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Effects of Some Organic Manures on N, P, K, Zn and Fe Uptake in Straw and Grains of Rice in the Soils of Lake Geriyo, Adamawa State, Nigeria

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Abstract: Pot experiments were carried out from January to July, 2013 to study the effects of some organic manure on uptake of N, P, K, Zn and Fe in straw and grains of rice in the soils of Lake Geriyo Irrigation Scheme, Adamawa State, Nigeria. Two types of organic manures; cow dung, poultry droppings and control were used for the experiment. Three levels of organic manures 5, 10 and 15 tons per hectare (tonha^{-1}) and two sampling time; maximum tillering and harvest were chosen. Results obtained revealed that nitrogen uptake in straw ranged from 15.07 to 18.11 and 15.62 to 18.32gkg^{-1} for the first and second experiments, respectively. Mean nitrogen uptake in grains of 8.80 and 9.44gkg^{-1} were also recorded for the first and second experiments, respectively. Mean of 2.04 and 32.84mgkg^{-1} and 2.31 and 33.28mgkg^{-1} were recorded for zinc and iron for the first and second experiments respectively. Level, type of organic manures as well as time of sampling significantly ($P<0.05$) influenced N, P and K uptake in both straw and grains of rice grown on the soil of Geriyo Irrigation Scheme. Zinc and Iron uptake in both straw and grains was however decreased with increasing organic manures application. While, reduced Iron uptake may not constitute a problem in the nutrition of rice, the antagonistic effect of the primary nutrients particularly P on zinc should be monitored to sustain yield.

Key words: N・P・K・Zn・Fe・Rice・Nigeria

INTRODUCTION

Plants require over twenty one (21) essential nutrient elements in varying amounts for various metabolic functions [1]. The availability of these nutrients in soil however varies widely and in most cases bears no relationship to plant requirements [1, 2]. The elemental composition of plants in another perspective reflects the relative amounts required for adequate plant growth [3]. Series of mechanisms are involved in formation, distribution and solubilization of these nutrients within soil and plant system [1, 3, 4]. Inherent and anthropogenic factors are involved in the dynamics of nutrient availability and uptake.

Fertilizer; organic and inorganic are applied to improve and sustain crop production, rejuvenate exhausted soils and make them sustainable. Apart from sustaining crop production and soil rejuvenation, the 21st century agriculture also emphasize making the environment friendly at the same time optimizing and synchronizing nutrient demand and requirements by crops. While, inorganic fertilizers are easier to handle, their cost, availability due inefficient distribution system and balance formulation constitute a problem in the sub-saharan Africa and the savanna region of Nigeria in particular. The organic sources of fertilizer are bulky and undergo series of reaction before being released for crop utilization especially if subjected to varied soil condition. In addition, the nutrients released are intimately interrelated with one another having either synergistic or antagonistic relationships. This complexity results to affect their availability and uptake.

Savanna soils are inherently low in native fertility [5, 6] and applied phosphorus is usually fixed as Fe-P, Al-P and/or Ca-P (Gillman, 1985); thus, rendering the P unavailable for plant uptake. Phosphorus is also the least mobile element in soil among the essential nutrient elements. Similarly, the availability of iron is affected by soil pH, soil oxygen and organic matter. Aerobic condition and alkaline pH tend to reduce the availability of iron by forming insoluble iron compounds while organic manure tends to increase the solubility of both P and iron [2].

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Considering phosphate rock as a non-renewable resource and its interaction with other nutrients, the relatively low availability of Phosphorus in tropical soils, phosphorus supply for plants growth must be rationalized. This is true especially for tropical soils that are dominated by Fe and Al oxides which strongly adsorb soluble phosphates from fertilizers. Similarly, negative relationships with other nutrients especially micronutrients notably iron which fluctuate under aerobic and anaerobic condition in redox reaction processes on flooded soils must be comprehended, its efficiency improved and relationships with other interacting nutrients balanced. Also, nutrition of cereals, rice in particular is greatly affected by Phosphorus and iron availability particularly under the condition in which rice is grown in most parts of savanna region, Adamawa State in particular.

MATERIALS AND METHODS

The study was conducted at Modibbo Adama University of Technology (MAUTECH), Yola, Adamawa State, Nigeria. The soil samples were collected from Geriyo, located 2km North of Jimeta metropolis, The locations lie between 12°21' to 22°18’ E latitude and 9°16’ to 19°19' N. longitude with altitude range of 150-180 m above the mean sea level. The site has a total irrigation area of about 350ha which is divided into three phases viz; phase I with developed irrigation area of 20 ha, phase II is divided into three with 2A(35ha), 2B(60ha) and 2C(45ha) making a total developed irrigation area of 140ha and phase III divided into two with 3A(140ha) and 3B(50ha) making a total developed irrigation area of 190ha. Soil samples were collected from phase II plots (2B and 2C) and phase III (3B) of the project which are used in rice production located in the lower section of the irrigation scheme.

