

Soil properties and nutrient uptake of coffee seedlings as influenced by NPK fertilizer formulations in Ibadan, Southwest, Nigeria

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This work was carried out in collaboration between the authors. IOS designed the study, wrote the protocol and wrote the first draft of the manuscript. AOSO managed the literature searches, analyses of data and managed the experimental process. All authors read and approved the final manuscript.

ABSTRACT

A greenhouse study was carried at Cocoa Research Institute of Nigeria, Ibadan (Lat. 7° 25' N Long. 3° 25' E) in 2010 to evaluate the effect of NPK fertilizer formulations on the nutrient uptake of coffee seedlings and soil physical and chemical properties in Ibadan, Southwest Nigeria. The treatments consisted of NPK-liquid fertilizer (20: 2: 4 + TE) applied at rate 5 and 10mls/15 litres of water and NPK-solid fertilizer (15:15:15) applied at 1, 3 and 5g/coffee seedling) and a control (no fertilizer application). The six treatments were replicated three times in a completely randomized design and data on growth of coffee seedlings were taken for six months. Results showed that all the fertilizers irrespective of rates of application and types of NPK formulations enhanced the nutrient uptake of coffee seedlings relative to control. Leaf N-uptake was significantly (P=0.05) enhanced due to application of NPK liquid fertilizer applied at 5mls/15 litres of water compared to the control and NPK liquid fertilizer applied at 10mls/15litres of water. Similarly, the leaf-P uptake was improved significantly (P=0.05) as a result of application of NPK solid applied at 5g/stand of coffee seedling compared to the control and other treatments. The leaf K-uptake also followed a similarly trend in which solid NPK fertilizer at 5g/plant consistently promoted (P=0.05) the K-uptake of coffee seedlings compared to liquid NPK applied at 10mls/15L of water. The pH of the soil was significantly (P=0.05) affected as a result of application of liquid NPK fertilizer at 5mls and 10mls /15 litres of water compared to NPK solid fertilizer. The organic carbon was not significantly (P=0.05) influenced as a result of NPK fertilizer formulations. The organic carbon decreased in the order of 1g NPK solid < 3g NPK solid < control < 5mls NPK liquid < 10mls NPK liquid. The total N in the soil was not significantly affected as a result of NPK fertilizer types applied. The total N in the soil was significantly (P=0.05) higher than all other treatments situations where NPK fertilizers were applied. The improved growth and nutrient uptake of coffee seedlings through the use of NPK fertilizer formulations particularly liquid NPK provides alternative fertilizer options to farmers as a means of promoting crop productivity.

