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RESEARCH PAPER

Effect of graded levels of nitrogen on micronutrient content, uptake and yield of paddy in Vertisols of TBP command

C.P. SANKALPA* AND J. VISHWANATH
Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, RAICHUR (KARNATAKA) INDIA (Email : sankalpacp@gmail.com)

Abstract : A field experiment was conducted during *Kharif* 2012 to study the effect of graded levels of nitrogen on micronutrient content, uptake and yield of paddy in Vertisols of TBP command at Agricultural Research Station, Gangavati. The experiment was laid out in Factorial Randomized Block Design with five treatments and three replications each. There were five levels of N (RDN, 20% extra RDN, 40% extra RDN, 60% extra RDN and 80% extra RDN) and paddy varieties (GGV-05-01 and BPT-5204) were grown with a spacing of 20 × 10 cm and following standard agronomic cultural practice. Plant height and number of tillers increased with the application of N up to 60 per cent extra RDN. Variety GGV-05-01 recorded higher plant height whereas higher number of tillers was recorded by BPT-5204. Yield attributes (panicle length, weight and test weight) and grain yield increased with increasing levels of N up to N_3 (RDF + 40% additional N) and the increase in grain yield (53.46 q ha^{-1}) was 5.7 per cent higher over control (RDF) (50.56 q ha^{-1}). GGV-05-01 recorded the highest grain yield (54.53 q ha^{-1}) compared to BPT-5204 (51.07 q ha^{-1}). The straw yield increased significantly up to N_5 (RDF + 80% additional N). The macro and micro nutrient content and uptake increased with increasing levels of N up to N_5 or N_4. GGV-05-01 recorded higher Fe and Cu content and uptake in grain compared to BPT-5204.

Key Words : Paddy, Nitrogen levels, Micronutrient uptake, Yield

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INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food for 65 per cent of the total population in India and is consumed by more than one half of the world's population (Ma *et al.*, 2007). It constitutes about 41.5 per cent of the total grain food production and 55 per cent of total cereal population (Yadav *et al.*, 2010). India has largest area under rice cultivation with an area of 44.40 million hectare and production of 104.32 million tonnes next to China. In Karnataka rice is cultivated in an area of 1.54 million hectare with an annual production of 3.9 million tonnes and productivity of 2974 kg ha^{-1} (Anonymous, 2010). The current global population of 6.4 billion is expected to reach 7.5 billion by 2020 and 9.0 billion by 2050 AD. According to Dobermann and Witt (2003), it will be necessary for rice yields in Asia to be increased by 25 per cent per annum between 2010 and 2020.

Gangavati in Tunga Bhadra Project (TBP) command area is called as 'Rice Bowl of Karnataka'. Nearly 60-65 per cent of 3.63 lakh ha of the command in Karnataka (comprising Bellary, Koppal and Raichur districts) is under paddy. Paddy is the maximum consumer of nitrogenous fertilizer constituting 1/3rd of the total nitrogen (N) consumption of the world. Thus, nitrogen is the most critical input that most frequently limits

* Author for correspondence

rice production and is the key input in nutrient management (Devi *et al*., 2012). In TBP command, intensive rice-rice cropping system involving twice or thrice the recommended dose of major nutrients, especially N with little or no organic resources is being practiced (Reddy, 2004) which has resulted in the decreased yields or attaining plateau in parts of the command. Micronutrient deficiency is also considered as one of the major causes of the declining productivity trends observed in rice growing countries. As reported by Rashid *et al*. (2004) even though micronutrients are required in relatively smaller quantities for plant growth, they are as important as macronutrient in rice production to obtain optimum yield and balanced nutrition. Ozanne (1955) and Loneragan and Webb (1993) reported that nitrogen application to the soil accelerates vegetative growth of plants and this may lead to Zn, Fe, Mn and Cu deficiency in soil.

It is reported that presence of major nutrients affect crop uptake of micronutrient due to either negative or positive interactions (Kumar and Babel, 2011). Although the effect of N fertilization on micronutrient deficiency has seldom been studied, several publications suggest that management of N fertilizer could affect the soil availability and grain micronutrient status. However, such information is not available for TBP command where rice is the staple food and nitrogenous fertilizers are being applied excessively. Hence, the present study was conducted to study the effect of graded levels of N on micronutrient uptake, growth parameters and yield of paddy in a Vertisol of TBP command.

