"Assessment of Soil Fertility through Response of Rice (*Oryza sativa* L.) to Nutrient Omission in *Alfisols* of *Kondagaon* District of *Chhattisgarh* in India"

ABSTRACT

The investigation was carried out with the aim to identify the specific yield limiting nutrients through response of rice to nutrient omission in pot culture under completely randomized design with 3 replications and 11 treatments during *kharif* season 2017 and to demonstrate the optimum use of identified limiting nutrients in wheat crop at field level in Kondagaon district during *rabi* season 2017-18. The treatments were formulated by keeping one treatment with application of all nutrients in optimum level and others by sequentially omitting each nutrient. The soil had a clay loam texture, neutral reaction (pH 6.6), normal electrical conductivity, medium organic C, available P and K, low available N and S, high available Ca, Mg, Fe, Mn and Cu and marginal available Zn and B. Omission of N and P nutrients significantly reduced the growth, yield and nutrients uptake by rice in comparison to all nutrients. The maximum grain yield of 73.0 g pot^{-1} was recorded, in all nutrients pot and 50.1 % reduction in grain yield of rice, from the maximum yield, was recorded in N omitted pots, followed by 18.8 % reduction in P omitted pots and omission of other nutrients didn't reduce the grain yield significantly indicating that only N and P were yield limiting nutrients. In field verification during *rabi* season, 19.0 % increase in wheat grain yield and 23.0 % increase in net return was recorded, due to optimum dose of identified yield limiting nutrients over farmer's practice dose. The results clearly indicate that the site specific nutrient management dose based on yield limiting nutrient identified through nutrient omission study was found economically profitable to the farmers.

Key words: SSNM, Yield limiting nutrients, Nutrient omission, Crop response.

INTRODUCTION

Adequate supply of plant nutrients decides optimum productivity of any cropping system. Even if, all other factors of crop production are in the optimum, the fertility of a soil largely determines the ultimate yield (Sekhon and Velayutham, 2002). 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). Soil fertility evaluation, thus, is the key factor for adequate and balanced fertilization of crops in high crop production systems. Soil and plant analyses are commonly performed to assess the fertility status of a soil with other diagnostic techniques including identification of deficiency symptoms and biological tests which are helpful in determining specific nutrient stresses and quantity of nutrients needed to optimize the yield (Havlin *et al*. 2007). However, the analytical results do not indicate the most limiting nutrient according to Liebig's law of the minimum "the minimum nutrient is the factor that governs and controls growth and potential yield of crop".

A nutrients 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. Conducting fertilizer field trials is an expensive task and time consuming process. This information can be generated through pot culture trial in controlled conditions through laboratory and greenhouses studies. This situation calls to identify the yield limiting nutrients for correcting the deficiencies and boosting the crop yield.

Rice (*Oryza sativa*), is an important staple food of India and continues to play a vital role in the national food and livelihood security system. India is having largest area under rice crop. However, productivity is lower than world's average productivity. The reason for low productivity is that rice is being grown in the country under various agro-ecologies in both irrigated and rainfed systems. States like Uttar Pradesh, Bihar, West Bengal, Orissa, Jharkhand, Chhattisgarh and Assam are having huge potential for rice cultivation and there is scope to increase productivity in this region.

The deficiency of some micro and secondary nutrients is one of the major causes for stagnation in crop productivity. 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).

Chhattisgarh State has four major soils type *i.e. Entisols, Inceptisols, Alfisols* and *Vertisols*. Almost all soils are deficient in nitrogen and phosphorus and medium to high in potassium. Zinc deficiency is also reported in some patches of *Alfisols* and *Vertisols* of this region. In view of continuous use of sulfur free complex fertilizers, chances of increase in S deficiency are likely. 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. In view of continuous use of high analysis fertilizer, multiple nutrient deficiencies are likely. High crop yields can only be achieved by correcting such deficiencies. Site specific nutrient management is of utmost importance for obtaining high yields on sustainable basis. (Sahu *et al.*2017). However, little is known about the sustainability of the current production systems, particularly systems with multiple cropping under minimum practice. Looking to very limited information on the proper and site specific nutrient doses to maximize yield of rice, present investigation was undertaken with the objective to assess the yield limiting nutrients based on rice response to nutrient omission and to demonstrate the optimum use of identified limiting nutrients and its comparison with farmer's fertilizer practice.

