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Crop Response Based Fertility Assessment of Soils of Chhattisgarh Plain Using 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, S, Fe, Mn, Cu, Zn, B and Mo. Grain and straw yields of rice were significantly reduced with the omission of N, P, Zn, S and B in all soils. Yield reductions were more pronounced with omission of N (68.7 % and 68.4 %, respectively) followed by P, Zn, S and B. During *Rabi* season, omission of N, P, S, Zn and B caused significant reductions in the fresh and dry weights of maize. Omission of N caused 63.8 % and 63.9 % reduction in fresh and dry weights respectively. Nitrogen was found to be the most yield limiting nutrient followed by phosphorus and sulphur in all the soils. Extents of limitations were more in Kanhar (Jora) and Matasi (Banrasi) soil as compared to Dorsa (Darba) soil.

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

Introduction

High crop yields can only be achieved when high yielding crop varieties are properly nourished in a correct amount and proper ratios. In addition to this limitation, low fertilizer efficiency, inadequacy of current fertilizer recommendations and the ignorance of nutrients other than N, P and K may limit crop production. Even if, all other factors of crop production are in the optimum, the fertility of a soil largely 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). 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). At several places, normal yield of crops could not be achieved despite balanced use of NPK due to micronutrient deficiency in soils (Sakal, 2001).

Soil fertility evaluation is the key for adequate and balanced fertilization in crop production. 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).
Among the various cropping systems, rice based cropping systems are the predominant systems in India. Managing the variability in soil nutrient supply that has resulted from intensive rice cropping is one of the challenges for sustaining and increasing rice yield in India. The use of plant nutrients in a balanced manner is the prime factor for efficient fertilizer program. Balanced nutrient use ensures high production level and helps to maintain the soil health and ensures sustainable agriculture
The nutrient omission trials provide a visible order of crop response to nutrient application. It 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 assess the fertility of soil using rice and maize as test crops in nutrient omission trials.

Materials and Methods

Location of the study 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, 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.

Experimental plan

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 ten treatments formulated in the experiments were T1 - All (N, P, K, S, Fe, Mn, Cu, Zn, B), T2 - (All – N), T3 - (All – P), T4 - (All– K), T5 - (All– S), T6 - (All– Ca), T7 - (All– Mg), T8 - (All– Cu), T9 - (All– Zn) and T10 - (All– B). 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.
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 soil was extracted by 0.5M $NaHCO_3$ (pH 8.5) as described by Olsen *et al* (1954) and phosphorus in the extract was determined by phosphomolybdenum blue with ascorbic acid as reducing agent as described by Watanabe and Olsen (1965). Soil potassium was extracted by shaking with neutral normal ammonium acetate for five minutes at a constant temperature (25^0C) as described by (Hanway and Heidel (1952) and then K in the extract was estimated by flame photometer. 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, S and B caused significant reductions in grain yields of rice. Highest yield (44.33 g/pot) was recorded in the treatment receiving all the nutrients. Omission of N reduced the yield by 68.7 % while P omission caused a yield reduction of 63.6 %. The per cent reduction in rice yields under different nutrients omitted pots were in the order of N > P > Zn (28.8 %) > S (20.1 %) >B (12 %). Mean grain yields of rice in K, Fe, Mn and Cu omitted pots did not vary significantly and were statistically at per with each other. Among three soil types, grain yield was significantly higher (35.14 g/pot) in Dorsa soil followed by Matasi (34.10 g/pot) and Kanhar (33.46 g/pot) soils. While observing critically the yield response due to different nutrient omission treatments, N and P omission significantly reduced the yields in all the three soils. Comparatively higher yields were observed in Kanhar soil compared to Dorsa and Matasi soils in N and P omitted pots. Omission of S and Zn resulted in higher yields in Dorsa soil followed by Matasi and Kanhar soils. B omission caused significantly lower yield in Kanhar soil (34.47 g/pot) than Dorsa (41.20 g/pot) soil. However, the grain yield in B omitted pot in Matasi soil was statistically at par with that of the treatment receiving all the nutrients. Similar results have also been reported by Suriya Arunroj *et al*. (2000). Under tropical climatic conditions, oxidation loss of organic matter results in low organic carbon and hence nitrogen. The soils were inherently low in available P (Table 2) and hence the omission of P caused more reduction in yields. Reduction in yields in Zn omitted pots may be attributed to low availability of Zn upon flooding because of formation of sparingly soluble sulphides and carbonates under anaerobic conditions (Yoshida *et al*. 1971). Yield reductions 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 (Table 2). Continuous use of di ammonium phosphate and other S free fertilizers in place of single superphosphate and other S containing fertilizers might be attributed in lower S contents in the soil (Biswas *et al*. 2004).. More yield reductions with omission of B in Kanhar soil may be attributed to reduced availability of B due to formation of Ca-borate and B-silicate (Sharma *et al.* 2003).

