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Influence of temperature dynamics on phosphorus availability in humid tropical Soils of southeastern Nigeria.

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ABSTRACT

This paper focused on the availability of the organic phosphorus in the humid tropical soil as influenced by the temperature dynamic in Imo State using forest and grassland at different soil depths. The result indicated that , the mean soil temperature dynamic in forested and grassland soils varied between 23.6-28.4ºC during dry season and , wet season varied between 17-21.2ºC with grassland recorded the highest mean values for the two seasons impinging upon the presence and activities of microorganisms in the soil. The phosphorus fraction recorded higher in the tropical forest topsoil during dry and wet season compared with the grass covered soil both having the mean values of (P) ranging between 1.7 -2.13 ($mg.kg^{-1}$) and 1.04-6.00 ($mg.kg^{-1}$) respectively. Also, tropical forested soil released Ca_2^+, Mg^{2+}, and K^+ from the litter layer because of a light to moderate temperature that retained on negative charges of the intact humus of the underlying soil. It was also observed that, both forest and grassland soils were highly acidic ranging between mean pH5.3-5.8 during dry and wet seasons respectively, but did not affect the formation of phosphorus in forest soil understudied. These therefore called for better farm practice (BFP).

Keywords: Temperature, Phosphorus Availability, Tropical Soil, Afforestation and grassland

1. Introduction

Temperature stresses (high and low temperature) are the major environmental factors affecting plant growth, development and also induce morphological, physiological and biochemical changes in plants [1]. According to a report of the Intergovernmental Panel on Climatic Change (IPCC) [2] the global mean temperature will rise 0.2 ºC per decade in the coming years. This change in global temperature may alter the geographical distribution and growing season of agricultural crops [3].

Soil temperature is one of the most important growth factors of plants, along with water, oxygen or plant nutrients [4, 5], [6]. Soil temperature is also a key factor controlling soil biological activity, the decomposition of soil organic matter and soil nutrient availability [7 - 9]. Soil temperature can be significantly influenced by cropping practices [10] soil water content [11, 12] and fallow types have found significant soil temperature differences between forest fallow, *Chromolaena odorata* fallow and *Imperata cylindrica* fallow in a close vicinity [12].

In agricultural systems P is needed for the accumulation and release of energy associated with cellular metabolism, seed and root formation, maturation of crops (especially cereals), crop quality and strength of straw in cereals. Despite the considerable amount of total phosphorus contained by tropical soils, phosphorus deficiency is one of the most important fertility problems in tropical agriculture [13]. According to [14], approaches on nutrient balances in African land use systems across different spatial scales found data confirming the trend of negative balances in the continent; for nitrogen and potassium for instance, more than 75% of selected studies had mean values below zero. In most of the agricultural systems, the maintenance of P availability to plants growing in these soils is one of the major challenges to be faced because a large portion of the soil P stock is fixed in forms largely unavailable for short term uptake resulting in low plant-available P concentrations [15]. Available P comprises free phosphate ions desorbed and/or dissolved from the soil solid phase or released from decomposing organic matter [16], and important part of P in soil is organically bound and plays a key role in the P cycle. The use of fertilizer to compensate for nutrient export by crops and for low nutrient content of highly weathered and leached soils has been tested in West, East and Southern Africa and yield increases have been reported [17- 20] . However, positive effects of fertilizer do not seem to be the general rule in the humid tropics [21].

Accordingly [22] observed that in tropical sub-humid soils the proportion of the more stable organic orthophosphate monoesters increased following changes in land use compared to that of natural forests. Better understanding of the effect of the temperature changes in humid tropical agro-ecosystems where phosphorus contributes significantly to sustainable crop production, because agricultural sector is under enormous pressure, to meet food demand of a projected population of 9.2 billion in 2050 [23] particularly meeting this demand together with increased challenges from climate change, competition from bioenergy, and land degradation [24] . Worldwide, 850 million people suffer from undernourishment [25] . Of this, 568 million undernourished people are in the Asia, 217 million in sub-Saharan Africa (SSA), 6 million in northern Africa, 47 million in Latin America and the Caribbean, 1 million in Oceania, and 11 million in the developed countries [25] . Yet, there is a great potential for increasing crop yields in most of these regions. Based on these, the objective of this study was to evaluate the influence of temperature dynamic on phosphorus availability in forest and grassland soils for nutrients evaluation for sustainability agriculture in humid tropical zone of Imo State, Nigeria.

