Impact of Fertilization and Planting Density of *Irvingia Wombolu* on the Physical and Chemical Properties of Soil

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Abstract. In a young *Irvingia wombolu* orchard established at the National Horticultural Research Institute (NIHORT), where yearly fertilization was done, the impact of this inorganic fertilization on the physical and chemical properties of an alfisol was investigated between 2006 and 2008. Pre-cropping soil sampling was done at 0-30cm soil depth with a soil auger using judgement composite sampling, while post-cropping soil sampling was done at 1.5m at each stand and bulked as a composite sample per treatment combination. The soil parameters analysed for were pH, total nitrogen (N), available phosphorus (P), exchangeable bases (sodium – Na, calcium – Ca, magnesium – Mg and potassium – K), base saturation, organic matter, micronutrients (zinc – Zn, copper – Cu and iron – Fe), particle size distribution, soil texture and bulk density. The treatments consisted of five fertilizer levels of NPK 20:10:10 (0, 75, 150, 225, and 300 kg/ha) while there were three plant densities (204, 238 and 286 plants/ha). The results after 2 years of fertilizer application showed that there was a slight change in soil physical properties and a significant increase in soil acidity with increasing fertilizer rates at a density of 286 plants/ha. The sand particles increased from 75.8% to 83.8% in 238 plants/ha under 150 kg/ha fertilization, and there was also a significant increase in available P from 1.55 mg/kg to 28.75 mg/kg, and in exchangeable K from 0.17 cmol/kg to 0.50 cmol/kg in 268 plants/ha and 238 plants/ha under 225 kg/ha and 150 kg/ha of fertilizer application, respectively. There was an increase in acidity with increased fertilization from 6.6 to 4.5 in 286 plants/ha, while at 204 plants/ha, there was a decrease in acidity with an increase in fertilization. Soil organic matter increased after cropping from 1.08 g/kg to as high as 3.59 g/kg after fertilization in all the plant populations showing no distinct trend. There was also a significant increase in Zn, Cu and Fe from 2.32 mg/kg to 86.65 mg/kg, 1.53 mg/kg to 2.22 mg/kg and 34.05 mg/kg to 137.25 mg/kg in 286 plants/ha, 238 plants/ha and 238 plants/ha under 75 kg/ha, 300 kg/ha and 150 kg/ha fertilizer application, respectively. Overall, this trial showed that application of inorganic fertilizer increased the acidity of the soil and the concentration of micronutrients. The application of inorganic fertilizer should be done with caution as its high dose led to increase in soil acidity resulting in restricted availability of some macronutrients especially K and Na.

Keywords: bush mango, Nigeria, plant population, soil nutrients, soil acidity

Introduction

Fruit tree crop production in Nigeria dates back to the early days of farming. These crops are categorized as either indigenous or exotic fruit tree crop species. Most of the indigenous fruit tree crop species located in the forest zone is lesser known, under-exploited and not purposely cultivated (Okafor, 1983; Isichei, 2005). *Irvingia wombolu* (Vermeosen), formerly known as *Irvingia gabonensis* var. *excels (Milber/Okafor)*, is found in the tropical rainforests of East, West and Central Africa (Harris, 1996; Tchoundjeu *et al.*, 2005). In Nigeria, the species is found in the Southern States and lower region of the Middle Belt States (Nzekwe *et al.*, 2005). The species and its close relative *Irvingia gabonensis*, formerly var. *gabonensis*, are collectively identified as Bush mango, due to their mango-like fruits. *Irvingia wombolu* fruit pulp is slimy to touch and very bitter to taste (Ejiofor *et al.*, 1987). The desired part of the species is the kernels, the cotyledons, popularly used in preparing a local soup that is highly cherished for its drawability. The Igbos call it 'Ogbono', Yorubas – 'Oro', the tree, and