MATERIAL AND METHODS

A field experiment was conducted during *Kharif* 2012 at Agricultural Research Station, Gangavathi situated on the latitude of 15^{0}-150^{1}-40^{11} North (latitude), longitude of 76^{0}-31^{1} -40^{11} East with an altitude of 419 meters above mean sea level and is located in North Eastern Dry Zone (Zone 3) of Karnataka. The soils of the experimental site was medium Vertisols derived from grainite-gneisses containing lime/soda-lime feldspar that are basic in nature.

The experiment was laid out in a Factorial Randomized Completely Block Design with five treatments (RDN, 20 % extra RDN, 40 % extra RDN, 60 % extra RDN and 80 % extra RDN) and replicated thrice and two varieties (GGV-05-01 and BPT-5204) were grown with spacing of 20 × 10 cm and following standard cultural practices as per package of practices.

Prior to the initiation of the experiment soil samples were collected to a depth of 30 cm with an increment of 15 cm and analyzed for basic properties *viz*., pH, ECe, OC, available NPK, Ca, Mg, S and Zn, Fe, Mn and Cu by following standard procedures. The data plant height and number of tillers at different physiological stages, plant nutrient content, grain and straw yield, yield-attributing characters (panicle length and weight and test weight) were collected. Grain and straw samples were also analyzed for their macro and micro nutrient content after digestion and following standard procedure.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Initial soil nutrient status:

The data on initial soil status is presented in Table 1. Average soil nutrient status indicated that pH was near neutral at 0-15 (pH 7.95) and 15-30 cm (pH 8.19) soil depths with slightly higher soil pH at lower compared to upper soil. Soluble salt contents in soils as indicated by ECe were less than 4 dS m^{-1} at the time of sampling at both depths (1.09 and 1.25 dSm^{-1} at 0-15 and 15-30 cm depths, respectively). Organic carbon (OC) content of the surface soil (0-15 cm) was higher (9.23 g kg^{-1}) than the subsurface soil (15-30 cm) (6.70 g kg^{-1}) as root biomass, decaying previous crop residues, FYM and other organic manure etc. added routinely add up to higher OC status in surface soil. Available N in surface soil (160 kg ha^{-1}) was greater than the subsurface soil (133 kg ha^{-1}) and the soils were low in available N both in surface and subsurface soil as per soil fertility ratings (< 280 kg ha^{-1}) (Tandon, 2005). Paul (2011) also reported lower initial available N status in soils of ARS, Gangavathi. Available phosphorus (P_2O_5) in surface soil (121 kg ha^{-1}) was greater than the subsurface soil (110 kg ha^{-1}) and the soils were high in P_2O_5 content both in surface and subsurface soil as per soil test rating (>55 kg ha^{-1}). Paul (2011) also reported a high initial available soil P_2O_5 contents varying from 101.2 to 136.4 kg ha^{-1} and 96.8 to 131.2 kg ha^{-1} in 0-15 and 15-30 cm soil depths at ARS, Gangavathi. Available potassium (K_2O) in surface soil (266 kg ha^{-1}) was greater than the subsurface soil (243 kg ha^{-1}) and the soils were medium in K_2O content both in surface and subsurface soil as per soil test rating (141-336 kg ha^{-1}). Paul (2011) also reported higher initial soil available K_2O in these soils. Patil and Sonar (1993), Kapoor *et al*. (1981) and Pal (1985) stated that in high pH soils as in the present study there could be greater dissolution of K bearing minerals leading to high K status. Available S in surface soil (18 ppm) was more than the subsurface soil (15.8 ppm) and the soils were medium (10-50 ppm) in sulphur content both in surface and sub surface soil.

Irrespective soil depths, initial average of exchangeable Ca and Mg in surface and subsurface soils were in high category as per soil test rating (>1000 and > 500 ppm, respectively). The findings are in agreement with the results of Paul (2011). As soil pH increases from neutral to alkaline the availability of exchangeable Ca and Mg increases gradually (Bacchewar and Gajbhiye, 2011). Higher Ca content in subsurface soil might be due to leaching, accumulation and precipitation of displaced Ca in the lower layers (Pathak and

Patel, 1980).