Straw Yield of Rice

The highest straw yield (Table 5) was recorded in the treatment receiving all the nutrients (53.27 g/pot). Omission of N and P reduced the yields more than the omission of other nutrients. The yield reduction in the N omitted pot was 68.4 % followed by P omission (63.8 %), Zn omission (28.5 %), S omission (20.9 %) and B omission (11.7 %). Mean straw yields of rice in K, Fe, Mn and Cu omitted pots did not vary significantly and were statistically at per with each other. Among three soil types, straw yield was significantly higher (42.37 g/pot) in Dorsa soil followed by Matasi (40.96 g/pot) and Kanhar (40.14 g/pot) soils. Straw yields were significantly affected due to omission of different nutrients in all the three soils. N and P omission resulted in higher yields in Kanhar soil than those in Dorsa and Matasi soils. S, Zn and B omission caused significantly lower yields in Kanhar soil than those in Dorsa and Matasi soils. However, the straw yield in B omitted pot in Matasi soil was statistically at par with that of the treatment receiving all the nutrients.

Fresh weight of Maize

It is obvious from the data presented in Table 6 that Omission of N, P, Zn, S and B significantly reduced the fresh weight of maize in different pots in comparison to the treatment receiving all the nutrients. Highest fresh weight (236.23 g/pot) was recorded in the treatment receiving all the nutrients. Omission of N and P reduced the fresh weight more than that of omission of other nutrients. Omission of N reduced the fresh weight by 63.8 % while P omission by 61.7 %. The per cent reductions in fresh weights under different nutrient omitted pots were in the order of N > P > S (17.5 %) > Zn (14.0 %) > B (10.5 %). Mean fresh weights of maize in Fe, Mn and Cu omitted pots did not vary significantly and were statistically at par with each other. Among three soil types, fresh weight was significantly higher in Dorsa soil (192.49 g/pot) followed by Matasi (190.72 g/pot) and Kanhar (185.82 g/pot) soils. Different nutrient omission treatments significantly reduced the fresh weights in all the three soils. Comparatively higher fresh weights were observed in Kanhar soil than Dorsa and Matasi soils in N omitted pots. Omission of S, Zn and B resulted in higher fresh weights in Matasi and Dorsa soils while the lowest fresh weights were observed in Kanhar soil (175.49, 186.54, and 198.62 g/pot respectively).

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. The highest dry weight was recorded in the treatment receiving all the nutrients (35.53 g/pot). N omission reduced the dry by 63.9 % whereas the P omission reduced the same by 61.8 %. Reductions in the dry weight of maize in Zn, S and B omitted pots were 14.5 %, 17.0 % and 10.1 %, respectively. Mean dry weights of Maize in K, Fe, Mn, Cu and B omitted pots were statistically at per with each other. The mean dry weights of maize in different soils varied significantly. Dry weight was significantly higher in Dorsa soil (29.02 g/pot) followed by Matasi (28.51 g/pot) and Kanhar (27.73 g/pot) soils. Application of different nutrient omission treatments significantly affected the dry weights of maize in all the three soils. N omission resulted in higher dry weight in Kanhar soil than those in Dorsa and Matasi soils. Omission of P caused higher dry weight in Dorsa soil compared to the Matasi and Kanhar soil. Zn, S and B omission caused significantly lower dry weights in Kanhar soil than those in Dorsa and Matasi soils. Dry weight of maize with B omission in Matasi (33.26 g/pot) soil did not vary significantly with that of the treatment receiving all the nutrients and were statistically at par with each other. Similar results have also been reported by Melteras *et al* (2004)

The reductions in dry weights were observed more with N omission. This indicates that N was the most yield limiting nutrients in all the soils followed by P. Under tropical climatic conditions, oxidation of organic matter occur which results in low organic carbon 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 reduction in dry weight. Reductions in 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 (Table 2). Higher adsorption and immobilization of S by heavy textured black soil (Tiwari *et al.*2006) might have resulted in lower dry weights in Kanhar soil. Lower dry weights of maize in Kanhar soil in comparison to Matasi and Dorsa soil in Zn omitted pots may be attributed to precipitation of Zn as $ZnCO_3$ and $Zn_3(CO_3)_2(OH)_2$ because of the presence of higher amount of $CaCO_3$ and comparatively higher pH in this soil (Hazra *et al*. 1987). More reductions in dry weights with omission of B in Kanhar soil may be attributed to reduced availability of B due to formation of Ca-borate and B-silicate).