MATERIALS AND METHODS

A pot culture study was undertaken at S.G. College of Agriculture and Research Station, Jagdalpur, Bastar (CG) during the kharif season 2017 to identify the specific yield limiting nutrients through response of rice (MTU-1001) to nutrient omission in the bulk soil samples collected from farmers field of *Alfisols* of *Kondagaon* district, and later on a demonstration was conducted at same farmers field at village – Badebendri, block and district – Kondagaon to demonstrate the effect of optimum use of identified limiting nutrients in wheat (GW-273) during *rabi* season 2017-18. The study site lies at $19^0$10' N latitude and $81^0$95 E longitude with an altitude of 550-760 meter above the mean sea level.

Experimental details

The experiment was laid out under completely randomized design with 3 replications and 11 treatments, formulated by keeping one treatment with application of all nutrients in optimum level and others by sequentially omitting each nutrient i.e. T1-all nutrients, T2- all nutrients – N, T3- all nutrients – P, T4- all nutrients – K, T5- all nutrients – S, T6- all nutrients – Fe, T7- all nutrients – Mn, T8- all nutrients – Cu, T9- all nutrients – Zn, T10- all nutrients – B, T11- all nutrients – Mo. Bulk soil samples representative of *Alfisols* of the district was collected from the farmer's fields for pot culture study. The processed and uniform soil samples were filled in plastic pots @ 20 kg and nutrients as specified above were applied through different sources taking care to avoid any precipitation during solution mixing and application. The optimum doses of nutrients were fixed in kg ha^{-1} as N -150, P_2O_5 - 100, K_2O - 100, S - 45, Fe - 20, Mn - 7.5, Cu - 7.5, Zn -7.5, B - 3 and Mo - 0.75 for SSNM dose. Rice (MTU-1001) was taken as test crop. The pots were maintained saturation with standing water and twenty five days old seedlings of rice (MTU-1001) were transplanted on 22^{th} July 2017. Three seedlings of MTU-1001 variety of rice were planted in three hills in each pot and water level was maintained at 3 cm throughout the crop season. 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 17th November, 2017. The effects of treatments were recorded in terms of yield, different yield attributing parameters and nutrient uptake by rice crop. The observations on plant height in cm and No. of tillers pot^{-1} were recorded at 90 and 60 DAS whereas No. of filled grains panicle^{-1}, test weight (weight of 1000 grains), grain and straw yield (g pot^{-1}) were recorded at harvesting.

Based on these results, N and P nutrients were identified as yield limiting nutrients and an optimum dose of identified yield limiting nutrients were formulated and tested in wheat crop (GW-273) during *Rabi* 2017-18 at farmer's field from where bulk soil samples were collected for pot experiment.The optimum dose also known as SSNM dose, formulated for *Alfisols* was 150 kg N, 100 kg P_2O_5, 100 kg K_2O ha^{-1}. The wheat crop was sown on 14th Dec 2017 and harvested on 14th April 2018. The farmer's used fertilizer dose at the rate of 80 kg N: 50 kg P_2O_5: 30 kg K_2O ha^{-1}. The effect of optimum/SSNM dose was compared with farmer's fertilizer practice.

Experimental soil

The initial physicochemical characteristic of the experimental soil (Alfisol) was determined (Table 1) using common field and laboratory procedures. The experimental soil was a clay loam, had a neutral soil reaction (pH 6.6), normal electrical conductivity (0.18 dS m^{-1}), medium organic C (0.59%), available P (12.8 kg ha^{-1}) and K (212 kg ha^{-1}), low available N (262 kg ha^{-1}) and S (18.9 kg ha^{-1}), high available Ca (1093 kg ha^{-1}), Mg (507 kg ha^{-1}), Fe (73.55 ppm), Mn (24.17 ppm) and Cu (1.17 ppm) and marginal available Zn (0.94 ppm) and B (0.64 ppm).