Initial average DTPA-Zn in surface soil (1.54 ppm) was greater than the subsurface soil (0.69 ppm). Initial average DTPA-Fe in surface soil (7.26 ppm) was greater than the subsurface soil (4.72 ppm) and the values were medium (2.5-10 ppm) as per soil test rating and were also above the critical level (*i.e.*, 2.5-4.5 ppm) which is considered to be optimum for paddy yields (Randhawa, 1978). Initial average DTPA-Mn in surface soil (5.44 ppm) was greater than the subsurface soil (2.66 ppm) and the values were medium (5-25 ppm) and low (<5 ppm) in surface and subsurface soils, respectively as per soil test rating. However, the DTPA-Mn at both the depths was above the critical level (1.0 ppm) identified for optimum rice yields (Randhawa, 1978). Initial average DTPA-Cu in surface soil (3.6 ppm) was greater than the subsurface soil (1.2 ppm) and the values were high (>2.5 ppm) and medium (<1.0-2.5 ppm) in surface and subsurface soils, respectively as per soil test rating. However, the DTPA-Cu at both the depths was above the critical level (0.2 ppm) identified for optimum rice yields (Randhawa, 1978).

Growth parameter and yield attributes:

Growth parameters :

Plant height increased across different physiological stages of crop *viz.*, active tillering (AT), panicle initiation (PI) and flowering (FL) (Table 2). At all the growth stages either N_4 (59.1, 76.2 and 82.7 cm) or N_5 (58.5, 79.4 and 85.5 cm) had significantly the highest plant height compared to other treatments however N_4 and N_5 were at par. Plant height responded to the increased levels of N up to N_4. This could be due to enhanced uptake of other nutrients like P and K and micronutrients which are depleted to a greater extent in soil in these treatments (data not shown) would have resulted in increased vegetative growth of plant with higher levels of N supplied to plant. The results are in agreement with the findings of Manzoor *et al.* (2006) and Chathurvedi (2005) who attributed to the enhanced leaf area resulting in more dry matter accumulation with increased availability of soil N because N has a significant influence on the vegetative growth of plant (Rojas *et al.*,1983 and Shukla *et al.*,1993). At all three stages, plant height varied significantly between varieties. The variety GGV-05-01 (62.5, 78.1 and 92.7 cm, respectively) had significantly higher plant height compared to BPT-5204 (51.2, 70.4 and 71.5 cm, respectively) at AT, PI and FL. No significant difference was observed among the interaction between levels of N and variety.

Number of tillers at AT stage increased with increased levels of N which might be attributed to more N supply to plant at active tillering stage (Kumar *et al.*, 2006). Wijebandara *et al.* (2007) reported that the availability of required quantity of N for long time was probably responsible for producing more number of effective tillers as is the case with higher levels of N applied in the present study. Among the N levels, N_3, N_4 and N_5 were at par (Table 2) with the maximum number of tillers observed in N_4 (15.8) reflecting that increase number of tillers could be expected up to the application of N_3. Kumari *et al.* (2000) also reported increase in number of productive tillers up to a certain level of N (120 kg ha^{-1}) and not beyond that. The results are in agreement with the findings of Manzoor *et al.* (2006), Guindo *et al.* (1994) and Wijebandar (2007). Between the varieties, BPT-5204 (15.7) recorded significantly higher number of tillers as compared to GGV-05-01 (13.6). Consequently, N_4V_2 (60% N in excess of RDN and BPT-5204) recorded significantly higher number of tillers (16.2) which

Table 1 : Soil chemical properties of experiment site

Soil properties	0-15 cm		15-30 cm	
	Range	Average	Range	Average
Soil pH (1:2.5 soil water extract)	7.85-8.09	7.95	8.01-8.44	8.19
Electrical conductivity, ECe (1:2.5 soil water extract) (dS m^{-1})	0.78-1.35	1.09	0.91-1.64	1.25
Organic carbon (g kg^{-1})	7.28-10.48	9.23	5.24-8.44	6.70
Major nutrients (kg ha^{-1})				
Available nitrogen	140-196	160	112-168	133
Available phosphorous (P_2O_5)	107-137.4	121	96.2-125.9	110
Available potassium (K_2O)	242-313	266	205-262	243
Secondary nutrients (ppm)				
Exchangeable calcium	6242-6920	6518	6440-6960	6778
Exchangeable magnesium	564-972	728	648-1368	1080
Available sulphur	16.5-20.5	18.0	13.0-17.25	15.8
DTPA extractable micronutrient (ppm)				
Zinc	1.10-1.91	1.54	0.34-1.08	0.69
Iron	5.15-9.21	7.26	3.08-8.18	4.72
Manganese	4.09-6.82	5.44	1.55-5.36	2.66
Copper	3.11- 4.15	3.60	0.54-2.29	1.20

was at par with N_4V_1 (15.5), N_5V_1 (15.2), N_5V_2 (15.2).