'Aaapon', the kernel. The Efiks call it 'Nbakpab-Uyo', and the Binis of Edo state, call it 'Ogwe' (Nzekwe *et al.*, 2008). Various research findings have reported that the kernels contain food nutrients in varying percentage (Ejiofor *et al*., 1987; Anegbeh *et al*., 1996). Udeala and Aly (1985) reported that it has potentials for pharmaceutical preparations. The kernel contains 71.97% fat and 8.65% protein (Effa & Iboh, 1990; Okolo, 1994). Presently, most farmers maintain mature bush mango trees that are already growing on their land and will also transplant wild seedlings onto their farm or grow up new seedlings (Ayuk *et al.*, 1999). *Irvingia* spp. have positive effects on the soils in which they grow, for example reducing soil bulk density and increasing levels of organic carbon and exchangeable potassium and magnesium ion. This makes them very suitable for use as agro-forestry tress in multi-storey crop set-up (Kang *et al.*, 1994). Most recent studies done on *Irvingia* spp. have focused on the harvesting, processing and marketing of the *Irvingia* fruits. Information on the nutrient requirement on this important crop is still scarce. Thus, there is need to further document the agronomic requirements for its production especially the soil nutrient requirement for different growing areas. This study was therefore carried out to evaluate the influence of fertilizer application and population density on the soil nutrient dynamics required for the optimal production of *Irvingia wombolu* in Ibadan, south western Nigeria

Materials and Methods

The evaluation of the soil nutrient dynamics within the *Irvingia wombolu* orchard established in 2006 was carried out in 2008 at the National Horticultural Research Institute, Ibadan Nigeria. This orchard was established using 8-month-old seedlings after proper land preparation through ploughing and harrrowing. The treatments imposed on the orchard were different rates of inorganic fertilizer and plant population densities. There were three population of 204 (7m x 7m), 238 (7m x 6m) and 286 (7m x 5m) plants/ha. The fertilizer treatment levels of 0, 75, 150, 225, and 300kg/ha was used with NPK 20:10:10 as the fertilizer source. Composite soil samples at 0-30 cm soil depth were taken with a soil auger during land preparation in May 2006. The sampling was done using judgement composite sampling technique prior to planting. A post-cropping soil analysis was done 28 MAT for each treatment combination to assess the effect of the fertilizer treatments and population density on the concentration of some soil nutrients. The sampling was done at the least distance of 1.5 m away from the plants in each plot. Core samples were pulled together based on the treatments to give a total of 15 composite samples. These samples were analysed for both physical and chemical properties. The soil samples were air-dried and crushed by hand to facilitate drying. Further crushing was done using mortar and pestle, sieved through a 2 mm sieve, and re-bagged for chemical analysis. The micronutrients determined were Fe, Cu, and Zn using hydrochlorous acid extraction (Baker & Amacher, 1982) and atomic absorption spectrophotometry (AAS) (Isaac & Korber, 1971). The particle size distribution was done using the hydrometer method (Bouyoucos, 1962). Total nitrogen was determined using the Kjeldahl method while available phosphorus was analysed using Bray P-1. Data obtained was analysed using descriptive statistics.

Results and Discussion

Soil Physical Properties

Soil Texture: The pre-cropping soil test results showed the soil texture was sandy loam with 75% sand, 17.4% silt and 6.8% clay content (Table 1). There was no change in the soil texture in all the populations with no fertilizer treatment though at 238 plants/ha, there was a change in texture from sandy loam to loamy sand (Table 2). Also at 286 plants/ha, there was no change in soil texture in all treatments while at 204 plants/ha, changes in texture from sandy loam to loamy sand were observed at 225 kg/ha and 300 kg/ha of NPK (20:10:10). The changes observed at 204 plant population per hectare could be due to low population density in combination with high fertilization resulting in leaching and loss of soil OM thereby increasing the sandiness of the soil from 75.8% to 79.8% (Table 2).

