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Nutrient omission: An plant nutrient deficiencies assessment technology of rice (*Oryza sativa*) in Inceptisols

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Abstract
Experiment was conducted on rice (*Oryza sativa*) during *Kharif*, 2015 at Instructional Farm of Krishi Vigyan Kendra, Raigarh (C.G.) to investigate the yield limiting nutrients through crop response in Inceptisols with rice (MTU-1010) as test crop. The experiments were laid out in Completely Randomized Design (CRD) with 11 treatments and 3 replications. Yield attributing characters *viz.* effective tillers, filled grains panicle^{-1} and grain and straw yields of rice were significantly influenced by nutrient omission treatments. The omission of N, P, S and Zn resulted in significant reductions in yield attributing parameters and grain and straw yields. Highest grain and straw yields (16.01 and 30.57 g pot^{-1}) were recorded with the treatment receiving all the nutrients whereas the lowest with omission of N (18.01 and 32.58 g pot^{-1}) followed by P, S and Zn omission. The omission of N reduced the grain yield by 47.64% while P omission reduced grain yield by 40.82% over the treatment receiving all nutrients. Per cent reduction of grain yield under different nutrient omitted pots followed the order N > P > S >Zn. The omission of N, P and S reduced the yield attributing parameters and grain and straw yields significantly over the treatment receiving all the nutrients. Nutrient uptake by rice was significantly reduced with omission of N, P and S. On the basis of per cent grain yield reduction, the limiting nutrients found in the order of N > P > S.

Keywords: Rice, nutrient omission, yield, nutrient uptake, Inceptisols

Introduction
Rice (*Oryza sativa* L.) is one of the most important staple food of more than 50 per cent of the global population. Rice is indeed one of the oldest types of cereal recorded in the history of mankind. Being the major source of food after wheat, it meets 43 per cent of calorie requirement of more than two third of the Indian population. In addition to being a major source of carbohydrates and also provides substantial amounts of a number of components which are essential or beneficial for health, notably protein, vitamins (notably B vitamins), dietary fiber, phyto-chemicals and reduced risk of cardio-vascular disease, type 2 diabetes, and forms of cancer (notably colo-rectal cancer). The cultivation of rice in intensive subsistence agriculture becomes synonymous with agriculture. India is the second largest producer of rice in the world being superseded only by China in the gross annual output. In South Asia, rice was cultivated on 60 million hectares (m ha), and production was slightly above 225 million tonnes (m t) of rice, accounting for 37.5 and 32 per cent of global area and production, respectively (Mohanty, 2014) [7]. At present it is being grown on an area of about 43.39 m ha with the production of 104.32 m t and average productivity of 2.4 t ha^{-1}. In Chhattisgarh, it occupied 3.82 m ha with the production of 6.09 m t and average productivity of 1.59 t ha^{-1} (Anonymous, 2016) [1]. Increasing crop production is imperative to meet the growing demand of the population in terms of food, fodder, fiber, fuel, timber and industrial raw material. A continuous increase in yield performance has been achieved through progress in breeding and improvements in crop management systems. Fertilizer use has been the key element of this remarkable situation including the high yielding genotypes to realize the potential yield. Presently there is either a plateau or decline in the productivity of many crops across the country, despite earlier steady increase in productivity. The stagnation in crop productivity has been found due to deficiency of some micro and secondary nutrients (Sakal 2001) [8]. Use of high analysis NPK fertilizers, free from micronutrients, limited use of organic manures and restricted recycling of crop residues are some important factors have 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 the soils.

