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IDENTIFICATION OF YIELD LIMITING NUTRIENTS IN SOILS OF DIFFERENT AGRO-CLIMATIC ZONES OF CHHATTISGARH BY NUTRIENT OMISSION TECHNIQUE

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ABSTRACT

Nutrient omission experiments were conducted at Instructional Farm in the Department of Soil Science and Agricultural Chemistry, College of Agriculture, I.G.K.V., Raipur, Chhattisgarh in Completely Randomized Design with two factors (treatments and soils) to identify yield limiting nutrients using rice and maize as test crops. Composited initial soil samples were analysed for pH, EC, organic carbon, CEC, available N, P, K, Ca, Mg, S, Cu, Zn, B and Mo. Grain and straw yields of rice were significantly reduced with the omission of N, P, Zn and S in all soils. Yield reductions were more pronounced with omission of N (68.8 % and 68.5 %, respectively) followed by P, Zn and S. During *Rabi* season, omission of N, P and S caused significant reductions in the fresh and dry weights of maize. Nitrogen was found to be the most yield limiting nutrient followed by phosphorus and sulphur in all the soils of three agro-climatic zones. Extents of limitations were more in Goda Chawar (Phunderdihari) soil as compared to Chawar (Rajpuri) soil in Northern hills zone. N, P and S were more limiting in Marhan (Madpal) soil in comparison to Tikra (Kachnar) and Mal (Chokar) soils in Bastar plateau. For crops cultivated under flooded condition such as rice, zinc becomes the limiting nutrient and affects crop growth and yield.

Keywords: Nutrient omission, yield reduction, limiting nutrient, dry weight

INTRODUCTION

Optimum productivity of any cropping system depends on an adequate supply of plant nutrients. Even if, all other factors of crop production are in the optimum, the fertility of a soil largely

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determines the ultimate yield. Soil fertility refers to nutrient supplying capacity of a soil for crop growth. It describes available nutrients status of the soil and its ability to provide nutrients for optimum plant growth (Dev,1997). Exploitive nature of modern agriculture involving use of high analysis NPK fertilizers, free from micronutrients as impurities, limited use of organic manures and restricted recycling of crop residues are some important factors having contributed towards accelerated exhaustion of secondary and micronutrients from soil. At several places, normal yield of crops could not be achieved despite balanced use of NPK due to micronutrient deficiency in soils (Sakal, 2001). When the soil does not supply sufficient nutrients for normal plant development and optimum productivity, application of supplemental nutrients is required. Fertilizer is one of the most important sources to meet this requirement. Indiscriminate use of fertilizers, however, may cause adverse effect on soils and crops both regarding nutrient toxicity and deficiency either by over use or inadequate use (Ray *et al*., 2000).

The proper rate of nutrient to be applied is determined by knowing the nutrient requirement of crops and nutrient supplying capacity of the soil. Diagnostic techniques including identification of deficiency symptoms, soil and plant analysis and biological tests are helpful in determining specific nutrient stresses and quantity of nutrients needed to optimize the yield (Havlin *et al*. 2007). Soil fertility evaluation, thus, is the key for adequate and balanced fertilization in crop production. Conducting fertilizer field trials is an expensive task. Therefore, it is necessary to obtain adequate information about the soil under study prior to establishing field trials. This is achieved through laboratory and greenhouses studies and pot experiments. Such information about the soil provides for clearer interpretation of all the field trials, prevents loss of trials due to a 'surprise' nutrient deficiency and assures that adequate amounts of deficient nutrients are applied to satisfy both soils complexing capabilities and the plant needs. Nutrient omission trial aims to find out the most limiting nutrients to the growth of a crop plant. If any element is omitted while other elements are applied at suitable rates and plants grow weakly, then the tested element is a limiting factor for crop growth. Conversely, if any element is omitted but plants are healthy, then that element is not a limiting factor for crop production. Taking these into account, the present investigation was carried out to identify yield limiting nutrients using rice and maize as test crops in nutrient omission trials.

