommended dose (200:60:60 kg NPK ha^{-1}) which might be low availability of nutrients to the crop for development of height and yield attributes.

Data (Table 1) indicated that the highest grain yield (88.08 q ha^{-1}), stover yield (105.69 q ha^{-1}) were noted under Site Specific Nutrient Management (225:60:80 kg NPK ha^{-1}) which was 19.3 and 12.0 % higher in grain yield and 19.3, 10.2 % higher in stover yield over the recommended dose (200:60:60 kg NPK) and STCR (250:50:50 kg NPK ha^{-1}). The performance of site specific nutrient management treatment was better over recommended practice for maize. It indicates that we need to the recommendation domain of maize owing to ever declining soil heaith, especially for some of the macro nutrients. Increasing levels of nutrients probably exerted a positive effect on the development of source and sink strength of the plants which ultimately resulted in higher yield.These findings are in conformity with the findings of Parthipan *et al.* (2003), Singh and Singh (2006), Singh *et al.* (2013) and Singh *et al.* (2014).

Table 2: Effect of planting density and nutrient management on yield, economics and nutrient uptake by rabi maize (mean of 2 years)

Treatments	Grain yield (q. ha^{-1})	Stover yield (q. ha^{-1})	Net profit (`. ha^{-1})	B:C ratio	Total Nutrient uptake (kg ha^{-1})		
					N	P	K
Varieties							
Shreeram-9682	70.87	85.00	71218.00	2.95	159.4	35.4	53.0
HM-7705	78.20	89.93	81973.00	3.24	175.9	39.1	58.6
CD (P=0.05)	2.25	2.65	375.00	0.12	6.5	2.25	3.5
Planting density							
60 x 20 (cm)	75.65	89.25	78335.00	3.14	170.2	37.8	56.7
50 x 20 (cm)	70.87	85.04	70722.00	2.91	159.4	35.4	53.1
CD (P=0.05)	2.00	2.50	415.00	0.11	6.15	2.0	2.65
Nutrients levels (NPK kg ha^{-1})							
RDF (200:60:60)	73.82	88.58	75406.00	3.04	166.0	36.9	55.3
STCR (250:50:50)	78.58	95.86	81798.00	3.16	176.8	39.2	58.9
SSNM (225:60:80)	88.08	105.69	97481.00	3.67	178.1	44.0	66.0
CD (P=0.05)	2.45	2.85	520.00	0.10	2.12	2.15	2.45

Data (Table 2) indicated that highest nutrient uptake (N 178.1, P44.0 andK 6600 kg^{-1}) were observed under 225:60:80 NPK (SSNM) kg ha^{-1}. The higher uptake under this treatment might be due to more nutrients availability and grain stover yield. The lower uptake (166.0:36.9:55.3 kg NPK ha^{-1}) was noted under RDF (200:60:60 kg NPK ha^{-1}).

The data on economics of treatments (Table 2) indicated that the higher profit of ` 97481 and B:C ratio (3.67) were recorded under SSNM (225:60:80 kg NPK ha^{-1}) and which was found 29.2, 19.1 % higher in net income and

20.7, 16.1% in B:C ratio over RDF (200:60:60 kg NPK ha^{-1}) and soil test crop response (250:50:50 kg NPK ha^{-1}), respectively. The lower net income (` 75406 ha^{-1}) and B:C ratio (3.04) were reported in RDF (200:60:60 kg NPK ha^{-1}).

On the basis of results, it may be concluded that hybrid HM-7705 with plant geometry (60 x 20 cm) and plant nutrient on the basis of site specific nutrient management produced higher yield and gave more net profits. Thus, SSNM may break the yield barrier of maize by enhancing yield through judicious exploitation of available nutrients by plants.

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ANALYSIS OF RAINFALL FOR DROUGHT OCCURRENCES IN MAYURBHANJ, ODISHA

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ABSTRACT

Assessment of drought occurrence is one of the most important steps in risk management of drought analysis. Drought is mostly the result of a decrease in precipitation in comparison with the mean value and would affect the quantities of soil moisture and water resources. It is, therefore, necessary to study the rainfall analysis for developing farming system which may help to increase and stabilize agriculture production through better use of natural resources. The analysis of 19 years (1979-2015) daily rainfall data of Mayurbhanj, Odisha has been carried out to determine the occurrence of drought. Based on weekly rainfall analysis, it was found that during 19 years, 51 % weeks were drought, 37 % normal and 12 % abnormal weeks. The results of the monthly rainfall analysis showed that about 64% of total number of months was normal. This analysis will help for crop planning and for design of soil and water conservation structure for future need.

Key words: Abnormal rainfall, crop planning, drought, rainfall analysis, normal

INTRODUCTION

Rainfall is the most important natural hydrologic event and is a unique phenomenon varying both in space and time. Rainfall distribution is very uneven and it not only varies considerably from place to place but also fluctuates from year to year. As a general rule, different regions assume a certain level of water shortage based on the long-term climatic conditions experienced by it. Therefore, any deviation from these levels creates either a conditions of drought or flood, depending on the intensity and duration of these deficits or surplus. Thus drought conditions vary among regions of differing climates should therefore be studied within a regional context (Demuth and Stahl 2001). Drought is a major natural hazard having severe consequences in regions all over India. The range of drought impacts is related to drought occurring in different stages of the hydrological cycle and usually different types of droughts are distinguished. The origin is a meteorological drought, which is defined as a deficit in precipitation. The basis of drought indices mostly depends on measurements as the deviations of precipitation values from the long-term mean value during a particular period of time. In response to the different impacts of drought in different regions, a large number of quantitative drought characteristics have been developed. The published summaries can be found (Heim 2002, Smakhtin and Hughes 2004 Hayes 2005). In the past many drought indices have been developed, as an useful and simple method for monitoring and assessment various categories of drought (Mishra *et al.,* 2010). In India, large parts of the country perennially reel under recurring drought. Over 68% of the total area is vulnerable to drought. The 'chronically drought-prone areas' is around 33% and receive less than 750 mm of rainfall, while 35%, classified as 'drought-prone' receive rainfall of 750-1,125mm. Several workers have done meteorological analyses based on rainfall data. Meteorologically a day is considered dry when it receives rainfall less than 2.5 mm (Chowdhary, 1979). According to the India Meteorological Department (IMD), meteorological drought occurs when the seasonal rainfall received over an area is less than 75% of its long-term average value. (Satapathy *et al.* 1998; 1999; Sharma *et al.* 1979, 1987a. and 1987b) analysed the rainfall using the definition of drought month as a month in which the actual rainfall is less than 50% of the average monthly rainfall. Sharma and Verma (1983) analyzed the drought using the definition of drought month, drought week and drought year for different regions as receiving actual rainfall equals to the 50% of the average rainfall.

MATERIALS AND METHODS

The study place, Mayurbhanj has an area of 10,418 km², and is located at 22.0087° N

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latitude and 86.4187° E longitude with an altitude of 559 m above mean sea level. Daily rainfall data of 19 years (1997-2015) was collected from India Meteorological Department (IMD) Pune to analyse the drought occurrence in the district. The daily rainfall data for each standard metrological week was added to compute the weekly rainfall. Similarly, the daily rainfall in each month was added to compute the monthly rainfall in a particular year. Also the annual rainfall was computed by adding the monthly rainfall in that particular year.The drought estimation was made by considering definition of different terms. Drought week/month was defined as receiving rainfall less than 50 % of the average weekly/monthly rainfall whereas normal week/month receiving rainfall in between 50–200% of average rainfall. Abnormal week /month was defined as any week receiving rainfall more than twice the average weekly rainfall.Sharma *et al.* (1978) had also defined yearly criteria for determination of drought years as any year receiving rainfall less than or equal to X-SD, Normal year is any year receiving rainfall in between the limits of X-SD to X+SD and abnormal year is the year receiving rainfall more than or equal to X+SD, where

X – Population mean I.E the mean yearly rainfall and

SD – Standard deviation with same unit as that of X

RESULTS AND DISCUSSION

Weekly analysis of rainfall data

The weekly rainfall data were analyzed to compute mean weekly rainfall, per cent drought, normal and abnormal weeks. The drought weeks were analyzed by using criteria as discussed earlier in methodology. The average maximum weekly rainfall was obtained in 28th M.W. (*i.e.* 114.47 mm).