Yield attributes :

Panicle length and weight increased with increasing levels of N. Treatment N_4 and N_5 recoded significantly higher panicle length and weight compared to N_1, N_2 and N_3 which is at par among them. Between the varieties GGV-05-01 recorded significantly higher panicle length (21.0 cm) and weight (23.7 g) compared to BPT-5204. Among the interactions N_4V_1 (26.10 g) recorded significantly higher panicle weight as compared to rest of the interactions except N_5V_1 (25.5 g).

Test weight also increased with increasing levels of N up to N_3 (12.62 g) which was significantly higher as compared to N_1 (11.35 g) and N_2 (11.34 g) but on par with N_4 (12.15 g) and N_5 (12.05 g). Between the varieties, GGV-05-01 recorded significantly higher test weight (12.22 g) as compared to BPT-5204 (11.58 g). No significant differences were observed due to interaction effect.

Grain and straw yields :

Application of N significantly enhanced the grain and straw yield of rice crop. Grain yield significantly increased with increasing levels of N up to the treatment N_3 which was 5.7 per cent higher (53.46 q ha^{-1}) and 2.9 per cent lower grain yield compared to control (50.56 q ha^{-1}) and N_4 (RDF + 60% additional N) (55.01 q ha^{-1}), respectively. Higher grain yield at increased levels of N to the extent of 40 per cent and beyond RDN could be related to the higher availability of N and Zn in soil (data not shown) with increased application of N (Liu *et al.*, 2005).

Variety GGV-05-01 recorded (54.53 q ha^{-1}) significantly 6.8% higher grain yield as compared to BPT-5204 (51.07 q ha^{-1}). Straw yield increased with increasing levels of N up to N_5 and significantly higher straw yield in N_5 (78.4 q ha^{-1}) compared to N_3 and N_4 could be attributed to the reason that any additional dose of N applied here in this case beyond 40 per cent of RDN might have been utilized for enhancing straw production rather than grain. Variety BPT-5204 recorded significantly higher straw yield (70.8 q ha^{-1}) compared to GGV-05-01 (65.8 q ha^{-1}). Higher straw yield and lower grain yield was observed in BPT-5204 compared to GGV-05-01 though the former had significantly more number of tillers.

Table 2 : Growth parameters of rice crop at different physiological stages as influenced by different treatments

Treatments	Plant height			No. of tillers at active tillering
	Active tillering	Panicle initiation	Harvesting	
Nitrogen levels				
N_1 :Control	54.5	69.8	79.2	14.2
N_2: RDF + 20% additional N	55.8	71.2	80.7	13.7
N_3: RDF + 40% additional N	56.3	74.8	82.5	14.6
N_4: RDF + 60% additional N	59.1	76.2	82.7	15.8
N_5: RDF + 80% additional N	58.5	79.4	85.5	15.2
S.E. ±	0.70	1.44	0.96	0.42
C.D. (P=0.05)	2.08	4.28	2.84	1.24
Variety				
V_1 : GGV-05-01	62.5	78.1	92.7	13.6
V_2 : BPT-5204	51.2	70.4	71.5	15.7
S.E. ±	0.44	0.91	0.61	0.26
C.D. (P=0.05)	1.32	2.71	1.80	0.79
Interaction				
N_1V_1	60.8	72.6	89.1	12.5
N_1V_2	48.3	67.0	69.3	15.9
N_2V_1	60.8	73.8	90.9	11.9
N_2V_2	50.8	68.7	70.5	15.4
N_3V_1	61.8	81.0	93.1	13.2
N_3V_2	50.9	68.5	72.0	16.0
N_4V_1	65.2	78.9	93.5	15.5
N_4V_2	53.1	73.5	72.0	16.2
N_5V_1	64.1	84.3	97.1	15.2
N_5V_2	52.8	74.4	73.93	15.2
S.E. ±	0.99	2.04	1.35	0.59
C.D. (P=0.05)	NS	NS	NS	1.76

NS: Non significant

Nutrient content and uptake in grain and straw :

Macronutrient (N, P and K) :