MATERIALS AND METHODS

Location of the site

Nutrient omission experiments were carried out in pots with soil collected from six different sites located in different agro-climatic zones of Chhattisgarh. Samples were collected from a depth of 15 cm using spade, composited and labelled properly. Details of soils collected and used for nutrient omission pot experiment is presented in Table 1. For evaluating the fertility status of soils,

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rice (Mahamaya) and maize (Vijeta) crops were taken as test crops during *Kharif season*, 2006 and *Rabi* Season, 2006-07, respectively at Instructional Farm in the Department of Soil Science and Agricultural Chemistry, College of Agriculture, I.G.K.V., Raipur, Chhattisgarh. Initial characteristics of different soils are mentioned in Table 2.

Table 1: Details of soil used for nutrient omission trials

S. No.	Location	Soil Type	Names given for Nutrient Omission Trials (Local Names)
1	Village- Phunderdihari, Tehsil – Ambikapur, District- Sarguja	Typic *Haplustepts*	Goda Chawar
2	Village- Rajpuri, Tehsil- Ambikapur, District- Sarguja	Typic *Haplustalfs*	Chawar
3	Village- Nardaha, Tehsil- Raipur, District- Raipur	Lithic *Ustorthents*	Bhata
4	Village- Madpal,Tehsil- Jagdalpur, District- Bastar	Lithic *Ustorthents*	Marhan
5	Village- Kachnar, Tehsil- Jagdalpur, District- Bastar	Lithic *Ustorthents*	Tikra
6	Village- Chokar, Tehsil- Jagdalpur, District- Bastar	Typic *Haplustepts*	Mal

Table 2: Initial characteristics of different soil

Soil Characteristics	Soil Type					
	Goda Chawar	Chawar	Bhata	Marhan	Tikra	Mal
pH	5.46	5.62	5.64	5.50	5.63	5.83
EC (dS m^{-1})	0.16	0.21	0.12	0.08	0.10	0.12
Organic Carbon (g/kg)	3.9	4.2	3.2	2.9	3.5	5.5
CEC (cmol(p+)/kg)	8.8	9.7	12.3	10.6	12.3	13.5
Sand (%)	62.2	41.7	75.3	73.3	71.2	68.4
Silt (%)	9.1	29.9	14.3	16.3	17.6	13.5
Clay (%)	28.7	28.4	10.4	10.4	11.2	18.1
N (kg/ha)	194.39	205.47	172.36	161.45	182.74	241.63
P (kg/ha)	8.96	9.45	8.65	7.63	8.82	10.07
K (kg/ha)	262.35	285.46	194.53	182.53	236.48	254.75
S (mg/kg)	11.06	11.45	10.51	10.39	11.32	11.58

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Ca (cmol(p+)/kg)	4.52	5.54	6.82	6.43	6.91	9.14
Mg (cmol(p+)/kg)	2.36	2.75	3.15	2.82	3.22	3.42
Fe (mg/kg)	75.63	66.32	50.74	70.63	54.58	45.65
Mn (mg/kg)	52.13	43.75	41.69	48.56	41.85	36.97
Cu (mg/kg)	2.61	2.64	2.49	2.58	2.52	2.43
Zn (mg/kg)	0.67	0.65	1.18	1.23	1.12	0.82
B (mg/kg)	0.24	0.32	0.28	0.26	0.30	0.35
Mo (mg/kg)	0.21	0.23	0.22	0.21	0.22	0.27

Formulation of treatments

Utilizing the concept of soil reaction and nutrient availability and reports of wide spread deficiency of sulphur, zinc and boron from different parts of the country, nutrient treatments were formulated. In one of the treatments, all the nutrients were applied while in others, one of the nutrient elements from all the nutrient treatments was omitted. Thus eleven treatments formulated in the experiments were T1 - All (N, P, K, S, Ca, Mg, Cu, Zn, B, Mo), T2 - (All – N), T3 - (All – P), T4 - (All– K), T5 - (All– S), T6 - (All– Ca), T7 - (All– Mg), T8 - (All– Cu), T9 - (All– Zn), T10 - (All– B) and T11 - (All– Mo). Treatments were laid out in Completely Randomized Design with two factors considering soil as one factor and treatments as second factor. Treatments were replicated thrice and the treatments within replications were re-randomized at three-week intervals during both the seasons. Source of nutrients and their application rate is presented in Table 3.