Keywords: NPK fertilizer, coffee seedlings, dry matter, nutrient uptake

39 INTRODUCTION

40 .Coffee is an important export crop traded globally and is a major foreign exchange earner for
41 many African and South American countries (1). In Nigeria, Robusta coffee (*Coffea canephora*
42 *Pierrie* ex. *Froehner*) constitutes up to 96%, while Arabica (*Coffea Arabica* Linus) is less than
43 4% (2)^[Ed.7]. Coffee was important for the Nigerian economy and for the livelihoods of its many
44 farmers between 1960s and the 1980s. The low price was mainly as a result of internationally
45 primary processing method in Nigeria^[Ed.8]. Production further declined^[Ed.9] due largely to old age
46 of plantations, poor yield resulting from poor planting materials, pests and disease attack. The
47 market situation became worse for farmers in 1985 after the abolition of the Nigerian
48 Commodity Board. The resultant effects are enormous which include, Nigerian coffee farmers
49 live in abject poverty owing to poor farm gate price of the commodity, farm abandonment among
50 others.^[Ed.10] The lack of government attention for coffee farmers on training, rehabilitation and
51 distribution of improved materials make the present scenario. In addition, policy support such as
52 compelling Nestle Nigeria Limited to buy Nigerian coffee and build model wet processing in
53 major coffee growing areas are lacking^[Ed.11]. Currently, the coffee market is to take advantage of
54 this positive trend^[Ed.12], there is need to assist the coffee farmers to increase yield through
55 efficient production methods particularly the use of inorganic fertilizers such as NPK fertilizers
56 to boost ~~its~~ coffee production^[Ed.13]. Fertilizers are applied to soils in order to maintain or improve
57 yields. Fertilizer additions can also have physico-chemical effects which influence soil
58 aggregation^[Ed.14] (3^[Ed.15]). Most soils upon which coffee is grown are generally poor in nutrients
59 such as nitrogen, phosphorus and potassium (4). In Nigeria, different NPK formulations (liquid
60 and solid) are ~~seen~~ found in the markets and they are being utilized by farmers for both arable
61 and some tree crops production. Liquid fertilizers are mostly foliar fertilizers that contain high
62 purity NPK and trace elements. Efficient fertilizers and fertilization methods have become the
63 sole answer to large growing demand for efficient farm product^[Ed.16]e. One of the most important
64 challenges facing advanced and progressive^[Ed.17] farmers is to provide crops with the optimal
65 quantity of nutrients in the most cost-efficient manner possible. For intensive high yield and
66 quality crop production, the best ever answer to this challenge is foliar spray nutrition where
67 soluble fertilizers are delivered to crops through foliar spray feeding system and thus ensures
68 plant nutrients such as nitrogen, phosphorous, potash and micronutrients are directed to the plant
69 through foliage in well balanced proportion (5). Foliar spray is a well-established tool to
70 supplement and to enrich plant nutrition^[Ed.18]. Countries like China, Vietnam and Indonesia have
71 found liquid fertilizers very helpful in increasing crop productivity particularly tree crops.^[Ed.19]
72 Nitrogen is an important structural component of many compounds necessary for plant growth
73 and development (6). It is also necessary for carbohydrate utilization, growth and development.
74 Phosphorus is a key element in the establishment of new plantations. However, in tropical
75 countries where coffee is cultivated, phosphorus is often the limiting nutrient. In fact, coffee soils
76 contain abundant phosphorus, but most of it fixed and unavailable to the plants. Sound
77 management of soil and other resources plays key role in productivity. Phosphorus plays a
78 significant role in cell division and root development (7). Potassium is vital for cell division,
79 formation and translocation of carbohydrates, activator of several enzymatic systems, and
80 regulation of osmosis or control of water in the plant and enhances the resistance of some plants
81 to certain diseases and insects attack. Hence, this study evaluated the effect of NPK fertilizer
82 formulations on the nutrient uptake of coffee seedlings and its implications on the physical and
83 chemical properties of the soil.^[Ed.20]

MATERIALS AND METHODS

The study was carried at Cocoa Research Institute of Nigeria, Ibadan (Lat. $7^{\circ} 25'N$, Long. $3^{\circ} 25'E$) in 2010 to evaluate the effect of NPK fertilizer formulations on the nutrient uptake of coffee seedlings in Ibadan, Southwestern Nigeria. The soil of Ibadan used for the study has been classified as Ferric Luvisols (8) FAO) and Ibadan series (9) Smyth and Montgomery) lying on at 122m above sea level. Top soil (0-30cm depth) was collected within the coffee plantations at Ibadan and was air-dried and sieved using 2mm sieve. The sieved soil was mixed with gutter sand [Ed.21] at 50:50 ratio and placed in five kilogrammes plastic buckets. The set-up was watered and allowed to equilibrate at field capacity for 48 hours. The treatments consisted of NPK-liquid fertilizer (20: 2: 4 + TE) applied at a rate of 5 - and 10mls/15 litres of water and NPK- solid fertilizer (15:15:15) applied at 1 -, 3- and 5g/coffee seedling) and a control (no fertilizer application). The six treatments were replicated three times in a completely randomized design and data on growth of coffee seedlings were taken for six months. The treatments were applied to two months old-coffee seedlings (two-leaf stage) in the greenhouse. The coffee seedlings that received NPK liquid fertilizer treatments were sprayed with the fertilizer dissolved in water and allowed to run freely [Ed.22] while the solid NPK fertilizer was applied in a ring form at the base of each seedling. The six treatments were replicated three times in a completely randomized design (CRD) and data on growth of coffee were taken for six months. [Ed.23] Watering was done regularly thrice a week. At the end of the experiment, destructive sampling was done and plant materials were separated into leaf, stem and roots and soil samples collected from each bucket for chemical analysis. The fresh plant samples were oven-dried at $72^{\circ}C$ to a constant weight for the dry matter yield to be obtained.

