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Original article

Nutritional Assessment of Old and Young Coffee/kola Intercropped Plantations for Management Needs in Ibadan and Kusuku Areas of Nigeria

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Abstract
Coffee and kola are cash crops of international market value with great contributions to Nigeria GDP. The need to increase their production under a limited land resource and to maintain stable ecosystem necessitated the establishment of coffee/kola plantations. However, intercropping increases the nutrient demand with consequent decline in overall crop production if not well managed. This study was conducted to determine appropriate nutrient needs under coffee/kola intercrop at different ages for appropriate soil fertility management, for sustainable coffee and kola production. An area of 1.0 ha at each location was marked out for soil, coffee and kola leaf samples collection. Soil samples were collected at 0-30cm; air-dried, sieved using 2mm sieve and mixed to form composite soil samples. Coffee and kola leaf samples were collected separately from 4 coffee and kola plants that were close to each soil sampling point and the leaf samples were oven dried at 70 ℃ to constant weight and milled. The soils samples were analysed for the soil particle size distribution and nutrient contents while the coffee and kola leaf samples were analysed for their nutrient contents. Results showed that SOC (9.50g/kg) and available P (1.35mg/kg) were lower than their corresponding critical values in Ibadan. Soil Ca (1.15cmol/kg) and Mg (7.48cmol/kg) in Kusuku and (2.74 and 0.85cmol/kg respectively) for Ibadan were lower for coffee production. Leaf macronutrient content was higher in young coffee/kola plantation at Ibadan while the old plot at Kusuku contains more micronutrient. The soils will therefore need the application of fertilizer materials to improve the soil organic C contents, correct the K/Mg ratio and supply the deficient nutrients for the two location soils. Application of 9.3 kg/ha P, 5.2 kg/ha K, 12.3 kg/ha Ca, 1.4 kg/ha Mg and 7.8 kg/ha Mn, 1.6 kg/ha Fe, 0.8 kg/ha Cu and 1.5 kg/ha Zn at Ibadan and 15.6 kg/ha Ca, 0.5 kg/ha Mg and 1.4 kg/ha Mn at Kusuku, would be needed to bring the location soils to optimal and sustainable production of coffee and kola plants in plantations. Preferably, application of organic manure at 1.0 t/ha/year in Kusuku and 4.1 t/ha/year in Ibadan is advised.

Keywords: Beverage crops, competition, intercropping, land use, productivity

Introduction

Coffee and Kola are commodity crops of international importance that have contributed to the growth of Nigeria gross domestic product (GDP) (Mustopha, *et al.*, 2022). Coffee is an evergreen shrub that is cultivated both in the temperate and tropic regions of the world. It belongs to family Rubiaceae, genus *Coffea* and can grow to about 9 meters height but by training can be kept to 4 meters height for ease of harvest. Kola on the other hand, is a tropical tree crop of the family Sterculiaceae, genus *Cola* which grows to about 20 meter height, and has been successively intercropped with crops like cocoa, citrus and oil palm (Burdock, *et al.*, 2009).

Coffee and Kola had witnessed increased international demand in recent times; this necessitated the need to increase their production by increasing yield per hectare or increasing the farm size through opening up new plantations. However, the problem of land availability and suitability for agricultural purpose has kept increasing due to community expansions as a result of ever increasing human population, land demand for other competitive uses, land degradation through soil erosion and decline in fertility amongst others (Ipinmoroti, *et al.*, 2005). Consequently, it is imperative to explore appropriate cropping systems that will maximize the use of available farm lands, reduce cost of production and bring about optimum yield. A practice that accommodates two or more perennial crops that are compatible in an intercropping system is inevitable and one of such practices is the coffee/kola intercrop.

Kola is planted at 9m x 9m resulting into much spacing between stands while coffee is planted at 3m x 3m. The wide open spaces between the kola stands are prone to erosion problems (Famaye, *et al.*, 2012). The marked differences both in height of coffee and kola plants and in their planting distances couple with the fact that they have similar weather requirements such as high humidity (Petek, *et al.,* 2005) make the planting together of the two crops a possibility. The practice of intercropping tree crops with arable and or other tree crops has been described as a veritable source of extra income to the tree crop farmers (Santini, *et al.*, 2019). Intercropping is one of the possible ways to proffer solutions to the problems of availability and costs of farm land and labour that have constituted serious bane to agricultural practices and productivity. With intercropping practices, the limited available agricultural lands are better utilized optimally. Tree/tree crop intercrop has been reported to control the ambient temperature and improves the establishment rate of the component crops (Omolaja, *et al.*, 2008; Araujo, *et al.*, 2015).