Table 1: Weekly average rainfall and criteria for drought, normal and abnormal weeks

Meteorological week number	Average weekly rainfall (mm)	Number of weeks		
		Drought weeks	Normal weeks	Abnormal weeks
18	24.24	6	11	2
19	30.09	10	5	4
20	36.46	6	11	2
21	59.18	3	14	2
22	60.58	6	10	3
23	75.39	5	13	1
24	73.02	6	11	2
25	63.45	5	13	1
26	76.21	5	12	2
27	77.09	6	12	1
28	114.47	3	16	0
29	96.91	3	16	0
30	103.52	2	16	1
31	75.52	4	15	0
32	84.89	5	13	1
33	99.33	3	16	0
34	64.87	4	15	0
35	70.05	7	10	2
36	76.75	4	15	0
37	58.28	4	15	0
38	91.57	5	12	2
39	42.32	8	7	4
40	53.83	8	8	3
41	27.67	12	4	3
42	18.00	12	4	3
43	9.35	10	5	4
44	12.62	14	2	3
45	2.84	14	1	4
46	4.11	13	3	3
47	2.34	16	1	2
48	2.38	17	1	1
49	2.92	17	0	2
Total		243	307	58

The maximum number of normal weeks obtained in 28th, 29th, 30th and 33rd M.W. (*i.e.* 16 times) out of 15 years rainfall data. The meteorological weeks from 18th S.M. week to 44th S.M. weeks are major rainy weeks (Table 1). It was found that, during 19 years period of rainfall data, 51 % weeks were drought, 37 % normal and 12 % abnormal weeks The minimum number of drought weeks has occurred 2 times in 30th M.W, while the maximum numbers of droughts were observed in 17 times in 48th and 49th week during the 19 years rainfall data.

Analysis of monthly rainfall data

The normal, abnormal and drought months were analyzed on the basis of definitions explained in the methodology. The rainfall for a monthly data to be a drought, abnormal or normal with the average rainfall has been shown in Table 2. The average maximum monthly rainfall was about 429.93 mm in the month of July. The average monthly rainfall was 148.86 mm. It was seen that arrival of monsoon is mainly during the end of May and withdrawal of monsoon occurs during first week of October so the main rainy season is from June to September. The months from January to April, received very less rainfall, *i.e.* the drought occurrence was very high during these months. The results of the rainfall analysis showed that about 64% of total numbers of month were normal for 19 years period. It can be seen from Table 2 that about 49 % of normal month occurred during monsoon season *i.e.* June to September whereas one time in June drought occurred. It was also seen that 30 % total number of months was drought month during 19 years period. Most drought occurred from January to April as that time there was very little rainfall whereas months of July, August and September did not suffer from drought in 19 years period. Abnormal months occurred in the month of January, February and April with an average rainfall of 15.89 mm, 17.27 mm and 53.56 mm respectively. Only 3 % of total number of months was abnormal in 19 years period.

Table 2: Number of drought, normal and abnormal months in 19 years period

Sr. No.	Average monthly rainfall (mm)	Number of months		
		Drought	Normal	Abnormal
January	15.89	11	5	3
February	17.27	10	8	1
March	24.03	10	9	0
April	53.56	9	9	1
May	181.55	2	17	0
June	302.04	1	18	0
July	429.93	0	19	0
August	360.07	0	19	0
September	283.28	0	19	0
October	95.65	6	11	2
November	15.13	8	10	3
December	7.95	13	2	4
Total		70	146	14

Analysis of yearly rainfall data

In Mayurbhanj district, the average annual rainfall was 1808.2 mm and value of S.D. were found to be 199.06. The drought, normal and abnormal years was determined by criteria as discussed earlier. Therefore, any year receiving rainfall less than or equal to 1609.14 mm will be drought year. Distribution of annual rainfall was shown in Table 3. Thus, as per the above definitions, 11% years (*i.e.* 2009 and 2010) were drought years. Any year receiving rainfall equal to or greater than 2007.26 mm will be abnormal. Thus, 26 % of total years for the period studied. The years receiving rainfall in between 1609.14 to 2007.26 mm will be normal years. Thus, remaining 63% of years (1997, 1998, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2012, 20014 and 2015) are the normal years for the period studied. Rainfall is the most important component in agriculture production and its spatial and temporal distribution is uneven uncertain and erratic in nature.

Table 3: Yearly intensity of drought in 19 years period

Year	Average rainfall (mm)	Category
1997	1700.2	Normal
1998	1631.9	Normal
1999	2174.4	Abnormal
2000	1739.3	Normal
2001	1800.4	Normal
2002	1804.3	Normal
2003	1803.8	Normal
2004	1750.3	Normal
2005	1705.2	Normal
2006	1898.6	Normal
2007	2025	Abnormal
2008	2055.7	Abnormal
2009	1557.3	Drought
2010	1498	Drought
2011	2083.4	Abnormal
2012	1631.4	Normal
2013	2122.1	Abnormal
2014	1627.2	Normal
2015	1747.3	Normal

More than 75% of rainfall occurs during 22nd to 42nd week . There is a good amount of rainfall in May which is considered as pre monsoon shower and helps in seed bed preparation. Thus crop planning is suggested based on 70% rainfall along with onset of effective monsoon and drought, normal and abnormal periods. This requirement is completed by rainy season and excess water may be stored for growing *Rabi* season crops.

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ISOLATION, IDENTIFICATION AND PATHOGENICITY OF *FUSARIUM UDUM* ISOLATES FROM PIGEONPEA

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ABSTRACT

Fusarium wilt is an important soilborne disease of pigeonpea, (Cajanus Cajan (L) Millsp) caused by fusarium udum. In this study, Fusarium udum causal organism of pigeonpea wilt has been isolated from infected pigeonpea plant by using tissue segment method on PDA medium. The pathogen was identified as F. udum based on morphological and cultural characteristics. In order to establish an effective evalutating method for F. udum pathogenecity, F. udum strain was tested on pigeonpea plant at young seedling stage. The results indicated that, in both root dipping and soil inoculation method, at three weeks of seedling after inoculation, the initial visible symptoms were loss of turgidity in leaves, slight interveinal clearing and the leaves retained on wilted plants. The mortality of seedlings was 33.8% and 66.2% respectively during 4 and 5 week after inoculation. In soil inoculation method the germination of seed was only 61.6 % in infested soil. The post emergence mortality was recorded 24.3% and 62.3%, respectively during fourth and fifth week after sowing.

Keywords: Isolation, pathogenicity**,** *Fusarium udum,* pigeonpea, wilt

INTRODUCTION

Pigeonpea (Cajanus cajan L. Millsp) is an important grain legume crop grown in India.It is grown in different states like Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh, Uttar Pradesh, Gujarat, Jharkhand, Rajasthan, Odisha, Punjab and Haryana. Pigeonpea is mostly consumed as dry split dhal besides several other uses of various parts of pigeonpea plant. It is an excellent source of protein (20-22%), supplementing energy rich cereal diets in a mainly vegetarian population. Pigeonpea is a multipurpose crop that fits very well in the context of sustainable agriculture. In addition to food, it can be used as fodder, feed, fuel, functional utility (for making baskets, huts, fences, etc.), fertilizer (fixes atmospheric nitrogen and releases phosphorus), forest use (re-forestation, lac production), and even for pharmaceutical purposes. However, the current production of pigeonpea in India cannot meet the domestic demand leading to a decrease in per capita availability of pigeonpea from 70 g to 35 g. Despite the fact that a large number of high yielding varieties and have been released, productivity in the crop remains stagnant around 650-700 kg ha^{-1}as compared to its potential yield (2500-3000 kg ha^{-1}). This gap may be attributed to several biotic and abiotic factors (Pulses handbook 2015 pp.-19). Under biotic factor Pigeonpea wilt is a major constraint to pigeonpea production, worldwide. The fungus can survive on infected plant debris in the soil for about three years and cause serious yield losses, sometimes around 100% in susceptible cultivars (Sahu and Verma, 2016). The disease occurs generally at seedling and flowering stage. Seeds harvested from wilted plants are lighter and dull than those from healthy plants. Considering this the present study was aimed to know the isolation, identification and pathogenicity of pathogenic fungus causing wilt of pigeonpea.