Table 1. Pre-cropping soil test results taken in 2006

Soil Parameters	Test Results
pH (H_2O)	5.1
Organic carbon (%)	0.63
Soil organic matter (g/kg)	1.08
Total nitrogen (g/kg)	0.12
Available phosphorus (mg/kg)	1.55
Exchangeable calcium (cmol/kg)	0.90
Exchangeable magnesium (cmol/kg)	0.63
Exchangeable sodium (cmol/kg)	0.02
Exchangeable potassium (cmol/kg)	0.17
Cation Exchange Capacity (cmol/kg)	1.82
Sand (%)	75.8
Silt (%)	17.4
Clay (%)	6.8
Bulk density (g/cm^3)	1.63
Soil texture	sandy loam (SL)

Table 2. Post-cropping soil test results taken in 2008

Treatments	**Soil Parameters**									
	pH	Total N (g/kg)	Avail P (mg/kg)	SOM (g/kg)	Exch. K (cmol/kg)	Copper (mg/kg)	Zinc (mg/kg)	Iron (mg/kg)	Texture	BD (g/cm^3)
P1T0	4.5	0.13	13.86	1.51	0.06	1.57	33.88	67.25	SL	1.59
P1T1	5.6	0.17	28.25	2.73	0.13	2.21	25.30	81.75	SL	1.6
P1T2	5.6	0.12	27.30	3.01	0.24	2.10	43.22	133.80	SL	1.59
P1T3	6.6	0.16	26.55	3.59	0.18	2.00	36.88	71.60	LS	1.64
P1T4	6.1	0.14	28.10	2.24	0.06	2.00	35.73	114.80	LS	1.6
P2T0	4.7	0.08	26.25	0.86	0.15	1.90	16.66	71.95	SL	1.6
P2T1	5.3	0.11	28.05	2.10	0.47	1.79	30.65	120.75	LS	1.65
P2T2	5.2	0.12	26.75	3.32	0.50	1.93	55.77	137.25	LS	1.6
P2T3	6.5	0.12	25.35	2.68	0.18	1.71	30.92	67.65	LS	1.59
P2T4	5.1	0.13	27.40	2.43	0.23	2.22	36.25	113.00	LS	1.64
P3T0	6.6	0.11	25.25	2.63	0.21	2.22	32.50	71.85	SL	1.63
P3T1	5.7	0.15	27.35	3.54	0.19	1.80	86.65	74.75	SL	1.59
P3T2	5.4	0.11	26.90	1.72	0.16	2.38	26.10	70.75	SL	1.57
P3T3	4.9	0.17	28.75	1.57	0.34	2.00	36.50	129.80	SL	1.53
P3T4	4.5	0.16	26.75	1.74	0.19	1.63	12.82	64.25	SL	1.54

Note: P1 – 204 plants/ha; P2 – 238 plants/ha; P3 – 286 plants/ha; T0 – 0 kg/ha (control); T1 – 75 kg/ha (NPK 20:10:10); T2 – 150 kg/ha (NPK 20:10:10); T3 – 225 kg/ha (NPK 20:10:10); T4 – 300 kg/ha (NPK 20:10:10); BD – bulk density; SL – sandy loam; LS – loamy sand

Bulk Density: soil compaction occurs when soil particles are pressed together, reducing the pore space between them thereby increasing the bulk density of the soil (Anikwe, 2006). Bulk density is the weight of solids per unit volume of soil. If it becomes too high, it can limit plant root growth. The specific bulk density that will adversely affect plant root growth and development depends on many factors including the parent material, soil texture, the crop being grown, and management history (USDA-NRCS, 1996). The pre-cropping bulk density was 1.63g/cm^3 (Table 1). Ideal bulk density for sandy loam and loamy sand soils should be

<1.40g/cm^3 and <1.60 g/cm^3 respectively (Arshad *et al.*, 1996). At 286 plants/ha, the bulk density ranged from 1.53 – 1.63 g/cm^3 and the texture was sandy loam and it reduced with increase in fertilization. This result indicates that the soil under this population is likely to restrict root growth of *Irvingia wombolu* (Table 3).