Nitrogen, P and K content and uptake in grain and straw increased with increasing levels of N which may be attributed to greater depletion of soil nutrients (data not shown) across the growth stages with enhanced dry matter production under high levels of soil N (Table 4). The results are in conformity with the findings of Pande *et al*. (1985) who reported that uptake of nutrients followed the trends of dry matter production which, in turn, was influenced by application of N. Nitrogen, P and K contents in grain and straw were significantly higher at N_5 compared to the rest of the treatments except N_4 which was at par with N_5. The contents and uptake of N, P and K in grain in N_4 was 1.63, 0.56, 0.62 per cent and 83.8, 30.7, 34.2 kg ha^{-1} and in straw 0.58, 0.068, 1.57 per cent and 41.5, 4.93, 112.7 kg ha^{-1}, respectively. In comparison to control, N_4 had 30.6, 60.0 and 12.7 per cent more NPK content in grain and 36.7, 75.4, 23.0 per cent more NPK uptake, respectively. The N, P and K contents and uptake were in accordance with the yield obtained with different levels of N applied wherein increased grain and straw yields were associated with increased contents and uptake of these major nutrients. However, though there were significant differences in content and uptake of N, P and K in grain at 40, 60 and 80 per cent excess of RDN, this has not resulted in significant increase in grain yield among these levels. The results are in agreement with the findings of Devi *et al*. (2012) who also reported that uptake of nutrients especially N by rice was more at 175 kg ha^{-1} as against 100, 125 and 150 kg ha^{-1} though the yields were significantly higher at 150 kg N ha^{-1}.

In general, neither varieties nor the intenarctive effects of N and variety showed significant difference with respect to content and uptake of N, P and K in grain and straw though V1 had significantly 6.7 per cent higher compared to V_2. This may be attributed to the significant difference in straw yield wherein V_2 had nearly 7.6 per cent more compared to V_1.

Micronutrients (Zn, Fe, Mn and Cu) :

The Zn and Fe content in grain increased with increase in levels of N applied (Table 5). The treatment N_5 had significantly higher Zn (25.3 ppm) and Fe (231.5 ppm) content over other treatments. The increase in Zn and Fe content in

Table 3 : Yield and yield attributes of rice crop as influenced by different treatments

Treatments	Panicle length (cm)	Panicle weight (g)	Test weight (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
Nitrogen levels					
N_1 :Control	18.5	18.7	11.35	50.56	61.1
N_2: RDF + 20% additional N	18.2	17.7	11.34	51.96	64.6
N_3: RDF + 40% additional N	18.6	22.0	12.62	53.46	65.4
N_4: RDF + 60% additional N	19.5	24.2	12.15	55.01	72.0
N_5: RDF + 80% additional N	19.5	24.3	12.05	53.01	78.4
S.E. ±	0.35	0.374	0.25	0.72	2.09
C.D. (P=0.05)	1.03	1.113	0.74	2.13	6.22
Variety					
V_1 : GGV-05-01	21.0	23.7	12.22	54.53	65.8
V_2 : BPT-5204	16.7	19.1	11.58	51.07	70.8
S.E. ±	0.22	0.24	0.16	0.45	1.32
C.D. (P=0.05)	0.65	0.70	0.47	1.35	3.93
Interaction					
N_1V_1	20.7	22.8	11.53	51.21	62.1
N_1V_2	16.2	14.6	11.17	49.92	60.1
N_2V_1	20.3	21.6	11.74	54.16	62.9
N_2V_2	16.1	13.8	10.93	49.76	66.3
N_3V_1	20.2	22.5	12.60	55.24	60.3
N_3V_2	17.1	21.4	12.64	51.68	70.4
N_4V_1	21.8	26.1	13.05	56.82	69.1
N_4V_2	17.2	22.3	11.25	53.20	74.9
N_5V_1	22.1	25.0	12.19	55.22	74.6
N_5V_2	17.0	23.2	11.91	50.81	82.2
S.E. ±	0.50	0.530	0.35	1.017	2.959
C.D. (P=0.05)	NS	1.57	NS	NS	NS

NS: Non significant

grain in N_5 was from 8.5 (N_4) to 23.6 per cent (N_2) and 9.8 (N_4) to 45.5 per cent (N_1), respectively compared to rest of the treatments. The Zn and Fe content in straw increased however with increase in levels of N up to N_3 only (47.5 and 313.5 ppm, respectively) and decreased later on with N_4 and N_5. The increase in Zn and Fe in straw in N_3 was from 7.2 (N_2) to 11 per cent (N_1) and 10.1 (N_4) to 21.4 per cent (N_5), respectively. Between the varieties Zn content in grain and straw was significantly higher (4.1 and 3.8%) in V_2 (22.7 ppm) compared to V_1 (21.8 ppm) whereas, Fe content in grain (215.8 ppm) and straw (268.8 ppm) was significantly higher (25.9 and 16.0%) in V_1 compared to V_2. Hao *et al*. (2007) in a study of the effects of N levels on concentrations of micronutrients (Fe, Mn, Cu and Zn) in shoot and the quality of rice also observed that the concentrations of the microelements in plant differed, suggesting that the characteristic expression of the two rice genotypes was not controlled by the amount of N fertilizer supplied. Pinasen *et al*. (2007) also shown that grain Fe content may vary between the varieties and the level of genetic variation need be considered when assessing for traits such as grain Fe for breeding programs. There was no significant difference due to interaction between levels of N and variety with respect of Zn content in grain and straw. In case of Fe, significant difference was observed where N_5V_1 and N_2V_2 recorded significantly higher Fe content (247.9 ppm) and uptake (349.8 ppm), respectively in grain and straw. The increase in grain and straw in N_5V_1 and N_2V_2 was from 2.7 (N_4V_1) to 77 per cent (N_1V_2) and 0.5 (N_3V_2) to 44.2 per cent (N_4V_1), respectively over rest of the treatments.