Phosphorus determination in plant samples.

The oven-dried samples were milled in an electric mill and nutrient analysis carried out for major nutrients in the leaves, stems and roots. Milled plant sample (0.55 g) was digested using tecator digestion system in a 70 ml Pyrex digestion tube. Five millilitres of $HNO_3.HCO_3$ reagent (2:1 v/v) were added into each tube under a fume chamber and allowed to stand overnight at room temperature. The tubes were then transferred into aluminium digestion block inside the fume chamber at a temperature of $150^{\circ}C$. The digestion was allowed for one and a half hours and the tubes removed, allowed to cool and 30 ml of distilled water was added into each tube. Stirring was done with vortex mixer and the content of each tube made up to 75 ml mark with distilled water. Phosphorus concentration was measured colorimetrically using vanado-molybdate method with a Jennway model colorimeter at $882\ \mu m$ wavelength.

Total N determination in plant samples.

Total N determination was carried out by weighing 0.24 g of milled plant samples into 75 ml digestion tubes, 3.0 ml conc. H_2SO_4 and 2.0 ml of H_2O_2 were added. The mixture was allowed to stand till the reaction ceased. The reaction tubes were placed on pre-heated digestion block at $370^{\circ}C$ for 20 minutes with full end plates. After cooling, 20ml distilled water was added to make up to 70 ml mark. Thorough shaking was done by inverting the digestion tube end-to-end. Total N (NH_4-N) was determined colorimetrically using the Technicon Autoanalyser II (10).

K determination in plant samples.

Finely ground plant samples (0.55g of leaf, stem and root) were placed in 30-ml porcelain crucible. The samples were ignited for 7 hours at a temperature of $450^{\circ}C$ and not exceeding $500^{\circ}C$. Greyish-white ashes were cooled on top of asbestos sheet and 5ml of 1 N HNO_3 solution was added. This was evaporated to dryness on a steam bath and returned to the furnace and heated at $400^{\circ}C$ for 10 minutes until a perfectly white ash was obtained. Ten millimetres 1 N HCl three

times and made up to volume with 0.1 N HCl solutions. The K-content of the sample was read on a Jennway (PFP7 model) at 766 μm wavelength

Nutrient uptake of kola seedlings^[Ed.24]

The nutrient uptake was calculated as the product of the nutrient concentration and dry matter yield: Uptake = Nutrient conc. X dry matter yield (11).

Soil analysis before planting

Samples of the soil used for the raising of coffee seedlings was taken from the top soil (0-30cm), air-dried and sieved for routine soil analysis. The particle size analysis was done using the hydrometer method (12). The soil pH (1:1 soil/water) was determined using a glass/calomel electrode system (13). The organic matter was determined by the (14). The soil K, Ca and Mg were extracted with IM NH_4OAC , pH 7 and their amounts determined on the flame photometer using appropriate element filters. The Mg content was read on an atomic absorption spectrophotometer (15). The exchangeable acidity (H^+ and Al^{3+}) was measured from 0.01M KCl extracts by titrating with 0.1M HCl (15). Percent N was determined using the microKjeldahl method (13). Available P was extracted using Bray P1 extractant and the extract was measured with the Murphy-Riley blue method (13) on a spectronic 20 instrument at 882 nm.