Table 3: Rates of application and nutrients used in Omission Trials

Nutrient	Nutrient Source	Nutrient Rate (kg/ha)*	Nutrient added (mg/pot)
N	Urea	120	535.60
P	$NaH_2PO_4.H_20$	35	156.22
K	KCL	50	223.17
S	Mg SO_4	30	133.90
Ca	$CaCl_2$. 2 H_20	75	334.75
Mg	$MgCl_2.6H_20$**	35	156.22
Cu	$CuCl_2$.2 H_20	5	22.32

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Zn	$ZnCl_2$	5	22.32
B	$Na_2B_4O_7.10\ H_20$	2	8.93
Mo	$Na_2MoO_4.2\ H_20$	0.5	2.23

*Same rates were used for both Rice and Maize crops

******Used for supply of Mg after adjusting the amount added through, $MgSO_4$

Soil preparation, planting, nutrient addition and observations recorded

Composited soils collected from different sites were air dried and filled in polyethylene lined pots at the rate of 10 kg per pot. The pots were maintained with 3 cm standing water and twenty one days old seedlings of rice (Mahamaya) were transplanted on 25th July, 2006. Three hills per pot were maintained in all the pots. Thereafter, full dose of all the nutrients except nitrogen was added to the soil in solution form. Nitrogen as urea was applied in three splits at transplanting, tillering and panicle initiation stage. Crop was grown till maturity and harvested on 30th October, 2006. During *rabi* season soils were replaced and the pots were filled in similar way. Ten uniform seeds of maize (Vijeta) were sown on 15th November, 2006 and sufficient water was added to bring the soil moisture content of each pot up to field capacity. Nutrients were added in the same way as explained for rice. Nitrogen as urea was applied in three splits. Maize plants were thinned to six per pot and maintained throughout. Crop was irrigated as and when required. Maize was harvested after 60 days of sowing. During both the season, rice and maize plants were observed for growth and deficiency symptoms, if appeared. After harvesting of rice, grain and straw yields were recorded while in case of maize fresh weight and dry matter yields were measured pot wise.

Soil Analysis

The processed initial soil samples were analysed in the laboratory for mechanical composition, pH, electrical conductivity, organic carbon and cation exchange capacity following standard methods and procedures. Soil pH was measured by glass electrode pH meter in 1:2.5 soil water suspensions after stirring of 30 minutes as described by Jackson (1973). The soil samples used for pH determination were allowed to settle down the soil particles for 24 hours. The conductivity of supernatant liquid was determined by conductivity meter as described by Jackson (1973). Organic carbon was estimated by wet digestion method of Walkley and Black (1934). Cation exchange capacity was determined by leaching the soil with neutral normal ammonium acetate as described by Jackson (1973). Mechanical Composition (Particle size analysis) was determined by international pipette method (Day, 1965). Available nitrogen was determined by alkaline $KMnO_4$ method as described by Subbiah and Asija (1956). Available phosphorus in the soil was extracted

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with Bray's P1 extractant (0.03 N NH_4F in O.025 N HCl solution) and phosphorus in the extract was determined by phosphomolybdenum blue with stannous chloride as reducing agent as described by Bray and Kurtz (1945). Soil potassium was extracted by shaking with neutral normal ammonium acetate for five minutes at a constant temperature (25^0C) as described by (Hanway and Heidel (1952) and then K in the extract was estimated by flame photometer. Available sulphur in the soil was extracted by 0.15% $CaCl_2$ solution (Williams and Steinbergs 1969) and content was determined by the turbidimetric method of Chesnin and Yien (1950). Exchangeable calcium and magnesium in the soil was extracted by neutral normal ammonium acetate. Contents in the extract were determined by titration with 0.01 N EDTA (Versinate) using ammonium purpurate and EBT indicators. Available Cu and Zn in the soil were determined by extraction with 0.005M diethylene triamine penta acetic acid (DTPA), 0.01M calcium chloride dihydrate and 0.1M tritehanol amine buffered at pH 7.3 (Lindsay and Norvell 1978) and reading the respective concentrations in atomic absorption spectrophotometer. Available boron in soil was extracted by boiling with water and the extracted boron in the filtered extract was determined by the azomethine-H method of Gupta (1967). Acid ammonium oxalate at pH 3.3 (Griggs reagent) was used as an extracting agent for the determination of available Mo in soils. Molybdenum content in the filtered extract was determined spectrophotomertically using Toluene-3, 4-dithiol.