Zinc and Fe uptake in grain increased significantly with

Table 4 : Nitrogen, phosphorus and potassium content (%) and uptake (kg ha^{-1}) by rice as influenced by different treatments

Treatments	Nitrogen				Phosphorous				Potassium			
	Content		Uptake		Content		Uptake		Content		Uptake	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Nitrogen levels												
N_1: Control (NPK: 150:75:75 kg ha^{-1})	1.21	0.47	61.3	28.9	0.35	0.053	17.5	3.23	0.55	1.34	27.8	81.7
N_2: RDF (NPK: 150:75:75 kg ha^{-1}) + 20% Extra N	1.27	0.47	66.2	30.6	0.41	0.062	21.1	3.97	0.56	1.43	28.9	92.2
N_3: RDF (NPK: 150:75:75 kg ha^{-1}) + 40% Extra N	1.42	0.54	75.8	35.4	0.48	0.065	25.5	4.22	0.57	1.46	30.7	95.3
N_4: RDF (NPK: 150:75:75 kg ha^{-1}) + 60% Extra N	1.53	0.58	83.8	41.5	0.56	0.068	30.7	4.93	0.62	1.57	34.2	112.7
N_5: RDF (NPK: 150:75:75 kg ha^{-1}) + 80% Extra N	1.58	0.63	83.8	49.1	0.59	0.069	31.3	5.44	0.60	1.54	31.6	120.7
S.E.±	0.03	0.02	1.72	1.49	0.01	0.001	0.90	0.20	0.02	0.032	0.93	3.69
C.D. (P=0.05)	0.10	0.05	5.10	4.43	0.046	0.004	2.68	0.6	0.05	0.09	2.76	11.0
Variety												
V_1: GGV-05-01	1.38	0.52	75.4	34.8	0.48	0.065	26.5	4.30	0.57	1.51	30.9	99.6
V_2: BPT-5204	1.43	0.55	72.9	39.4	0.47	0.062	23.9	4.42	0.59	1.42	30.3	101.4
S.E.±	0.02	0.01	1.09	0.94	0.01	0.009	0.57	0.13	0.01	0.02	0.58	2.3
C.D. (P=0.05)	NS	NS	NS	2.80	NS	0.003	1.70	NS	NS	0.06	NS	NS
Interaction												
N_1V_1	1.24	0.43	63.6	27.0	0.33	0.055	16.7	3.43	0.52	1.43	26.6	88.7
N_1V_2	1.18	0.51	68.9	30.8	0.37	0.050	18.3	3.03	0.57	1.24	28.5	74.7
N_2V_1	1.26	0.46	68.5	28.7	0.43	0.067	23.0	4.19	0.54	1.44	29.4	90.6
N_2V_2	1.28	0.49	63.8	32.5	0.39	0.057	19.2	3.75	0.57	1.41	28.5	93.7
N_3V_1	1.37	0.50	75.5	30.3	0.50	0.064	27.4	3.85	0.56	1.48	30.8	88.9
N_3V_2	1.47	0.57	76.5	40.4	0.46	0.065	23.6	4.59	0.59	1.44	30.6	101.7
N_4V_1	1.46	0.58	83.0	40.0	0.56	0.069	32.0	4.75	0.61	1.63	34.6	112.3
N_4V_2	1.59	0.57	84.7	42.9	0.55	0.068	29.3	5.10	0.63	1.51	33.3	113.0
N_5V_1	1.57	0.64	86.5	47.8	0.61	0.071	33.5	5.28	0.60	1.58	33.2	117.3
N_5V_2	1.60	0.61	81.1	50.3	0.57	0.068	29.1	5.61	0.59	1.51	30.0	124.0
S.E.±	0.05	0.02	2.43	2.11	0.02	0.002	1.28	0.28	0.02	0.045	1.31	5.22
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS=Non-significant

