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Macro- and Micronutrient Uptake in Rice + Cowpea Production System as Influenced by Mineral Nitrogen and Crop Population

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Abstract
The study was aimed at evaluating macro- and micronutrient uptake of rice and cowpea when grown in sole and mixture populations under varying levels of density (5x 10^4, 10x 10^4 and 20 x10^4plants/ha) and nitrogen (0,15,30 and 45kgN/ha), using urea as nutrient source. Results obtained showed that uptake of nitrogen increased with increasing rates of nitrogen fertilizer in both crops used for the study. In both sole and mixture populations, 45kgN/ha (50000plants/ha) and 30kgN/ha (200000plants/ha) recorded the lowest nitrogen uptake value of 0.12 and 0.14mg/plant respectively. Mean P uptake in the second in the cropping was reduced by 35.3% over the first cropping. Medium density of 100000plants/ha gave the highest K value of 0.45mg/ha during the first cropping. Uptake of potassium, phosphorus, sodium, calcium and magnesium and microelements were generally higher in cowpea than rice. Values of zinc uptake in shoots of both rice and cowpea were very low ranging from 0.00002 to 0.000075mg/plant in rice and 0.00011 and 0.0017mg/plant in cowpea. Increasing plant population density generally depressed uptake of both macro- and microelements in both rice and cowpea. Results from this study indicate that the high plant densities reduce nutrient uptake of crops, hence farmers should select optimum densities that will maximize crop nutrition and consequently yield.
Keywords: nutrient uptake, cowpea, rice, nitrogen fertilizer, plant population

INTRODUCTION

The growth of crops can be improved by application of fertilizer. Nitrogen (N) is an important essential nutrient element whose deficiency in the soil limits the growth of rice (Jacquoit and Courtois, 1987) and other cereals(Ghosh *et al.* 2006). Nutrient uptake of rice influences yields directly (Zhang and Wang, 2005). The effect of nitrogen on the yield of rice depends not only on the total uptake of nitrogen by the rice plant throughout the growing period, but also on the nitrogen uptake pattern i.e. the individual portions of nitrogen assimilated by the rice plant at different stages of growth (Zhu et al., 1983).

Usually transport of N is oriented acropetally, that is the direction of mobility is towards the apex of the plant and is transported up in the xylem. Thus, the ability of the crop to absorb, transport and accumulate the use of mineral elements depend on the fertility of the soil (Blaha, *et al*., 1997). Low soil fertility affects the stability of the crop shoot yield. Randall et al. (2006) reported that the inclusion of legumes such as cowpea and soybean in maize-based cropping systems were found to increase N supply.

In a related study, Gardner and Boundy (1983), observed that N, P and Mn contents of wheat intercropped with lupine were unaffected by intercropping. Shelton and Humphreys (1975) reported significantly reduced P content of rice intercropped with *Stylosanthes*, but had no effect on rice content. Aggarwal and Garrity (1987), also reported a 66% increase in rice N uptake per unit area of intercrop with legumes. They further observed a rise of 30% in N content in the rice grain from a cowpea/rice intercrop and a 37% from the rice/lablab intercrop.

The grain yield of the crop has a direct relationship with uptake of nutrients. Hence the aim of this study was to investigate the effect of N fertilizer and cropping density on the uptake of macro- and micronutrients of rice and cowpea planted sole and in mixtures.

MATERIALS AND METHODS

Two field experiments were conducted in the 2003 and 2004 planting seasons in the Delta State Agricultural Development (ADP) Research Farm at Agbarho (Lat. 35^0 34'N and Long. 5^0 53'E) in the wet humid rain forest zone of southern Nigeria. Mean monthly temperature, relative humidity and rainfall were 28^0C, 84% and 2116mm respectively for 2004.

The trial was made up of four N- fertilizer rates (0, 15, 30 and 45kgN/ha), three cropping densities (5 x10^4, 10x 10^4, and 20 x 10^4 plants/ha) and three cropping patterns (sole rice, sole cowpea and rice/cowpea mixture). In treatments with mixtures, rice and cowpea were planted in a 1:1 proportion. However, in the 2004 experiment no mineral fertilizer was applied. This was aimed at evaluating the residual effect of nitrogen fertilizer on the nutrient uptake of the crops. The three factors were combined in a 4x3x3 factorial experiment with three replications, and laid out in a randomized complete block design. Each plot had an area of $12m^2$. The crops used for the study were upland rice var. FARO 46 and cowpea var. Ife Brown.

