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SOIL NUTRIENT DYNAMICS AS INFLUENCED BY ORGANOMINERAL FERTILIZERS AND TEA SEEDLING NUTRIENT UPTAKE IN NIGERIA

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Abstract

Cocoa husk, cow dung, poultry droppings, siam weed - *Chromolaena odorata* and tea fluff are common farm wastes in Nigeria. They were used as manures as sole and in combination with inorganic fertilizer as organominerals (OMF), compared to NPK (5:1:1) a reference fertilizer, to supply 150 kg N ha^{-1} to potted tea seedlings in the open nursery space at Ibadan (lowland ecology) and Kusuku (highland ecology) of Nigeria. The manure based fertilizer treatments resulted in significantly ($P<0.05$) higher tea dry matter yield than the reference fertilizer - NPK (5:1:1) and between 44.5 – 146 % at Ibadan (lowland ecology) and 29.9 – 233 % at Kusuku (highland ecology) than the control (without fertilizer). Tea plant nutrient uptake, residual soil nutrient and organic matter build-up were more in the organic based fertilizers treatments compared to NPK.

Introduction

Tea (*Camellia sinensis L*) is the cheapest and most common beverage drink in Nigeria. Local tea production accounts for less than 20 % of total consumption, while more than 80 % of the balance is imported (Esan, 1996). Commercial tea production is localized to the Mambilla Plateau, with limited land for plantation expansion but research has indicated the feasibility of producing tea in the lowland areas that cut across three agro-ecological zones (south west, south east and north east). In all the zones, the soils are highly leached with very low soil N, available P and basic elements (Ipinmoroti, 2006). Presently, quantity of tea produced in Nigeria is inadequate to meet the demand of local tea processing industries, due mainly to soil nutritional problems. Hence, there is need for adequate fertilizer application for optimum tea production on these soils.

In Nigeria, inorganic fertilizers are in short supply, costly and not affordable by farmers (Adeoye et. al., 2005). The soils are equally low in organic matter content, which, as it is for other tropical soils, is the determinant factor of soil fertility and main nutrient storage depot of the soils. It contributes about 30 – 80 % of the cation exchange capacity (CEC) of Nigerian soils (Ayoola and Agboola, 2002) because the soils are dominated mainly by kaolinitic (1:1) clay type with less than 10 % CEC with persistent low crop yields being experienced by farmers, Research effort was therefore geared towards the use of organic based nutrient sources on tea field, to alleviate the problems of the farmers in terms of reduced production cost and to maintain good soil conditions over a long period of usage on a sustainable basis. This paper presents the result of an experiment on the effect of organic nutrient sources, with and without chemical fertilizer supplement, compared to NPK (5:1:1), the reference fertilizer, as nutrient supply to tea plants at Ibadan and Kusuku (lowland and highland) areas in Nigeria.

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Materials and methods

Five readily available farm wastes of plant (cocoa husk, siam weed and tea fluff) and animal (cow dung and poultry droppings) origins were collected from plantations (cocoa husk and siam weed – *Chromolaena odorata*), factories (tea fluff), abattoir (cow dung) and poultry pens (poultry droppings), where they are generated in large quantities but with disposal problem. The manure samples were wet digested and analyzed for their phosphorus, potassium, calcium and magnesium contents according to IITA (1979). Nitrogen was determined by the kjeldahl method. The soils for the pot experiment were collected from fallowed plots previously cultivated to arable crops in mixed cropping system at Ibadan and Kusuku and analyzed for nutrient contents. Total nitrogen was by kjeldahl apparatus, available phosphorus by Bray's 1 method (Bray and Kurtz, 1945). The exchangeable cations were extracted with 1N ammonium acetate and determined using atomic absorption spectrophotometer (AAS).