The annual rainfall of the area ranges from 700-1000mm and temperature ranges from 15.2 - 39°C with a mean of 26.7 °C and 27.8°C throughout the year for southern and northern parts of the state respectively. The amount of sunshine hours ranges from 2500 in the south to 3000 hours in the extreme north and with 20-30 % and 70 % relative humidity in the month of January-March and August and September respectively [8].

Gleyic Cambisol dominates Geriyo irrigation project [9]. The soils occur on level to gently undulating floodplains and alluvial terraces of the river systems of the state. They are deep, poorly drained, medium textured and dominantly young without much horizon differentiation [9]. The dominant soil type is clay-loam in texture [9-11].

Experimental Materials: Two organic materials; Cow dung and poultry (Broilers) droppings sourced from the University farm and other farms around were used. Nine kg (9 kg) of soil samples (at field moisture condition) was collected from Geriyo and weighed into perforated plastic pots of height = 23.5cm, diameter = 22.5cm. This was kept under submergence and FARO 44 (SIPI692033) rice seed variety was planted into the pots.

Preparations of the Organic Manures: The organic materials; Cow dung and Poultry droppings were air dried and ground using porcelain mortar and pestle, sieved through a 2-mm sieve for laboratory analysis. Manure for incorporation into the experimental pots was ground to increase the surface area, before incorporating it into the soil for ease of decomposition.

Organic Manure Characterization and Plant Sample Analysis: The two organic materials (Cow dung and poultry droppings) were analyzed for pH, organic carbon, total nitrogen, organic phosphorus and total potassium contents. The pH of the organic materials was determined in 1: 2 organic matters to water ratio [12]. The organic carbon content of the organic materials was determined using NYC - 12 muffle furnace as described by Kanwar and Chopra [12]. The nitrogen content of the organic materials was determined as described by Kanwar and Chopra [12]. The P and K in the organic materials were determined as described by Kanwar and Chopra [12].

The plants (two seedling from each pot) were harvested at maximum tillering (9 weeks after emergence) and at harvest (maturity), washed and separated into roots and shoots at nine weeks after emergence, roots, shoots and grains at maturity. Samples were oven dried for a week and ground for uptake analysis [13]. The ground plant samples were digested with a 2:1 mixture of nitric and perchloric acids. Nitrogen in the sample was determined using macro kjeldahl digestion method. Phosphorus in the digest was measured calorimetrically by the vanadomolybdate yellow method; K was determined using flame photo meter. Zinc and iron in the digest were determined using atomic absorption spectrometry [14] at the Adamawa state University (Department of Chemistry Laboratory).

Soil Sampling and Preparation: Soil samples were taken randomly across the experimental field (Geriyo) to a depth of 20 cm and bulked for laboratory analysis before the commencement of the research. In the laboratory, the soil samples were air-dried, crushed using a porcelain mortar and pestle and then sieved through a 2-mm mesh sieve. The sieved samples were stored in labeled polythene bags for laboratory analysis.

Manure Incorporation: The ground manures were applied at the recommended rate of 60 Kg P/ha of single super phosphate (SSP) for rice on savanna soils [15] by incorporating the manures into the soil to hasten the decomposition of the organic materials a month before the rice seeds were planted. The total amount of the organic material applied was estimated based on the result of the soil routine analyses conducted, the total P content of the organic material analyzed and recommended rate of SSP (60 kg P/ ha) for rice plants.

Water Supply: Water was added to the experimental pots daily during the incubation period to reach a moisture content of 60 % of the maximum water holding capacity of the soil as described by Fadly [16]. To determine the amount of water that was to saturate the soil, the pots were weighed while watering in order to reach the proper weight of 60 % water holding capacity of the soil [16]. The level of submergence of soil under was increased as the seedlings grow and subsequently maintained at about 5 cm throughout the growing season [13].

Direct Planting of Paddy Rice Seeds: The seeds were planted directly approximately one month (30 days) after incorporating the organic materials in to the submerged soil. Six to eight seeds of the FARO 44 rice variety were planted per pots and were thinned to two seedlings per pot two weeks after emergence [13].

Weed Control: Weeds were controlled by hand picking on a regular basis.