However, multiple crops on a piece of land do results to nutrient management issues amongst other problems that need conscientious efforts to resolve, to achieve optimum production of the component crops on a sustainable basis (Aderolu, *et al.*, 2014; Zhu, *et al.*, 2015). Presently, appropriate nutrient need on Coffee/kola intercropped plantations at different ages for adequate soil fertility management is lacking. Hence, the need for existing young and old plantations of Coffee/Kola intercropped to be assessed for their soils and leaf nutrient contents for information on their nutrient status. This would serve as basis for nutrient recommendations for enhanced production of both perennial crops. The objective of the study therefore was to evaluate the soils and leaf nutrients status of young and old Coffee/kola intercropped plantations for appropriate soil nutrient management practices that would promote fruits yield on a sustainable basis.

Materials and Methods

The study was conducted in two agro-ecological locations of Ibadan (7˚ 10N; 3˚ 52E) that lies within the forest savannah zone of South Western Nigeria with average rainfall of 1,106.5 mm, relative humidity of 75.1%, temperature of 23.7-34.2 ℃ and Kusuku (6˚ 53N; 11˚ 8E), which lies on the cool mountainous highland area of Mambilla in North Eastern Nigeria with rainfall of 1,750mm, relative humidity of 79% and temperature 19.0-24.5 ℃. At Ibadan location, a 5 year old candidate plot with young coffee/kola intercrop was used while at Kusuku, a 30 year old coffee/kola intercrop plantation was selected.

An area of 1.0 ha was marked out for soils, coffee and kola leaf samples collection at each location. Soil samples were collected in a stratified sampling method at 10 sampling points per location using soil auger from 0-30cm depth. Soil samples per plot were air-dried, sieved with 2mm sieve and mixed to form composite soil samples. Coffee and kola leaf samples were collected from 4 coffee and kola plants that were close to each soil sampling point. The leaf samples were oven dried at 70 ℃ to constant weight and milled with stainless hammer mill. The soil samples were analysed for the soil particle size distribution, pH, OC, ECEC, BS, EA, N, P, K, Ca, Na, Mg, Mn, Zn, Cu and Fe, while the coffee and kola leaf samples were each analysed for N, P, K, Ca, Na, Mg, Mn, Zn, Cu and Fe contents.

The soil particle size distribution was determined by the hydrometer method (Gee and Bauder, 1986). The soil pH was measured electronically with glass electrode pH meter in soil/water ratio of 1:2.5 (Mclean, 1982). Soil organic carbon content was determined by wet dichromate oxidation method (Nelson and Sommers, 1982), while total N was determined by the micro Kjeldahl digestion method (Bremmer, 1996). The available P was determined by Bray I method (Bray and Kurtz, 1945), while the exchangeable cations were determined by leaching 5gm soil with 50ml of 1N NH_4OAC at pH=7 and the K, Na, Ca and Mg were measured by atomic spectrophotometer (AAS) according to AOAC, 1990. The soil exchangeable acidity (Al^{+3} and H^+) was by leaching the soils with 1.0NKCl and titrated with 0.05NNaOH and HCl solutions (Mclean, 1982) while the effective cation exchangeable capacity (ECEC) was by summation of the exchangeable cations and acidity contents.

Coffee and leaf samples were digested using nitric-perchloric-sulphuric acid mixture (AOAC, 1990). The N content was determined by micro-Kjeldah method and P by Vernadomolybdate colorimetric. The K was analysed by flame photometer while the Ca, Mg and Zn were by AAS. The analytical results were compared with each crop corresponding soil and foliar nutrient critical needs (Egbe *et al.*, 1989; FAO, 2005).