2. Materials and methods

2.1 Environmental setting

Ihiagwa lies on Latitude 5º 21'N and 7º 15' E in the humid rainforest agro-ecological zone, Imo State, Nigeria. The mean annual rainfall is about 2019 mm, annual daily temperature of 28ºC and a mean relative humidity of 78% [26]. Its cropping pattern is predominantly cassava based, with few scattered wild palms. The cropping history is dominated by cassava/maize intercrop with limited inorganic fertilizer use. The practice of bush fallow of 5 years average length is predominant for fertility restoration. The soil type is an Ultisol (USDA classification system) derived from coastal plain sand and having kaolinite as the dominant clay mineralogy. Soil color is dark brown with a weak fine granular structure. Earthworm activity is evident. It is well drained and on a flat topography of elevation of 91 m above sea level [26].

2.2 Soil Sample Collection Techniques

Sample locations were traversed and soil samples were collected along the traversed line from 0-15 cm, 15-30 cm , 30-45cm, 45-60cm and 60-75cm soil depths with auger, the sampled soils were air dried, sieved to pass through the 2 mm diameter sieve and the fine earth fraction used for physical and chemical analyses.

2.3 Laboratory Analysis of sampled soils

Mechanical analysis of sampled soils was performed by dry sieving [27]. The particle size distribution was determined by the hydrometer method in which 50 g of sieved air dried soil was weighed into 250 ml beaker and 100 ml of calgon added and allowed to soak for 30 min. It was transferred to a dispersing cup and the suspension stirred for 3 min with mechanical stirrer. The suspension was transferred to a sedimentation cylinder and filled to the mark with distilled water. A plunger was inserted and used to mix the content thoroughly. The stirring was stopped and the time recorded. The soil pH was determined in water using a glass electrode pH meter. Organic carbon was determined by oxidizing soil sample with dichromate solution and later titrated with ferrous sulphate solution [28] . The total nitrogen was determined using micro-kjeldahl method and the available phosphorus calorimetrically by the molybdenum blue method. The exchangeable cations were extracted by leaching 5g of soil with 50ml of ammonium acetate at pH 7. The potassium and sodium in the leachate were determined with a column model 21 flame spectrophotometer while the calcium and magnesium were determined with atomic absorption spectrophotometer. The exchangeable acidity was determined by adding barium chloride buffer solution to soil sample and titrated against 0.1 N HCl. Above all, percentage base saturation (% BS) was calculated by expressing the exchangeable Na and K as percentage of CEC.

3. Results and discussion

Table 1-2 shown temperature of the soils sampled from grassland and forested soils during dry and wet seasons and different depths. Table 3-6 indicated the results of the physical and chemical parameters of the grassland and forested soils during dry and wet seasons.

Table 1: Temperature Changes in Forested and Grassland Soils during Dry Season.

Items	Unit	Soil Depths in (cm)					Mean
		0-15	15-30	30-45	45-60	60-75	
Forested Soil	ºC	35	30	28	18	7	23.6
Grassland Soil	ºC	40	36	30	21	15	28.4

Source: Authors Fieldwork/Laboratory Analysis, 2015

Table 2: Temperature Changes in Forested and Grassland Soils during Rainy Season.

Items	Unit	Soil Depths in (cm)					Mean
		0-15	15-30	30-45	45-60	60-75	
Forested Soil	ºC	29	25	16	10	5	17
Open Soil	ºC	31	29	21	14	11	21.2

Source: Authors Fieldwork/Laboratory Analysis, 2015

Table 3: Physical and chemical Characteristics of Grassland Soils during Dry Season.