Conclusions

The present work concludes that nitrogen was found to be the most yield limiting nutrient next to phosphorus. Other nutrient elements which were found to be limiting includes zinc, sulphur and boron in almost all the soils of Chhattisgarh plain. Extents of limitations were more in Kanhar (Jora) soil followed by Matasi (Banrasi) and Dorsa (Darba) soil.

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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- Banrasi, Tehsil-Raipur, District- Raipur	Typic Haplustepts	Matasi
2	Village- Darba, Tehsil-Raipur, District- Raipur	Typic Haplustalfs	Dorsa
3	Village- Jora, Tehsil-Raipur, District- Raipur	Typic Haplusterts	Kanhar

Table 2: Initial characteristics of different soil

Soil Characteristics	Soil Type		
	Matasi	**Dorsa**	**Kanhar**
pH	6.66	7.22	7.53
EC (dS m^{-1})	0.13	0.14	0.24
Organic Carbon (g/kg)	3.8	4.9	5.1
CEC (cmol(p+)/kg)	19.6	31.5	41.5
Sand (%)	61.2	46.5	21.4
Silt (%)	22.5	26.1	28.2
Clay (%)	16.3	27.4	50.4

N (kg/ha)	212.55	223.82	238.45
P (kg/ha)	11.74	10.92	9.68
K (kg/ha)	276.57	321.62	388.43
S (mg/kg)	11.76	11.64	9.87
Ca (cmol(p+)/kg)	11.34	18.72	30.23
Mg (cmol(p+)/kg)	5.81	8.13	9.34
Fe (mg/kg)	38.25	23.58	19.67
Mn (mg/kg)	29.08	16.64	8.95
Cu (mg/kg)	2.48	1.96	0.79
Zn (mg/kg)	0.74	0.68	0.47
B (mg/kg)	0.41	0.34	0.25
Mo (mg/kg)	0.29	0.32	0.32

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	[1]Mg SO_4	30	133.90
Fe	$FeSO_4.7H_20$, [2]$FeCl_3$.	15	60.12
Mn	$MnSO_4$. H_20 [3]$MnCl_2.4H_20$	10	40.17
Cu	$CuCl_2$.2 H_20	5	22.32
Zn	$ZnCl_2$	5	22.32
B	$Na_2B_4O_7$.10 H_20	2	8.93

*Same rates were used for both Rice and Maize crops

[1]Used for supply of S after adjusting the amount added through, $FeSO_4.7H_20$ and $MnSO_4$. H_20

[2] Used for supply of Fe only for S omission treatment

[3]Used for supply of Mn only for S omission treatment

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

Treatments (T)	Matasi	Dorsa	Kanhar	T – Mean
All	42.58 a	44.69 a	45.71 a	44.33 a (100)*
All – N	13.48 g	13.70 f	14.42 g	13.87 g (31.3)
All – P	15.59 f	16.34 e	16.45 f	16.13 f (36.4)
All – K	39.45 bc	40.49 b	41.33 b	40.43 b (91.2)
All – S	36.51 d	38.54 c	31.32 d	35.46 d (79.9)
All – Fe	39.63 bc	40.72 b	41.35 b	40.57 b (91.5)
All – Mn	39.33 c	40.56 b	40.98 b	40.29 b (90.9)
All – Cu	40.51 bc	40.62 b	41.07 b	40.73 b (91.8)
All – Zn	32.57 e	34.54 d	27.54 e	31.55 e (71.2)
All – B	41.36 ab	41.20 b	34.47 c	39.01 c (88.0)
S - Mean	34.10 B	35.14 A	33.46 C	34.24