Soil analysis after the experiment

At the end of the study, soil samples were taken from each plastic bucket, air-dried, sieved and analysed for nutrient contents as described earlier.

Statistical Analysis

Analysis of variance was performed on all data to test the treatment effect on different parameters measured using a GenStat 8th Edition. Least Significant difference ($p < 0.05$) was used to separate the means.

RESULTS AND DISCUSSION

The physical properties of the soil indicated that the sand, silt and clay fractions were respectively 892, 143 and 165 g/kg soil (Table 1). [The soil is a sandy loam](#). The clay+ silt content of 308g/kg soil were sufficient to hold enough water for sustainable coffee plant growth and to guard against short duration drought [according to](#) Egbe *et al.* (17) cited by Ipinmoroti *et al.* (18). The pH, organic carbon, total N and available P were 6.5, 9.8g/kg, 2.0g/kg and 8.0mg/kg soil respectively. The exchangeable cations (K^+ , Ca^{2+} and Mg^{2+}) of the soil were 0.5, 10 and 2cmol/kg soil. ~~The soil is sandy loam.~~^[Ed.25] The pH of the soil was adequate for coffee production. The soil is marginal in terms of nutrient compositions particularly N, P and K (19,20). The NPK liquid fertilizer contained 20%, 2% and 4% for N, P, and K with some trace elements (TE) respectively while the solid NPK fertilizer had 15% N, 15% P and 15% K (Table 2). NPK fertilizer formulations had positive influence on the nutrient uptake of coffee seedlings. The leaf N-uptake was significantly ($P=0.05$) enhanced due to application of NPK liquid fertilizer applied at 5mls/15 litres of water compared to the control and NPK liquid fertilizer applied at 10mls/15 litres of water (Table 3). This could be as a result of its quick absorption through the leaves unlike when it is applied through the soil. This is consistent with the views of

Haggai and Aliyu (5) while working analyzing on effects of powerplant-liquid fertilizer^[Ed.26] and conventional NPK fertilizer on the growth and yield of maize. They found that uptake of nutrients through foliage is considerably faster than through roots and foliar spray is also the method of choice^[Ed.27] preferable when prompt correction of nutrient deficiencies is required^[Ed.28]. However, Application of NPK liquid fertilizer at 10mls/15L of water seemed to depress the nutrient uptake of coffee compared to the control^[Ed.29]. Although the manufacturer's recommendation was 10mls/15 L of water for adult plants in the field^[Ed.30] particularly for cocoa and other fruit trees, this recommendation might be excessive for seedlings which caused the depression in the nutrient uptakegrowth of coffee seedlings.^[Ed.31] It would be interesting to present total plant dry weight – are the seedlings stronger? YOU ONLY FOCUS ON CONCENTRATION IN THE PLANT MATERIAL AND SUGGEST THAT THIS IS RELATED TO PRODUCTIVITY. I FEELTHAT READERS MAY WORRY THAT THIS IS RATHER LIMITED. However, the leaf-P uptake was improved significantly ($P=0.05$) as a result of application of NPK solid applied at 5g/stand of coffee seedling compared to the control and other treatments. The leaf-K uptake also followed a similarly trend in which solid NPK fertilizer at 5g/plant consistently promoted ($P=0.05$) the K-uptake of coffee seedlings compared to liquid NPK applied at 10mls/15 litres of water. The stem and root N-uptake was significantly ($P=0.05$) affected due to application of liquid NPK fertilizer applied at 5mls/15 litres of water compared to the control and other treatments (Table 3). The superior performance of NPK liquid fertilizer on nutrient uptake of coffee seedlings^[Ed.32] could be attributable to the presence of some trace elements in it as claimed by the manufacture^[Ed.33] ^[Ed.34]. The P-uptake in the stem and the root of coffee seedlings was not significantly affected by NPK fertilizer formulations. The stem P-uptake ranged from 0.38 to 0.68mg/plant in the control and 5gNPK/plant respectively while root P-uptake ranged from 0.24 in the control to 0.46 mg/plant in NPK solid fertilizer applied at 5g/plant. Similarly, the K-uptake of stem and root of coffee seedlings was not significantly influenced by the application of NPK fertilizers (Table 3). The stem K-uptake was in the order of 10mlsNPK liquid fertilizer < control < 1gNPK solid < 3gNPK solid < 5mls NPK < 5g NPK solid. The trend in the root K-uptake was not different from the stem K-uptake. The effect of NPK liquid fertilizer applied at 5mls/15 litres of water was comparable to NPK (15: 15: 15) nutrient uptake of coffee seedlings. However, earlier reports by Yaduvanshi (21) and Adeniyi and Ojeniyi (22) both agreed that application of NPK fertilizer generally enhanced the nutrient uptake of N, P and K of crops.^[Ed.35] This might be due to the fact that some of the soil applied nutrients were immobilized by soil micro-fauna, soil organic matter and other edaphic factors thereby making them unavailable to the seedlings.^[Ed.36] This observation is consistent with the earlier findings of Ibiremo *et al.* (23) in which NPK fertilizer imposed depression on the growth parameters of cocoa in the field^[Ed.37].