Fresh plant shoots of rice and cowpea from plots were randomly selected and bulked based on treatments and dried in an oven at 65^{0}C till constant weight for dry matter. Total N analysis and elemental composition of macro- and micronutrients on dry matter basis were determined using methods described by AOAC (1990) after they had been dried in a stainless hammer mill with 1mm screen. The nutrient uptake for both rice and cowpea were determined as the product of the shoot dry matter and the concentration of the nutrient found in the plant material (Pal, 1991; Preetha *et al*., 2005).

RESULTS

Nitrogen uptake: Nitrogen uptake at 15kgN/ha, but higher rates of 30 and 45kgN/ha reduced N uptake in sole rice stand. However, in mixture rice populations, nitrogen uptake increased with increasing rate of applied fertilizer nitrogen up to 30kgN/ha. In both sole and mixture rice populations, 45kgN/ha (50000 plants/ha) and 30kgN/ha (200000 plants/ha) recorded the lowest nitrogen uptake value of 0.12 and 0.14 mg/plant respectively. N uptake in mixtures was generally higher than the sole rice crops. In mixture rice populations with applied nitrogen, N uptake was generally higher at low and medium population densities, but with the unfertilized rice plants, N uptake reduced with increasing density. N uptake values ranged from 0.11 to 0.26mg/plant in the second cropping season. Increasing plant population density reduced N-uptake in rice shoots (Table 1).

N uptake values for cowpea ranged from 0.32 to 14.43mg/plant and 0.48 to 12.32mg/plant in the first and second cropping seasons respectively. In both cropping seasons, N uptake reduced with increasing cowpea populations in the sole and mixture stands. N uptake in cowpea showed no consistent trend with rate of applied fertilizer nitrogen in both sole and mixture cowpea population (Table 2).

Phosphorus uptake: P uptake did not show any consistent relationship with increasing nitrogen application. However, increasing plant population density and intercropping with cowpea resulted in high P uptake in rice shoots for both cropping seasons. Mean P uptake in the second cropping was reduced by 35.3% over the first cropping (Table 1). In cowpea, no trend with nitrogen application rate was observed for both cropping seasons (Table 2). Range of P uptake in shoot was 0.67 to 3.28mg/plant and 0.48 to 2.67mg/plant in the first and second cropping respectively. P uptake in the mixture cowpea shoots was higher than the sole stands; and increasing population density reduced P uptake.

Potassium uptake: Applied fertilizer nitrogen increased K uptake in sole and mixtures of rice. While the range of values of K uptake in rice was 0.19 to 1.18mg/plant for the first cropping, the second cropping was between 0.80 to 3.69mg/plant. Second cropping had lower K uptake than the first. In sole rice stands, K uptake showed no consistent pattern with population density. There was no consistent relationship between rate of applied nitrogen and K uptake (Table 1).

Cowpea K uptake increased with increasing applied nitrogen in both sole and mixtures. Similar trend was also observed in the second cropping. K uptake in cowpea shoot ranged from 0.96 to 6.45mg/plant (first cropping) and0.80 to 3.69mg/plant (second cropping). High K uptake values were obtained in cowpea plants with low population density (Table 2).

Sodium uptake: Although increasing applied fertilizer nitrogen increased Na uptake in both sole and mixture rice populations, 45kgN/ha, appears to slightly depress sodium uptake. However, Na uptake showed consistent depression with residual nitrogen from the previous year's application. Lowest shoot Na uptake (0.05mg/plant) was obtained from sole rice of 30kgN/ha at low density (50000plants/ha), while the highest Na uptake value (0.39mg/plant) was from sole rice of 30kgN/ha at high density. Intercropping slightly raised rice Na uptake in both cropping seasons (Table 3).

Cowpea shoot uptake ranged from 0.24 to 1.06mg/plant and 0.27 to 1.99mg/plant in the first and second cropping respectively. Sodium uptake in the second cropping was increased by 8.0% on the average. Na uptake values in the cowpea shoot increased low plant population density in both cropping seasons. Intercropping with rice slightly raised Na uptake of cowpea (Table 4).

***Calcium uptake*:** Range of Ca uptake varied form 0.10 to 0.33mg/plant and 0.09 to 0.24mg/plant in first and second cropping seasons respectively for rice shoot. Increasing population density generally reduced Ca uptake in both cropping seasons (Table 3).