Chhattisgarh state has four major soils types *i.e.* Entisols, Inceptisols, *Alfisols* and *Vertisols*. Almost all soils are deficient in nitrogen and phosphorus and medium to high in potassium. In view of continuous use of sulphur free complex fertilizers, chance of increase in sulphur deficiency is likely. Sulphur deficiency is commonly observed in Inceptisols. Other micronutrients like Fe, Mn, Cu, B and Mo may be sufficient for low to medium level of crop production but may not be sufficient for high level of crop production. High crop yields can only be achieved when crop are properly nutritioned in a correct amount and proper ratios. Ignorance of nutrients other than N, P and K may also limit crop production. Keeping these aspects in view, the present study was undertaken to assessment of nutrient deficiencies in rice through nutrient omission to achieving attainable yield in Inceptisols of Chhattisgarh.

Materials and Methods

The study was carried out on rice *(Oryza sativa)* during *Kharif,* 2015 at Instructional Farm of Krishi Vigyan Kendra, Raigarh (C.G.) to investigate the yield limiting nutrients through crop response in Inceptisols of Raigarh. The experimental site is located on the Northern part of Chhattisgarh state and lies at 21°54'N latitude and 83°24' E longitude with an altitude of 215 m above the mean sea level (MSL). Characteristics of the soils (Inceptisols) are presented in Table 1. The experiments were laid out in completely randomized design with three replications. The treatments were T_1 All (N, P, K, S, Ca, Mg, Cu, Zn, B, Mo), T_2 All – N, T_3 All – P, T_4 All – K, T_5 All – S, T_6 All – Ca, T_7 All – Mg, T_8 All – Cu, T_9 All – Zn, T_{10} All – B and T_{11} All – Mo (Table 2). Twenty one days old seedlings of rice (MTU-1010) were transplanted on 6th July, 2015 and the pots were maintained with 3 cm standing water during the crop growing period. The crop was harvested on 9th October, 2015. At harvest yield data of grain and stover of rice was recorded. Nitrogen content was estimated by micro-kjeldahl method (Jackson, 1973) [5]. Phosphorus and potassium contents in triacid (HNO_3, $HClO_4$ and H_2SO_4 in 10:4:1 ratio) were determined by vanadomolybdate yellow colour and flame photometer methods. Sulphur, calcium, magnesium, zinc, iron, copper and boron were determined in diacid (HNO_3 and $HClO_4$ in 10:4 ratio) by turbidimetric (Chesnin and Yien, 1951) [3], versenate (Chang and Bray, 1951) [2], atomic absorption spectrophotometer and azomethine-H (Gupta, 1967) [4] methods. Nutrient uptake was calculated by multiplying grain and straw yields with their respective nutrient contents.

Results and Discussion

Yield attributes

The effective tillers pot^{-1} varied from 9 to 12, filled grains panicle^{-1} varied from 96.33 to 103.67 and test weight varied from 22.93 to 24.09 g (Table 3). The omission of nitrogen, phosphorus, and sulphur significantly reduced the effective tillers pot^{-1} and grains panicle^{-1}. Significantly highest number of effective tillers (12) and grains panicle^{-1} (103.67) were observed in the treatment receiving all the nutrients (T_1) and lowest in N omitted pots followed by omission of P, S and Zn. Test weight of rice grain not affected by nutrient omission. Higher yield attributes of rice due to application of all nutrients is attributed to improvement in growth which in turn translocation of photosynthates and nutrients in the reproductive parts resulted more yield attributes (Singh, 2018 and Singh *et al*. 2018) [10, 11].