Table 1 Initial physicochemical characteristics of experimental soils

S. No.	Soil Characteristics	Value	Rating
1.	**Mechanical Analysis**		
	Sand (%)	38	Clay loam
	Silt (%)	32	
	Clay (%)	30	
2.	**pH (1:2.5 soil: water suspension)**	6.6	Neutral
3.	**Electrical Conductivity (dS m^{-1})**	0.18	Normal
4.	**Organic C (%)**	0.59	Medium

5.	**N Available (kg ha^{-1})**	262	Low
6.	**P Available (kg ha^{-1})**	12.8	Medium
7.	**K Available (kg ha^{-1})**	212	Medium
8.	**S Available (kg ha^{-1})**	18.9	Low
9.	**Ca Available (kg ha^{-1})**	1093	High
10.	**Mg Available (kg ha^{-1})**	507	High
11.	**Fe Available (mg kg^{-1})**	73.55	High
12.	**Mn Available (mg kg^{-1})**	24.17	High
13.	**Zn Available (mg kg^{-1})**	0.94	Marginal
14.	**Cu Available (mg kg^{-1})**	1.17	High
15.	**B Available (mg kg^{-1})**	0.64	Marginal

RESULTS AND DISCUSSION

Growth and yield attributes of rice

The effects of missing nutrients on growth and yield attributes (plant height, tillers, effective tillers, filled grains per panicle and test weight) of rice recorded during the kharif season of 2017 in the soils collected from *Alfisol* of *Kondagaon* district are described here. The growth and yield attributes of rice were significantly affected by omission of different nutrients (Table 2).

Plant height

The data presented in Table 2 clearly indicated that the plant height of rice at 90 DAT significantly differed with various nutrient omission treatments imposed. The highest plant height of rice were recorded under treatment T1 where all the nutrients were supplied whereas significantly lower plant height were found under the treatments missing N and P nutrients, as compared to T1 indicating the need of application of these nutrients in Alfisols of *Kondagaon* district.

Since N is an important constituent of amino acids, proteins and protoplast, its application had a more pronounced effect on plant growth and development through better utilization of photo-synthates and more vegetative growth. These results are in conformity of the findings of Singh (2008) and Sharma *et al.* (2000). P omission had also exhibited a significant effect on plant height. Optimum P availability is essential for normal growth and development and the utilization of other nutrients, particularly N. The significant crop response to P application was also reported by many workers (Ahmed *et al.*, 2010 and Mc Beath *et al.*, 2007).

Tillers per pot

The results pertaining to effect of missing nutrients on tillers pot^{-1} recorded at 60 DAT of rice crop grown in *Alfisol* of *Kondagaon* district is presented in the Table 2. Number of tillers per pot was significantly influenced by different missing nutrient treatments imposed. N and P omission treatments showed significantly reduced number of tillers in Alfisols of *Kondagaon* in comparison to treatment that received all nutrients and other nutrient omission treatments.

N plays a key role in tillers bearing of rice followed by P. On an average, 21 tillers of rice were observed at 60 DAT in treatment T_1 which received all nutrients and the various nutrients omission treatments had reduced number of tillers. Omission of N and P reduced the number of tillers as these two nutrients have major role in tillers bearing of the crop. Many researchers have also concluded the importance of N and P in tillering of rice (Singh 2008, Sharma *et al.* 2000, Ahmed *et al.*, 2010 and Mc Beath *et al.*, 2007).

Effective tillers per pot

Average effective tillers per pot were ranged from 17.0 to 21.3 in *alfisol* of Kondagaon district under study (Table 2). Omission of different nutrients significantly reduced the effective tillers of rice. Omission of N and P treatments significantly reduced the effective tillers of rice as compared to treatment that received all nutrients and other nutrients omission treatments. Many researchers have also concluded the importance of N and P in tillering of rice (Singh 2008, Sharma *et al.* 2000, Ahmed *et al.*, 2010 and Mc Beath *et al.*, 2007).