Calcium uptake in cowpea was very high ranging from 2.68 to 10.76 (first cropping) and 1.83 to 9.42 mg/plant (second cropping). Ca uptake decreased with increasing density. Intercropping cowpea with rice slightly depressed Ca uptake in cowpea in both seasons (Table 4)

Magnesium uptake: Although high densities (200,000 plants/ha) depressed Mg uptake in rice shoot, low densities generally recorded the lowest value of 0.05mg/plant, while medium density (100, 000 plants/ha) gave the highest value of 0.45mg/plant during the first cropping. Mg uptake in the second cropping ranged from 0.04 to 0.14mg/plant. Mg uptake in the second cropping was depressed by 40% over the first cropping on the average (Table 3).

Lowest Mg uptake value (0.19mg/plant) was obtained form the unfertilized cowpea at high plant population density (200,000plants/ha) while the highest value (5.60mg/plant) was observed on 30kgN/ha mixture cowpea with high plant population. However Mg uptake decreased with plant density, except mixed cowpea with 30 and

45kg/ha applied nitrogen, where Mg uptake increased with density (Table 4). Lowest value from second cropping was 0.38 mg/plant. This was obtained from first season unfertilized mixed cowpea plants. Highest value (3.38mg/plant) was recorded in mixtures of medium density (100,000 plants/ha) with previous 15kgN/ha application.

Iron uptake*:* Nitrogen application did not have any appreciable effect on Fe uptake of rice shoots. Similar trend was observed between Fe uptake and plant density or intercropping with cowpea. Uptake of iron was totally non –existent in about 50% of rice plants, as indicated by its absence in the tissues (Table 5). Highest value (0.061mg/plant) was observed in unfertilized plants, but it slightly increased in 0.063mg/plant in the same treatment in the following year. In cowpea, highest values of 3.67 and 2.74mg/plant were obtained for the first and second cropping seasons respectively.

Zinc uptake*:* Value of Zinc uptake in shoots of both rice and cowpea were very low. In rice, values range from 0.00002 to 0.00025mg/plant to 0.000075mg/plant in the first and second cropping seasons respectively. In cowpea shoots, highest values obtained were 0.00011 and 0.0017 mg/plant for the first and second cropping seasons respectively. Zinc uptake decreased with density in both rice and cowpea.

Copper uptake*:* Rice shoot Cu uptake ranged from 0.015 to 0.058mg/plant in the first cropping and 0.009 to 0.56 in the second cropping. Cu uptake in cowpea was higher with values ranging from 0.12 to 0.71mg/plant and 0.01 to 0.61mg/plant in the first and second cropping respectively. Generally, Cu uptake decreased with population density in both cropping seasons. (Tables 5 and 6)

DISCUSSION

Increased N-uptake with increasing nitrogen rate might be due to the aboveground mass at maturity with increased rate. Similar results were observed by Dobermann *et al.* (2003). In a related study, Yassen *et al*.(2006) noted that increased N-uptake and content in grain and straw with N-application. From the results of nitrogen uptake, it can be deduced that N uptake of cowpea is generally higher than that of rice. Also, nitrogen uptake by sole rice was lower in the mixed stands in both cropping seasons. The low value of nitrogen uptake in rice is an indication of competitive interactions between the component crops in the intercrop. This was further supported by Giller (1992) who noted that in an intercrop, competition might affect the ability of the non-reference crop to access soil nitrogen.

Nitrogen uptake was higher with intercrop than the sole crops. Intercrop competition is likely to alter the root pattern and timing of nitrogen uptake of the intercropping plants when compared with sole crops (Giller, 1992). The higher nitrogen uptake in mixtures compared with sole-crop system is evidence that the presence of a cereal or grass has a specific effect on the release of nitrogen from actively growing roots of the legumes as earlier reported by Eaglesham (1980).

An overview of uptake of the macronutrients (phosphorus, potassium, sodium, calcium and magnesium) for both cowpea and rice shows that cowpea nutrient uptake was generally higher than rice. This may be associated with the relative high cowpea dry matter accumulation capacity than that of rice. Related study by Beligar (1986) showed that with high dry matter accumulation of maize it was able to take up more nutrients than alfalfa in a mixture. Nutrient uptake of phosphorus, potassium, sodium and calcium were more in the intercrops than the sole rice and cowpea crops. Gardney and Boundy (1983) in a related study noted that P contents of wheat intercropped with lupine were significantly higher than those of wheat grown alone. The low magnesium content of intercropped rice in this study may be due to the reduced photosynthetic rate as a result of the competitive cowpea which may have hindered physiological processes such as nutrients translocation (Aduayi, 1972).