Items	Unit	Soil Depths (cm)					Mean
		0-15	15-30	30-45	45-60	60-75	
pH(H_20)		5.44	6.66	5.44	5.80	5.56	5.8
Sand	%	92.80	88.80	86.80	82.80	85.20	87.3
Silt	%	2.00	2.00	8.00	2.00	2.00	3.2
Clay	%	5.20	9.20	5.20	15.20	13.00	9.6
Texture		SL	SL	SL	SL	SL	Sand
O.C	gkg^{-1}	1.14	0.92	0.82	0.79	0.78	0.89
O.M	gkg^{-1}	1.97	1.59	1.41	1.37	1.35	1.54
TEA		0.80	0.40	0.40	0.60	0.30	0.5
Al+	Cmol.kg -	0.50	0.10	0.10	0.40	0.20	0.26
H+		0.30	0.30	0.30	0.20	0.10	0.24
TN		0.09	0.08	0.07	0.06	0.07	0.074
Ca++		2.00	2.80	2.40	1.20	1.20	1.92
Mg++		1.20	2.00	1.60	0.80	0.80	1.28
K+		0.11	0.09	0.13	0.12	0.11	0.112
Na+		0.29	0.23	0.17	1.14	0.30	0.43
CEC		4.38	4.52	4.67	2.86	2.71	3.83
BS	%	81.7	92.7	91.4	79.0	88.9	86.74
Avail. P	$mg.kg^{-1}$	1.30	1.15	2.45	0.95	1.35	1.7

Source: Authors Fieldwork/Laboratory Analysis, 2015

Table 4: Physical and chemical Characteristics of Forested Soil during Dry Season.

Items	Unit	Soil Depths (cm)					Mean
		0-15	15-30	30-45	45-60	60-75	
pH(H_20)		5.43	5.44	5.18	5.34	5.22	5.3
Sand	(%)	91.8 0	90.8	86.80	78.87	76.80	85.01
Silt	(%)	4.00	4.00	8.00	2.00	4.00	4.4
Clay	(%)	4.40	5.20	5.20	19.20	19.20	10.6
Texture		SS	SS	LS	SL	SL	Sand
O.C	$g.kg^{-1}$	1.62	1.14	1.06	1.08	0.92	1.16
O.M	$g.kg^{-1}$	2.79	1.97	1.82	1.86	1.56	2
TEA		2.79	1.97	1.82	1.86	1.56	2
Al+	$Cmol.kg^{-1}$	0.50	0.60	0.60	0.40	0.40	0.32
H+		0.30	0.40	0.30	0.30	0.20	0.3
TN		0.20	0.20	0.30	0.10	0.20	0.2
Ca++	$Cmol.kg^{-1}$	0.13	0.09	0.18	0.09	0.08	0.11
Mg++		2.60	2.40	1.60	1.60	2.80	2.2
K+		1.60	1.26	1.00	0.80	2.00	1.53
Na+		0.14	0.13	0.11	0.22	0.67	0.25
CEC		0.21	0.17	0.19	0.27	0.27	0.22
BS	%	90.1	86.6	82.8	87.9	92.7	88.02
Avail. P	$mg.kg^{-1}$	2.30	3.00	2.50	1.75	1.10	2.13

Source: Authors Fieldwork/Laboratory Analysis, 2015

Table 5: Physical and chemical Characteristics of Grassland Soils during Rainy Season.