Filled grains per panicle

Similar trend were also observed for number of filled grains per panicle of rice which varied from 87.7 to 132.7 in *Alfisol* of *Kondagaon*. The treatments missing N and P nutrients recorded significantly lower filled grains per panicle as compared to Treatment T_1 which received all nutrients (Table 2). Many researchers have also similar view (Singh 2008, Sharma *et al.* 2000, Ahmed *et al.*, 2010 and Mc Beath *et al.*, 2007).

Test weight

A close examination of the data pertaining to test weight (1000 grain weight) presented in Tables 2 showed that the test weight of rice grain didn't varied significantly with different treatments. In general, the test weight of rice grain varied from 25.2 to 25.7g in *Alfisol* of *Kondagaon* district.

Test weight (weight of 1000 rice seed) of rice did not differ significantly with respect to the application of different treatments in this study in both the soils. However, omission of N and P pots had reduced the test weight as compared to those of all other treatments. It is universally truth that N and P are the most important major nutrients require for tillering, root growth and general plant vigor that affect ultimately filled grains and test weight. The reduced effective tillers, number of filled grains per panicle and test weight were recorded in present study caused omission of N and P treatments. Many researchers have also similar view (Singh 2008, Sharma *et al*. 2000, Ahmed *et al.*, 2010 and Mc Beath *et al.*, 2007).

Table 2: Yield attributing characters of rice (MTU- 1001) in relation to different nutrient omission treatments in *Alfisol* of *Kondagaon* district

Treatments		Plant height (cm)	Tillers (No. pot^{-1})	Effective tillers (No. pot^{-1})	Filled grains (No. panicle^{-1})	Test weight (g 1000 grains^{-1})
T_1	All	101.3	24.3	21.3	132.0	25.7
T_2	All-N	82.3	19.3	17.0	87.7	25.2
T_3	All-P	91.4	22.0	18.7	120.0	25.3
T_4	All-K	100.8	23.7	21.3	130.3	25.6
T_5	All-S	98.6	22.7	21.3	126.7	25.4
T6	All-Fe	99.6	24.0	21.7	131.0	25.5
T_7	All-Mn	99.7	23.7	21.7	131.0	25.5
T_8	All-Cu	98.7	23.3	21.3	129.3	25.5
T_9	All-Zn	98.5	23.3	21.3	127.0	25.4
T_{10}	All-B	98.5	23.0	20.3	128.3	25.5
T_{11}	All-Mo	99.7	23.7	21.7	132.7	25.5
SEm (±)		**0.99**	**0.71**	**0.78**	**2.07**	**0.11**
CD at 5% level		**2.93**	**2.07**	**2.33**	**6.14**	**NS**

Grain and straw yields of Rice

The results pertaining to grain and straw yields of rice as influenced by different treatments are illustrated in Table 3.

Grain yield of Rice

The highest grain yield of 73.0 g pot^{-1} was recorded in the treatment T1 that received all nutrients and they were at par with those of other treatments which were missing K, S, Fe, Mn, Cu, Zn, B and Mo (Table 3). Omission of N and P significantly reduced the grain yields of rice. The yield decrements due to omission of different plant nutrients from SSNM (All) were estimated and critically observed the limiting nutrients which reduced the yield by 10% from the maximum yield obtained by SSNM treatment. The omission of N and P reduced the grain yield by 50.1 and 18.8 %.

Considerable reductions in grain yield due to these nutrients might be due to their insufficient/marginal level. Similar results have also been reported by Segda *et al*. (2005), Kumar et al. (2018a), Kumar et al. (2018b), Kumar et al. (2020) and Atnafu et al. (2021). Some of the secondary and micro nutrients omission may not have reduced the yield from the maximum yield statistically significant manner however; such nutrients can be treated as hidden hunger and needs application for maximum yield. On the basis of yield performance, the yield limiting nutrients may be put in the order of N > P.