This is supported by Bamjoko and Sobulo (1986) who noted that rice is a crop more suitable for flooded condition. They further stressed that the ability of the rice plant to transport oxygen to the roots is sometimes counter productive for upland conditions as it oxidizes the rhizosphere and renders certain nutrients like iron less available to the crop. The higher nutrients uptake in both macro – and micronutrients may be due to the alteration of the root pattern and timing of nutrient uptake of intercropped plant when compared with the sole crops. Innis (1997) noted that different root system are able to harness more water and nutrients than is the case when the roots of only one species are present.

Nutrient uptake for both macro- and micronutrients decreased with planting density in both rice and cowpea. This may be due to reduction in plant biomass with density. Beligar (1986) noted that the differences in nutrient accumulation by plants are assumed to be depending on dry weight of plant.

The low zinc uptake in cowpea and rice in this study relative to values obtained in Nigeria soils by Lombin (1983) which are within the range of 16.0 to 44.2mg/kg may be due to soil reaction. The critical soil pH value in so far as plant availability of zinc is concerned, has been put at about 6.5 to 6.6 (Wear, 1956). The highly acidic soil is likely to have posed a serious impediment to zinc uptake by crops in the area of study.

Chude *et al.* (1983) reported the effect of source of nitrogen on micronutrients and showed that ammonium nitrate increased uptake of Fe, Al, Cu and Zn but not Mn. However, in this study nitrogen fertilizer rate with urea as nutrient source did not show any consistent trend with micronutrient uptake.

CONCLUSION

The reduction in plant biomass with increasing plant population decreased nutrient uptake of both macro- and micronutrients in this study. This indicates that high densities are detrimental to nutrition of crops. Hence it is advisable for farmers to select optimum densities which do not compromise crop yield since uptake of nutrients is a major determinant of yield, especially in rice – cowpea intercropping.

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Table 1. Effects of nitrogen fertilizer and planting density on uptake of nitrogen, phosphorus and potassium in rice

	Nitrogen (mg/plant)				Phosphorus (mg/plant)				Potassium (mg/plant)			
	CS-1		CS-2		CS-1		CS-2		CS-1		CS-2	
	Sole	Mixed	Sole	Mixed	Sole	Mixed	Sole	Mixed	Sole	Mixed	Sole	Mixed
0kgN/ha												
50000	0.39	0.20	0.16	0.17	0.12	0.12	0.10	0.10	0.39	0.27	0.23	0.28
100000	0.29	0.20	0.17	0.13	0.12	0.16	0.13	0.10	0.75	0.31	0.22	0.24
200000	0.33	0.17	0.21	0.12	0.12	0.14	0.05	0.14	0.41	0.62	0.29	0.50
15kgN/ha												
50000	0.24	0.18	0.17	0.33	0.11	0.61	0.11	0.14	0.50	0.48	0.50	0.41
100000	0.51	0.22	0.18	0.16	0.25	0.16	0.13	0.11	0.58	0.54	0.28	0.44
200000	0.15	0.14	0.12	0.13	0.14	0.07	0.09	0.07	0.63	0.22	0.47	0.25
30kgN/ha												
50000	0.15	0.49	0.14	0.21	0.09	0.29	0.09	0.09	0.19	1.01	0.22	0.57
100000	0.14	0.49	0.20	0.26	0.07	0.21	0.08	0.18	0.24	0.74	0.28	0.56
200000	0.39	0.32	0.16	0.19	0.25	0.15	0.10	0.11	1.18	0.51	0.45	0.46
45kgN/ha												
50000	0.37	0.12	0.20	0.19	0.19	0.18	0.13	0.12	0.75	0.78	0.39	0.54
100000	0.16	0.16	0.17	0.18	0.13	0.12	0.10	0.13	0.46	0.44	0.17	0.55
200000	0.19	0.27	0.11	0.14	0.11	0.11	0.09	0.09	0.32	0.39	0.28	0.36
Mean	0.28	0.25	0.16	0.18	0.14	0.19	0.10	0.12	0.53	0.53	0.32	0.43
SD	0.12	0.12	0.03	0.06	0.06	0.14	0.20	0.03	0.26	0.22	0.11	0.12
CV (%)	42.86	48.00	18.75	33.33	42.85	73.68	20.00	25.00	49.06	41.51	34.38	27.91