MATERIALS AND METHODS

Isolationand identification

Fusarium udum from pigeonpea (Cajanus cajan) plants with wilt symptoms were collected from IGKV farm Raipur district in Chhattisgarh and were studied for their pathogenicity in 2012.The pathogen was isolated by tissue segment method on PDA medium. The entire work of isolation and purification was done in isolation chamber and laminar air flow, which was sterilized by alcohol and UV tube light, prior to use. The infected roots of each infected pigeonpea plant samples were split opened longitudinally with the help of sterilized scalpel.

The root parts showing brown discoloration of vascular tissues were cut into small bits and washed well in running tap water. The bits were then surface sterilized with 0.1% mercuric chloride ($HgCl_2$) solution for 1 minute followed by three washing with sterilized distilled water, dried by placing in between the two sterile blotters and finally kept on previously poured potato dextrose agar (PDA) medium in petridish for isolation of fungus. The plates were then incubated at temperature 28±1°C in BOD incubator. The plates were observed after mycelial growth from the infected bits. Mycelial bits of suspected *Fusarium* sp. were transferred to PDA slants and maintained after confirmation. Identification of the isolated species was done by comparing the characters pertinent to morphology and microscopic examination details with the characters described by Booth (1998).

Pathogenicity

Pathogenicity of isolated *F. udum* was done by following Koch'spostulate.

Soil inoculation method

The sterilized soil inoculated with test fungus *F. udum* isolated from diseased plants. The infested soil was used in plastic cups for sowing seeds of pigeopea variety. A suitable control was maintained as sterilized soil (uninoculated). Pigeonpea seeds were surface sterilized with 0.1% $HgCl_2$ for few seconds followed by three washing with sterilized distilled water. Five seeds were placed in each plastic cup and twenty replications were maintained for inoculated and uninoculated (control treatment). These cups were kept in growth chamber. Observations on pre and post- emergence mortality were recorded till five weeks of growing period.

Root Dipping Method

The isolated fungus was multiplied in 100 ml Potato Dextrose broth medium in 250 ml conical flask. A five mm disk of seven days old fungal culture was placed in each flask containing 100 ml broth and incubated at 28 ± 1°C for seven days. After incubation the entire fungal mat bearing conidia from each flask was macerated in mortar-pestle and macerated fungal growth was suspended in 100 ml distilled water and spores concentration was maintained at $2x10^6$ conidia/ml. Test seedlings of 8-10 days old, grown in pots containing sterilized soil:sand in the ratio of 7:3 were removed very carefully and dipped in the spore suspension for atleast 5 minutes (Haware and Nene, 1994). The seedlings were then transplanted back in their respective pots. Seedlings dipped in sterilized water for five minutes and transplanted back in same pots served as control. Twenty replications were maintained for culture and control. Observations of wilt were recorded after appearance of symptoms till five weeks of growing period.

RESULTS AND DISCUSSION

In culture, the fungal colony (*F. udum*) was observed to be white, cottony with profuse, fluffy aerial mycelium which gradually turned yellowish brown. The mycelium is septate and hyaline. The fungal hyphae produces three types of spores within the host tissues; microconidia, macroconidia and chlamydospores. The microconidia are minute, elliptical, curved and unicellular with one or two septa and measure 5-15 X 2-4 µ. The macroconidia are long, curved, pointed at the tips with 3-4 septa and measure 15-50 X 3-5 µ. Chlamydospores are oval, single or in chains, terminal or intercalary. Based on the characters of the colony and morphological features of conidiophores and conidia, the fungus was identified as *Fusarium udum* Butler.

Table 1: Pathogenicity test of *Fusarium udum* by soil inoculation method

Particulars	Germination (%)*	Post - emergence mortality (%)*	
		4^{th} week	5^{th} week
Inoculated	61.60	24.35	62.34
Control	100	0.00	0.00

**Average of twenty replications*

For proving the pathogenicity by soil inoculation method, the sterilized soil inoculated with test fungus *F. udum* which was isolated from diseased plants, the germination of seed was only 61.60 % in infested soil, while highest germination i.e. (100%) was recorded in control (unsterilized soil)s. The post emergence mortality was recorded 24.35% and 62.34% respectively during 4^{th} and 5^{th} weeks after sowing while no mortality was recorded in control.

Table 2: Pathogenicity test of *Fusarium udum* by root dipping method

Particulars	Seedling mortality (%)*	
	4th week	5th week
Inoculated	33.80	66.20
Control	0.00	0.00

**Average of twenty replications*

The investigation was very close to the observation of Pawar *et al.* (1993) who worked on evaluation of pigeonpea lines for wilt resistance and showed that wilt usually occurred around 30 days after sowing and increased in severity during maturation and also reported that mortality in susceptible checks was 100 percent..

In root dipping method after 18 days of inoculation, the leaves exhibited typical symptoms like loss of turgidity; slight interveinal clearing in leaves of the artificially inoculated plants and after 30 days of plant growth symptoms also appeared on the collar region of stem. The initial characteristic internal symptom of wilt was the browning of the xylem vessels from the root system to the stems. The mortality of seedlings was 33.80% and 66.20% respectively during 4th and 5th week after inoculation. On the other hand in control (root dipping with sterilized water) did not show any sign of leaf yellowing and seedling mortality till five weeks after inoculation.The investigation was very close to the observation of Haware and Nene (1994) who studied a rapid method for inoculating pigeonpea seedlings with *Fusarium udum* involving root dip of test plants and revealed that in the root dip technique, >90% incidence of wilt within 20-26 days then 100% at 30 days after inoculation. Phipps and Stipes (1973) studied root dip method for the testing of Fusarium wilt pathogenicity on *Mimosa* and reported that the root dip method resulted in a high percentage of wilted plants in all cultivars.

It may be concluded that the morphological characters of the re-isolated organisms were similar to original culture of the pathogen in all respects. Hence, the causal agents of the disease were confirmed as *Fusarium udum*.

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RESPONSE OF BLACK PEPPER TO FOLIAR APPLICATION OF MAGNESIUM AND BORON

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ABSTRACT

A green house experiment was conducted at College of Agriculture, Padannakkad, Kerala to study the response of black pepper to foliar application of magnesium and boron. The experiment was laid out in completely randomized design replicated thrice with nine treatments using Panniyur-1 as the test variety. The results revealed that the foliar application of 1% $MgSO_4$ + 0.5% borax increased B and Mg content in pepper leaves.In general B and Mg content in leaves increased up to 6 MAP followed by a reduction at 9 MAP irrespective to various treatments. The maximum leaves vine^{-1} (48.6), leaf area (95.10cm^{-2}) and branches vine^{-1} (11.00) were recorded with 1% Mg SO_4 + 0.5% borax foliar application. The lowest values of these growth characters were recorded under control. The spikes vine^{-1} (38.33), berries spike^{-1} (102.0), 100 berry weight (6.61g) and berry yield (122.0 g) were recorded by foliar application of 1% $MgSO_4$ + 1.0% borax. The highest oleoresin (11.73%) and piperine (5.87%) content were obtained with foliar application of 1% $MgSO_4$ + 1% borax. Foliar application of 1% Mg SO_4 + 0.5% borax proved next best treatment in improving these parameters.

