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Evaluation of phosphorus and exchangeable bases status of soil under rubber plantation of different ages in south-eastern Nigeria

Ekaette Usenetim Ekukinam[1], Anthony Inah Iwara[1], Bayero Sule Gani[2]

[1]Department of Geography, University of Ibadan, Oyo State, Nigeria
[2]Dept. of Agricultural Economics, University of Ibadan, Oyo State, Nigeria

Email address

iwaradream2008@gmail.com (A. I. Iwara)

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Abstract

In this paper, the levels of available phosphorus (Av. P), exchangeable Ca, Mg, Na and K were evaluated under rubber plantation of different ages in Calabar, Cross River State. Soils were sampled under rubber plantations of 7, 16, 39 and 41 years. In each of the rubber plantation, five plots of 10m x 10m were established and surface soil samples (0-10cm) were randomly collected. Result showed that the contents of Av. P, Ca, Mg and K varied significantly among the rubber plantations. Av. P level in the rubber plantation soils declined substantially by 62.6 per cent with increasing age of rubber tree. The Av. P content under the 7-year rubber plantation (36.16 mg/kg) was rated very high, while the content under 41-year rubber plantation (13.52 mg/kg) was rated moderate. The levels of exchangeable Ca, Mg and K in the rubber soils declined with the age of rubber tree and were inadequate in comparison with some critical limits. The study called for proper management of soils under rubber plantation to reduce soil deterioration and maintain soil conditions for improved rubber production.

Keywords

Rubber Plantation, Rubber Age, Available Phosphorus, Exchangeable Bases

1. Introduction

Available phosphorus and exchangeable bases are among the 17 nutrients essential for plant growth. Phosphorus is one of the major soil nutrients that are required by plants in relatively large amount because it plays a vital role in nearly every plant process that involves energy transfer. However, among the nutritive elements essential for plant growth, only calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) are found in exchangeable form in the soil (I). These soil nutrients become depleted in the soil following the cultivation of forest tree. The depletion in soil nutrients among other factors is attributed to the dominance of a single tree species (2). In the rainforest belt of southern Nigeria, rubber tree (*Hevea brasiliensis* Muel. Argo.) is one of the major forest trees grown to meet the increased demands for latex production. Like other forest trees such as teak, oil palm, cashew and kola nut, rubber plantation has a lot of ecological and edaphic effects on the soil and the atmosphere. In Calabar, Cross River State, rubber is grown in large commercial scale and it contributes a significant proportion of export earnings. Plantations are generally known to bring about modifications in the edaphic, micro-climatic, flora, fauna and other components of the ecosystem through bio-recycling of mineral elements and changes in flora and fauna composition (3 - 4). According to Aweto (2) monoculture plantation such as rubber plantation may affect soil chemical properties through nutrient depletion from the soil into the tree components (leaves, twigs, branches and stem log) as well as modifies the chemical status of the soil since the litter

layer and organic matter is dominated by a single species.

In the literature, several studies have been carried out to assess the effect of forest trees on soil properties. For example, (5) studied soil fertility variations within a rotation period in teak plantations in Kerala. Result showed that soils of both teak plantations and natural forest were poor in exchangeable phosphorus. The fertility index values first decrease and then increase with age of plantations. Yasin et al., (6) showed that the age of rubber tree strongly affected the physical and chemical properties of soil. Organic carbon and total nitrogen contents decreased from 3.02%, 2.66%, 1.96%, in the forest plot, crab grass plot and 1-year plantation plot, and then increased to 2.33% and 2.49% in the 10-years and 15-years plantation plots respectively. Similar pattern was also found for soil pH, available phosphorous, exchangeable base cations, cation exchange capacity and base saturation decreased from the 1st to 10-years old plantation plots. The present study contributes to the buildup of studies on tree crops, but with particular focus on rubber plantation. This study specifically examined the varying levels of available phosphorus and exchangeable bases of soils under rubber plantation of different ages.

2. Materials and Methods

2.1. Study Area

The study was carried out in PAMOL (Nigeria) Limited Rubber Estate in Calabar Cross River State between the 7th and 9th of February, 2010. PAMOL (Nigeria) Limited is located in Odukpani L.G.A of Cross River State, Nigeria. It lies between latitudes 050 00′ and 050 12′ north and longitudes 080 15′ and 080 28′ east (7). The area has annual rainfall values of 2000 – 3000mm. The mean annual rainfall is 210 and 30 0C, while relative humidity ranges from 75 – 80%. Ultisols are the main soil type in the area. Predominant vegetation in the area is the tropical rainforest subdivided into the dry land rainforest and the fresh water swamp (moist) rainforest. Trees/shrubs found in the area include *Elaeis guineensis, Funtumia elastica, Pentaclethra macrophylla, Hevea brasiliensis* and *Anthocleista vogelii* among others (7).