CS-1: First cropping season CS-2: Second cropping season

Table 2. Effects of nitrogen fertilizer and planting density on uptake of nitrogen, phosphorus and potassium in cowpea

	Nitrogen (mg/plant)				Phosphorus (mg/plant)				Potassium (mg/plant)			
	CS-1		CS-2		CS-1		CS-2		CS-1		CS-2	
	Sole	Mixed	Sole	Mixed	Sole	Mixed	Sole	Mixed	Sole	Mixed	Sole	Mixed
0kgN/ha												
50000	11.91	2.26	6.57	3.97	2.14	1.26	1.33	0.60	2.96	1.52	1.66	1.51
100000	5.61	3.17	4.75	4.13	1.24	1.25	1.05	0.65	0.96	1.87	1.20	1.71
200000	1.11	3.11	1.10	3.17	1.17	0.67	0.74	0.71	1.54	1.11	1.06	1.26
15kgN/ha												
50000	8.48	9.39	8.65	12.32	0.88	0.82	1.27	2.05	1.65	3.07	1.81	2.67
100000	7.78	7.51	6.58	6.62	1.02	1.12	0.95	1.86	1.55	2.49	1.31	2.07
200000	2.50	8.88	1.91	4.08	0.67	1.09	0.46	0.89	1.20	1.69	0.80	1.05
30kgN/ha												
50000	7.31	10.68	7.66	10.58	2.34	0.97	1.51	1.80	2.14	1.74	2.36	2.56
100000	3.40	9.72	3.10	9.16	1.11	1.53	0.87	1.60	1.06	1.58	1.05	1.89
200000	4.22	7.81	2.75	7.63	1.23	1.50	0.48	1.36	1.23	1.98	0.92	1.65
45kgN/ha												
50000	3.27	12.51	5.06	12.14	1.44	3.28	1.83	2.67	1.93	6.45	2.36	3.69
100000	4.51	14.43	4.76	7.04	1.51	2.64	1.92	1.67	1.58	4.91	2.09	2.49
200000	0.32	5.09	0.48	4.19	1.06	1.48	0.81	1.26	1.28	2.56	1.15	1.84
Mean	5.04	7.88	4.68	7.09	1.32	1.47	1.10	1.43	1.59	2.58	1.48	2.03
SD	3.20	3.69	2.50	3.18	0.47	0.73	0.46	0.61	0.53	1.51	0.53	0.73
CV (%)	63.49	46.82	53.42	44.85	35.61	49.66	41.82	42.66	33.33	58.53	35.81	35.96

CS-1: First cropping season CS-2: Second cropping season

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Table 3. Effects of nitrogen fertilizer and planting density on uptake of sodium, calcium and magnesium in rice

	Sodium(mg/plant)				Calcium(mg/plant)				Magnesium(mg/plant)			
	CS-1		CS-2		CS-1		CS-2		CS-1		CS-2	
	Sole	Mixed	Sole	Mixed	Sole	Mixed	Sole	Mixed	Sole	Mixed	Sole	Mixed
0kgN/ha												
50000	0.10	0.07	0.23	0.08	0.15	0.14	0.12	0.10	0.11	0.15	0.05	0.15
100000	0.24	0.09	0.18	0.08	0.14	0.19	0.09	0.10	0.08	0.12	0.05	0.11
200000	0.11	0.18	0.08	0.09	0.25	0.26	0.14	0.16	0.26	0.17	0.11	0.08
15kgN/ha												
50000	0.16	0.13	0.15	0.12	0.19	0.29	0.18	0.19	0.12	0.05	0.11	0.05
100000	0.14	0.15	0.16	0.13	0.26	0.33	0.16	0.21	0.45	0.08	0.10	0.08
200000	0.19	0.07	0.14	0.06	0.23	0.15	0.16	0.09	0.08	0.06	0.05	0.06
30kgN/ha												
50000	0.05	0.33	0.06	0.19	0.15	0.31	0.14	0.23	0.19	0.23	0.06	0.05
100000	0.07	0.23	0.11	0.21	0.13	0.37	0.13	0.24	0.08	0.06	0.10	0.13
200000	0.39	0.18	0.09	0.14	0.26	0.12	0.11	0.18	0.26	0.13	0.04	0.06
45kgN/ha												
50000	0.23	0.27	0.14	0.19	0.27	0.17	0.16	0.16	0.21	0.19	0.11	0.13
100000	0.14	0.15	0.11	0.17	0.13	0.10	0.15	0.12	0.13	0.13	0.10	0.14
200000	0.10	0.13	0.07	0.11	0.13	0.10	0.10	0.11	0.13	0.11	0.09	0.08
Mean	0.16	0.17	0.13	0.13	0.19	0.21	0.14	0.16	0.18	0.12	0.08	0.09
SD	0.09	0.08	0.05	0.05	0.06	0.09	0.03	0.05	0.10	0.05	0.03	0.04
CV (%)	56.25	47.06	38.46	38.46	31.58	42.86	21.43	31.25	55.55	41.67	37.50	44.44