Results and Discussions

Results on soils of both locations showed that the Ibadan soil had higher sand content (734g/kg) compared to the Kusuku soil (658g/kg). The silt and clay contents were 180 and 86 g/kg respectively for Ibadan, while it was 294 and 48 g/kg soil for the Kusuku soil. On the overall, both soils were sandy loam in texture (Table 1) however, the silt + clay content for the Ibadan soil (266 g/kg) was lower than 320g/kg ideal for the tree crop cultivation while the Kusuku soil with 342 g/kg was higher than the critical (Egbe, *et al.*, 1989). This indicates that the Kusuku soil would be able to retain much water and nutrients compared to the Ibadan soil for plant needs. Hence, there will be need for improvement on the Ibadan soils through organic matter build up by way of organic manure application and other good agricultural practices to make the soils have ability to retain much water and nutrients for plant use. Good agricultural practices such as intercropping with legumes (e.g. beans) and cover crops (e.g. melons) where feasible to enhance the soil organic matter content. Water holding capacity of a soil is primarily controlled by the soil physical properties and the soil organic matter content (De Jonge, *et al.*, 2007; Kamur, *et al.*, 2020; Zhang, *et al.*, 2021). Similar suggestions had been advanced by Ipinmoroti and Ogeh (2014) for tree crop plantations in Uhonmora area of Edo, Nigeria

Table 1: Soil separate composition and texture

Location	Sand	Silt	Clay	Texture
	←	g/kg	→	
Kusuku	658	294	48	Sandy loam
Ibadan	734	180	86	Sandy loam

Soil pH and Organic Carbon Contents

The soil chemical analytical results (Table 2) showed that the Kusuku soil was more acidic compared to that of Ibadan. However, the soil pH of 5.9 for Kusuku and 6.4 for Ibadan were within range for coffee and kola production (Egbe, *et al.*, 1989). Soil organic carbon in Kusuku (32.1g/kg) was higher than the critical value of 30.0g/kg ideal for cultivation of tree crops while that for Ibadan (9.50g/kg) was lower than the critical. Organic matter contents form important properties of the soil as it affects the soil pH and influences the soil nutrient dynamics, and their availability to plants (Basharat, *et al.*, 2020; Allam, *et al.*, 2022). Therefore, there is the need for suitable good agricultural practices on the use of farm wastes to maintain and increase the soil organic matter content to sustain soil nutrient availability and their uptakes for profitable coffee and kola production on the soils and more importantly, for the Ibadan location.

Soil Macronutrient Contents and Base Saturation

The soil N content for Kusuku (2.13g/kg) and Ibadan 1.00g/kg followed the same trend with the soil organic C contents. However, the quantity of N in the soils was adequate in comparison to the critical value of 0.90g/kg for coffee and 1.00g/kg for Kola cultivation. This ordinarily indicated that the coffee and kola crops should not be faced with inadequate supply of N from the soils.

The available P content for Kusuku soil (18.97mg/kg) was above the critical level of 6.00mg/kg for coffee and 3.70mg/kg for kola cultivation (Tables 2 and 3), while the Ibadan soil has available P value of 1.35mg/kg that was lower than the critical values for both coffee and kola plants. The Ibadan soil therefore need P fertilizer supply in order to meet the soil requirements for sustainable coffee and kola production. Phosphorus fertilizer amendment is much needed for the Ibadan soils in that P plays important roles in plant metabolism that affects plant growth, development, yield and produce quality (Duan *et al.*, 2022). The soil exchangeable K values for both locations indicated that the Kusuku soil was higher in K contents than the soil critical values for coffee and kola cultivation while in Ibadan, the soil K level was only sufficient for Kola but not for coffee (Tables 2 and 3). This implies the need for K fertilizer application in Ibadan to meet the coffee plants K requirement.

Table 2: Some soil chemical and nutritional composition for Ibadan and Kusuku study locations

Location	pH	N	OC	P	K	Ca	Mg	Na	EA	ECEC	BS
		g/kg		mg/kg	←		cmol/kg		→		%
Kusuku	5.90	2.13	32.1	18.97	0.41	1.15	0.75	0.48	0.132	9.62	98.63
Ibadan	6.64	1.00	9.50	1.35	0.14	2.74	0.09	0.25	0.08	3.85	98.29

Table 3: Soil and leaf nutrients critical levels for coffee and Kola

Plant	OC	N	P	K	Ca	Mg	Mn	Fe	Cu	Zn
	← g/kg →		mg	←	cmol	→	←	mg/kg	→	
Coffee	30.0	0.90	6.00	0.40	0.89	0.80	<50	2-20	0.3-10	2-10
Kola	30.0	1.00	3.70	0.12	0.80	0.08	45-80	10.50	5-20	10.40
					Leaf critical levels					
		←		%	→		←	mg/kg	→	
Coffee	-	1.10	0.07	1.40	0.37	0.13	50-100	70-200	16-20	15-20
Kola	-	1.09	0.08	1.20	0.47	0.34	40-70	100-250	35-70	35-100