2.2. Soil Sampling

Soils were sampled under rubber plantations of 7, 16, 39 and 41 years. In each of the rubber plantation plot, five plots of 10m x 10m were established and surface (0-10 cm) soil samples were randomly collected with a soil auger. The soils were put in polythene bags with labels, air-dried and taken to the laboratory for analysis of the selected chemical properties. Available phosphorus was determined by the method of Bray and Kurtz (8). The soils were leached with 1M neutral ammonium acetate to obtain leachates used to determine exchangeable bases.

2.3. Data Analysis

Soil data were analyzed using table, average and One-Way Analysis of Variance (ANOVA).

3. Result

3.1. Soil Chemical Properties

The proportion of available phosphorus (Av. P) and exchangeable bases is presented in Table 1 and Figures 1 - 4. The content of Av. P of soils under the rubber plantation declined substantially with increasing age of rubber trees. The highest Av. P value of 36.16 mg/kg was recorded in soil under the 7-year rubber plantation, while soil under the 41-year rubber plantation had the lowest value of 13.52 mg/kg. There was 62.6 per cent decrease in the concentration of Av. P in the soil with increasing age of rubber plantation (considering the 7-year and 41-year plantation). The amount of Av. P varied significantly among the rubber soils ($p<0.05$). The high proportion of Av. P in soil under the 7-year rubber plantation may be attributed to the abundance of herbaceous vegetation with high litter input. The increased in litter inputs and in situ decomposition favoured the increase in Av. P. The Av. P content of the soils under rubber plantations of 7-year rubber soil (36.16 mg/kg) was rated very high, while the content under 41-year rubber plantation (13.52 mg/kg) was rated moderate as value was within the threshold of 10 – 16 mg/kg recommended by (9). The proportion of exchangeable bases (Ca, Mg, Na and K) varied substantially across soils under the rubber plantation. According to Lovblad et al., (10) base cations are the most prevalent, exchangeable and weak acid cations in the soil. Calcium (Ca^{2+}), magnesium (Mg^{2+}) potassium (K^{+}) and sodium (Na^{+}) are the primary base cations in the soil.

Lovblad et al., (10) further noted that these ions, except for Na^{+} are nutrients required for forest ecosystems and are of importance for the sustainability of ecosystem. In the studied soils, the proportion of Ca and Mg were comparatively high in soils under the 7-year rubber plantation and low under the 41-year rubber plantation. Similar result has been reported elsewhere. For instance, Yasin et al., (6) found the highest content of exchangeable Ca, Mg, K and Na under the 1-year old rubber plantation. The content of exchangeable calcium (Ca) and magnesium (Mg) reduced drastically with increasing age of rubber plantation; the values of Ca and Mg ranged from 0.14 to 0.88 cmol/kg. The proportion of Ca decreased by 63.6 per cent, while that of Mg decreased by 41.7 per cent. On the other hand, the level of Na was 0.72 cmol/kg under the 16-year plantation, this value decreased by 11.1 per cent to 0.64 cmol/kg after 25 years (41-year plantation). For K, it content increased with increasing age of rubber plantation; there was 50 per cent increase in K proportion in soils under the rubber soil (between the 7-year and 41-year rubber plantation). The proportions of Na and K ranged from 0.06 to 0.72cmol/kg. There were significant variations in the contents of Ca, Mg and K among the rubber soils ($p<0.05$), while the content of Na did not vary ($p>0.05$).

The high content of exchangeable Ca and Mg in the early periods of rubber cultivation (7 - 16-years) is attributed to the presence of undergrowth and the development of dense overhead canopy which protected the soil from the direct impact of rain. However, the low exchangeable Ca and Mg

content observed in the 39 – 41-year rubber plantation is blamed on the scanty undergrowth and canopy gaps which did not afford the soil adequate cover resulting in the leaching of base cations to the deeper layer of soil. This condition enhances intensive leaching of base cations (6). According to Haque & Lupwayi (11) the exchange complex (exchangeable bases) is dominated by exchangeable Ca, followed by exchangeable Mg, and that exchangeable K and Na are minor components of the exchange complex. Thus, exchangeable Ca and Mg levels in soils under the rubber plantations were inadequate in comparison with the critical limit of <5.0 and 1.5 cmol/kg respectively (Sanchez et al., 1982 cited by 12). In addition, K level in the rubber plantation was also inadequate in comparison with the critical limit of 0.20 cmol/kg (Onyekwere et al., 2001 cited in 13; Sanchez et al., 1982 cited in 12). In Nigeria, (9) placed the critical value of exchangeable K at 0.6 – 0.8 cmol/kg. This further implies that the content of exchangeable K is grossly inadequate under the rubber plantation. These values when compared with those obtained for the studied soils show very low values for the rubber plantations. However, the generally low levels of exchangeable bases across the rubber plantation soils are attributed to the high precipitation in the area resulting in the leaching of base cations. This is affirmed by Yasin et al., (6) that tropical climate with high precipitation experience intensive leaching of base cation. Also, soil of the study site is dominated by Ultisols, hence, the low base cations in the respective rubber plantation is understandable as the soil type belongs to highly weathered soil. This assertion likewise agrees with those of (14) that Ultisols are characterized by low content in base cations and pH. However, the general result showed substantial declined in the levels of Av. P and exchangeable bases in soils under rubber plantation with increasing age.