CD at 0.05 probability level, **T = 1.03, S = 0.57, TxS = 1.82**

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 %

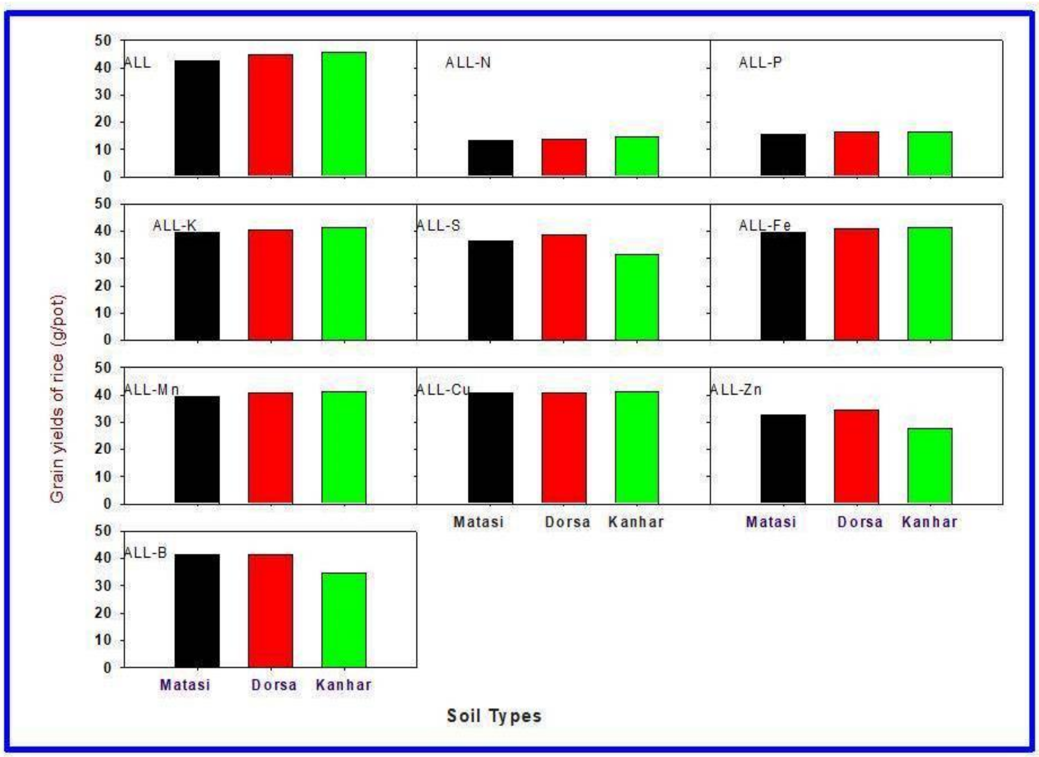

Figure: 1 Grain yield of rice (g/pot) in relation to different treatments as affected by soil type

Table: 5 Straw yield of rice (g/pot) in relation to different treatments as affected by soil type

Treatments (T)	Matasi[1]	Dorsa[2]	Kanhar[3]	T – Mean
All	51.40 a	53.73 a	54.69 a	53.27 a (100)*
All – N	16.41 h	16.67 f	17.41 g	16.83 g (31.6)
All – P	18.71 g	19.47 e	19.58 f	19.26 f (36.2)
All – K	47.41 cd	48.62 b	50.50 b	48.85 b (91.7)
All – S	43.64 e	46.48 c	36.27 d	42.13 d (79.1)
All – Fe	47.57 cd	49.46 b	49.45 b	48.82 b (91.6)
All – Mn	46.67 d	48.62 b	49.32 b	48.50 bc (91.0)
All – Cu	48.54 bc	49.48 b	49.41 b	49.14 b (92.2)
All – Zn	39.45 f	41.48 d	33.33 e	38.09 e (71.5)
All – B	49.81 ab	49.72 b	41.48 c	47.00 c(88.3)
S - Mean	40.96 B	42.37 A	40.14 C	41.16

CD at 0.05 probability level, T = 0.94, S = 0.52, 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 %

Table: 6 Fresh weight of maize (g/pot) in relation to different treatments as affected by soil type

Treatments (T)	Matasi[1]	Dorsa[2]	Kanhar[3]	T – Mean
All	225.49 a	237.66 a	245.53 a	236.23 a (100)*
All – N	83.65 g	85.46 g	87.53 h	85.55 h (36.2)
All – P	86.56 f	92.49 f	92.43 g	90.49 g (38.3)
All – K	208.57 d	218.53 c	224.86 b	217.32 c (91.9)
All – S	200.60 e	197.35 e	175.49 f	191.15 f (82.5)
All – Fe	220.47 b	217.52 c	216.42 c	218.14 b (92.3)
All – Mn	219.35 b	218.95 c	215.55 c	217.95 b (92.2)
All – Cu	219.50 b	218.62 c	215.21 c	217.78 b (92.2)
All – Zn	218.49 c	215.68 d	186.54 e	206.90 e (86.0)
All – B	224.55 a	222.68 b	198.62 d	215.28 d (89.5)
S - Mean	190.72 B	192.49 A	185.82 C	189.68