Key words: Magnesium, boron, black pepper, oleoresin, piperine

INTRODUCTION

Black pepper (*Piper nigrum*L.), the king of spices is mainly cultivated in warm, humid and high rainfall regions. It is an economically important and widely used spice crop indigenous to the Western ghats of Kerala. The dried berry obtained from the vines has a commercial value as an important spice condiment used all over the world. It is also valued for its oleoresin and medicinal properties. The low productivity of black pepper in India is due to poor genetic potential of the vines, high population of senile and unproductive vines, losses caused by pests, diseases and soil constraints. Among these, soil related stress like acidity and nutrient deficiencies are major ones. Pepper requires a porous friable soil, having good drainage, adequate water holding capacity, rich in humus and essential plant nutrients. In Kerala, pepper is cultivated in laterite soils, which is acidic, generally low in plant nutrients, low in cation exchange capacity with weak retention capacity of bases applied as fertilizers. So the secondary and micronutrient deficiencies are frequent in these soils. Magnesium is an important element required for the growth of pepper plant. It plays an important role in photosynthesis. It also plays an important role in the cell energy balance, interacting with the pyrophosphate structure of nucleotide tri and di-phosphates (Igamberdiev and Kleczkowski, 2003). Magnesium deficiency in plants often results in ultra structural changes especially in chloroplast, well before visible foliage symptoms are obvious. This is accompanied by impairment of photosynthesis (Sun and Payn, 1999). The total magnesium reserves in Kerala soils are poor and thus magnesium can be considered as a critical element in the acid soils of Kerala. Magnesium application is required for crops grown in soils with magnesium content below the critical limit of 120 mg kg^{-1}. Boron is an important essential micronutrient required for plant growth and reproduction (Siddiky*et al.,* 2007). Boron has a primary role in cell wall biosynthesis, cell division, lignification of cell wall, membrane function, RNA metabolism, indole acetic acid (IAA) production, phenol metabolism, carbohydrate metabolism, sugar transport, nucleotide synthesis, respiration (Sims and Jhonson, 2003). Boron deficiency symptoms in black pepper are yellowing starting from the centre to the extremities in younger leaves. Malformed terminal buds show reduced development and development of dark spots between veins and leaf margins. Some younger leaves are curved downside with a rosette appearance (Velso*et al.,* 1998). These symptoms are widespread in the pepper growing

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areas of Kerala. Application of B is essential for crops grown in soils with available B below critical limit of 0.5 mg kg^{-1}. The present investigation was therefore, undertaken to study the response of black pepper to foliar application of magnesium and boron.

MATERIALS AND METHODS

A green house experiment was conducted at College of Agriculture, Padannakkad during 2012-14. Three months old black pepper var. Panniyur-1 (bush) plants were planted into the earthen pots filled with twenty kilograms of laterite soil. The experimental soil was sandy clay loam belonging to order Inceptisol, having pH 5.81, EC 0.18 dSm^{-1}, organic carbon 17 g kg^{-1}, available nitrogen 460.5 kg ha^{-1}, available P_2O_5 10.8 kg ha^{-1}, available K_2O 98.7 kg ha^{-1}, available Mg 14.80 mg kg^{-1} and available B 0.30 mg kg^{-1}. The experiment was laid out in completely randomized design replicated thrice with nine treatments using Panniyur-1 as the test variety. There were 9 treatments *viz.,* T_1- 0.5% $MgSO_4$, T_2- 0.5% $MgSO_4$ + 0.5% borax, T_3- 0.5% $MgSO_4$ + 1% borax, T_4-1% $MgSO_4$, T_5- 1% $MgSO_4$ + 0.5% borax , T_6-1% $MgSO_4$ + 1% borax, T_7-0.5% borax, T_8-1% borax and T_9- control. Nitrogen, P and K fertilizers were applied as per package of practices recommendations. Magnesium as magnesium sulphate and boron as borax solutions (0, 0.5 and 1%) were sprayed at now flushing and spike initiation stage. Leaf samples were collected at 3, 6 and 9 months after planting and analyzed for boron and magnesium content. Magnesium was determined in di acid (HNO_3 and $HClO_4$) mixture with the help of flame photometer. Boron was analysed by azomethen-H colorimetric method (Bingam, 1982). The oleoresin content of dried berries was estimated using the Soxhlet method of extraction as per Horwitz (1980). The piperine content in dried berries of pepper was determined by uv-spectrophotometric method described by Kolhe *et al.* (2011). Observations *viz.,* leaves $vine^{-1}$, branches $vine^{-1}$, leaf area, yield and yield attributes, and quality parameters were recorded. The results obtained were statistically analyzed using statistical analysis software (SAS).

RESULTS AND DISCUSSION

The boron content of leaves increased from 3 MAP to 6 MAP. At 6 MAP, treatment T_6 (1% $MgSO_4$ + 1% borax) recorded highest boron content of 57.34 mg kg^{-1} (Table 1). At nine months after planting, there was a decline in boron content in all treatments compared to previous stage. There was significant difference among treatments with respect to boron content in leaves. At 9 MAP, highest value was obtained in T_6 (51.83 mg kg^{-1}) and minimum in control (Table 1). The higher dose of foliar B application increased the B status in leaves, indicating that B is absorbed by leaves and is redistributed to developing sinks (Akram *et al.* 2006). Foliar application of 1% Mg SO_4+ 0.5% borax, being at par with 1% Mg SO_4 + 1% borax , also increased the boron content in leaves at all the stages of growth over other treatments. Foliar application of Mg did not affect the B content in leaves significantly over control at all the stages of growth. The leaves of plants grown under control treatment had minimum values of boron content at all the stages of growth.

Table 1: Effect of foliar application on boron and magnesium content in pepper leaves at different stages

Treatments	Boron (mg kg^{-1})			Magnesium (%)		
	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP
T_1 – 0.5% $MgSO_4$	31.82	27.83	21.83	0.30	0.53	0.31
T_2 – 0.5% $MgSO_4$ + 0.5% borax	36.65	45.00	36.65	0.28	0.52	0.31
T_3 – 0.5% $MgSO_4$ + 1% borax	36.66	45.00	40.00	0.27	0.53	0.33
T_4 – 1% $MgSO_4$	32.33	27.66	23.83	0.28	0.60	0.39
T_5 – 1% $MgSO_4$ + 0.5% borax	34.16	54.16	49.65	0.30	0.66	0.41
T_6 – 1% $MgSO_4$ + 1% borax	38.00	57.34	51.83	0.28	0.66	0.38
T_7 – 0.5% borax	35.83	50.33	48.00	0.27	0.24	0.19
T_8 – 1% borax	37.50	52.19	49.82	0.28	0.24	0.17
T_9 – control	30.00	26.50	21.66	0.29	0.21	0.14
CD (5%)	NS	6.22	6.62	0.01	0.03	0.02

After three months of planting the highest content of magnesium in leaves was noticed in T_1 (0.30%) and T_5 (0.30%) which were significantly higher than other treatments. At six months after planting the highest magnesium content in leaves was recorded in T_5 (0.66%) (Table 1). At nine months after planting, the highest value was recorded in T_5 (0.41%), which was significantly higher than other treatments. Application of higher doses of Mg SO_4 helped in the better absorption and translocation of Mg to pepper leaves. Treatments T_5 and T_6 were almost equally effective in improving the magnesium content in leaves at all the stages of growth. This clearly indicates positive influence of treatments on magnesium nutrition of pepper.Foliar application of boron did not influence the Mg content in leaves markedly at all the stages of growth..The lower values of Mg content in leaves at all the stages of growth were recorded under control. The treatment T_6 (1% $MgSO_4$ + 1.0% borax) recorded maximum leaves vine^{-1} (48.6), leaf area (95.10 cm^2) followed by T_5 treatment. The maximum branches vine^{-1} (10.00) was recorded in T_6 (Table 2) and minimum under control.