RESULTS AND DISCUSSION

Grain yield of Rice

The data presented in the Table 4 and Figure 1 clearly indicated that irrespective of the soil types, omission of N, P, Zn and S caused significant reductions in grain yields of rice in comparison to the treatment receiving all the nutrients. Omission of N and P reduced the yields more than that of omission of Zn and S. Highest yield (39.32 g/pot) was recorded in the treatment receiving all the nutrients. Omission of N reduced the yield by 68.8 % while P omission caused a yield reduction of 64.5 %. The per cent reductions in rice yields under different nutrient omitted pots were in the order of N > P > Zn (26.1 %) > S (16.6 %). Per cent yields in K, Mg, Cu and B omitted pots were statistically at par with each other. Among the soil types, grain yield was significantly higher in Mal soil (33.17g/pot) followed by Chawar, Tikra, Bhata, Goda Chawar and the lowest grain yield (29.72 g/pot) was associated with Marhan. Mean grain yields in Goda Chawar (30.11 g/pot) and Marhan (29.72 g/pot) soils were statistically at par with each other. Grain yields due to different nutrient omission treatments were significantly affected in all the six soils. N omission resulted in lowest grain yield (11.43 g/pot) in Bhata soil whereas lowest yields with P and S omission were observed in Marhan soil (12.63 and 30.65 g/pot respectively). Lower grain yields in Zn omitted pots were associated with Goda Chawar soil. Similar results have also been reported by Haefele and Wopereis (2005). The high temperature prevailing in the area is responsible for oxidation of organic matter resulting in low organic carbon and available nitrogen in these soils (Singh and

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Agrawal 2005). The soils used in experiment were slightly acidic in reaction. On flooding, the pH of soil increased which caused a decrease in the solubility of the native soil zinc. The increased pH might have favoured precipitation of some amount of Zn as hydroxides and also its adsorption on the freshly formed hydrated oxides of iron and manganese, which are known to have strong scavenging action for Zn because of their high surface area (Singh *et al*. 1999) and have resulted in lower yields with Zn omission. The S contents of these soils were in the lower margin of medium category and organic carbon contents were also less (Table 2) which supplied less sulphur causing reductions in yields with the omission of S. Addition of sulphur (S) through traditional fertilizers (single superphosphate, ammonium phosphate) is decreasing and a recent trends in the use of di ammonium phosphate and other fertilizers which do not contain S is responsible for low contents of S in the soils (Subba Rao *et al*. 2001). On the basis of yield performance the yield limiting nutrients in these soils may be put in the order of N > P > Zn > S