Table 3. General relationship of soil bulk density to root growth based on soil texture

Soil Texture	Ideal Bulk Density (g/cm^3)	Bulk Densities that may affect root growth (g/cm^3)	Bulk density that restrict root growth (g/cm^3)
1. Sands, loamy sand	<1.60	1.69	>1.80
2. Sandy loams, loams	<1.40	1.63	>1.80
3. Sandy clay loams, clay loams	<1.40	1.60	>1.75
4. Silts, silt loams	<1.30	1.60	>1.75
5. Silty clay loams	<1.40	1.55	>1.65
6. Sandy clay, silty clay, Some clay loams (35-45% clay)	<1.10	1.49	>1.58

Source: Arshad *et al.* (1996)

Soil Chemical Properties

Soil pH: The soil pH prior to cropping was strongly acidic at 5.1 (Table 1). This can affect the growth of crops and also the availability of soil nutrients. The post cropping results (Table 2 and Figure 1) showed a change in the soil pH with different trends under different population densities and fertilization. At 286 plants/ha, there was a reduction in pH from 6.6 (neutral) to 4.5 (very strongly acidic) with increase in fertilization from 0 kg/ha to 300 kg/ha of NPK 20:10:10 (Table 2). However, at 204 plants/ha, an increase in pH from 4.5 (very strongly acidic) to 6.6 (neutral) was observed with increase in fertilization from 0 kg/ha to 225kg/ha of NPK 20:10:10. Soil pH influences the availability of plant nutrients as well as the activities of microorganisms (Brady and Weil, 1999). In strongly acidic soils (pH 4 – 5), the availability of macronutrients Ca, Mg, K, P, N and S is curtailed. The sources of acidity include parent materials, leaching of bases, crop removal, organic matter and fertilizers (Brady and Weil, 1999). In contrast, availability of micronutrients (Fe, Mn, Zn, Cu and Co) in strongly acid soils is increased even to the extent of toxicity to higher plants and microorganisms.

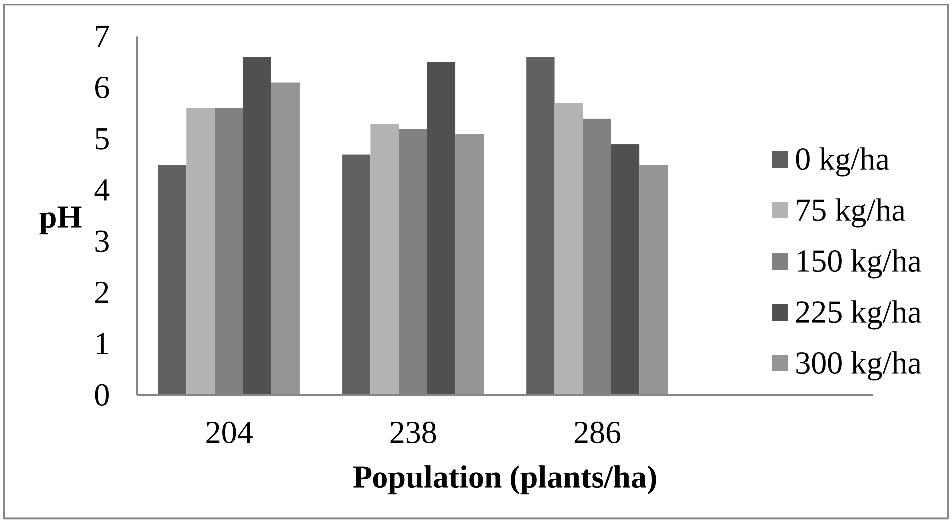

Figure 1. Effect of fertilizer application and population density of *Irvingia wombolu* on the soil pH of an Alfisol grown in south western Nigeria