The farm wastes were pulverized and used as manure. Their application was based on the nitrogen contents, used alone and in mixture with NPK (5:1:1) as organomineral fertilizer (OMF) at ratios 3:1 (OMF_1) and 1:1 (OMF_2). The reference fertilizer (NPK 5:1:1), was compounded from the mixture of urea for N, single super phosphate (SSP) for P and muriate of potash (MOP) for K. Ten liter sized black plastic pots were filled with 10 kg soils and about one year old tea seedlings of similar sizes, raised in 1 kg soil in polythene bags were transplanted into the pots. There were five manures, five OMFs, one NPK (5:1:1) and control (no fertilizer, for a total of twelve treatments replicated 4 times in a randomized complete block design (RCBD). The fertilizers were applied at equivalent rate of 150 kg N ha^{-1}. The pots were watered twice per week and hand weeded every 3 months. After 18 months of growth, the tea seedlings were uprooted, washed fresh, dried to constant weight in the oven at 70 ^{O}C, weighed and milled. Representative samples were taken, wet digested and analyzed. Nutrient uptake in the tea plants were calculated using the formula:

Uptake = Dry matter yield x nutrient content. Soils in pots were removed, sample taken, air dried and analyzed. Tea dry matter yield and nutrient uptake values were subjected to ANOVA and mean differences separated by Duncan multiple range test (DMRT) at P<0.05.

Results

The pre-planting soil nutrient contents at Ibadan and Kusuku respectively were 1.1 and 1.7 g/kg N; 4.63 and 2.15 mg/kg P; 0.63 and 1.31 cmol/kg K; 1.65 and 2.41 cmol/kg Ca; 0.31 and 0.39 cmol/kg Mg; 1.42 and 1.72 g/kg OC. These levels of the nutrients in the soils were considered too low for sustainable tea cultivation when compared with their calculated critical values (Egbe et al., 1989). The low nutrient levels are typical of most tropical soils (Sander, 2002). The soils would therefore need nutrient addition for optimal crop performance. The analytical results of the farm wastes showed that the nutrient contents were between 0.29 – 3.54 % N, 0.15 – 1.55 % P, 0.83 – 3.96 % K, 0.64 – 3.55 % Ca and 0.23 – 0.54 % Mg (Table 1). The C-to-N ratio was between 8.7 – 25.6, thus indicating that they could easily decompose and release nutrients for plant use.

Table 1: Some nutrient contents of organic wastes used

Nutrient (%)	Cocoa husk	Cow dung	Poultry droppings	Siam weed	Tea fluff
N	1.46	1.29	3.54	2.47	2.92
C	37.38	16.51	30.80	42.98	36.50
C/N	25.60	12.80	8.70	17.4	12.5
P	0.15	0.60	1.55	0.21	0.30
K	3.96	0.83	1.83	3.08	2.16
Ca	0.77	1.57	3.55	1.21	0.64
Mg	0.33	0.43	0.54	0.76	0.23

The fertilizers resulted to significantly (P<0.05) higher tea dry matter yield (DMY) than control at both locations, while manures and OMFs were generally higher than NPK (Table 2). The

Table 2: Mean tea seedling dry matter yield (g/plant)

Treatment	Ibadan			Kusuku		
	Manure	OMF_1	OMF_2	Manure	OMF1	OMF2
Cocoa husk	11.20a	11.72b	20.51a	36.90a	30.60c	30.02b
Cow dung	12.82a	20.30a	18.50a	29.50b	28.42c	25.10c
Poultry dropping	9.69b	18.23a	15.32b	28.88b	33.05b	34.36a
Siam weed	10.14b	14.76b	13.56b	29.20b	24.90d	25.05c
Tea fluff	12.45a	17.49a	15.07b	34.01a	37.21a	25.12c
NPK	7.54c	8.12c	7.19c	20.32c	19.88e	21.09d
Control	5.21d	5.83d	5.94d	16.44d	15.36f	16.05e