Table 2: Effect of foliar application of Mg and B on growth parameters of black pepper

Treatment	Leaves vine^{-1}	Total Leaf area (cm^2)	Branches vine^{-1}
T_1 – 0.5% $MgSO_4$	43.66	85.93	7.33
T_2 – 0.5% $MgSO_4$ + 0.5% borax	45.00	87.92	7.65
T_3 – 0.5% $MgSO_4$ + 1% borax	47.66	88.12	8.33
T_4 – 1% $MgSO_4$	45.66	88.07	8.00
T_5 – 1% $MgSO_4$ + 0.5% borax	47.00	94.00.	9.33
T_6 – 1% $MgSO_4$ + 1% borax	48.60	95.10	10.00
T_7 – 0.5% borax	41.33	87.04	7.60
T_8 – 1% borax	45.33	89.93	8.33
T_9 – control	40.00	81.15	6.33
CD (5%)	12.25	8.24	0.83

The foliar application of magnesium increased the chlorophyll content and photosynthetic rate of the plants which is translated into higher dry matter production. This coupled with the influence of boron on the enzyme system and metabolism of the plant resulted in more number of leaves, leaf area and branches. The role of Mg and B in cell differentiation and development, translocation of photosynthates and growth regulators from source to sink also contributed to the above parameters. Similar results were reported by Mostafa *et al.* (2007).

Table 3: Effect of foliar application of B and Mg on yield and yield attributes of black pepper

Treatment	Spikes vine^{-1}	Spike length (cm)	Spike yield (fresh) (g vine^{-1})	Berries spike^{-1}	100 berry weight (g)	Spike dry yield (g vine^{-1})	Dry berry Yield (g)
T_1 – 0.5% $MgSO_4$	33.00	10.55	311.9	89.00	5.75	117.3	108.6
T_2 – 0.5% $MgSO_4$ + 0.5% borax	35.66	11.56	324.2	89.86	5.94	121.4	110.0
T_3 – 0.5% $MgSO_4$ + 1% borax	36.66	11.66	326.4	95.40	5.88	122.8	113.5
T_4 – 1% $MgSO_4$	34.33	11.88	325.9	94.92	6.00	120.3	113.3
T_5 – 1% $MgSO_4$ + 0.5% borax	36.00	12.22	340.0	100.60	6.37	126.0	120.7
T_6 – 1% $MgSO_4$+1% borax	38.33	13.66	335.7	102.00	6.61	128.0	122.0
T_7 – 0.5% borax	32.00	10.22	308.0	88.20	6.39	116.6	101.6
T_8 – 1% borax	35.66	10.24	310.7	90.93	6.41	123.9	111.6
T_9 – control	30.66	9.22	300.4	84.73	4.36	100.1	90.43
CD (5%)	4.26	1.05	12.43	5.19	1.09	10.81	12.01

Yield and yield attributes

Foliar application of 1% $MgSO_4$ + 1% borax recorded minimum number of spikes per vine (38.33), berries per spike (102.0), 100 berry weight (6.61 g) and berry yield (120.0 g). The maximum spike length was measured in T_6 (11.56 cm). The highest spike yield (385.7 g vine^{-1}) and spike yield (dry) (128.0 g vine^{-1}) was recorded in T_6 treatment (Table 3) which may be due to higher requirement of boron for reproductive growth than vegetative growth. Boron increases flower production and retention, pollen tube germination and seed and fruit setting (Oosterhuis, 2001). More number of spikes and higher 100 berry weight due to application of Mg and B might be due to involvement of B in reproductive growth as B improves the spike fertility.The higher amounts of B and Mg used in spraying proved superior to lower levels of these elements in respect of yield attributes and yield. The minimum values of yield attributes and yield were recorded under control.

Quality parameters

The contents of oleoresin and piperine contents in black pepper ranged from 11.14 to 11.73% and from 5.06 to 5.87%, respectively. The foliar application of 1% $MgSO_4$ + 1% borax (T_6) recorded highest oleoresin content of 11.73% which was on par with T_5 (11.51%) (Table 4). The highest content of piperine was recorded in T_6 (5.87%) (Table 4). The minimum values of oleoresin and pipperine content in black pepper were recorded under control.Boron is required for many enzymatic processes, which might have contributed to the improved quality parameters of black pepper as reported by Villarias*et al.,* 2000. This might also be attributed to the fact that magnesium act as an activator or co-factor of many enzymes in plants and in various metabolic process as reported by Cowan, (2002).

Table 4: Effect of foliar application of Mg and B on quality parameters of black pepper

Treatments	Oleoresin (%)	Piperine (%)
T_1–0.5% $MgSO_4$	11.32	5.51
T_2–0.5% $MgSO_4$ + 0.5% borax	11.34	5.61
T_3–0.5% $MgSO_4$ + 1% borax	11.42	5.80
T_4 – 1% $MgSO_4$	11.26	5.89
T_5 – 1% $MgSO_4$ + 0.5% borax	11.51	5.80
T_6 – 1% $MgSO_4$ + 1% borax	11.73	5.87
T_7 – 0.5% borax	11.34	5.25
T_8 – 1% borax	11.45	5.36
T_9 – control	11.14	5.06
CD (5%)	0.26	0.33

It may be concluded from the study that foliar application of Mg and B (1% Mg SO_4 + 0.5% borex) proved superior in respect of leaf nutrient content,yield parameters and berry yield, oleoresin and piperine content in black pepper. Foliar application of Mg and B may be recommended for the successful cultivation of black pepper in the area.

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EFFECT OF SOIL FERTILITY AND IRON LEVELS ON YIELD, QUALITY AND NUTRIENT UPTAKE IN ONION IN ALLUVIAL SOIL

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ABSTRACT

A field experiment was conducted at R. B. S. College Research farm Bichpuri, Agra (U.P.) during rabi season to study the effect of graded levels of soil fertility (control, 50,75 and 100% RD of NPK) and iron (0,5,10 and 20 kg Fe ha^{-1}) on yield attributes, yield, quality and uptake of nutrients in onion (Allium cepa L.). The experiment was laid out in randomized block design with sixteen treatment combinations and three replications. The results revealed that the fresh weight of a bulb and yields increased significantly with 100% RD of NPK over control. The yields of onion bulb were significantly lower with the sub-optimal doses of NPK. Application of 100% NPK produced 28.13 tonnes ha^{-1} bulb and dry matter yield (4.30 tonnes ha^{-1}) of onion which was significantly superior to 75 and 50% NPK. The content and yield of protein in onion bulbs increased significantly with an increase in level of soil fertility. The maximum protein content (4.81%) and protein yield (20.68 q ha^{-1}) were obtained with 100% NPK. The uptake of N, P, K, S, Fe and Zn by onion bulbs was found to be associated with production of dry matter resulted by application of 100% NPK. Application of 10 kg Fe ha^{-1} gave the highest yield of bulbs (23.73t ha^{-1}) which was 15.4% more than that of control. Application of iron increased the content (4.50%) and yield (16.33 q ha^{-1}) of protein up to 10 kg Fe ha^{-1}. The minimum value of Zn uptake by onion bulbs was recorded at 20 kg Fe ha^{-1}. Iron application up to 10 kg ha^{-1} significantly increased the uptake of N, P, K and S by the onion bulb over control followed by a reduction at 20 kg Fe ha^{-1}. Available nutrient status of post harvest soil was higher with 100% NPK level over control except those of iron and zinc. The lowest values of nutrients status were recorded under control. The status of N and Fe improved up to 20 kg Fe ha^{-1}. On the other hand, status of P and K decreased at 20 kg Fe ha^{-1} over 10 kg Fe ha^{-1} and zinc over 5 kg Fe ha^{-1}.