increase in levels of N applied up to N_4 only (Table 5). The treatment N_4 (23.1 g ha^{-1} and 1165 g ha^{-1}) had 10.6 (N_3) to 23.1 per cent (N_1) and 9.1 (N_3) to 44.5 per cent (N_1) higher Zn and Fe uptake in grain, respectively. Zinc uptake in straw also increased significantly with increase in levels of N applied up to N_4 only which may be attributed to increase in dry matter and content of nutrient in grains. The treatment N_4 (341.4 g ha^{-1}) had 10.0 (N_3) to 30.8 per cent (N_1) higher Zn uptake in grain. Iron uptake in straw increased significantly only up to N_2 (2031 g ha^{-1}) which was 18.0 per cent more than N_1 (control).The BPT-5204 (V_2) had significantly higher Zn (327.3 g ha^{-1}) and Fe (2198.2 g ha^{-1}) uptake in straw compared to GGV-05-01, respectively. No significant interaction effect was observed for Zn uptake in straw. The treatment N_3V_2 (2456.3 g ha^{-1}) had 15.1 (N_5V_2) to 50.4 per cent (N_1V_2) significantly higher Fe uptake in straw.

The Mn and Cu content in grain also increased but only up to certain level of N applied *i.e.*, N_3. The treatment N_3 had significantly higher Mn (66.0 ppm) and Cu (3.81 ppm) content over N_2 and N_1. The increase in Mn and Cu content in grain in N_3 was from 11.9 (N_1) to 8.6 per cent (N_2) and 32.3 (N_1) to 11.7 per cent (N_2). Treatment N_3 (317.1 ppm) and N_4 (2.74 ppm) had significantly higher Mn and Cu content in straw over N_1 and N_2 and N_1, N_2 and N_3, respectively. Manganese uptake in grain and straw increased with increasing level of N up to N_3 (353.6 and 20.4 g ha^{-1}) and was significantly higher than N_1 and N_2 only. Treatment N_3 had 19.9 (N_1) to 11.9 per cent (N_2) and 49.6 (N_1) to 17.0 per cent (N_2) more Mn uptake in grain and straw, respectively. Treatment N_3 (20.4 and 16.5 g ha^{-1}) had 39.7 (N_1) to 14.6 per cent (N_2) and 98 (N_1) to 20 per cent (N_3) more Cu

Table 5 : Micronutrient content (ppm) and uptake (g ha^{-1}) of rice grain and straw as influenced by different treatments