CD at 0.05 probability level, T = 0.94, S = 0.52, TxS = 1.62

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 %

Table: 7 Dry weight of maize (g/pot) in relation to different treatments as affected by soil type

Treatments (T)	Matasi[1]	Dorsa[2]	Kanhar[3]	T – Mean
All	34.76 a	35.39 a	36.43 a	35.53 a (100)*
All – N	12.55 e	12.85 d	13.13 f	12.84 e (36.1)
All – P	12.98 e	13.87 d	13.86 f	13.57 e (38.2)
All – K	30.59 d	32.85 bc	33.65 b	32.36 b (91.1)
All – S	30.76 d	31.58 c	26.13 e	29.49 d (83.0)
All – Fe	32.61 bc	32.68 bc	32.51 b	32.60 b (91.8)
All – Mn	32.82 bc	32.97 bc	32.19 b	32.66 b (91.9)
All – Cu	33.15 b	32.95 bc	32.23 b	32.78 b (92.2)
All – Zn	31.59 cd	31.75 c	27.80 d	30.38 c (85.5)
All – B	33.26 a	33.27 b	29.32 c	31.95 b (89.9)
S - Mean	28.51 B	29.02 A	27.73 C	28.42

CD at 0.05 probability level, T = 0.88, S = 0.49, TxS = 1.51

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 %

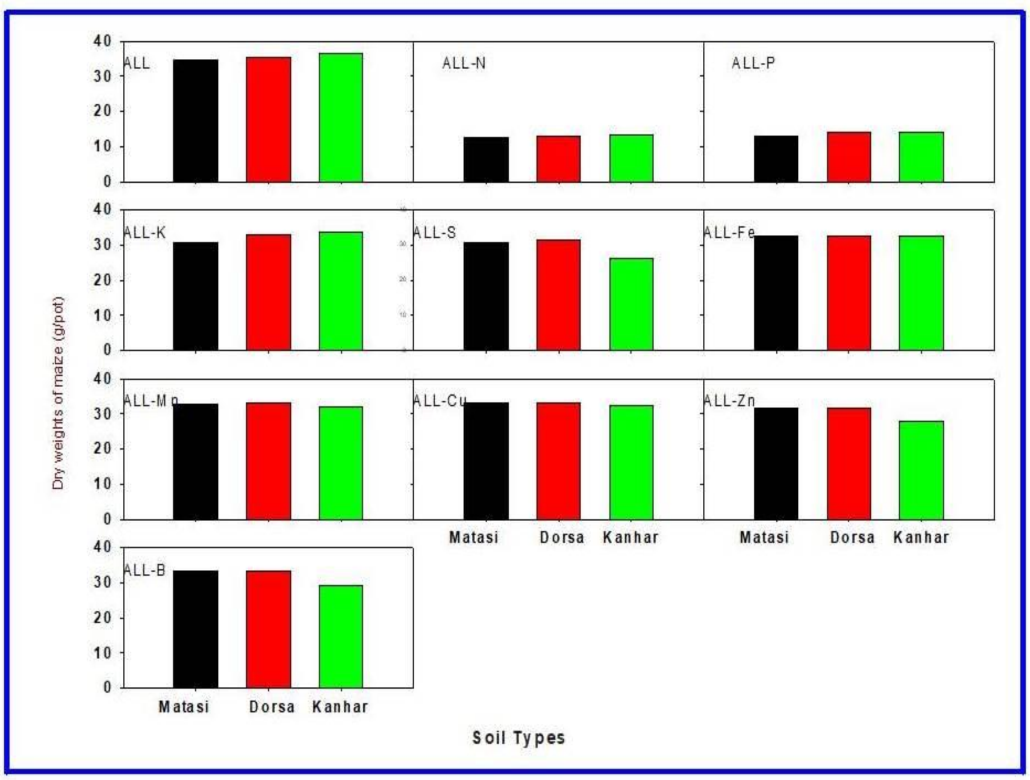

Figure: 2 Dry weight of maize (g/pot) in relation to different treatments as affected by soil type