ASSESSMENT OF THE NUTRIENT STATUS OF SOIL UNDER *Chromolaena odorata* L. (SIAM WEED) FALLOW IN MONIYA, OYO STATE SOUTHWESTERN NIGERIA

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Abstract

In Nigeria, soil fertility restoration for improved agricultural production is a recurrent issue of immense importance mostly with her ever increasing population currently above 150 million. Therefore, identifying sustainable ecological practice to improve soil fertility is one of the surest ways to enhance food security. The study examined the trend in soil nutrient under the canopy of Chromolaena odorata of zero, 6 months, 1 yr and 2 yr fallows. The grid system of sampling was employed to collect soil samples from ten quadrats of 5m x 5m in each of the Chromolaena fallows. Result showed that C. odorata, a plant of secondary succession had significant effect on the buildup of nutrients in the soil, as the contents of soil properties under the canopy of C. odorata progressively increased with the age of fallows, which perhaps was affected by the increase in Chromolaena plant and cover. The pH level of soils under the canopy of C. odorata especially in the 2nd year fallow considerably favoured the increase in the contents of essential elements in the soil. However, to improve soil fertility, the study suggested that C. plantshould be planted along with staple crops to help minimize nutrient loss, and also, fallows with C. plantsshould be allowed for a reasonable number of years to facilitate nutrient accretion before cultivation.

Keywords: *Chromolaena Density, Nutrient Status, Physical and Chemical Properties, Nutrient Accretion*

Introduction

In the tropics mostly Nigeria, soil fertility restoration for improved agricultural production is a recurrent issue of immense importance mostly with her ever increasing population currently above 150 million. On this basis, identifying sustainable ecological practice to improve soil fertility is one of the surest ways to enhance food security. Nevertheless, soil fertility continues to be a problem in many parts of the country as a result of the clearing and modification of forest mostly for agricultural production. The clearing of forest coupled with high temperature and precipitation accelerates soil erosion resulting in nutrient elements loss in dissolved and solid bound forms (Offiong and Iwara, 2011). However, after the cultivation of food crops, farmlands are deliberately allowed to fallow, a process for fertility restoration (Styger *et al*., 1999; Styger and Fernandes, 2005). During this process, different plant species immediately invade the area, and the commonest is *Chromolaena odorata* otherwise referred in this part of the country as "Awolowo". *C. odorata* according to Roder *et al*., (1995), Koutika and Rainey (2010) is a member of the family *Asteraceae*, a perennial shrub forming dense tangled bushes of about 1.5 - 2.0 m in height, sometimes reaching 6 m. *C. odorata* is characteristically a plant of secondary succession that invades fallows or newly cleared lands, and is often shaded out when forest trees and shrubs are fully established.

The plant is acknowledged by earlier scholars to enhance the buildup of nutrients in soil under its canopy (Obatolu and Agboola, 1993; Ilori *et al*., 2011). It is indeed, a common and predominate fallow plant in most habitats except undisturbed rainforest where its density is sparse. According to Koutika and Rainey (2010), *C. odorata* is present in different agricultural systems of its native continent (subtropical and tropical America), but also of colonized continents such as Asia, Africa, mainly in slash-and-burn systems and Oceania. In Nigeria and Southwestern ecological zone in particular, *C. odorata* grows easily and usually

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dominates newly cleared and abandoned farmlands (fallows); this plant species are one of the earlier colonizers that facilitate the buildup of nutrients in the soil for subsequent colonizers. Nevertheless, apart from colonizing fallows and naturally accreting nutrient in the soil, local farmers in the area use the plant as a way of augmenting fertility as green manure. *C. odorata* regenerates and colonises fallow lands or newly cleared piece of land through its roots or by high seed production and wind which enhances its dispersal (Koutika and Rainey, 2010).

The increasing population accompanied with the demand for housing and other infrastructures have resulted in the dwindling of farmlands, with significant effect on fallow periods. The implication of this is shortening of fallow periods; as a result, farmlands cannot adequately regenerate their organic matter and nutrient status. In order to replenish the fertility of arable lands within a short period of time and to ultimately increase food production, fallow management techniques that incorporate plant species which can quickly produce biomass and compete successfully with other weeds as well as have high litter fall and mineralization are required to enhance sustainable conservation of soil fertility (Akobundu *et al*., 1999). However, the effect of *C. odorata* on the buildup of nutrients in the soil is well recognized. On this note, different of studies have been carried out to assess the nutritional status of *C. odorata* in the soils (Agbim, 1987; Obatolu and Agboola, 1993; Jubril and Yahaya, 2010; nutrient buildup of soils under *C. odorata* with other plant species or a mature forest (Slaats *et al*., 1998; Fening *et al*., 2009; Yahaya and Edicha, 2010; Murphy *et al*., 2010), but the trend of increase in nutrients in soil under the canopy of *C. odorata* at varying fallow ages has been little investigated. This study therefore examines the trend of nutrient buildup (physical and chemical properties) in soil under the canopy of *C. odorata* of different fallow ages.