Experimental Layout: Completely Randomized Design (CRD) replicated three (3) times was laid out with the following factors:

- Organic manure source (three treatments): control, cow dung and poultry droppings
- Organic manure level (three treatments): 5 ton ha^{-1}, 10 ton ha^{-1} and 15 ton ha^{-1}.
- Incubation time (two treatments); maximum tillering and harvest.

Data Collection: The plants (two seedling from each pot) were harvested at maximum tillering (9 weeks after emergence) and at harvest (maturity), washed and separated into roots and shoots at nine weeks after emergence, roots, shoots and grains at maturity. Samples were oven dried for a week and ground for uptake analysis [13]. The ground plant samples were digested with a 2:1 mixture of nitric and perchloric acids. Nitrogen in the sample was determined using macro kjeldahl digestion method. Phosphorus in the digest was measured calorimetrically by the vanadomolybdate yellow method; K was determined using flame photo meter. Zinc and iron in the digest were determined using Atomic Absorption Spectrometry [14].

Data Analysis: The data collected were analyzed using Statistical analysis software (SAS) [17] and the means were separated using least significant difference (LSD) [18].

RESULTS AND DISCUSSION

Results of the effect of organic manures; cow dung and poultry droppings on nitrogen uptake in both straw and grains was significant ($P<0.01$) in the two experiments conducted (Tables 2 and 3). Level of organic manures as well as time of sampling had significant ($P<0.01$) influence on the concentration of N in both straw and grains. The increase in N concentration in rice straw and grains with the application of organic materials may be attributed to the better nutrients availability as well as the improvement of soil physical, chemical and biological conditions [19, 20] provided by the application of organic manures. These improvements created better soil fertility status resulting in more nutrients available for rice growth [21]. Similarly, N concentration in grains at harvest was greater than at maximum tillering. This could probably be attributed to the fact that no grain yield was recorded at maximum tillering as the plants were still at the vegetative stage of growth. However, the higher concentration of N in straw recorded at maximum tillering may not be unconnected to the fact that most of the N were deposited at the shoots acting as sink [1], while the lower N concentration in straw recorded at harvest may be as a result of N translocation to the grains at maturity. In addition, in most cereals, considerable proportion of the

Table 1: Characterization of Organic Manures

	Moist (%)	N (g/kg)	P (mg/kg)	%K	OC (g/kg)	pH
Poultry droppings	28.45	21.6	4250	3.01	220.1	8.2
Cow dung	34.63	19.2	800	2.75	318.2	7.8

Table 2: Effect of Rate, Time of submergence and Source of Organic Manures on N, P, K, Zn and Fe Uptake in Straw and Grains in First Experiment

	Grains					Straw				
	N	P	K	Zn	Fe	N	P	K	Zn	Fe
Trts	(g/kg)			(mg/kg)		(g/kg)			(mg/kg)	
RATE										
5 ton ha^{-1}	8.28^{b}	0.80^{c}	5.72^{b}	0.570^{a}	33.11^{b}	16.72^{b}	1.20^{b}	18.43^{c}	0.97^{a}	29.49^{ab}
10 ton ha^{-1}	8.92^{a}	0.85^{b}	5.69^{b}	0.74^{a}	33.77^{a}	16.88^{b}	1.55^{a}	19.49^{b}	0.99^{a}	28.99^{b}
15 ton ha^{-1}	9.20^{a}	0.89^{a}	6.06^{a}	4.80^{a}	31.63^{c}	17.29^{a}	1.55^{a}	20.54^{a}	0.97^{a}	30.28^{a}
Mean	8.80	0.85	5.82	2.04	32.84	16.95	1.43	19.49	0.98	29.56
LSD	0.55	0.004	0.11	7.10	0.58	0.30	0.18	0.65	0.080	1.13
TIME										
Max.tillering	0.000^{b}	0.000^{b}	0.000^{b}	0.00^{a}	0.000^{b}	17.84^{a}	1.47^{a}	21.98^{a}	0.70^{b}	32.94^{a}
Harvest	17.60^{a}	1.69^{a}	11.64^{a}	4.07^{a}	65.68^{a}	16.06^{b}	1.39^{a}	17.00^{b}	1.26^{a}	26.18^{b}
Mean	8.80	0.85	5.82	2.04	32.84	16.95	1.43	19.49	0.98	29.56
LSD	0.55	0.004	0.11	7.10	0.58	0.30	0.18	0.65	0.080	1.13
SOURCE										
Control	7.81^{b}	0.66^{c}	5.45^{c}	0.81^{a}	36.06^{a}	15.07^{c}	1.15^{c}	16.87^{c}	1.14^{a}	36.65^{a}
Cow dung	9.19^{a}	0.88^{b}	6.13^{a}	0.52^{a}	31.47^{b}	17.68^{b}	1.47^{b}	19.56^{b}	0.95^{b}	22.59^{c}
Poultry D.	9.41^{a}	0.99^{a}	5.89^{b}	4.78^{a}	30.97^{b}	18.11^{a}	1.66^{a}	22.03^{a}	0.84^{c}	29.45^{b}
Mean	8.80	0.85	5.82	2.04	32.84	16.95	1.43	19.49	0.98	29.56
LS	0.55	0.004	0.11	7.10	0.58	0.30	0.18	0.18	0.080	1.13