Macronutrients: Plants take up nitrogen (N) from the soil solution mainly as nitrates and ammonium ions. Nitrate anions simulate an increase in the pH of the soil solution while ammonium cations decrease the pH (Chude *et al.*, 2004). The nitrogen content of surface soils ranges from 0.02 to 0.5%. This is below the critical level of plant N requirement of 2.0%. Also, the mineral forms of N are soluble in water and are easily lost from soils through leaching and volatilization. This explains the N concentrations in the soil after fertilization which ranged from 0.08 – 0.13 mg/kg at 238 plants/ha, 0.11 – 0.16 mg/kg at 286 plants/ha, and 0.12 – 0.17 mg/kg at 204 plants/ha (Figure 2). In the pre-cropping soil test result, available phosphorus (P) was curtailed to an extremely low level of 1.55 mg/kg possibly due to the low pH (5.1) but there was a geometric increase in the concentration of P to 28.75 mg/kg after fertilization. The post-cropping soil test results (Table 2) showed an increase in available P in all the population densities with increase in fertilization. P is a critical element in agriculture. The problem of P in soil fertility is three fold. The total P level is low and is mostly unavailable for plants uptake because they are highly insoluble. When soluble forms are added to the soil, they are also fixed and in time form unavailable forms, leaving only about 10-15% for plant utilization. The initial concentration of K in the soil prior to transplanting was 0.17 cmol/kg which is low since fertility ratings for low K concentration is <0.15 cmol/kg. The fertilization of the *Irvingia wombolu* orchard increased the K content of the soil at 0-30 cm soil depth in all the population except at 204 plants/ha where lower levels of K were observed after fertilization (Table 2 and Figure 3). This observation could be due to the characteristic nature of K as an element that is subject to leaching and removal by plants especially in a low-density plant population. Potassium is generally high in most mineral soils, but very large proportion is unavailable to plants. The problem of K fertility is rarely one of total supply but rather of adequate supply of available forms. And the availability of this form of K at depths below the plough layer is difficult.

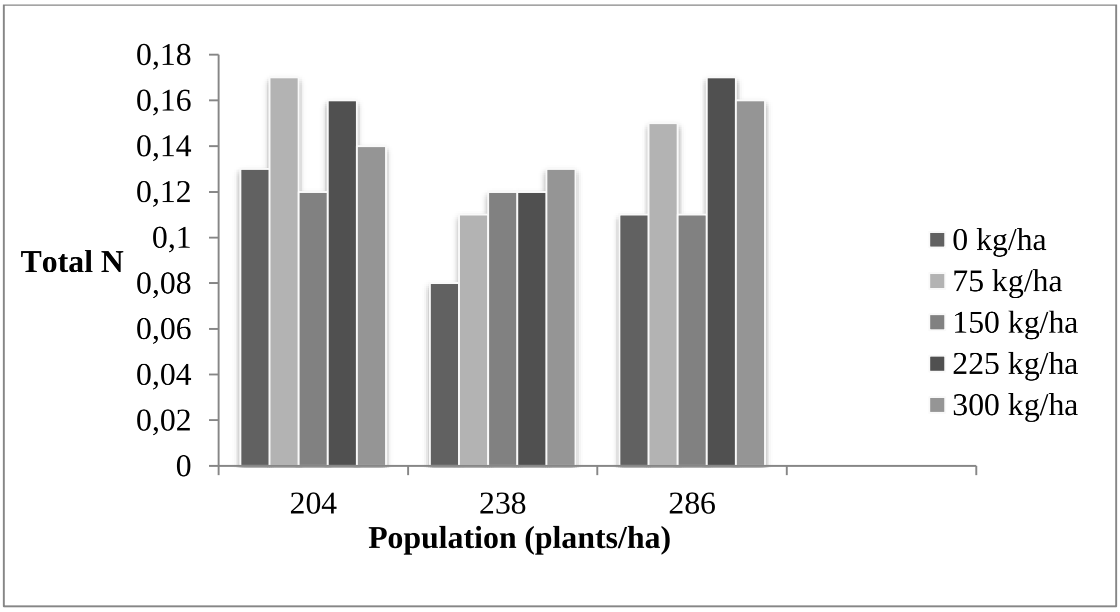

Figure 2. Effect of fertilizer application and population density of *Irvingia wombolu* on the total N of an Alfisol grown in south western Nigeria