Items	Unit	Soil Depths (cm)					Mean
		0-15	15-30	30-45	45-60	60-75	
pHH20		5.43	5.06	5.98	5.79	4.92	5.4
Sand	%	81.20	85.20	79.20	79.20	77.20	80.4
Silt	%	2.00	2.00	4.00	2.00	4.00	2.8
Clay	%	17.00	13.00	17.00	19.00	17.00	16.6
Texture		SL	LS	SL	SL	SL	SL
O.C	$g.kg^{-1}$	1.08	0.66	0.36	0.52	0.46	0.62
O.M	$g.kg^{-1}$	1.86	1.14	0.62	0.89	0.79	1.06
TEA		050	0.60	0.50	0.30	0.30	0.44
Al+		1.10	0.40	0.20	1.10	0.10	0.58
H+		1.40	1.20	0.30	0.20	0.20	0.66
TN		0.09	0.05	0.03	0.04	0.04	0.05
Ca++		2.00	1.60	1.60	1.20	2.80	1.84
Mg++		1.60	1.00	0.80	0.80	2.00	1.1
K+		0.34	0.08	0.37	0.16	0.12	0.81
Na+		0.19	0.12	0.13	1.17	1.14	0.55
CEC	mg	4.65	3.40	3.30	2.63	25.36	7.87
BS	%	89.2	82.3	84.8	88.5	94.4	87.8
Avail. P	$mg.kg^{-1}$	1.75	0.80	0.73	1.00	0.90	1.04

Source: Authors Fieldwork/Laboratory Analysis, 2015

Table 6: Physical and chemical Characteristics of Forested Soil during Rainy Season.

Items	Unit	Soil Depths (cm)					Mean
		0-15	15-30	30-45	45-60	60-75	
pH (H_20)		4.67	5.92	4.95	5.25	5.06	5.17
Sand	%	86.80	78.80	86.80	77.80	72.80	80.6
Silt	%	8.00	4.00	4.00	2.00	2.00	4.00
Clay	%	5.20	17.20	19.20	20.20	25.20	17.4
Texture		LS	LS	LS	LS	Scl	LS
O.C	$g.kg^{-1}$	2.45	2.31	1.84	1.06	0.92	1,72
O.M	$g.kg^{-1}$	4.23	3.99	3.17	1.82	1.58	2.96
TEA		1.20	0.70	1.00	0.40	1.00	0.86
Al+		0.60	0.50	0.70	0.20	0.70	0.54
H+		0.60	0.30	0.30	0.20	0.30	0.34
TN		0.21	0.19	0.16	0.09	0.70	0.27
Ca++		3.60	4.00	2.40	3.20	1.60	3.00
Mg++		1.60	1.20	1.60	1.60	0.80	1.04
K+		0.12	0.14	0.11	0.12	0.06	0.11
Na+		0.17	0.23	0.15	0.08	0.27	0.18
CEC	mg	6.69	6.67	5.26	5.40	3.73	5.6
BS	%	82.1	88.8	80.9	82.5	73.1	81.5
Avail. P	$mg.kg^{-1}$	7.60	9.75	4.60	4.80	3.00	6.00

Source: Authors Fieldwork/Laboratory Analysis, 2015

From the results in Table 1-2, soil temperature recorded in the forested and grassland soils during dry season ranged between 7-35ºC with the mean value of 23.6ºC, 15-40ºC with the mean value of 28.4ºC. The result obtained from the current research is in line with the finding of [30] who opined that temperature just below the soil surface (l-2 cm) may reach 27-32^0 C (80-90^{0}F) in summer. This temperature normally is optimum for root and organism activity provided moisture is available. Based on the result, variations in temperature were recorded between the two land covers, with forested land having the lowest temperature dynamic and grassland land having the highest value. This then means that forested soil not subjected to thermal shock can retain most of the elements leached from above [31]. In line with this forested soil Ca_2^+, Mg^{2+}, and K^+ released from the litter layer because of a light to moderate temperature that retained on negative charges of the intact humus of the underlying soil. The moderate temperature and availability of the fallen leaves and soil microorganisms in forested soil helped in soil formations than grassland with high temperature what is detrimental to soil ecosystems. This result is in line with the finding of [32] who observed that, the P amount of this fraction is higher for the legume covered soil when compared with the grass covered soil. The permanence of leguminous plants on the topsoil after the cut promoted an increase in P diester/P monoester ratios. These findings can be accounted for an enhancement of P availability to plants in soils with thick canopy [32] .Equally forested soil recorded highest organic matter (OM) compared to that of grassland during dry and wet seasons respectively. This observation was in line with the findings of [33], who observed that low content of organic matter in the grassland may due to technical clearing of the land that degraded the debris that resulted to the mechanical removal of the topsoil, also the exposure and the post clearing management practices that promoted higher oxidation rate due to higher isolation as a result of bareness of the soil cover compared to that of the forest land. Organic matter reflects the level of soil fertility in the tropical soils. The values for the soils were low and decreased with depth. Accordingly, [34;35], observed that surface litter from vegetation promotes humus formation in forest soils due to high faunal and floral activities because of mainly favorable temperature and soil moisture contents that bring about rapid mineralization of organic matter with resultant accumulation of phosphorus.