OMF_1 = Organic + NPK (3:1); OMF_2 = Organic + NPK (1:1)

values were between 44.5 – 248 % and 29.4 – 125 % higher than the control at Ibadan and Kusuku respectively. The DMY from manure based fertilizer treatments indicated that CD followed by TF were more outstanding at Ibadan, while it was PD followed by CH at Kusuku (Table 2). The OMF of TF and PD were best at Ibadan; while it was TF based OMF_1 and CH based OMF_2 at Kusuku. It thus showed location differences in response of the tea seedlings to the fertilizer types. The Kusuku values were generally higher than the *correspond*ing treatments at Ibadan. The DMY values were in similar trends with values reported by Wanyoko and Mwakha (1991) in Kenya and by Ipinmoroti et al. (2002) in Nigeria, when manures were used on tea seedlings both as alone and in mixtures with mineral fertilizers. The results indicated that the organic based fertilizers are better storehouse for essential nutrients and their subsequent supply to plants (Adeoye et al., 2005). Better performance of tea seedlings under organic based fertilizers may stem from additional supply of Ca, Mg and micronutrients, essential for optimal tea growth, but are lacking in the NPK (5:1:1). The cow dung, poultry droppings, siam weed - *Chromolaena odorata* and tea fluff were better utilized as OMF_1, and cocoa husk as OMF_2 at both locations.

Manures and OMFs were generally superior to NPK and control in enhancing N, P, K, Ca and Mg uptake by tea seedlings (Table 3). Probably be due to slow and steady nutrient release by the organic nutrient sources, which were readily made available compared to the fast released and easily leached nutrients from NPK.

Table 3: Tea seedling nutrient uptake (mg/plant)

Treatment	Ibadan					Kusuku				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Manure										
CH	770d	15d	264b	67b	18c	1610a	39a	999a	99a	54b
CD	1630a	33a	248b	75b	44a	1360b	41a	887b	96a	58b
PD	890d	21c	229b	62b	24c	1310b	36a	865b	70c	51c
SW	740d	20c	245b	57b	28c	1400b	34a	887b	82b	51c
TF	900c	27b	284b	99a	27c	1650a	33a	990a	98a	57b
OMF_1										
CH	880d	21c	211c	77b	31b	1480b	28b	893a	96a	47c
CD	970c	26b	287b	91a	45a	1490b	33a	849b	97a	63a
PD	1220b	37a	371a	84a	48a	1440b	33a	917a	99a	59b
SW	920c	24c	253b	56b	48a	1350b	25b	816b	98a	47c
TF	1330b	40a	296b	90a	53a	1580a	26b	779c	99a	56b
OMF_2										
CH	1090c	27b	194c	69b	43a	1590a	31a	935a	99a	51c
CD	870d	21c	197c	59b	32b	1180c	24b	716c	93a	49c
PD	940c	26b	275b	83a	39b	1450b	36a	904a	99a	63a
SW	770d	21c	185c	71b	37b	1250c	28b	727c	89b	47c
TF	960c	28b	230c	79b	43a	1220c	27b	755c	76c	49c
NPK	790d	22c	209c	68b	31b	1180c	28b	779c	77c	50c
Control	660e	12e	178d	43c	21c	1020d	16c	763c	54d	45d

CH = Cocoa husk, CD = Cow dung, PD = Poultry droppings, SW = Siam weed, TF = Tea fluff, OMF_1 = Organic + NPK (3:1); OMF_2 = Organic + NPK (1:1)

Similar observations have been reported for tea and coffee seedlings (Wanyoko and Mwakha, 1991; Obatolu, 1991). Nutrient uptake at Kusuku were significantly ($P<0.05$) higher than at Ibadan. Except for CH, OMFs were optimal at 3:1 mixtures.

Soil N content after 18 months of tea cropping was higher at Kusuku than at Ibadan, probably due to the warmer weather conditions at Ibadan which must have resulted in higher N volatilization and losses. Soil N at both locations was however higher than the pre-planting soil nutrient contents, for all the manure based fertilizer treatments, while NPK and control led to lower N contents (Table 4). Similar trend was observed for the soil available P, exchangeable K, Ca and Mg at both locations.