CS-1: First cropping season CS-2: Second cropping season

Table 4. Effects of nitrogen fertilizer and planting density on uptake of sodium, calcium and magnesium in cowpea

	Sodium(mg/plant)				Calcium(mg/plant)				Magnesium(mg/plant)			
	CS-1		CS-2		CS-1		CS-2		CS-1		CS-2	
	Sole	Mixed	Sole	Mixed	Sole	Mixed	Sole	Mixed	Sole	Mixed	Sole	Mixed
0kgN/ha												
50000	0.71	0.34	0.39	0.36	10.76	5.04	5.24	4.58	3.18	1.02	1.69	1.20
100000	0.35	0.35	0.32	0.38	4.85	3.69	4.07	3.98	1.01	0.85	0.90	0.89
200000	0.40	0.24	0.30	0.27	6.91	2.08	3.82	2.94	0.19	0.66	0.38	0.80
15kgN/ha												
50000	0.46	0.77	0.59	0.67	8.77	7.24	8.65	6.93	1.97	3.46	1.90	2.67
100000	0.37	0.56	0.36	0.48	9.11	5.67	5.38	4.59	2.00	4.51	1.76	3.38
200000	0.27	0.36	0.22	0.27	3.18	5.68	1.83	3.21	3.66	2.41	1.56	1.68
30kgN/ha												
50000	0.50	0.39	0.53	0.50	7.66	4.63	8.01	6.80	5.01	1.67	3.34	2.94
100000	0.35	0.29	0.29	0.42	2.68	3.13	3.49	4.16	1.84	2.24	1.22	2.63
200000	0.32	0.33	1.99	0.37	4.75	4.30	3.35	3.80	1.05	5.60	1.19	2.44
45kgN/ha												
50000	0.43	1.06	0.58	0.79	6.17	10.45	7.96	9.42	3.05	3.00	3.88	2.55
100000	0.46	0.90	0.50	0.46	6.16	9.58	6.97	5.43	1.19	5.27	2.09	2.59
200000	0.26	0.43	0.31	0.36	3.53	3.82	4.30	3.35	1.12	7.00	2.05	2.09
Mean	0.41	0.50	0.53	0.44	6.16	5.44	2.11	4.93	2.11	3.14	1.79	2.16
SD	0.12	0.25	0.46	0.15	2.39	2.42	1.32	1.83	1.32	1.98	0.85	0.80
CV (%)	29.27	50.00	86.80	34.09	38.80	44.49	62.56	37.12	62.56	63.06	47.49	37.04

CS-1: First cropping season CS-2: Second cropping season

Table 5. Effects of nitrogen fertilizer and planting density on uptake of iron, ,zinc and copper in rice