Source: Egbe *et al.*, 1989; FAO, 2005

Soil Ca contents for Kusuku and Ibadan locations (1.15 and 2.74 cmol/kg respectively) were lower compared to the critical value of 8.9cmol/kg for coffee cultivation while the values were adequate for kola cultivation. It has been demonstrated that calcium is very vital for plant growth and diseases resistance while its deficiency results to physiological disorder in plants (Hochmal, *et al.*, 2015). This suggests the need for Ca fertilizer application in both locations to be able to meet the Ca needs for coffee. The soil exchangeable Mg for Kusuku (7.48 cmol/kg) and Ibadan (0.85 cmol/kg) were adequate for kola cultivation but not adequate for coffee cultivation when compared to their critical values (Table 3). Magnesium fertilizer application becomes imperative in both locations for the soils to meet up with the Mg requirements of the coffee plants. Mg deficiency has been reported to affect the processes of plant photosynthesis and resulting to, amongst others, shorten leaf life (Wang *et al*., 2020).

On the overall, the Kusuku soils were inadequate in the Ca and Mg contents for coffee production; it therefore means that combined production of coffee and kola under coffee/kola intercrop in the Kusuku soils would be problematic without adequate supply of Ca and Mg fertilizers. Whereas in Ibadan, only N was adequate in the soil, while P, K, Ca and Mg were inadequate for coffee production. Hence, for optimal performance of coffee and kola in the coffee/kola intercrop production, the soils need the application of P, K, Ca and Mg supplying fertilizers. Considering the K/Mg ratios of the soils for coffee and kola production, the soil K/Mg ratio should be 2.0. However, the K/Mg ratio for Ibadan was 1.56 while it was 0.55 for Kusuku. This indicates that there was nutrient imbalance in the soils at both locations, and this is expected to negatively affect nutrient absorption and utilization by the coffee and kola plants and need be corrected.

Soil Micronutrient

The soil micronutrient contents for both locations (Table 4) showed that Mn levels were lower than the recommended values for the cultivation of coffee and kola. The data further indicated that the soil Fe, Cu and Zn contents were sufficient for coffee and kola cultivation at the Kusuku, while they were only sufficient for coffee plants at Ibadan and not for kola cultivation. With this trend, it therefore indicated that Mn fertilizer will be needed in both locations to achieve optimal production of both coffee and kola in the coffee/kola intercrop. However for Ibadan location, the Fe, Cu and Zn supplying fertilizers must be applied along with Mn to meet the complete requirements of the nutrients for coffee and kola production. Adequate supply of the micronutrients is needed because they are important for metabolism, without which, plant growth and development would be retarded, leave chlorosis and fruits production would be disrupted, with resultant general low yield to be obtained (Basharat *et al.*, 2020).

Table 4: Soil micronutrient contents of the study locations in Ibadan and Kusuku

Location	Mn	Fe	Cu	Zn
	←	mg/kg	→	
Kusuku	42.95	41.05	5.15	32.85
Ibadan	11.13	5.07	0.91	3.31

Coffee and kola Leaf Nutrient Contents

The plant leaf nutrient contents at Ibadan indicated that the young coffee plants were adequate in supply for all the nutrients except Mn, while the kola was deficient only in Zn content. This trend suggests that the young coffee and kola plants were able to get sufficient supply of the soil nutrients to meet their requirements for growth. This may not be sustainable in the long run with continuous aging of the crops along with fruits bearing and produce harvest. This was because the soil was insufficient in its levels of Ca, Mg and Mn. In Kusuku, the old coffee plants were low in N, K, Ca and Mg contents, while the kola plants were in short supply of P in addition to those stated above for coffee. Only the micronutrients were adequate in the coffee and kola leaves. It was observed that despite the sufficiency of the macronutrients in the soil, especially for kola, they did not reflect in the plant leave contents. This trend might be due to the competitions between the coffee and kola for the available amounts of nutrients in the soil, that they became insufficient to meet the joint needs of both crops.