Straw yield of rice

The highest straw yield of 88.7 g pot^{-1} was recorded in the treatment T1 that received all nutrients and was at par with those of other treatments which were omitted out K, S, Fe, Mn, Cu, Zn, B and Mo nutrients (Table 3). Omission of N and P nutrients significantly reduced the straw yield of rice in comparison to the treatment that received all the nutrients and other missing nutrient treatments. Omission of N and P reduced the straw yield by 49.0 and 19.5 %. The per cent reduction in straw yield under different nutrient omitted pots was in order of N>P.

Result clearly showed that N is the most critical nutrients that affect the grain yield considerably followed by P. Omission of all other nutrients did not indicate yield reduction, significantly. Segda *et al.* (2005) and Mishra *et al*. (2007) have also reported similar trends in grain and straw yield of rice.

Large reductions in the grain and straw yield of rice were observed with the omission of N and P as compared to the other nutrient omission treatments. The yield reductions were more pronounced 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 loss of organic matter results in low organic carbon (Singh *et al.*, 2000 and Singh and Agrawal, 2005). Since organic matter content is an indicator of available N status of soils, the soils of the area are also dominantly low in respect of available N. The soils were inherently low to medium in available P and hence the omission of P caused more reduction in yields.

Table 3: Grain and straw yield of rice as affected by different treatments in *Alfisol* of Kondagaon district

Treatments		Yield (g pot^{-1})		% reduction in yield from T_1	
		Grain	Straw	Grain	Straw
T_1	All	73.0	88.7	-	-
T_2	All-N	36.5	45.2	50.1	49.0
T_3	All-P	59.3	71.4	18.8	19.5
T_4	All-K	72.2	87.1	1.1	1.8
T_5	All-S	67.5	83.2	7.5	6.2
T_6	All-Fe	70.7	86.7	3.1	2.3
T_7	All-Mn	72.9	88.4	0.1	0.3
T_8	All-Cu	71.3	86.1	2.3	2.9
T_9	All-Zn	68.5	83.4	6.2	6.0
T_{10}	All-B	67.5	82.9	7.6	6.5
T_{11}	All-Mo	72.7	88.5	0.5	0.2
SEm (±)		**2.72**	**3.39**	-	-
CD at 5% level		**8.09**	**10.08**	-	-

Nutrient uptake

Uptake of N, P and K by rice

It is clear from the Table 4 that the mean total N, P and K uptake by rice were significantly affected with application of different treatments.

N uptake

The highest N uptake (1.29 g pot^{-1}) was recorded in the treatment that received all the nutrients followed by Mn (1.28 g pot^{-1}), Mo (1.27 g pot^{-1}), Cu (1.24 g pot^{-1}), K (1.23 g pot^{-1}), Ca (1.22 g pot^{-1}), S (1.19 g pot^{-1}), Zn (1.18 g pot^{-1}) and B (1.17 g pot^{-1}) omitted pots (Table 4). N omission treatment recorded lowest N uptake (0.64 g pot^{-1}) followed by P omission pots (1.04 g pot^{-1}). Higher uptake of N by rice with application of N has also been observed by Bhuiyan *et al.* (1986). The reduction in uptake of N with omission of N application has also been reported by Mishra *et al.* (2007).

P uptake

The highest P uptake (0. 28 g pot^{-1}) was recorded in the treatment that received all the nutrients and was statistically higher than N and P omitted pots and at par with other nutrient omitted pots (Table 4). Lowest P uptake (0.12 g pot^{-1}) was observed in N omitted pots followed by P (0.22 g pot^{-1}) omitted pots. The similar findings were also reported by Mishra *et al*. (2007).

K uptake

The highest K uptake (1.57 g pot^{-1}) associated with the treatment that received all the nutrients followed by Mn (1.55 g pot^{-1}), Mo (1.54 g pot^{-1}), K (1.53 g pot^{-1}), Fe and Cu (1.49 g pot^{-1}), Zn (1.48 g pot^{-1}), B (1.45 g pot^{-1}) and S (1.44 g pot^{-1}), omitted pots (Table 4). Lowest K uptake (0.78 g pot^{-1}) was observed in the N omission treatment (T2) which was significantly lower than all the other treatments. Omission of P also caused significantly lower uptake of K over other treatments but it was significantly higher than N omission. The similar findings were also reported by Mishra *et al.* (2007).