Key words: Iron, soil fertility, yield, quality, nutrient uptake onion

INTRODUCTION

Onion (*Allium cepa L*) is one of the most important commercial vegetable crop grown all over the world. Onion has culinary, dietary and medicinal important in daily life of Indian people and due to its export trade, it is also a major vegetable crop to gain foreign currency. Increasing productivity of onion with high quality is an important target of onion growers. Onion requires substantial amounts of plant nutrients and responds very well to the added fertilizers (Verma *et al.* 2014) The productivity of soil depends upon the adequate and balanced amount of all the essential nutrients including micronutrients (Fe). Among the various agronomic practices use of sub-optimum and imbalanced fertilization are responsible for low productivity of onion. Use of optimum fertilization is the key factor in increasing the productivity which can be realized with the judicious application of plant nutrients to onion crop. Intensive cropping along with lower use of organic manures and very low rates of application or practically no use of iron in soils have led to depletion of the reserves of Fe in soils, limiting the crop productivity. The low yields of bulb crops and poor quality of the produce are due to various constraints including micronutrient management. Iron is essential in both plant and animal nutrition. Iron is a structural component of porphyrin molecules cytochromes, haemes, hematin, ferrichrome and leg-haemoglobin involved in oxidation-reduction reactions in respiration. It is an important part of the enzyme nitrogenase which is essential for nitrogen fixation through nitrogen fixing bacteria. The ferrodoxins are Fe-S proteins and are the first stable redox compound of the photosynthetic electron transport chain (Havlin *et al.* 2014).. However, such information on iron nutrition of onion crop under different fertility levels is not available for onion under agro-climatic conditions of Agra region. Therefore, a field experiment was conducted to study the effect of Fe and soil fertility on yield, quality and nutrient uptake by onion in alluvial soil.

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MATERIALS AND METHODS

Field experiments were conducted at R.B.S. College Research farm (Agra). The climate of the study area is semi-arid with an average rain fall of about 650 mm per annum, about 80% of which is received during June to September. The soil of the experimental field was sandy loam in texture, having pH 8.1, organic carbon 3.9 g kg^{-1} and available N, P, K, Fe and Zn 145, 9.2, 115 kg ha^{-1}, 4.2 and 0.55 mg kg^{-1}, respectively. The experiment was laid out in randomized block design with three replications. The treatments included four levels each of soil fertility (control, 50, 75 and 100% RD of NPK) and Fe (0.5, 10 and 20 kg Fe ha^{-1}). Recommended dose of N, P and K(150 kg N, 100 kg P_2O_5 and 50 kg K_2O ha^{-1}) were applied as urea, di-ammonium phosphate and muriate of potash, respectively. Potassium and phosphorus were applied at planting but the crop received nitrogen in two splits, half as basal and half at 60 days after planting. Iron was applied as ferrous oxide at the time of planting. The seedlings of onion cv Nasik Red N-53 were planted in mid December during both the years. The spacing adopted was 20x10 cm. Onion crop was irrigated after planting and later as and when required. The crop was harvested at physiological maturity and yield data were recorded. The yield attributes of onion crop were recorded at harvest. Processed bulb samples were analyzed for their nutrients by digesting the samples using di-acid mixture (HNO_3 : $HClO_4$:10 : 4) followed by estimation of Fe and Zn on an AAS. Phosphorus, K and S were determined by vanadomolybdophosphoric yellow colour method, flame photometer (Jackson 1973) and turbidimetric method (Chesnin and Yien 1951), respectively. Nitrogen content was determined following micro Kjeldahl method. The proteln content was computed from the nitrogen content multiplied by a factor 6.25. The uptake of nutrients was then computed from their concentrations in bulb samples and bulb dry matter yield.

RESULTS AND DISCUSSION

Yield attribute and yield

The weight of a bulb increased significantly with successive increase in fertility levels up to 100% RDF (Table 1) which may be attributed to increased dry matter as a result of increased cell division and enlargement due to the application of NPK nutrition. The improvement in bulb weight due to fertility levels might have resulted in better interception and utilization of radiant energy leading towards higher photosynthesis and finally more accumulation of dry matter in onion bulbs. A perusal of data (Table 1) revealed that the application of graded doses of Fe to onion significantly enhanced the weight of a bulb over control. The maximum weight (61.7 g) of a bulb was recorded with the application of 10 kg Fe ha^{-1} over rest of the levels of iron. The increase in weight of bulb may be due to low available Fe status of the soil. There was a reduction in weight of bulb with 20 kg Fe ha^{-1} over 10 kg Fe ha^{-1}. Choudhary *et al.* (2015) reported similar results.

Table 1: Effect of Soil fertility and iron levels on yield and quality of onion (mean of two years)

Treatments	Weight of bulb (g)	Yield (t ha^{-1})		Protein content (%)	Protein yield (q ha^{-1})
		Fresh bulb	Dry matter		
Soil fertility					
Control	60.9	16.76	2.71	3.75	10.16
50% NPK	77.3	20.15	3.08	4.12	12.68
75% NPK	82.4	24.91	3.86	4.37	16.86
100% NPK	92.8	28.13	4.30	4.81	20.68
SEm±	2.46	0.13	0.22	0.16	1.40
CD (P= 0.05)	4.95	0.27	0.45	0.33	2.81
Iron (kg ha^{-1})					
0	75.8	20.57	3.13	4.12	12.89
5	78.6	22.55	3.44	4.37	15.03
10	81.0	23.73	3.63	4.50	16.33
20	78.0	23.10	3.53	4.37	15.88
SEm±	2.46	0.13	0.22	0.16	1.40
CD (P= 0.05)	4.95	0.27	0.45	0.33	2.81

Grading doses of fertilizer application had significant effect on bulb yield, dry matter yield of bulb. The yields increased with an increase in dose of fertilizer over control. Application of 100% RDF recorded the highest bulb yield (28.13 t ha^{-1}) being 12.9 and 20.1% higher over 75 and 50% RDF. This may be owing to build up to soil fertility that led to increased nutrient availability. There was a continuous and significant increase in dry matter yield of onion bulbs at each level of NPK addition over control. The difference in increase obtained in the yields at 75 and 100% NPK indicates the superiority of optimal dose apparently because the yield may be economically increased. Similar results were reported by Singh and Pandey (2006) and Singh *et al.* (2015). Application of 10 kg Fe ha^{-1} produced significantly higher bulb yield and bulb dry matter yield in comparison to control (Table 1). The highest mean bulb yield and dry matter yields of bulbs were recorded with the application of 10 kg Fe ha^{-1}, which were respectively, 15.3 and 16.0% higher than of the control. The response of onion to Fe may be due to low available Fe status of the soil. Similar results were reported by Chandel *et al.* (2013) and Choudhary *et al.*(2015).

Quality

The successive increase in fertility levels up to 100% RDF significantly increased protein content and protein yield (Table 1) over control. The increase in protein content with increasing fertility levels may be the result of enhancement in amino acid formation. Our results confirm the findings of Pachauri *et al.* (2003). The protein yield increased significantly up to 100% RDF over control. The wide vareations in protein yield were largely due to the differences in bulb yield because protein yield is the resultant of bulb yield and protein content. These results are in agreement with the findings of Singh and Pandey (2006).Application of iron increased the protein content in onion bulb and this increase was significant over control. The maximum value of protein content (4.50%) was noted at 10 kg Fe ha^{-1}. This increase in protein content with iron application may be attributed to its involvement in nitrogen metabolism. Similar results were reported by Chandel *et al.* (2013). The protein production increased from 12.89 q ha^{-1} at control to 16.33 q ha^{-1} with 10 kg Fe ha^{-1}. The increase in protein yield with iron application may be ascribed to greater bulb production.

Table 2: Effect of soil fertility and iron levels on uptake of N, P, K, S (kg ha^{-1}) and Fe and Zn (g ha^{-1}) by onion (mean of two years)

Treatment	Nitrogen	Phosphorus	Potassium	Sulphur	Iron	Zinc
Soil fertility						
Control	16.3	3.0	12.7	7.6	99.2	84.0
50% NPK	20.3	4.0	15.4	8.9	122.6	107.1
75% NPK	27.0	6.2	20.8	12.0	161.3	153.6
100% NPK	33.1	7.7	25.4	14.2	187.5	173.6
SEm±	2.32	0.39	1.12	0.60	9.6	7.1
CD (P= 0.05)	4.66	0.78	2.25	1.21	19.3	14.3
Iron (kg ha^{-1})						
0	20.6	4.7	16.3	9.4	93.9	119.7
5	24.1	5.8	18.8	10.6	127.5	127.5
10	26.2	5.4	19.2	11.2	166.1	134.6
20	24.8	4.9	18.0	10.2	193.8	126.0
SEm±	2.32	0.39	1.12	0.60	9.6	7.1
CD (P= 0.05)	4.66	0.78	2.25	1.21	19.3	14.3

Nutrient uptake

The uptake of N by onion bulb with fertility levels varied from 16.3 to 33.1 kg ha^{-1}. The increase in N uptake may be attributed to increased N content in bulbs along with bulb dry matter yield. The uptake of nitrogen by onion bulbs increased significantly with lower levels of iron addition followed by a reduction at 20 kg Fe ha^{-1}. The maximum value of N uptake (26.2 kg ha^{-1}) was recorded at 10 kg Fe ha^{-1}. The increase in N uptake with lower levels of iron may be due to higher bulb production.