Insufficient supplies of the nutrients were more pronounced on the old coffee/kola plot compared to the young coffee/kola plot. This was in trend with Gobi *et al.* (2019) who reported that nutrient uptake was higher in younger plants because of their well-developed healthy root system compared to the older plants. The insufficient nutrient contents in the crops, especially for the old coffee/kola plantation, might have been made more pronounced due to the imbalance K/Mg ratio in the soils that was less than 2.0. The K/Mg ratio was 0.55 for the old coffee/kola intercropped plantation in Kusuku, while it was 1.56 for Ibadan. Imbalance K/Mg ratio in the soils always leads to poor nutrient absorption in the soils by tree crops as corroborated by Ipinmoroti and Ogeh (2014).

The Ibadan location therefore, needs adequate Mn and Zn supplying fertilizers in order to meet the requirements for optimum growth performance of the coffee and kola plants. On the other hand, the Kusuku location needs the application of fertilizers that will supply adequate amount of N, P, K and Mg for the coffee and kola plants. The marked differences between the locations and plantation age, suggests the need for a soil testing programme to be put in place to ensure that soils of coffee/kola plots are regularly tested as the plantations advanced in age. This will provide information on the nutrient dynamics in the coffee/kola intercropped plantations, for possible fertilizer needs and their applications, to guide against crops production failure.

Table 5: Coffee and Kola Leaf Nutrient Contents

Properties	Coffee		Kola	
	Ibadan	Kusuku	Ibadan	Kusuku
Organic C	13.95	20.41	16.75	20.14
N	1.53	1.07	1.12	0.94
C/N	10.91	19.07	14.96	21.33
P	0.07	0.11	0.09	0.06
K	1.83	0.52	1.26	0.31
Ca	0.50	0.61	0.48	0.46
Mg	0.31	0.10	0.41	0.27
Na	0.46	0.29	0.15	0.22
Mn	28.00	271	42.11	151.21
Fe	330.00	944	140.82	244.51
Cu	21.32	40.40	50.62	70.11
Zn	41.38	248.10	31.45	301.42

Soil Nutrient Needs on Plot Basis

Based on the soil nutrient deficiency, the soils will need application of fertilizer materials to improve the soil organic C contents, correct the K/Mg ratio and supply the deficient nutrients for the two locations. Application of 9.3 kg/ha P, 5.2 kg/ha K, 12.3 kg/ha Ca, 1.4 kg/ha Mg, 7.8 kg/ha Mn, 1.6 kg/ha Fe, 0.8 kg/ha Cu and 1.5 kg/ha Zn at Ibadan; 15.6 kg/ha Ca, 0.5 kg/ha Mg and 1.4 kg/ha Mn at Kusuku, would be needed to bring the location soils to optimal production. However, due to scarcity of inorganic fertilizers (Ibrahim, *et. al.*, 2014), the prohibitive high costs (Omotesho, *et al.*, 2012) and their negative environmental effects (Ibrahim, *et. al.*, 2014; Kamur, *et al.*, 2020) as well as the inherent low SOC, it was calculated that application of organic manure at 1.0

t/ha/year in Kusuku and 4.1t/ha/year in Ibadan will be sufficient to rectify the deficit nutrients, correct the soil K/Mg ratio imbalance and build up the soil organic matter for sustainable growth and production of coffee and kola plants in the coffee/kola intercropped plantations. The practice of good agricultural practices that incorporate the planting of arable crops especially legumes such as cowpeas, soyabeans; and cover crops such as egusi melon, water melon into coffee/kola plantations at the juvenile stage will enhance the build-up of soil organic matter and nutrient contents. In addition leaf-fall of coffee and kola in the plantations would also build up the SOM as well as protect the soil from soil erosion and leaching of soil nutrients.

Conclusion

The study showed that the two locations differ greatly in their soil nutrients and organic C contents. The Kusuku location soil was however richer in nutrients compared to the Ibadan location. The soil K/Mg ratio imbalance was however more critical in Kusuku than in Ibadan. The marked differences between the locations and plantation age, calls for systematic soil testing programme to ensure that coffee/kola plots are regularly tested as the plantation ages, to provide information on nutrient dynamics in plantations for ease of management. The soils therefore need application of fertilizer materials for optimal production However, due to scarcity and cost of inorganic fertilizers and their negative environmental effects, coupled with the inherent low SOC in the soils, it was calculated that application of organic manure at 1.0 t/ha/year in Kusuku and 4.1 t/ha/year in Ibadan will be sufficient to rectify the soil nutrient deficiencies for sustainable growth and production of coffee and kola plants in the coffee/kola intercropped plantations. Intercropping with appropriate arable crops where feasible will enhance SOM and nutrient contents.