Table 4: Total uptake of N, P and K (g pot^{-1}) by rice (MTU1001) in *Alfisol* of Kondagaon district

Treatments		Total uptake (g pot^{-1}) by rice		
		N	P	K
T_1	All	1.29	0.28	1.57
T_2	All-N	0.64	0.12	0.78
T_3	All-P	1.04	0.22	1.24
T_4	All-K	1.23	0.27	1.53
T_5	All-S	1.19	0.24	1.44
T6	All-Fe/Ca	1.22	0.26	1.49
T_7	All-Mn/Mg	1.28	0.26	1.55
T_8	All-Cu	1.24	0.24	1.49
T_9	All-Zn	1.18	0.24	1.48
T_{10}	All-B	1.17	0.24	1.45
T_{11}	All-Mo	1.27	0.26	1.54
SEm (±)		**0.052**	**0.019**	**0.061**
CD at 5% level		**0.153**	**0.057**	**0.181**

Secondary nutrients uptake by rice

It is obvious from the data presented in Table 5 that the mean total uptake of secondary nutrients by rice was significantly affected with application of different nutrient omission treatments.

Ca uptake

Omission of N and P treatments caused significant reductions in the Ca uptake in comparison to all the other treatments (Table 5). Highest Ca uptake (0.78 g pot^{-1}) was observed with the treatment receiving all the nutrients followed by Mn (0.76 g pot^{-1}), Fe, Cu and Mo (0.75g/pot), K (0.74 g pot^{-1}), Zn (0.72 g pot^{-1}) and S and B (0.70 g pot^{-1}), omitted pots and were statistically at par with each other and significantly higher than N and P omission treatments. Whereas the least Ca uptake was observed with N omission (0.39 g pot^{-1}) followed by P omission (0.61 g pot^{-1}) with significant difference between them. The similar findings were also reported by Kumar et al. (2018a), Kumar et al. (2018b) and Kumar et al. (2020).

Mg uptake

The highest Mg uptake (0.45 g pot^{-1}) was associated with the treatment that receive all the nutrients followed by K and Mn (0.43 g pot^{-1}), Fe, Cu, Zn and Mo (0.42 g pot^{-1}) and S and B (0.40 g pot^{-1}) omitted pots and they were statistically at par with each other and significantly higher than N and P omission pots (Table 5). The lowest Mg uptake (0.23 g pot^{-1}) was observed in the treatment missing N (T2) followed by the treatment missing P (0.37 g pot^{-1}). Omission of N and P caused significantly lower uptake of Mg over other treatments. The similar findings were also reported by Kumar et al. (2018a), Kumar et al. (2018b) and Kumar et al. (2020).

S uptake

Omission of N, and P caused significantly lower uptake of S by rice as compared to treatment receiving all nutrients and other nutrient omission treatments (Table 5). Highest S uptake (0.21 g pot^{-1}) was found in Mo missing plots followed by treatment receiving all the nutrients (T1), Mn and Cu (0.20 g pot^{-1}), K and Zn (0.19 g pot^{-1}) and S, Fe and B (0.18 g pot^{-1}) omitted pots and all these were statistically at par with each other and significantly higher than N and P. Whereas, the least S uptake (0.10 g pot^{-1}) was recorded in N omitted pots followed by P (0.16 g pot^{-1}) omission pots. The similar findings were also reported by Kumar et al. (2018a), Kumar et al. (2018b) and Kumar et al. (2020).