Max. = Maximum, Poultry D. = Poultry droppings, N = nitrogen, P = phosphorus, K = Potassium, Zn = zinc, Fe = iron

Table 3: Effect of Rate, Time and Source of Organic Manures on N, P, K, Zn and Fe Uptake in Straw and Grains in Second Experiment

	Grains					Straw				
	N	P	K	Zn	Fe	N	P	K	Zn	Fe
Trts	(g/kg)			(mg/kg)		(g/kg)			(mg/kg)	
RATE										
5 ton ha^{-1}	9.13^{b}	0.81^{b}	5.82^{b}	0.66^{a}	33.78^{b}	16.84^{c}	1.06^{b}	20.62^{a}	1.51^{a}	30.40^{a}
10 ton ha^{-1}	9.49^{a}	0.92^{a}	5.80^{b}	0.61^{a}	34.11^{a}	17.14^{b}	1.45^{a}	19.81^{b}	1.53^{a}	30.50^{a}
15 ton ha^{-1}	9.69^{a}	0.92^{a}	6.17^{a}	5.65^{a}	31.96^{c}	17.51^{a}	1.45^{a}	20.35^{a}	1.51^{a}	30.87^{a}
Mean	9.44	0.88	5.93	2.31	33.28	17.16	1.32	20.26	1.52	30.59
LSD	0.229	0.072	0.112	8.362	0.206	0.237	0.129	0.271	0.044	0.579
TIME										
Max.tillering	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{a}	0.00^{b}	18.32^{a}	1.33^{a}	23.42^{a}	1.20^{b}	33.86^{a}
Harvest	18.87^{a}	1.77^{a}	11.86^{a}	4.61^{a}	66.57^{a}	16.01^{b}	1.31^{a}	17.09^{b}	1.83^{a}	27.32^{b}
Mean	9.44	0.88	5.93	2.31	33.28	17.16	1.32	20.26	1.52	30.59
LSD	0.229	0.072	0.112	8.362	0.206	0.237	0.129	0.271	0.044	0.579
SOURCE										
Control	8.43^{b}	0.69^{b}	5.60^{c}	0.71^{a}	36.41^{a}	15.62^{b}	0.95^{c}	17.36^{c}	1.75^{a}	37.56^{a}
Cow dung	9.85^{a}	0.96^{a}	6.22^{a}	0.58^{a}	31.81^{b}	17.88^{a}	1.34^{b}	21.20^{b}	1.34^{c}	23.83^{c}
Poultry D.	10.03^{a}	1.01^{a}	5.97^{b}	5.63^{a}	31.64^{b}	18.00^{a}	1.67^{a}	22.21^{a}	1.45^{b}	30.38^{b}
Mean	9.44	0.88	5.93	2.31	33.28	17.16	1.32	20.26	1.52	30.59
LSD	0.229	0.072	0.112	8.362	0.206	0.237	0.129	0.271	0.044	0.579

Max. = Maximum, Poultry D. = Poultry droppings, N = nitrogen, P = phosphorus, K = Potassium, Zn = zinc, Fe = iron nitrogen translocated to the developing grains is taken up by the roots during grain filling period [1]. Pillai [22] reported that N, P and S, which are essential constituents of proteins, are absorbed rapidly during the active vegetative growth stage and are subsequently translocated to the grain after flowering. This also concurred with the findings of Sukristiyonubowo *et al.* [23]. They reported higher N concentration in grain compared to that of straw and linked the result to the higher protein content in rice grain than in straw and explained that higher N, P and K uptake takes place at harvest.