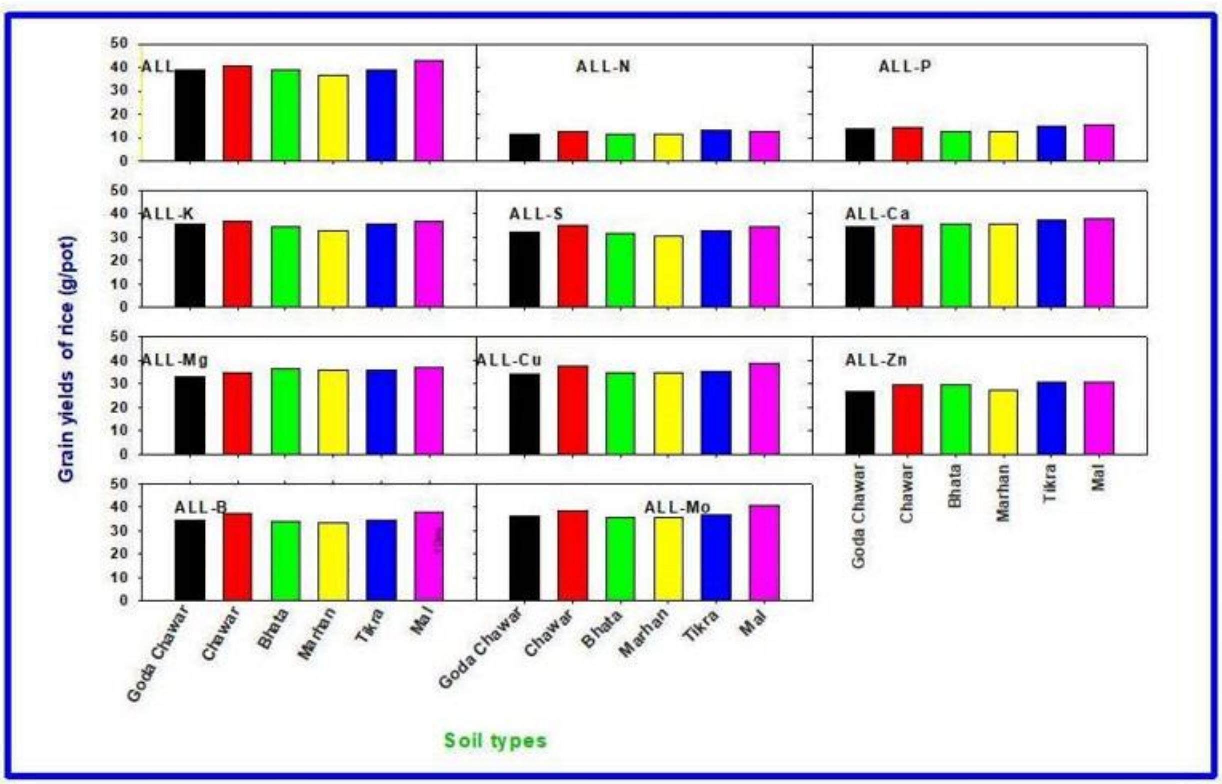

Figure 1: Grain yield of rice (g/pot) in relation to different treatments as affected by soil types

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Table 4: Grain yield of rice (g/pot) in relation to different treatments as affected by soil types

Treatments (T)	Goda Chawar	Chawar	Bhata	Marhan	Tikra	Mal	T-Mean
All	38.67 a	40.39 a	38.67 a	36.65 a	38.77 a	42.74 a	39.32 a (100)*
All - N	11.68 g	12.71 g	11.43 g	11.54 f	13.38 g	12.73 h	12.25 h (31.2)
All - P	13.76 f	14.54 f	12.74 g	12.63 f	14.76 g	15.29 g	13.95 g (35.5)
All - K	35.66 bc	36.71 c	34.52 cd	32.84 c	35.57 cd	36.95 d	35.37 d (89.6)
All - S	32.42 d	34.82 d	31.63 e	30.65 d	32.63 e	34.53 e	32.78 e (84.9)
All - Ca	34.25 cd	35.12 d	35.63 bc	35.63 ab	37.58 ab	38.02 cd	36.04 c (91.6)
All - Mg	32.86 d	34.93 d	36.34 b	35.67 ab	35.59 cd	36.92 d	35.39 d (90.0)
All - Cu	34.38 cd	37.61 b	34.63 bc	34.63 b	35.46 cd	38.78 c	35.91 cd (91.3)
All - Zn	26.60 e	29.55 e	29.37 f	27.53 e	30.58 f	30.73 f	29.06 f (73.9)
All - B	34.65 c	37.40 bc	33.58 d	33.49 bc	34.62 d	37.52 cd	35.21 d (89.5)
All - Mo	36.31 b	38.47 b	35.66 bc	35.68 ab	36.62 bc	40.61 b	37.23 b (94.7)
S - Mean	30.11 DE	32.02 B	30.38 D	29.72 E	31.41 C	33.17 A	31.14

CD at 0.05 probability level, T = 0.65, S = 0.48, TxS = 1.60

In a column, means followed by common small letters and in a row, means followed by common capital letters are not significantly different at 0.05 probability level.