Table 5: Total Ca, Mg and S uptake (g pot^{-1}) by rice in *Alfisol* of Kondagaon district

Treatments		Total uptake (g pot^{-1}) by rice		
		Ca	Mg	S
T_1	All	0.78	0.45	0.20
T_2	All-N	0.39	0.23	0.10
T_3	All-P	0.61	0.37	0.16

T_4	All-K	0.74	0.43	0.19
T_5	All-S	0.70	0.40	0.18
T6	All-Fe	0.75	0.42	0.18
T_7	All-Mn	0.76	0.43	0.20
T_8	All-Cu	0.75	0.42	0.20
T_9	All-Zn	0.72	0.42	0.19
T_{10}	All-B	0.70	0.40	0.18
T_{11}	All-Mo	0.75	0.42	0.21
	SEm (±)	**0.035**	**0.026**	**0.011**
	CD at 5% level	**0.104**	**0.077**	**0.032**

Micronutrients uptake by rice

The data in Table 6 showed the mean total uptake of micronutrients as influenced by different nutrient omission treatments.

Fe uptake

The maximum Fe uptake (23.3 mg pot^{-1}) was recorded in the treatment that received all the nutrients followed by Mn and Mo (22.9 mg pot^{-1}), K (22.6 mg pot^{-1}), Cu (22.2 mg pot^{-1}), Fe (22.0 mg pot^{-1}), Zn (21.7 mg pot^{-1}), S (21.5 mg pot^{-1}) and B (21.4 mg pot^{-1}) omission treatments and they are statistically at par with each other (Table 6). Omission of N, and P caused significant reductions in Fe uptake by rice and least Fe uptake (11.8 mg pot^{-1}) was found in N omission treatment followed by Fe uptake (18.6 mg pot^{-1}) in P omission treatment. The similar findings were also reported by Kumar et al. (2018a), Kumar et al. (2018b) and Kumar et al. (2020).

Mn uptake

The highest Mn uptake (32.9 mg pot^{-1}) was associated with Mo omitted pots followed by the treatment that receive all the nutrients (33.0 mg pot^{-1}), Mn (32.3 mg pot^{-1}), Fe (32.0 mg pot^{-1}), K (31.8 mg pot^{-1}), Cu (31.6 mg pot^{-1}), Zn (31.2 mg pot^{-1}), B (30.8 mg pot^{-1}) and S (30.4 mg pot^{-1}) omitted treatments and all were at par with each other (Table 6). The lowest Mn uptake (16.3 mg pot^{-1}) was observed in the treatment that didn't receive N (T2). Omission of N and P caused significantly lower uptake of Mn as compared to treatment receiving all nutrients. The similar findings were also reported by Kumar et al. (2018a), Kumar et al. (2018b) and Kumar et al. (2020).

Zinc uptake

The highest Zn uptake (4.56 mg pot^{-1}) was found in Mn omission treatment followed by Mo omission (4.55 mg pot^{-1}), All, treatment that received all the nutrients (4.52 mg pot^{-1}), Fe and Cu omission (4.49 mg pot^{-1}), K (4.48 mg pot^{-1}), Zn (4.33 mg pot^{-1}), Mo (4.26 mg pot^{-1}) and S (4.24 mg pot^{-1}) omission treatments and they were at par with each other (Table 6). Lowest Zn uptake (2.30 mg pot^{-1}) was recorded in the treatment T_2 that didn't receive N. Omission of N and P caused significantly lower uptake of Zn as compare to treatment receiving all nutrients. The similar findings were also reported by Kumar et al. (2018a), Kumar et al. (2018b) and Kumar et al. (2020).

Cu uptake

The total uptake of Cu varied with different nutrient omission treatments (Table 6). The highest uptake of Cu (0.92 mg pot^{-1}) was registered in treatment that received all nutrients and Mn omitted treatment and they were closely followed by omission of K and Mo (0.91 mg pot^{-1}). The significantly reduced uptake of Cu (0.47 mg pot^{-1}) was found in N omission treatment followed by P (0.47 mg pot^{-1}) omission treatment as compared to the treatment that received all nutrients. The similar findings were also reported by Kumar et al. (2018a), Kumar et al. (2018b) and Kumar et al. (2020).