NPK fertilizer formulations did not significantly affect the textural compositions of the soil (Table 4). This is in agreement with the views earlier expressed by Agbede (6) that textural compositions of soil could not be affected within a short period as a result inorganic fertilizer application.^[Ed.38] The mean values for sand, clay and silt compositions were 765, 139 and 96g/kg soil respectively. Haynes and Naidu (3) opined that fertilizer additions can also have physico-chemical effects which influence soil aggregation. However, the pH of the soil was significantly ($P=0.05$) affected as a result of application of liquid NPK fertilizer at 5mls and 10mls /15 litres of water compared to NPK solid fertilizer^[Ed.39]. This could be attributable to crop removal which

induces replacement anions with OH⁻ of Fe and Al. This observation is consistent on the view expressed by Law-Ogbomo and Osaigbovo (24). The organic carbon was not significantly influenced as a result of NPK fertilizer formulations (Table 4). The organic carbon decreased in the order of 1g NPK solid < 3gNPK solid < control < 5mls NPK liquid < 10mls NPK liquid^[Ed.40]. The total N in the soil was not significantly affected as a result of NPK fertilizer types applied. The total N in the soil was significantly (P=0.05) higher than all other treatments situations where NPK fertilizers were applied. The reason for this trend is not easily discernible. The available P in the soil was significantly (P=0.05) increased as a result of NPK-solid applied at 3 and 5 g/plant compared to the control and other treatments. The exchangeable K also followed similar trend in which NPK solid fertilizer applied at 3 and 5 g/plant increased the soil exchangeable K significantly. (P=0.05) compared to other treatments. This may be as a result direct application of solid NPK to the soil particularly when the K test value is not critically deficient as the case of this soil being used for this investigation. The increase in the total N, available P and exchangeable K values is consistent with the findings of Yaduvanshi (21). The soil C:N ratio was also significantly (P=0.05) affected by the application of NPK liquid fertilizer at 10mls/15 litres of water compared to the control and the NPK solid fertilizer (Table 4).