Yield

Irrespective of treatments, the grain and stover yields of rice varied from 16.01 to 30.57 g pot^{-1} and 18.01 to 32.58 g pot^{-1}, respectively. Highest grain yield (30.57 g pot^{-1}) was recorded in the treatment receiving all the nutrients (T_1) and lowest grain yield (16.01 g pot^{-1}) was associated with omission of N. Grain yields with omission of P, S and Zn were 18.09, 24.61 and 28.16 g pot^{-1}, respectively and significantly lower than the treatment receiving all the nutrients. The omission of N reduced the yield by 47.64, P by 40.82 and S by 19.51, respectively. Highest straw yield (32.58 g pot^{-1}) of rice was recorded in $T_{1,}$ where all the nutrients were applied and lowest (18.01 g pot^{-1}) in T_2 where N was omitted. The omission of N, P and S resulted in significantly lower straw yields. The omission of N, P and S significantly reduced rice grain yield over the treatment receiving all the nutrients. Highest grain yield (30.57 g pot^{-1}) was recorded in the treatment receiving all the nutrients (T_1). Rice grain yields with omission of N, P and S were 16.01, 18.09 and 24.61 g pot^{-1}, respectively and were significantly lower over treatment receiving all the nutrients (T_1). The omission of N reduced grain yield by 47.64% while P and S reduced the yield to the extent of 40.82% and 19.51%, respectively. Omission of N, P and S caused significant reductions in straw yields of rice in comparison to the treatment receiving all the nutrients (T_1). The highest straw yield (32.58 g pot^{-1}) was recorded in the treatment receiving all the nutrients (T_1). Similar trends in grain and straw yield of rice have also been reported by Mishra *et al*. (2007) [6].

The grain and straw yield reductions were observed more with N and P omission followed by S and Zn omission. This indicates that N was the most yield limiting nutrients in soils followed by P. Under tropical climatic conditions, oxidation loss of organic matter results in low organic carbon and ultimately in available nitrogen causing much reduction in yields (Singh *et al.* 2000) [12]. The soils are low to medium in available P, S and Zn and hence the omission of these nutrients caused significant reduction in yield.

Nutrient uptake

Total uptake of nutrients by rice was highest in T_1 treatment which received all nutrients and generally lowest was recorded in N omitted pots (Table 4 and 5). Nitrogen uptake by rice ranged from 258.7 to 520.2 mg pot^{-1}. Total N uptake was found maximum in the treatment where all the nutrients were applied (T_1) and minimum with N omission pots with a significant difference. Uptake of N with omission of P, S and Zn was significantly lower than uptake under T_1 treatment. Total P uptake was found lowest (66.9 and 68.9 mg pot^{-1}) in P omitted pots. Highest P uptake was associated with the treatment receiving all the nutrients closely followed by omission of Mo, B, Fe, Mn, Cu, Ca, Mg and K with an insignificant difference to treatment T_1. Total K uptake by rice was found maximum in the treatment where all the nutrients were applied (T_1). K uptake in N, P, K, S and Zn omitted pots were significantly lower than T_1 treatment. Omission of N, P and S reduced K uptake significantly in comparison to T_1 treatment. However, omission of other nutrients could not affect K uptake significantly over T_1 treatment. Total S uptake was found maximum in the treatment where all the nutrients were applied (T_1) and minimum in the treatment where N was omitted soils. Irrespective of treatments and soils type, the S uptake was ranged from 45.24 to 89.74 mg pot^{-1}. The omission of N, P and S significantly reduced S uptake by rice over T_1 treatment. Mg omission reduced S uptake significantly over T_1 treatment. Total uptake of Ca was found maximum (291.7 mg pot^{-1}) in the treatment where all the nutrients were applied (T_1) and minimum (156.4 mg pot^{-1}) in N omitted pots. Uptake of Ca with omission of N, P, S, Ca and Mg declined significantly as compared to treatment T_1. Maximum Mg uptake (167.87 mg pot^{-1}) was recorded in treatment T_1 and minimum (88.9 mg pot^{-1}) in the N omitted treatment and difference was significant. The uptake of Mg with omission of P, S and Mg were significantly lower than the uptake observed with T_1. Maximum Zn uptake was found in the treatment receiving all the nutrients (T_1) and minimum in N omitted pots and the difference was significant. Significantly lower Zn uptake was also observed with omission of P, S, Zn, Cu and Mg. Omission of N, P and S reduced the total Cu uptake significantly. Highest Cu uptake (0.37 mg/pot) was associated with treatment T_1. The uptake of Cu with omission of N, P, S and Zn was remarkably lower than uptake by $T_{1.}$ Omission of N, P and S caused significant reductions in Cu uptake by rice. Total uptake of B was found highest in T_1 treatment. Significantly lower B uptake was associated with omission of N, P, S, B, and Zn. Uptake of B with omission of N, P, S and B reduced significantly than uptake with $T_{1.}$ Omission of N, P, S and Zn significantly reduced the total Fe uptake by rice in comparison to the treatment receiving all the nutrients (T_1). Maximum total Fe uptake (8.12 mg pot^{-1}) recorded in T_1 treatment and minimum (5.35 mg pot^{-1}) in N omitted pots and the difference was significant. The uptake of Fe with omission of P, S and Zn reduced remarkably over T_1. Omission of N, P and S significantly reduced Mn uptake and the reduction was more pronounced with N omission. Maximum Mn uptake (11.45 mg pot^{-1}) was recorded in T_1 treatment and minimum (7.51 mg pot^{-1}) in the treatment where N was omitted. Mn uptake with omission of P, S and Zn was significantly lower than uptake by T_1. Application of all nutrients (T_1 treatment) increased the grain and straw yields as well as the nutrient concentrations resulted more uptake of nutrients. Generally significantly lower nutrients uptake by rice was observed with nitrogen, phosphorus, sulphur and zinc omission because of low grain and straw yields. These results are in accordance with those of Mishra *et al.* (2007) [6] and Singh (2016) [9].