* Figures in parenthesis indicate the % yield considering the yield in the treatment receiving all the nutrients as 100 %

Straw yield of Rice

Omission of N, P, Zn and S caused significant reductions in straw yields of rice in comparison to the treatment receiving all the nutrients (Table 5). The highest straw yield (47.06 g/pot) was recorded in the treatment receiving all the nutrients. Omission of N and P reduced the yields more than the reduction due to omission of other nutrients. The yield reduction in the N omitted pot was 68.5 % followed by P omission (64.4 %), Zn omission (27.7 %) and S omission (16.7 %). Per cent yields in K, Ca, Mg and Cu omitted pots were statistically at par with each other. Among the soil types, straw yield was significantly higher (39.70 g/pot) in Mal soil followed by Chawar (39.05 g/pot), Tikra (37.26 g/pot), Goda Chawar (36.48 g/pot), Bhata (36.07 g/pot), and Marhan soil (35.95 g/pot).Straw yields due to different nutrient omission treatments were significantly affected in all the six soils. Omission of N, P and S significantly reduced the straw yields and lowest yields were observed with Marhan soil (13.44, 14.83 and 36.60 g/pot respectively) whereas the

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corresponding highest yields were associated with Mal soil. Zn omission resulted in highest yield in Mal soil (36.75 g/pot) and the corresponding lowest yield was observed in Goda Chawar soil.

Fresh weight of Maize

It is obvious from the data presented in Table 6 that omission of N, P and S significantly reduced the fresh weights of maize in different pots in comparison to the treatment receiving all the nutrients. Highest fresh weight (222.48 g/pot) was recorded in the treatment receiving all the nutrients. Omission of N reduced the fresh weight by 67.3 % while P omission by 62.7 %. The per cent reduction in fresh weights under different nutrient omitted pots were in the order of N > P > S (14.4 %) > K (10.7 %) > Mg (9.7 %). Lowest reduction in the fresh weight of maize was observed in Cu omitted pot. Reduction in fresh weight under Mo omitted pot (9.6 %) was more than that of B omission (8.9 %). Among soil types, significantly higher fresh weight was observed in Mal soil (193.31g/pot) followed by Tikra (186.39 g/pot), Chawar (185.87 g/pot), Goda Chawar (178.37 g/pot), Bhata (171.80 g/pot) and Marhan (170.31 g/pot) soils. Omission of different nutrients resulted in significant reductions in the dry weights of maize in all the soils. Lower fresh weights were recorded in Marhan soil with the omission of all the nutrients except Ca and Mg. Omission of Ca and Mg resulted in lowest fresh weights in Bhata soil. Highest fresh weights were recorded in Mal soil in all the treatments.

Dry weight of Maize

The data presented in the Table 7 and Figure 2 revealed that omission of N, P and S caused significant reductions in the dry weight of maize in comparison to the treatment receiving all the nutrients. Omission of S caused more reduction in dry weight than the omission of other nutrients but the reductions were lower in comparison to N and P omission. Reductions in the dry weight of maize in different nutrient omitted pots were in the order N (67.5 %) > P (63.0 %) > S ((14.6 %) > K (10.3 %) > Mg (10.2 %). Dry weights of maize in the K, Ca, Mg, Zn, B and Mo omitted pots were statistically at per with each other. Lowest reduction in the dry weight of maize was observed in Cu omitted pot. The mean dry weights of maize in different soils varied significantly. Dry weight of maize was highest in Mal soil (29. 17 g/pot) and lowest in Marhan soil (24.40 g/pot). Application of different nutrient omission treatments significantly affected the dry weights of maize in all the six soils. Omission of different nutrients resulted in lower dry weights in Marhan soil in comparison to other soils. Higher dry weights of maize were recorded in Mal soil with omission of different nutrients. Similar results have also been reported by Melteras *et al* (2004). Under tropical climatic conditions, oxidation of organic matter occur which results in low organic carbon (Singh and Agrawal 2005) and hence low available nitrogen status in soils. The soils were inherently low in available P (Table 2) and hence the omission of P caused more reductions in fresh and dry weights. Availability of P is reduced in acid soils due to adsorption of P in surfaces

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of Fe/AL oxides and precipitation as $AlPO_4$ and $FePO_4$ (Havlin *et al*.2007). On the basis of performance the next element which limited the fresh and dry weights of maize was sulphur (S) in all the soils. Reductions in fresh and dry weights with S omission may be attributed to less supply of S, since the available S in these soils were in the lower margin of medium category Biswas *et al* (2004). On the basis of yield performance the yield limiting nutrients in these soils may be put in the order of N > P > S