B uptake

The highest B uptake (1.33 mg pot^{-1}) was associated with the treatment that received all the nutrients followed by K, Mn, Mo, Fe, Cu, S, Zn, and B omitted pots and was statistically at par with each other (Table 6). Lowest B uptake (0.64 mg pot^{-1}) was observed in the treatment missing N (T2). Omission of N and P caused significantly lower uptake of B as compared to the treatment receiving all nutrients. The similar findings were also reported by Kumar et al. (2018a), Kumar et al. (2018b) and Kumar et al. (2020).

Table: 6. Total uptake of Fe, Mn, Zn, Cu, and B (mg pot^{-1}) by rice (MTU 1001) in *Alfisol* of Kondagaon district

Treatments		Total uptake of micronutrients (mg pot^{-1}) by rice				
		Fe	Mn	Zn	Cu	B
T_1	All	23.3	32.9	4.52	0.92	1.33
T_2	All-N	11.8	16.3	2.30	0.47	0.64
T_3	All-P	18.6	26.6	3.71	0.74	1.01
T_4	All-K	22.6	31.8	4.48	0.91	1.30
T_5	All-S	21.5	30.4	4.24	0.86	1.22
T6	All-Fe	22.0	32.0	4.49	0.89	1.26

T_7	All-Mn	22.9	32.3	4.56	0.92	1.30
T_8	All-Cu	22.2	31.6	4.49	0.90	1.26
T_9	All-Zn	21.7	31.2	4.33	0.86	1.22
T_{10}	All-B	21.4	30.8	4.26	0.86	1.20
T_{11}	All-Mo	22.9	33.0	4.55	0.91	1.29
SEm (±)		**1.11**	**1.29**	**0.21**	**0.04**	**0.06**
CDat5%level		**3.29**	**3.81**	**0.63**	**0.11**	**0.16**

Field verification of identified yield limiting nutrients

Based on the response of rice crop to nutrient omission treatments during *Kharif* season 2017, the yield limiting nutrients were identified in *Alfisol* of Kondagaon district. The yield limiting nutrients identified in *Alfisol* of *Kondagaon* district were N and P. These identified yields limiting nutrients were verified in a field verification trial at farmers field, from where the bulk soil was collected for pot experiment, through applying these nutrients @ 150 kg N and 100 kg P_2O_5 ha^{-1} in wheat crop variety: GW-273 during *rabi* season 2017-18. This dose is also known as SSNM dose.

The wheat crop was sown on 14th Dec 2017 and harvested on 14th April 2018. The farmer's used fertilizer doses at the rate of 80 kg N: 50 kg P_2O_5: 30 kg K_2O ha^{-1}. The final grain yields of wheat at farmer's fields under both the doses were recorded and the comparison is presented in Table 7.

Grain yield and economics of wheat crop

The wheat grain yields (Table 7) at farmer's fields were higher in SSNM dose applied, based on yield limiting nutrients, as compared to that of farmer's practice dose. The economic analysis of both the fertilizer doses reveled that the SSNM dose had higher gross return, net return and B: C ratio as compared to farmers practice dose. The similar findings were also reported by Kumar et al. (2018a), Kumar et al. (2018b) and Kumar et al. (2020).

This result confirms that the yield limiting nutrients nitrogen and phosphorus identified in *Alfisol* of *Kondagaon* district in pot culture experiment were the yield limiting nutrients and the SSNM dose based of yield limiting nutrients, was economically profitable to the farmers.

Table 7: Grain yield and economics of wheat in relation to SSNM and Farmer's dose in *Alfisol* of *Kondagaon*

S. No.	Nutrient Dose	Yield (q ha^{-1})	Cost of cultivation	Gross return	Net return	B:C ratio
1	SSNM	30.7	32214	61400	29186	1.91
2	FFD	25.8	27869	51600	23731	1.85
Difference		4.9	4345	9800	5455	0.05
% Change		19.0	15.6	19.0	23.0	2.9

CONCLUSION

The results can be summarized that nitrogen and phosphorus was identified as yield limiting nutrients in Alfisol of Kondagaon and the site specific nutrient management dose based on these yield limiting was found economically profitable.

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