The result from the study shows that grassland soil recorded higher temperature than forested soil that affected soil ecosystem adversely. This is in line with the observations that, high temperature stress induces morphological and [36], anatomical [37] as well as physiological and biochemical changes in soils and plants. It induces the changes in water relations [38 - 40], accumulation of compatible osmolytes [41, 42] decrease in photosynthesis [43, 44], hormonal changes [45] and cell membrane thermo-stability [46].

Microbial growth and activity are highly determined by soil pH [47, 48]. It was also observed that, both forest and grassland soils were highly acidic ranging between mean pH5.3-5.8 during dry and wet seasons respectively. The result conforms with the finding of Soils of the humid tropics and indeed Southeastern Nigeria are acidic and contain appreciable mineral oxides [49]. [50] Have also argued that the pH range of 4.5 to 6.0 supports optimum bacterial and fungal growth. High pH in sub-soil during wet season may be due to leaching of chemicals through percolating water. Availability of organic C is important in controlling nutrient cycling and soil biological activity. Greater organic C content in forest tropical soils indicated more microbial biomass, which may be due to increased moisture content. The finding of present study was in conformity with the work of [50 - 52]. Fine particles (clay) help in retention of more organic C and TKN in forest soil than grassland soil. Reference [50] has also reported a similar result. Increased TKN in broad-leaved forest depicted high rate of litter decomposition, the decomposition rate is more rapid on nitrogen rich site [53]. More release of nutrients in broad-leaved forests indicated enhanced rate of decomposition of mixed litter, which could be attributed to its diverse chemical composition as compared to single species litter. Chemical composition of the leaf litter determines rate of decomposition [54], and nutrient supply to the soil due to decomposition of litter is enhanced from monoculture to polyculture [55], [56]. Low available phosphorus in top-soils of grassland during season may due to luxuriant growth of herbaceous species and tree seedlings that leads to more uptakes of phosphorus, and reduced mineralization and/or increased nutrient loss from top-soil through leaching and runoff [57] Normally, nutrient poor soil shows high C:N ratio [50] . The increased C: N ratio from broad-leaved to pine forest indicated that the soil in former case is nutrient rich, and in later case nutrient poor. High C:N ratio indicated low nitrogen content and/or high organic C content in the soil.

4. Conclusions

Phosphorus is an essential element for plant growth and its input has long been recognized as essential to maintain economically viable levels of crop production. In agricultural systems P is needed for the accumulation and release of energy associated with cellular metabolism, seed and root formation, maturation of crops (especially cereals), crop quality and strength of straw in cereals. In natural (i.e. non-agricultural) systems, P is recycled to soil in litter, plant residues and animal remains [58]. In line with this, the study has exposed the fact that moderate temperature in forest cover, soil moisture and other soil conditions can activate soil microorganisms to decay organic matter to form humus resulting to the formation available phosphorus than grassland with high temperature that exposed to topsoil to direct solar radiation whose impacts are soil degradations, hence loss of soil fertility to support food production for the teeming population.

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