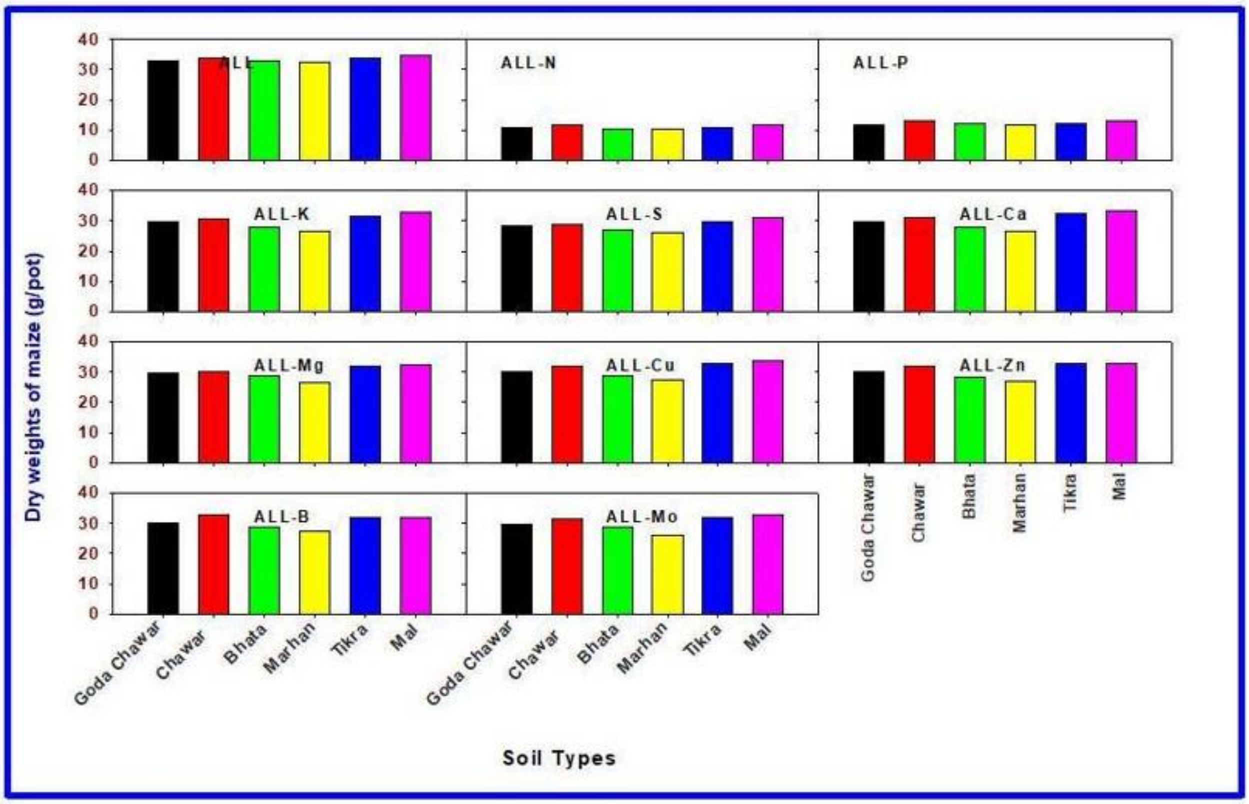

Figure 2: Dry weight of maize (g/pot) in relation to different treatments as affected by soil types

CONCLUSIONS

In the light of nutrient omission trials conducted, it can be concluded that nitrogen was found to be the most yield limiting nutrient followed by phosphorus, sulphur and zinc in all the soils of three agro-climatic zones. Extents of limitations were more in Goda Chawar (Phunderdihari) soil as compared to Chawar (Rajpuri) soil in Northern hills zone. N, P and S were more limiting in Marhan (Madpal) soil in comparison to those of Tikra (Kachnar) and Mal (Chokar) soils in Bastar plateau. For crops cultivated under flooded condition such as rice, zinc becomes the limiting nutrient and it affects growth and yield adversely.

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