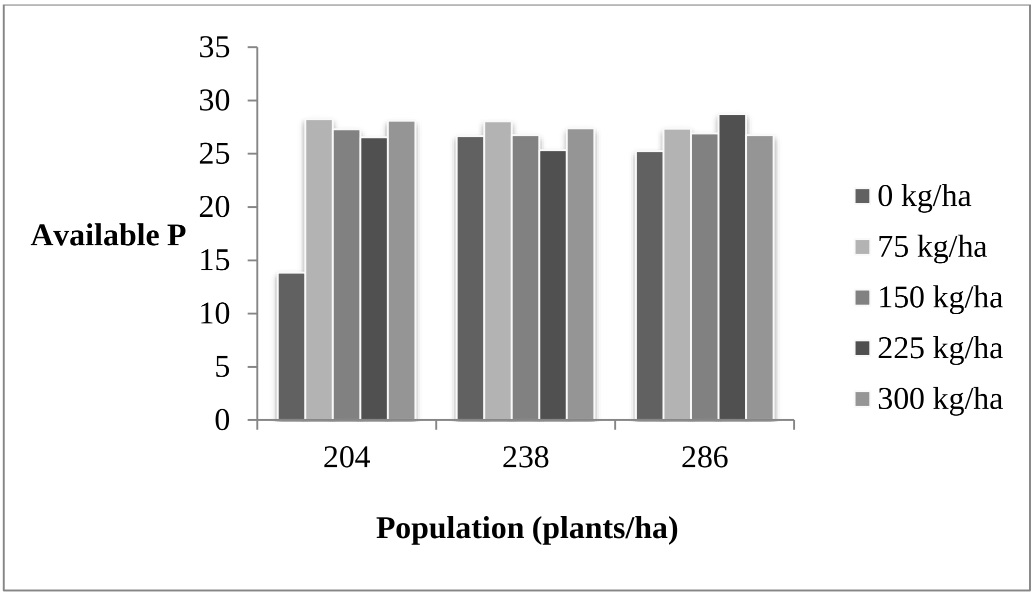

Figure 3. Effect of fertilizer application and population density of *Irvingia wombolu* on the concentration of phosphorus on an Alfisol grown in south western Nigeria

Micronutrients: Micronutrient deficiencies arise from low levels in the soil and their unavailability to growing plants. Toxicity of micronutrients retards plant growth. Micronutrient's function to the plant is wide and vast from one nutrient to the other. Zinc is involved in the biosynthesis of indole acetic acid, assists the utilization of P and N in plants, and also plays a role in nucleic acid and protein synthesis. The recommended soil Zn level above which addition of fertilizer is unnecessary is >5 mg/kg (Chude *et al.*, 2004). The concentration of Zn was low in prior to planting and fertilization but increased geometrically after fertilization to as high as 86.65 mg/kg (Table 2). Since soil concentration range of 70-400mg/kg total Zn is classified as critical, above which toxicity is likely (Alloway, 1990), caution need to be applied when adding fertilizers that increase the concentration of zinc in the soil. Also, the results showed that Zn concentrations increased after the application of fertilizers.

Conclusions

The results indicate that fertilizer application irrespective of population density of *Irvingia wombolu* influenced both the physical and chemical properties of the alfisol under investigation. It can thus be concluded that the application of inorganic fertilizer increased the acidity of the soil and the concentration of micronutrients. Therefore, the application of inorganic fertilizer should be done with caution as its high dose led to increase in soil acidity resulting in unavailability of some macronutrients.

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