Treatments	Zinc				Iron				Manganese				Copper			
	Content		Uptake		Content		Uptake		Content		Uptake		Content		Uptake	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Nitrogen levels																
N_1 :Control	20.6	42.8	104.0	261.1	159.2	281.9	806	1721	59.0	226.9	297.9	1385	2.88	1.63	14.6	10.0
N_2: RDF + 20% additional N	20.4	44.3	106.2	286.0	167.0	313.3	869	2031	60.8	274.2	315.9	1770	3.41	2.15	17.8	13.9
N_3: RDF + 40% additional N	21.6	47.5	115.7	310.4	198.5	313.5	1112	2064	66.0	317.1	353.6	2072	3.81	2.49	20.4	16.5
N_4: RDF + 60% additional N	23.3	47.4	128.0	341.4	210.8	284.6	1109	2059	68.2	302.3	375.6	2169	3.52	2.74	19.4	19.8
N_5: RDF + 80% additional N	25.3	44.8	133.7	350.6	231.5	258.2	1230	2023	68.2	271.8	361.1	2135	3.48	2.59	18.5	20.3
S.E.±	0.36	0.88	2.41	9.61	4.23	6.98	37.2	70.6	1.55	8.17	9.9	59.5	0.12	0.09	0.67	0.80
C.D. (P=0.05)	1.1	2.62	7.15	28.6	12.6	20.7	110.6	209.7	4.60	24.3	29.4	176.7	0.36	0.27	2.0	2.37
Variety																
V_1 : GGV-05-01	21.8	44.5	119.0	292.5	215.6	268.8	1190	1761	64.0	271.4	349.8	1783	3.85	2.17	21.0	14.4
V_2 : BPT-5204	22.7	46.2	116.0	327.3	171.2	311.7	861	2198	64.8	285.5	331.9	2030	2.99	2.47	15.3	17.7
S.E.±	0.23	0.56	1.52	6.08	2.68	4.41	23.5	44.65	0.98	5.17	6.26	37.6	0.08	0.06	0.43	0.53
C.D. (P=0.05)	0.68	1.66	NS	18.1	7.95	13.1	70.0	132.6	NS	NS	NS	111.7	0.23	0.17	1.26	1.50
Interaction																
N_1V_1	20.3	43.2	104.9	268.0	178.3	291.4	913	1808	55.0	225.2	280.9	1399	3.23	1.65	16.5	10.2
N_1V_2	20.8	42.3	103.9	254.2	140.0	272.3	699	1633	63.0	228.5	340.8	1371	2.53	1.62	12.6	9.8
N_2V_1	20.3	43.2	109.9	271.8	175.5	275.1	950	1730	60.0	259.2	325.1	1630	4.04	1.99	21.9	12.5
N_2V_2	20.6	45.3	102.4	300.3	158.6	351.6	788	2333	61.6	289.2	306.8	1910	2.77	2.30	13.8	15.3
N_3V_1	21.4	46.4	119.0	279.7	234.8	277.2	1386	1671	67.3	313.7	371.5	1889	4.22	2.21	23.3	13.3
N_3V_2	21.8	48.6	113.0	341.1	162.2	349.8	837	2456	64.9	320.6	335.6	2254	3.39	2.77	17.5	19.6
N_4V_1	22.6	45.7	128.6	316.1	241.3	243.9	1331	1686	69.9	300.5	397.4	2062	3.83	2.48	21.8	17.2
N_4V_2	23.9	49.0	127.3	366.7	180.2	325.3	887	2433	66.5	304.2	353.9	2278	3.21	3.00	17.0	22.4
N_5V_1	24.3	44.0	134.1	327.0	247.9	256.6	1368	1911	67.8	258.7	374.1	1934	3.92	2.55	21.6	19.0
N_5V_2	26.2	45.6	133.4	374.2	215.1	259.7	1093	2135	68.6	284.9	348.2	2336	3.05	2.64	15.5	21.6
S.E.±	0.52	1.25	3.40	13.6	5.99	9.87	52.7	99.83	2.19	11.5	14.0	84.1	0.17	0.13	0.95	1.13
C.D. (P=0.05)	NS	NS	NS	NS	17.8	29.3	156.5	296.6	NS	NS	NS	NS	NS	NS	NS	NS

NS: Non-significant

uptake in grain and straw, respectively. Between the varieties no significant difference observed with respect to Mn uptake in grain whereas V_1 recorded significantly higher Cu uptake in grain compared to V_2. BPT-5204 recoded significantly higher Mn and Cu uptake in straw compared to V_1. No significant difference was observed with respect to interaction of N levels and variety.

In general, Zn, Fe, Mn and Cu concentration and uptake in grain and straw increased with increase in the levels of N applied and then decreasing or maintaining after certain level of N. The results are in agreement with the findings of Hao *et al*. (2007) who revealed that the concentrations of Fe, Mn, Cu and Zn in most parts of rice shoot increased with increasing level of N fertilizer compared with control (no N fertilizer application) indicating that the transportation ability of microelements from root to shoot in rice was improved with N fertilizer application. Further, Hao *et al*. (2007) observed that perhaps micronutrient concentrations in grain increase with increasing N application rate but stop increasing and remain at the same level once some critical N rate is applied as noticed in the present study. Gao and Cynthia (2011) also reported that in a pot study where the soil was fertilized with 0.01 or 5.0 mg kg^{-1} Zn, increasing N supply not only increased root Zn uptake, but also increased the root-to-shoot translocation and remobilization of Zn to wheat grain. Prom-u-Thai and Rerkasem (2003) in an experiment to study the effect of nitrogen levels (0, 60 and 120 kg ha^{-1}) on iron concentration in rice grain in five genotypes found that nitrogen fertilizer generally increased N and Fe content of the rice.

Conclusion :

Application of increased levels of N resulted in increase in the grain Zn, Fe, Mn and Cu contents and uptake by crop. Accordingly, grain yield also increased with increased levels of N applied. According to genetic potential, varieties differed in their grain yield as there was no significant interaction effect. Significant difference in grain Fe content between the varieties and the effect of N in increasing its level needs to be noted as far as identifying varieties to overcome Fe malnutrition and appropriate level of N to be applied. Overall, with the soil condition under which the present study was conducted indicate that increased levels of N has beneficial effect on increasing grain yield to certain extent as long as the micronutrient availability in soil is above the critical level as observed in the present study.

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