Choudhary *et al.* (2015) also reported similar results The application of higher level of fertility (100% RDF) gave significantly higher uptake of phosphorus in dry matter of bulb and it was higher by over medium (75%) and lower (50%) level of fertility (Table 2). The utilization of P by onion bulbs increased significantly with lower levels of Fe over control. The higher level (20 kg Fe ha^{-1}) caused a significant reduction in P uptake by onion crop over 10 kg Fe ha^{-1}. This reduction may be due to reduction in dry matter yield of onion bulbs. Similar results were reported by Chandel *et al.* (2013). The significantly higher uptake of potassium by onion bulb was recorded under higher level of fertility. It was higher by 22.1 and 65.0% over medium and low level of fertility, respectively. The K uptake by onion bulbs increased significantly and consistently up to 10 kg Fe ha^{-1}. Thereafter, a reduction in potassium uptake by onion bulbs was noted at 20 kg Fe ha^{-1}. Increasing levels of soil fertility improved the uptake of sulphur by onion bulb and maximum value of 14.2 kg ha^{-1} was recorded under 100% NPK. The S uptake by onion bulbs increased significantly with increasing levels of Fe over control (Table 2) which may be due to increased availability of S in soil. In onion bulbs, S uptake ranged from 9.4 (control) to 11.2 kg ha^{-1} (10 kg Fe ha^{-1}). The iron uptake by onion bulbs also increased significantly due to fertility levels. It varied from 99.2 to 187.5 g ha^{-1}. The maximum iron uptake was recorded with the application of 100% NPK. Application of Fe progressively increased its uptake by onion bulb up to 20 kg Fe ha^{-1}, it was significantly higher over control with all levels of iron. This increase may be due to increased availability of iron in soil (Chandel *et al.,* 2013). Increasing levels of fertility significantly increased the uptake of zinc in onion bulbs over control. The zinc uptake increased from 84.0 g ha^{-1} at control to 173.6 g ha^{-1} with 100% NPK. The increase in Zn uptake may be attributed to enhanced Zn content in onion bulbs along with dry matter yield of bulbs. The Fe application had significant effect on Zn uptake by the onion bulb. The highest level of Fe (20 kg ha^{-1}) reduced the Zn uptake compared with its lower l as a result of lower content of Zn in bulbs.

Table 3: Effect of soil fertility and iron levels on status of available nutrients in post harvest soil N, P, K, S (kg ha^{-1}) and Fe and Zn (mg kg^{-1}) by onion

Treatment	Nitrogen	Phosphorus	Potassium	Iron	zinc
Soil fertility					
Control	100.4	7.5	106.4	6.15	0.49
50% NPK	139.7	10.0	116.0	7.45	0.51
75% NPK	170.6	13.7	129.5	7.03	0.52
100% NPK	185.3	15.2	138.0	5.72	0.50
SEm±	5.04	0.45	1.82	0.65	0.015
CD (P= 0.05)	10.13	0.91	3.65	1.31	NS
Iron (kg ha^{-1})					
0	140.4	11.8	121.0	3.75	0.51
5	147.0	12.2	122.6	5.10	0.52
10	152.3	12.0	124.0	7.25	0.50
20	156.3	10.4	122.3	10.25	0.49
SEm±	5.04	0.45	1.82	0.65	0.015
CD (P= 0.05)	10.13	0.91	NS	1.31	NS

Soil fertility

Available nitrogen status in post harvest soil improved significantly with all the levels of NPK fertilizers, the increase being 44.6 kg ha^{-1} in 100% NPK treatment as compared to the initial value (145 kg ha^{-1}). Increase in available N due to graded levels of NPK fertilizers has been reported by Verma *et al.* (2014). Available N status of the soils also improved with Fe levels indicating beneficial effect of iron addition. Available phosphorus status in soil increased with all the fertility levels over control. There was a significant increase in available P content in soil with increasing levels of NPK fertilizer and relatively higher amount was noted in 100% NPK level. This may be attributed to the increased amount of P in soil due to application of phosphatic fertilizers. Addition of 20 kg Fe ha^{-1} reduced the available P content in soil over control. Increasing levels of NPK fertilizers improved the status of available K in soil after the harvest of onion crop over control. The highest level (100% NPK) proved more beneficial in respect of available K content in soil. The amount of available K in soil also improved with application of iron but the difference were statistically non-significant between the levels of iron. Data on available iron content (Table 3) clearly show that available Fe content in post harvest soil increased with fertility levels over control. The maximum and minimum values were recorded under 50% NPK and control, respectively. There was a significant build up available iron in soil due to different levels of iron and maximum value of available Fe was recorded under 20 kg Fe ha^{-1}.Available Zn status depleted under control which may be attributed to higher uptake of native zinc by the crop. Application of NPK levels slightly improved the status of available Zn over control. The effect of NPK levels on zinc status in post harvest soil was statistically non-significant. The amount of available Zn in soil also slightly improved with lower levels of Fe but this improvement was statistically non-significant.

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Short communication

STATUS OF POTASSIUM IN PEARL MILLET SOILS OF AGRA, UTTAR PRADESH

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Sound knowledge about soil fertility status is very much relevant for indentifying constraints in crop husbandry for attaining sustained productivity and facilitating agro-technology transfer programme. Potassium is one of the three essential primary nutrients for fostering crop production. Potassium functions in plant metabolism particularly in photosynthesis, respiration and enzyme activation. It plays an important role in the maintenance of the cellular membrane and keeping the protoplasm in a proper degree of hydration by stabilizing the emulsions of highly colloidal particles. Potassium deficiency influences metabolic processes, primarily related to photosynthesis and synthesis and translocation of enzymes. Potassium is involved in water relations, charge balance and osmotic pressure in the cells and across membranes (Havlin *et al.* 2014).Cultivation of pearl millet, an important kharif crop of Agra region, with very low rate or no application of potassium results in poor yield and causes depletion of potassium reserves in soil. Also these soils being coarse textured and low in organic matter, are more prone to leaching of soluble K beyond root zone.Not much work has been done in Agra district on the status of potassium in soil and pearl millet plants. Hence an attempt was made to assess the status of potassium in pearl millet soils in relation to soil and plants properties.

One hundred samples of soil (0-20 cm) and pearl millet plants from collected from various places of Agra district. The climate of the study area is semi-arid with an average rainfall of about 650 mm per annum, about 80% of which is received duringJune to Septembber. These soil samples were analyzed for EC, pH, organic carbon and free lime by standard procudes(Jackson 1973).Extraction of total potassium was done through percloric acid digestion of soil(Jackson 1973). Available K was extracted with 1N NH_4 O Ac (pH 7). Plant samples were digested with diacid (HNO_3 and $HClO_4$) mixture. The estimation of K in soil and plant extract / digest was done flame photometrically.