From these results, it may be concluded that application of N, P, K, S and Zn might be benifecial under Inceptisols of Chhattisgarh state for achieving higher productivity of rice. Nitrogen and phosphorus are most limiting nutrients and their omission caused drastic reduction of yield.

Table 1: Characteristic of experimental soils (Inceptisols)

S. No.	Characteristics of soils	Values of soils
		Inceptisol
1	pH	6.81
2	EC (dSm^{-1})	0.12
3	Organic carbon (g kg^{-1})	5.3
4	CEC (cmol(p+) kg^{-1})	18.6
5	Available N (kg ha^{-1})	235
6	Available P (kg ha^{-1})	14.2
7	Available K (kg ha^{-1})	337
8	Available S (kg ha^{-1})	22.3
9	Available Ca (kg ha^{-1})	1848
10	Available Mg (kg ha^{-1})	856
11	Available Fe (mg kg^{-1})	28.35
12	Available Mn (mg kg^{-1})	19.52
13	Available Cu (mg kg^{-1})	2.01
14	Available Zn (mg kg^{-1})	1.41
15	Available B (mg kg^{-1})	0.53

Table 2: Source and rates of nutrient used in nutrient omission trial

Nutrient	Rate (kg ha^{-1})	Source	Remark
N	150	[1]Urea	[1]Added after adjusting the amount added through DAP
P	100	[2]KH_2PO_4/DAP	[2]Used in N omission treatment,
K	80	*MOP	*Added after adjusting the amount added through KH_2PO_4 in N omission treatment,
S	45	[3]Bentonite S	[3]Added after adjusting the amount added through, $FeSO_4.7H_2O$, $MnSO_4.H_2O$, $CuSO_4.5H_2O$ and $ZnSO_4.7H_2O$
Ca	110	[4]$CaCl_2.2H_2O$	[4]Used in Mg omission treatment
Mg	55	MgO	-
Fe	20	$FeSO_4.7H_2O$ [5]$FeCl_2$	[5]Used in S omission treatment
Mn	15	$MnSO_4.H_2O$ [6]$MnCl_2$	[6]Used in S omission treatment
Cu	7.5	$CuSO_4.5H_2O$ [7]$CuCl_2.2H_2O$	[7]Used in S omission treatment
Zn	7.5	$ZnSO_4.7H_2O$ [8]$ZnCl_2$	[8]Used in S omission treatment
B	3	H_3BO_3	-
Mo	0.75	$NaMoO_4.2H_2O$	-

Table 3: Effect of nutrient management practice on yield attributes and yields of rice under Inceptisols.