Increasing P concentration in straw and grains with the source of applied organic manures (poultry dropping) may be attributed to the ability of Poultry manure to supply phosphorus more readily to plants than other organic manure sources [24]. Phosphorus concentration also increased with increasing levels of organic manures (Table 2 and 3). This is in contrast with the findings of De Datta [25], who reported that P concentration showed declining trend with increasing P levels. However, the increasing P concentration with levels of organic manures may be attributed to increased N concentration at higher levels of organic manures. Rahman [26] reported that higher concentration of N in plants was in response to increased P and K concentrations in the organic manures added. Synergistic relationship between N and P has been reported by DeDatta, [25]; Barker and Pilbeam, [2]; Brady and Weil, [4]. Phosphorus concentration was higher in rice grains than in straw. This also agrees with the findings of De Datta [27]; Pillai [22]; Sukristiyonubowo *et al.* [23].

The concentration of K in both grains and straw were increased with increasing level and source of organic manures ((Tables 2 and 3). This may be attributed to the enhanced nutrient availability and suitable soil condition for proper plant growth provided by the application of organic manures. It may also be linked to the production of maximum dry matter weight [28]. Pillai [22] reported that K is absorbed at a rate matching the rate of dry matter production over the growth period. Although the highest concentration of K in straw was recorded at maximum tillering, total K concentration in the plant (grain K + straw K) was recorded at harvest. This is in line with the findings of Pillai [22] that K concentration was decreased gradually during the earlier growth of the plant but it was increased from flowering until ripening. Also, Sukristiyonubowo *et al.* [23] reported that highest N, P and K uptakes are taken place at harvest stage. This result was in line with the findings of De Datta, [27]; Sukristiyonubowo *et al.,* [23]; Pillai, 2006; Rahman, 2010, who reported higher K concentration in straw than in grains. They explained that elements that form immediate components of proteins have a high rate of mobility, while those that are continuously absorbed until senescence have a relatively low mobility. They also presented nutrient mobility in rice plant in this sequence P > N > S > Mg > K > Ca, since K is relative immobile in rice and not a component of proteins, it is mostly concentrated in the straw. Islam *et al*. [29] also recorded higher K concentration in straw than in grains.

Contrary to the results of N, P and K concentrations recorded in both straw and grains, Zn concentrations in grains irrespective of treatment was not significant ((Tables 2 and 3). The insignificant difference recorded in Zn concentration in grains irrespective of treatment was also reported by Islam *et al.* [29], while working with aman rice (BRRI dhan 32) and explained that Zn uptake by the crop was closely associated with grains and straw yield. However, the higher zinc concentrations recorded in straw at harvest compared to grains may be attributed to uptake efficiency and increased capacity to transport by the crop which is one of the varietal characteristics. Zinc concentration was decreased with the application of organic manures. This may be due to decreased Zn availability as a result of increased organic chelates in the soil [30, 31]. It may also be due to the increased N and P antagonism. Antagonistic effect of increased N and P on Zn uptake in soil and straw have been reported [32, 26].

Iron concentration in both straw and grains was significantly influenced ($P<0.05$) by rate, time and source of organic manures applied (Tables 2 and 3). Similarly, iron concentration in both straw and grains in both experiments was increased with increasing rate up to 10 tons/ha,while the control had the highest Iron concentration followed by poultry droppings (Tables 2 and 3). The increased iron concentration in both straw and grains may be a reflection of the solubility of ferrous ion (Fe^{2+}) and its hydrolysis contributing towards the total soluble iron in the soil solution [33]. Romheld and Nikolic [33] reported that the presence of microorganisms around growing roots causes the redox potential in the rhizosphere to drop because of the microbial oxygen demand which serve to increase concentration of Fe^{2+} for plant uptake. The lower Iron concentration in treated organic manure pots may be due to increased microbial activity and the production of alkaloids which serve as chelates for Fe with consequent reduction in its availability in soils [33, 4]. However, the decrease in Fe concentration in both straw and grains after reaching climax may be due to the utilization of nitrate by the crop as their predominant nitrogen source which alkalize the rhizosphere thereby contributing to Iron stress [33]. This also concurred with the findings of Mengel and Guertzen [34]. It may also be due to increased supply of N and P on application of organic manures with consequent antagonistic effect on Fe [1]. Zheng *et al*. [35] and Rahman [26] also reported depressed Iron availability with increased N and P supply. It may also be as a result of dilution effect on micronutrients. However, Fe concentration in grain was higher than in straw. This is in line with those obtained by Pillai, [22].

CONCLUSION

Application of organic manures significantly influenced N, P and K uptake in both straw and grains of rice grown on the soil of Geriyo Irrigation Scheme. Zinc and Iron uptake in both straw and grains were however decreased with increasing rates of organic manures application. While, reduced Iron uptake may not constitute a problem in the nutrition of rice, the antagonistic effect of the primary nutrients particularly P on Zn should be monitored to sustain yield.

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