Conflict of Interest

The authors have no conflict of interest related to the work presented in this manuscript.

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References

Aderolu, I. A., Babalola, F. D., Ugioro, O, Anagbogu, C. F., Ndagi, I., Mokwunye F. C., Mokwunye, I. U., Idrisu, M. and Asogwa, E. U. (2014): Production and marketing of coffee (Coffea robusta) in Kogi State, Nigeria: challenges and recommendation for intervention. *J. Soc. Sci. Res*. 3(2): 207-215.

A.O.A.C. (1990): Official methods of Analysis, 15th Edition, Association of Official Analytical Chemists. Washington DC, 774-784.

Allam, M., Radcetti, E., Quiintarelli, V., Petrioselli, V., Marinari, S. and Mangirelli, R. (2022): Influence of organic and mineral fertilizers on soil organic carbon and crop productivity under different tillage systems: A Meta-Analysis. *Agriculture*, 22(4): 464-482. https://odi.org/10.3390/agriculture 12040464

Araujo, A. V., Fabio, L. P., Marcos, G. O., Jose, R. M. P., Antelmo, R. F. (2015): Microclimate and vegetative growth of Comilon coffee consorted with banana trees. *Coffee Science*, 2: 214-222.

Basharat, A. B., S. T. Islam, A. Ali, B. A. Sheikh, L. Tariq, S. U. Islam and Hassan-Dar, T. U. (2020): Role of Micronutrients in Secondary Metabolis m of Plants. In: Aftab; T., Hakeem, K. R. (eds.) Plant M icronutrients. Spinger, Cham. https://doi.org/10.1007/978-3-030-49856-6_13

Bray, R.A. and Kurtz, L.T. (1945): Determination of total organic and available forms of phosphorus in soils. *Soil Science*, 59: 39-45.

Bremmer, J.M. (1996): Methods of Soil Analysis, Part 3. Soil Science of America and America Society of Agronomy, SSSA Book series No. 5, Madison, USA.

Burdock, G. A., Carabin, I. G. and Crincoli, C. M. (2009): "Safety Assessment of Kola Nut Extract as a Food Ingredient". *Food and Chemical Toxicology*, 47 (8): 1725–32. https://doi,org/:10.1016/j.fct.2009.04.019 PMID 19394393

De Jonge, L.W., Moldrup, P. and Jacobson, O.H. (2007): Soil-water content dependency of water repellency in soils: effects of crop type, soil management, and physical-chemical parameters. Soil Sci., 172, 577-588.

Duan, X., Liu, W., Wang, X., Zhang, L., Liu, S., Guo, L., Guo, D., and Hou, X. (2022): Effects of Phosphorus Fertilization on Growth Characteristics, Fatty Acid Composition, and Seed Yields of Fengdan. *HortScience*, 57(6), 733-740.

Egbe N.E, Ayodele E.A. and Obatolu, C. R. (1989): Soil and nutrition of Cocoa, Coffee, Kola, Cashew and Tea. *In: Progress in Tree Crop Research (2nd ed) CRIN Ibadan* 28-30.

Famaye, A.O., Iremiren, G. O., Ayegboyin, K. O. and Adejobi, K. B. (2012): Evaluation of coffee intercropped with rice and plantain at early stage of field establishment in Nigeria. *Agricultural Sciences*, Vol. 3 (3): 347-350. DOI:10.4236/as.2012.33039

FAO (2005): State of the World Forests 2005. Food and Agricultural organization of the United Nations, Rome. https://fao.org/docrep/pdf/007/y5574e/y5574e00.pdf

Gee, W.B. and Bander, J.W. (1986): Particle Size Analysis. In Kite, A. Ed., Method of Soil Analysis, Part 1. Physical and mineralogical method, Agronomy Monograph No. 9, 2nd Edition, *American Society of Agronomy/Soil Science Society of America*, Madison, WI 383-411

Gobi, R., Singh, C. S., Balasubramanian, A., Sathiyamurthi, S. and Stalin, P. (2018): Effect of nitrogen and spacing on grain yield and nutrient uptake of rice under SRI. *Plant Archives*, 19 (1): 750-752.