Conclusion^[Ed.41]

The improved growth and nutrient uptake of coffee seedlings through the use of NPK fertilizer formulations particularly liquid NPK provides alternative fertilizer options to farmers as a means of promoting crop productivity.^[Ed.42] Liquid NPK fertilizer could easily be applied in combination with other agro-chemicals such as fungicides and insecticides without increasing the cost of production^[Ed.43].^[Ed.44]

Table 1: Physical and chemical characteristics of soil used

Soil Properties	Unit	Value
Physical		
Sand	gkg ⁻¹	748.00
Silt	“	113.00
Clay	“	138.08
Textural class		Sandy loam
Chemical		
pH(H ₂ O) 1:1	-	6.08
Organic carbon	gkg ⁻¹	3.50
Total Nitrogen	“	0.60
C:N		7.25
Available phosphorus	mgkg ⁻¹	9.60

Exch. Bases		
K ⁺	cmolkg ⁻¹	0.12
Ca ²⁺	“	8.09
Mg ²⁺	“	0.91
Na ⁺	“	0.19
Exch. Acidity		
Mn ²⁺	mgkg ⁻¹	0.13
Al ³⁺	“	0.13
H ⁺	“	0.04
Base saturation	%	96.00

Table 2: Chemical composition of Fertilizer materials used for the study

Fertilizer materials	Chemical composition (%)			
	N	P	K	Ca
NPK(Liquid)+ TE	20	2	4	-
NPK(Solid)	15	15	15	-

TE- Trace Elements

Table 3: Nutrient Uptake of coffee seedlings as influenced by NPK fertilizer formulations in Ibadan, Southwestern Nigeria

Treatment	Leaf Nutrient Uptake (mgplant ⁻¹)			Stem Nutrient Uptake (mgplant ⁻¹)			Root Nutrient Uptake (mgplant ⁻¹)		
	N	P	K	N	P	K	N	P	K
Control	90.80	1.28	209.70	26.43	0.38	51.45	17.17	0.24	40.12
5mls NPK- L	143.90	1.45	206.90	56.28	0.56	67.95	37.65	0.38	54.56
10mlsNPK- L	87.10	1.59	185.80	26.24	0.47	46.65	16.91	0.31	36.08
1g NPK-S	123.60	1.79	235.20	34.97	0.50	55.45	23.68	0.34	45.32
3g NPK –S	106.50	1.71	288.80	27.46	0.43	62.10	16.34	0.26	44.08
5g NPK –S	123.90	2.43	319.40	35.93	0.68	75.50	24.00	0.46	64.24
LSD(0.05)	48.56	0.87	95.40	14.07	0.36	39.15	14.10	0.22	28.56
CV (%)	8.90	9.10	10.78	6.50	6.00	5.00	3.40	4.00	4.56

NPK-L (20-2-4+TE liquid fertilizer), NPK - S (NPK 15-15-15 solid fertilizer)

Table 4: Soil physical and chemical properties as influenced by NPK fertilizer formulations in Ibadan, Southwestern Nigeria

Treatment	Soil physical properties				Soil chemical properties				
	Sand gkg ⁻¹	Clay gkg ⁻¹	Silt gkg ⁻¹	pH	Org.C gkg ⁻¹	Total N gkg ⁻¹	Avail. P mgkg ⁻¹	Exch. K cmolkg ⁻¹	C:N
Control	748.00	139.20	112.80	6.08	0.35	0.06	9.60	0.12	7.25
5mls NPK- L	768.00	139.20	92.80	6.23	0.37	0.04	8.60	0.09	9.00
10mlsNPK- L	768.00	139.20	92.80	6.20	0.46	0.03	9.30	0.10	15.88
1g NPK- S	768.00	139.20	92.80	6.01	0.26	0.03	14.40	0.15	8.33
3g NPK- S	768.00	139.20	92.80	5.79	0.32	0.04	21.70	0.18	11.30
5g NPK- S	768.00	139.20	92.80	5.38	0.39	0.03	28.80	0.21	13.78
LDS(0.05)	5.04	4.89	4.88	0.38	0.21	0.03	12.62	0.21	6.55
CV (%)	2.50	2.50	2.02	3.40	28.2	36.3	30.30	11.20	28.60

NPK-L (20-2-4+TE liquid fertilizer), NPK - S (NPK 15-15-15 solid fertilizer)

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