	Iron (mg/plant)				Zinc (mg/plant)				Copper (mg/plant)			
	CS-1		CS-2		CS-1		CS-2		CS-1		CS-2	
	Sole	Mixed	Sole	Mixed	Sole	Mixed	Sole	Mixed	Sole	Mixed	Sole	Mixed
0kgN/ha												
50000	0.000	0.039	0.000	0.000	0.00025	0.00003	0.00002	0.00024	0.024	0.037	0.019	0.038
100000	0.021	0.058	0.000	0.032	0.00006	0.00004	0.00004	0.00003	0.030	0.044	0.025	0.027
200000	0.016	0.061	0.018	0.063	0.00008	0.00004	0.00003	0.00005	0.039	0.030	0.022	0.029
15kgN/ha												
50000	0.016	0.004	0.005	0.054	0.00005	0.00005	0.00006	0.00005	0.029	0.052	0.028	0.029
100000	0.000	0.000	0.020	0.005	0.0001	0.00008	0.00005	0.00006	0.034	0.039	0.016	0.039
200000	0.000	0.000	0.003	0.000	0.00005	0.00004	0.00004	0.00003	0.027	0.020	0.024	0.025
30kgN/ha												
50000	0.000	0.000	0.000	0.000	0.00003	0.00011	0.00004	0.00006	0.027	0.046	0.022	0.034
100000	0.000	0.000	0.000	0.000	0.00002	0.00007	0.00004	0.00008	0.017	0.058	0.026	0.056
200000	0.000	0.000	0.000	0.000	0.00006	0.00006	0.00003	0.00005	0.053	0.046	0.022	0.025
45kgN/ha												
50000	0.019	0.000	0.000	0.000	0.00005	0.00007	0.00004	0.00006	0.055	0.035	0.022	0.029
100000	0.027	0.000	0.035	0.005	0.00003	0.00004	0.00003	0.00005	0.015	0.034	0.011	0.040
200000	0.049	0.006	0.007	0.002	0.00003	0.00004	0.00002	0.00004	0.038	0.030	0.009	0.026
Mean	0.012	0.015	0.007	0.013	0.00011	0.00006	0.00004	0.00077	0.032	0.039	0.021	0.033
SD	0.015	0.023	0.011	0.022	0.00013	0.00022	0.00012	0.00009	0.012	0.010	0.006	0.009
CV (%)	125.0	153.33	157.14	169.23	118.18	38.60	34.29	119.48	37.50	25.64	28.57	27.24

CS-1: First cropping season CS-2: Second cropping season

Table 6. Effects of nitrogen fertilizer and planting density on uptake of iron, zinc and copper in cowpea

	Iron (mg/plant)				Zinc (mg/plant)				Copper (mg/plant)			
	CS-1		CS-2		CS-1		CS-2		CS-1		CS-2	
	Sole	Mixed	Sole	Mixed	Sole	Mixed	Sole	Mixed	Sole	Mixed	Sole	Mixed
0kgN/ha												
50000	1.220	0.000	0.030	0.000	0.00044	0.00087	0.00017	0.00090	0.47	0.35	0.29	0.39
100000	0.058	0.000	0.050	0.0024	0.00017	0.00087	0.00017	0.0011	0.30	0.33	0.25	0.39
200000	0.015	0.353	0.013	0.315	0.0016	0.00045	0.00011	0.00065	0.25	0.24	0.19	0.29
15kgN/ha												
50000	0.020	0.577	0.008	0.956	0.0010	0.00143	0.00076	0.00072	0.22	0.71	0.26	0.61
100000	1.030	1.504	0.466	0.626	0.0008	0.00060	0.00056	0.00028	0.09	0.47	0.05	0.34
200000	0.430	0.690	0.243	0.435	0.00048	0.00038	0.00027	0.00026	0.07	0.17	0.06	0.17
30kgN/ha												
50000	1.447	0.000	1.274	0.0017	0.0017	0.00041	0.0015	0.00071	0.55	0.13	0.59	0.35
100000	0.038	1.665	0.313	1.240	0.00078	0.00046	0.00072	0.00051	0.27	0.36	0.26	0.34
200000	0.130	0.541	0.081	0.542	0.00082	0.00045	0.00060	0.00045	0.22	0.36	0.18	0.28
45kgN/ha												
50000	0.252	3.270	0.387	2.745	0.00147	0.00008	0.00121	0.00085	0.39	0.48	0.55	0.57
100000	0.756	3.670	0.019	1.784	0.00119	0.00011	0.00150	0.00053	0.32	0.86	0.34	0.38
200000	0.305	1.600	0.011	1.177	0.00084	0.00061	0.00086	0.00042	0.24	0.12	0.19	0.01
Mean	0.475	1.160	0.241	0.819	0.00094	0.00056	0.00070	0.00062	0.28	0.38	0.27	0.34
SD	0.489	1.19	0.349	0.790	0.00045	0.00035	0.00047	0.00024	0.13	0.22	0.16	0.15
CV (%)	102.95	102.95	144.81	96.46	47.87	62.50	67.14	38.71	46.43	57.89	59.26	44.12

CS-1: First cropping season CS-2: Second cropping season