Hochmal A. K., Schulze S., Trompelt K. and Hippler, M. (2015): Calcium-dependent regulation of photosynthesis. *Biochim. Biophys. Acta - Bioenerg*., 1847: 993–1003.

Ibrahim, M., Tassi'U, Y. R., Umma, M. and Dongora, I. I. (2014): The effects of inorganic fertilizers on soil characteristics and production of egg plant (Solanum melongena L.) in Warawa area of Kano state. *Standard Research Journal of Agricultural Science*, Vol, 2 (8): 129-135.

Ipinmoroti R.R, Iloyanomon, C.I. Ogunlade, M.O, Adebowale, L.A and Iremiren, G.O (2005): Land use and soil properties in relation to cocoa, kola, coffee and cashew establishment. *Nigeria Journal of Soil Science*, VOL. 15 (2): 45-50.

Ipinmoroti, R.R. and Ogeh, J.S. (2014): Soil nutrient dynamics under old and young cocoa, coffee and cashew plantations at uhonmora, Edo State, Nigeria. *Journal of Tropical Soils*, Vol.19 (2): 75-80. DOI: 10.5400/jts.2013;19.2.75.

Kamur, Y.R, Kaushal, S., Kaur, G. and Gulati, D. (2020): Effect of soil organic matter on physical properties of soil. *Just Agriculture*, Vol. 1 (2): 25-29. DOI: https://doi.org/10.3390/agriculture10110544

Maclean, E.O. (1982): Soil pH and lime requirement. In: Methods of Soil Analysis Part 2. A. L. Page (ed) Am. Soc. Agron. Madison 101 USA: 199-234.

Mustopha, F. B., Adesanya, K. A. and Aremu-Dele, O. (2022): Production trend of coffee in Nigeria: A review. *World Journal of Advanced Research and Reviews*, 13(03), 137–146 2022 Article DOI: https://doi.org/10.30574/wjarr.2022.13.3.0182

Nelson, D.W. and Sommers, L. E. (1982): Organic carbon and soil extracts. In: Methods of soil Analysis. Part 2- Chemical and microbiological properties. Agronomy Monograph No.9, 2nd Edition. American Society of Agronomy, Soil Science Society of America, Madison, WI, USA, 539 -579.

Omolaja, S. S, Ipinmoroti R.R. and Adeyemi, E. A. (2008): Effects of Tea/Eucalyptus intercrop on the yield and quality of some tea [*Camellia sinensis* (L.) O Kuntze] Clones at Mambilla Plateau, Nigeria. *Moor Journal of Agric. Research*. Vol.9:45-53.

Omotesho, A. O., Fakayode, S. B. and Tariya, Y. (2012): Curtailing fertilizer security and climate change: An appraisal of factors affecting organic material use option in Nigeria agriculture. *Ethiopian Journal of Environmental Studies and Management*, 5(3): 281-290.

Petek, M. R., Alteia, S. T. and Zorzenon, M. (2005): "Genetic variability for frost resistance among Coffea accessions assessed in the field and in a cold chamber". *Brazilian Archives of Biology and Technology*, 48 (1): 15–21.

Santini, P.T., Barbosa, R.A., Almeida, L. G., de Souza, K. R. D., Rodrigues, J. P., Barbosa, A.D. and Alves, J. D. (2019): Spatial-temporal patterns of coffee physiology. *Coffee Science*, 14(3): 291-301.

Wang Z., Hassan M. U., Nadeem F., Wu L., Zhang F. and Li, X. (2020): Magnesium fertilization improves crop yield in most production systems: a meta-analysis. *Front. Plant Sci*. 10, 1727.

Zhang, Y., Wang, K., Wang, J., Liu, C. and Shangguan, Z. (2021): Changes in soil water holding capacity following vegetation restoration on the Chinese Loess Plateau. *Scientific Reports*, Vol.11: 1-11 https:doi.otg//10.1038/s1598-88914-0

Zhu, Q., Riley, W., Tang, J. and Koven, C. D. (2015): Multiple soil nutrient competition between plants, microbes, and mineral surfaces: Model development, parameterization, and example applications in several tropical forest. *Bio-geosciences Discuss*, 12, 4057–4106, DOI: 10.5194/bgd-12-4057-2015.