Table 1: Some physic-chemical properties and status of potassium in pearl millet soils and plants

Soil Characteristic	Range	Mean
pH (1:2.5)	7.5 - 8.9	8.3
EC (dSm^{-1})	0.10 - 0.50	0.24
Organic carbon (g kg^{-1})	1.5 - 6.0	3.7
$CaCO_3$ (g kg^{-1})	5.0 - 25.0	10.0
Total K (%)	1.05 - 2.25	1.66
Available K (kg ha^{-1})	60.0 - 200.0	117.6
Potassium in plants (%)	1.50 - 2.35	1.98

Pearl millet growing soils were alkaline in reaction , pH ranging from 7.5 to 8.9. The EC of the soil-water suspension (1:2.5) ranged between 0-10 and 0.50 dSm^{-1}. Organic carbon ranged from 1.5 to 6.0 g kg^{-1} with a mean value of 3.7 g kg^{-1}. The results showed that 80% soils were rated as low in the organic carbon content. The amount of free line in these soils ranged from 5.0 to 25.0 g kg^{-1} with a mean value of 10 g kg^{-1}. The total potassium content of the studied ranged from 1.05 to 2.25% with a mean value of 1.66 percent. These values were fairly comparable to the results reported by Chand and Swami (2000) for the soils of Bhartpur

(Rajasthan) and Singh *et al.* (2010) for the soil of Agra (Uttar Pradesh). These results suggested that the coarse textured soils would be depleted of soil potassium sooner than fine textured ones, therefore, continuous monitoring of soil potassium status is essential. Total potassium did not have any significant percent relationship with soil properties (Table 2).

Table 2: Relationship between soil properties and potassium in pearl millet soil

Soil Characteristic	Total K	Available K
pH	0.080	0.110
EC	0.131	0.368**
Organic carbon	0.179	0.401**
$CaCO_3$	0.012	0.051

*** Significant at 1% level*

The content of available K in pearl millet soils varied from 60.0 to 200.0 kg ha^{-1} with a mean value of 117.0 kg ha^{-1}. About 57 percent soils were rated as low in available K. Similar results were respected by Singh etal. (2010). Available K had significant relationship with total K ($r=0.71^{00}$). It had significant positive relationship with organic carbon and EC (Table 2). Similar results were reported by Kumar etal. (2009). Available K also had positive relationship with pH and C_aCO_3 but the values were non-significant. The content of potassium in pearl millet plants varied from 1.50 to 2.35% with a mean value of 1.98 percent. The extent of deficiency of K in pearl millet plants was of the order of 40 percent. Available K was found to have significant and positive relationship ($r = 0.75^{00}$) with plant potassium. It was evident from the results that availability of K to plants is largely dependent on the status of potassium in soils.

From the results, it may be concluded that pearl millet soils were low in organic carbon and available potassium. About 40% plants of pearl millet were found to contain low amounts of K in their leaves, Hence the soils require attention regarding management practices and regular monitoring of soil potassium for better crop production.

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Short communication

RESPONSE OF LUCERNE TO SULPHUR APPLICATION IN ALLUVIAL SOIL

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Lucerne (medicago sativa) is primanily a rabi fodder crop and it is usually grown on marginal lands with poor fertility status. The low yield of lucerne is not only due to cultivation on marginal lands, but also because of inadeguate and imbalanced fertilization. Among the several constraints improper nutrifionhal management is an important impediment for increasing the productivity. After NPK, Sulphur is the fourth plant nutrient whose deficiency is widespread in India and considered as the quality- and quantity- limiting factor particularly for legmes (Upadhyay, 2013). Sulphur plays an important role in growth and developement of crops as it is a constituent of amino acids like methionine cysteine and cystine needed for the synthesis of proteins. Information of sulphur management in lucerne is lacking in Morena (M.P.). Thus the present study was undertaken to evaluate the effect of graded doses of sulphur on yield, uptake of nutrients and quality of lucerne.

Field experiment was conducted at ZARS Research farm Morena (M.P.). The climate of the study area is semi-arid with an average rain fall of about 700 mm per annum, about 80% of which is received during June to September. The soil of the experimental field was sandy loam in texture, having pH 7. 8 organic carbon 4.1g kg^{-1} and available N, P, K, and S 175, 9.2, 155 and 16.5 kg ha^{-1}, respectively. The experiment was laid out in randomized block design with four replications. The treatments included five levels of S (0, 15, 30, 45 and 60 kg S ha^{-1}). Recommended dose of N, P and K (20 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1}) were applied as di-ammonium phosphate and muriate of potash, respectively. Potassium and phosphorus were applied at sowing. Sulphur was applied as elemental sulphur at the time of sowing. The Lucerne seeds were sown at the rate of 15 kg ha^{-1} in the second week of October during 2013-14. Lucerne crop was irrigated as and when required. The crop was harvested at 60 days after sowing and yield data were recorded. Processed plant samples were analyzed for their nutrients by digesting the samples using di-acid mixture (HNO3: HClO4:10: 4). Phosphorus and Sulphur were determined by vanadomolybdophosphoric yellow colour method (Jackson 1973) and turbidimetric method (Chesnin and Yien 1951), respectively. Nitrogen content was determined following micro Kjeldahl method. The protein content was computed from the nitrogen content multiplied by a factor 6.25. The uptake of nutrients was then computed from their concentrations in plant samples and dry matter yield.

Table 1: Effect of sulphur levels on yield, quality and uptake of nutrients in lucerne .

Sulphur (Kg ha^{-1})	Green foliage Yield(t ha^{-1})	Dry matter yield (t ha^{-1})	Protein contain%	Uptake of nutrients (kg ha^{-1})		
				Nitrogen	Phosphors	Sulphur
0	8.33	1.79	18.8	54.3	4.7	3.5
15	9.28	2.00	19.1	61.2	5.6	4.6
30	10.00	2.15	19.3	66.6	6.4	5.3
45	9.79	2.13	19.6	66.8	6.8	5.9
60	9.00	1.95	19.7	61.2	6.4	5.5
Semi	0.15	0.04	0.012	1.05	0.051	0.025
CD(p=0.05)	0.49	0.14	0.139	3.48	0.170	0.081

Application of varying doses of sulphur had significant effect on the green foliage and dry matter yield of lucerne. The green foliage yield increased from 8.33 to 10.00 t ha^{-1} progressively with increase in the level of S from 0 to 30 kg ha^{-1}. The corresponding increase in dry matter yield was from 1.79 to 2.15 t ha^{-1}. Increase in yield under sulpur levels might be

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due to improved availability of the S, which in turn enhance the plant metabolism and photosynthetic activity resulting in to better growth development and yield. These results confirm the forming of Jat etal (2013).The higher levels of S (45 and 60 kg p2o5) tended to reduce the yields over 30 kg S-1 which may be attributed to imbalanced nutrition of crops .

The protein content in lucerne crop increased significantly from 18.8 to 19.7% with increasing levels of sulphur from 0 to 60 kg S ha^{-1}. The positive response to added sulphur is assigned to low status of available sulphur of soil. This beneficial effect of S may also be due to stimulating effect of applied S in the synthesis of protein. Similar results were reported be Upadhyay (2013).

The nitrogen uptake by lucerne crop increased significantly with increased levels of S up to 30 kg ha^{-1} . The nitrogen uptake values at 0 and 30 kg S ha^{-1} were 51.3 kg ha^{-1} and 66.6 kg ha^{-1}, respectively. This increase in N uptake might be attributed to increased N content and dry matter yield. Similar results were reporded by upadhyay (2013). Application of sulphur significantly increasesd the uptake of P by crop over control. The increase in P uptake by lucerne crop due to sulphur application was from 4.7 to 6.2 kg ha^{-1} with 45 kg S ha^{-1} (table 1).The results corroborate the findings of Tripathi etal (2011). this increase in P uptake by the crop may be attributed to higher dry matter yield along with improved P content with sulpur application.The uptake of S by lucerne crop increased significantly with S application at different levels over control due to increase in yield and S concentration in plants. The sulphur uptake by the crop increased from 3.5 to 5.9 kg ha^{-1} with 45 kg S ha^{-1}. Similar results were reported by Tripathi etal (2011).

From the result, it may be concluded that the application of 30 kg S ha^{-1} may be recommended for lucerne in alluvial soils of Morena (M.P.). Application of 30 kg S ha^{-1} gave higher values of nutrient uptake, quality and yield of lucerne.

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