Table 1. *Chemical properties of soil*[a]

Chemical Properties	7-year plot	16-year plot	39-year plot	41-year plot	F-values
Av. P (mg/kg)	36.16±5.72	21.90±6.31	15.38±4.37	13.52±2.51	4.303*
Exch.Ca (cmol/kg)	0.88±0.10	0.38±0.05	0.67±0.05	0.32±0.09	11.70**
Exch. Mg (cmol/kg)	0.24±0.03	0.16±0.01	0.18±0.01	0.14±0.01	6.584*
Exch. Na (cmol/kg)	0.56±0.09	0.72±0.02	0.69±0.06	0.64±0.03	1.485 ns
Exch. K (cmol/kg)	0.06±0.01	0.07±0.00	0.10±0.01	0.09±0.01	4.519*

[a]values are means ± standard errors.
* Difference between means is significant at 5% alpha level.
** Difference between means is significant at 1% alpha level.
ns: Difference between means was not significant at 5% alpha level.

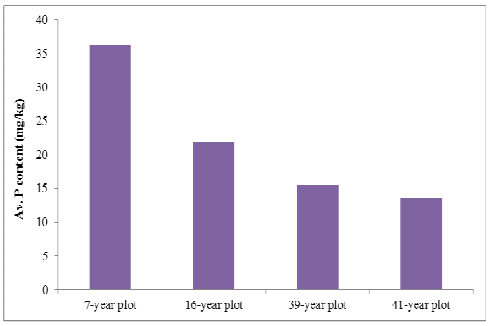

Fig 1. *Av. P contents across the plots*

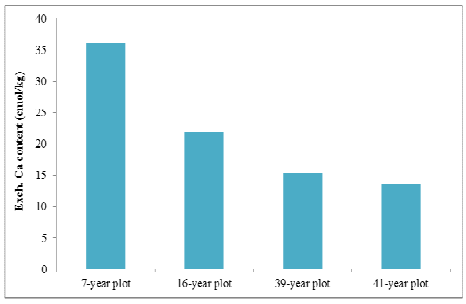

Fig 2. *Exch. Ca contents across the plots*

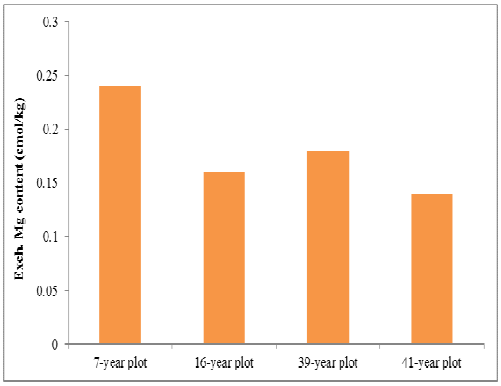

Fig 3. *Exch. Mg contents across the plots*

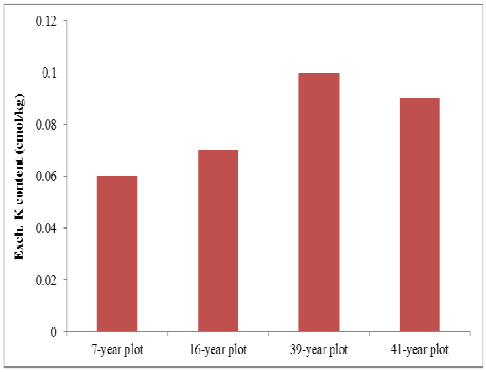

Fig 4. *Exch. K contents across the plots*

4. Conclusion

The result showed that substantial amounts of Av. P, Ca, Mg and K were depleted in soils under rubber plantation with increasing age of cultivation. The study simply indicated that rubber plantation like other tree crops had adverse effect on the nutritional status of the soil underneath it. It therefore calls for the proper management of soils under rubber plantation to reduce soil deterioration and maintain soil conditions for improved production

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