Table 4: Some soil nutrient contents after 18 months of tea cropping

Treatments	Ibadan					Kusuku				
	N	K	Ca	Mg	P	N	K	Ca	Mg	P
	g/kg	← cmol/kg →			mg/kg	g/kg	← cmol/kg →			mg/kg
Manure										
CH	2.2a	1.1a	2.4a	0.6b	5.9c	4.6a	1.7b	2.8b	0.5a	8.5a
CD	2.0a	0.7b	2.3a	0.6b	5.1d	4.8a	1.6b	3.0b	0.5a	2.6e
PD	2.0a	0.8b	1.7d	0.5b	11a	4.3b	1.6b	3.1a	0.5a	4.7c
SW	2.0a	0.8b	1.9c	0.5b	6.1c	4.8a	1.5b	3.2a	0.5a	6.6b
TF	2.0a	0.8b	2.3a	0.8a	5.2d	4.2b	1.6b	2.6b	0.5a	8.1a
OMF_1										
CH	2.0a	0.9b	1.8d	0.5b	4.7d	4.1b	1.6b	2.8b	0.4b	2.7e
CD	1.9b	0.7b	1.6e	0.6b	5.0d	4.2b	1.7b	3.1a	0.5a	6.1b
PD	1.9b	0.8b	1.8d	0.5b	9.8b	4.4b	1.8b	2.7b	0.5a	2.4e
SW	2.0a	1.1a	2.5a	0.6b	4.9d	4.0b	1.7b	3.2a	0.5a	2.5f
TF	1.9b	0.9b	2.2b	0.5b	4.7d	4.2b	1.6b	3.0a	0.4b	2.4f
OMF_2										
CH	1.9b	0.8b	1.7d	0.5b	4.8d	4.5a	2.2a	3.0a	0.5a	2.5e
CD	1.9b	0.7b	2.0c	0.6b	4.9d	4.5a	1.7b	2.8b	0.5a	2.3e
PD	2.1a	0.7b	2.2b	0.6b	6.3c	4.1b	1.6b	2.7b	0.5a	2.7e
SW	1.9b	0.8b	2.2b	0.4c	4.7d	4.5a	1.5b	2.8b	0.4b	3.6d
TF	1.9b	0.9b	2.0c	0.6b	4.7d	4.1b	1.4c	2.8b	0.5a	2.5e
NPK	1.0c	0.5c	1.1f	0.2d	3.3e	1.4c	1.2c	1.8c	0.3b	2.1e
Control	o.5d	0.3c	0.9f	0.2d	1.8f	0.8d	0.9d	1.3d	0.1c	1.3f

CH = Cocoa husk, CD = Cow dung, PD = Poultry droppings, SW = Siam weed, TF = Tea fluff, OMF_1 = Organic + NPK (3:1); OMF_2 = Organic + NPK (1:1)

The soil OC increased from 1.42 g/kg at Ibadan to a range of 2.2-3.1 g/kg and from 1.71 g/kg at Kusuku to a range of 2.9-4.3 g/kg under manure treated soils. The values were reduced to 1.35 and 1.22 g/kg for NPK and control at Ibadan; to 1.67 and 1.55 g/kg for same treatments at Kusuku. The OMF_1 was more effective than OMF_2 on soil nutrient and OC builds up. Soil nutrient and organic carbon status after tea cropping showed that continuous tea production with sole use of NPK as nutrients source would in the long run lead to soil physical, chemical and eventually, biological degradation and impoverishment. Soil fertility management that would improve the soil organic matter (SOM) is needed for tropical soils, Nigeria inclusive, because of the inherent low SOM, clay contents of mostly kaolintic (1:1) type and low CEC (Ogunwale et al., 2002). The results indicated that without organic based nutrient addition to the soils, there would be threat to sustainable tea production. There is need for Mg supply under NPK and the control to prevent manifestation of Mg deficiency. This amendment is very much needed, particularly for the Kusuku soil where initial soil K/Mg ratio was much higher than 2, indicating K and Mg nutrient imbalance which can lead to Mg deficiency.

Conclusion

Response of tea to the fertilizers showed that their addition is needed for optimal tea production on the soils. Manures and their combined use with NPK resulted in better soil nutrient condition, tea growth and nutrient uptake than NPK. Cow dung, poultry droppings, siam weed (*Chromolaena odorata)* and tea fluff were optimal at OMF_1, and cocoa husk at OMF_2 are recommended.

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