Treatments		Effective tillers	Grains $panicle^{-1}$	Test weight (g)	Grain yield (g pot^{-1})	% reduction over all	Straw yield (g pot^{-1})
All	All	12	103.67	24.09	30.57	-	32.58
All –N	All – N	9	96.33	22.93	16.01	47.64	18.01
All –P	All – P	10	98.33	23.49	18.09	40.82	20.00
All –K	All – K	11	101.94	23.68	29.77	2.62	31.25
All –S	All – S	10	100.25	23.76	24.61	19.51	25.62
All –Fe	All – Ca	11	102.33	23.70	28.73	6.02	30.64
All –Mn	All – Mg	11	102.61	23.74	28.82	5.74	29.78
All –Cu	All – Cu	11	102.33	23.76	28.08	8.15	30.55
All –Zn	All – Zn	11	101.87	23.85	28.16	7.88	30.81
All –B	All – B	11	102.66	23.87	28.41	7.08	31.08
All –Mo	All – Mo	12	103.00	23.92	29.25	4.32	32.30
S.Em±		0.36	0.86	0.82	1.16	-	1.00
C.D.at 5%		1.12	2.66	NS	3.59	-	3.09

All = N, P, K, S, Ca, Mg, Cu, Zn, B, Mo

Table 4: Effect of nutrient management practice on macro and secondary nutrients uptake by rice under Inceptisols

Treatments		Nutrient uptake (mg pot^{-1})					
		N	P	K	S	Ca	Mg
All	All	520.3	129.9	566.0	89.7	291.7	88.9
All –N	All – N	258.7	66.9	305.8	45.2	156.4	102.6
All –P	All – P	298.2	68.9	343.1	52.5	175.9	159.4
All –K	All – K	492.6	122.9	527.7	83.8	279.8	130.7
All –S	All – S	398.6	100.4	442.7	64.1	224.1	157.4
All –Fe	All – Ca	476.3	121.1	533.2	82.3	252.7	140.8
All –Mn	All – Mg	472.2	119.6	521.6	78.8	261.0	157.1
All –Cu	All – Cu	467.4	118.9	527.2	82.2	273.3	157.5
All –Zn	All – Zn	467.5	120.7	528.0	81.5	271.4	159.6
All –B	All – B	472.5	122.7	535.5	81.3	276.5	167.8
All –Mo	All – Mo	495.0	125.7	557.2	85.0	287.8	88.9
S.Em±		17.6	3.9	16.9	2.8	9.4	4.7
C.D.at 5%		54.5	12.2	52.4	8.9	29.4	14.5

All = N, P, K, S, Ca, Mg, Cu, Zn, B, Mo

Table 5: Effect of nutrient management practice on micronutrients uptake by rice under Inceptisols

Treatments		Nutrient uptake (mg pot^{-1})				
		Zn	Cu	B	Fe	Mn
All	All	2.12	0.37	0.63	8.12	11.45
All –N	All – N	1.07	0.20	0.31	5.35	7.51
All –P	All – P	1.21	0.23	0.32	6.02	8.56
All –K	All – K	1.95	0.36	0.57	7.36	10.34
All –S	All – S	1.49	0.30	0.44	7.05	9.82
All –Fe	All – Ca	1.87	0.35	0.57	7.56	10.99
All –Mn	All – Mg	1.85	0.34	0.56	7.60	10.42
All –Cu	All – Cu	1.83	0.33	0.56	7.50	10.66
All –Zn	All – Zn	1.66	0.34	0.56	7.06	10.05
All –B	All – B	1.89	0.35	0.47	8.08	11.38
All –Mo	All – Mo	2.03	0.36	0.59	8.56	11.19
S.Em±		0.07	0.01	0.03	0.04	0.52
C.D.at 5%		0.23	0.04	0.09	0.89	1.24

All = N, P, K, S, Ca, Mg, Cu, Zn, B, Mo

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