Materials and Methods

Study area

The study area is at the hinterland of Moniya located in Akinyele Local Government Area of Oyo State. It is between latitude 7^0 $20^{'}$N and 7^0 $28^{'}$N and between longitude 3^0 $50^{'}$E and 3^0 $57^{'}$E. The area experiences the moist maritime Southwest Monsoon from March to October (Wet Season) and the North-Easterly wind from November to February (Dry Season). The predominant land-use of the area is agriculture with most of the land areas used for subsistence arable farming largely by farmers from the city centre. The vegetation of the area can be classified as moist semi-deciduous forest under which the soil of the study area is formed (Aweto, 1981). The soils contain very high reserves of weatherable weathered materials characterized with very high base saturation. The chemical characteristics of the soil however vary considerably, depending on the site history and land-use. The organic matter content of soils of the study area is less in farmland persistently cropped and areas recently left to fallow. They are however much higher in areas of mature woody fallow vegetation.

Soil Sampling

The procedure of data collection began with a reconnaissance survey to the area, during which *Chromolaena* fallows of zero (inception of fallow), 6 months, 1yr and 2yrs were identified and delineated for soil sampling. Identification of *Chromolaena* fallows was done with the assistance of the local farmers. After identification and delineation of the fallows, soils were then collected under the canopy of *Chromolaena* plant of zero age (inception of fallow, immediately after harvest), 6 months, 1yr and 2yrs fallow using a soil auger. In each identified *Chromolaena* fallow, soil samples were collected from a delineated plot of 70m x 5m. The plots were located within the same environment less than 200m apart; as such, they have similar soil, topography and climate. In each of the *Chromolaena* fallow plot, ten plots of 5m x 5m were established using the grid system of sampling. In each plot, 5 surface (0-15 cm) soil samples were randomly collected with a soil auger and then composited.

Laboratory Analysis

The soils were put in polythene bags with labels; they were thereafter air-dried and taken to the laboratory for analysis of soil physical and chemical properties. Particle size composition was determined using the hydrometer method (Bouyoucos 1926); organic carbon by the Walkley-Black method (1934) after which values obtained were multiplied by 1.724 (Aweto 1981) to convert to organic matter; total nitrogen by the Kjeldahl method (Bremner and Mulvaney 1982); available phosphorus was determined by the method of Bray and Kurtz (1945). The soils were leached with 1M neutral ammonium acetate to obtain leachates used to determine exchangeable bases and soil cation exchange capacity, while pH values were determined using a glass electrode testronic digital pH meter with a soil: water ratio of 1:2.

Data Analysis

The obtained soil data were analyzed using One-Way ANOVA to determine if there are significant variations in the levels of physical and chemical properties among *C. odorata* fallows.

Result and Discussion

Physical Properties of Soils

The particle size composition of soil under *Chromolaena odorata* of different ages or fallow history is shown in fig 1 – 3. The soils are principally sandy loam with sand constituting more than 60% of the inorganic mineral fragment in the soil (fig 1). Sand content under *Chromolaena odorata* soils of varying ages varied significantly ($p<0.01$) with the inception of fallow (zero fallow) having the highest mean proportion of 68.5%. The lowest proportion of sand was recorded in the 2nd year fallow. The high content of sand in the zero fallow may be attributed to the effect of erosion and leaching as well as the sparse density of *Chromolaena* cover. This may have led to the translocation and loss of clay minerals and silt (Brady & Weil, 2005). There was no significant variation ($p>0.05$) in proportion of silt in the soil. The highest content of silt was obtained in the 2nd year and 1st year fallow with mean values of 17.27% and 15.07% respectively, while the lowest amount was recorded in the inception stage (fig 2). This implies that silt content under canopy of *C. odorata* increases with the age of fallow. The increase is attributed to the development of dense cover which helps to suppress soil erosion. There is also a steady increase in clay content with increasing fallow ages, as clay content increased between the 1st year and 2nd year fallow with mean values of 19.15% and 22.32% respectively (fig 3). The clay content of soils under the canopy of *C. odorata* did not vary ($p>0.05$). The particle size composition of soils under the canopy of *C. odorata* is texturally similar, being sandy loam and having been derived from the same parent material (granite) under the same climate and topography.

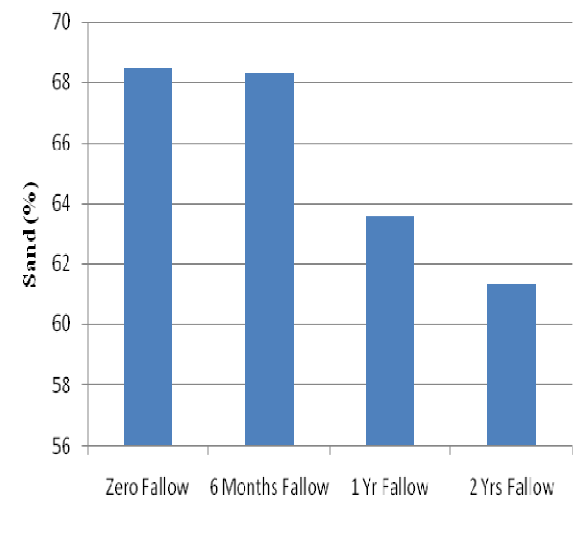

Fig 1: Sand content in *Chromolaena fallow*

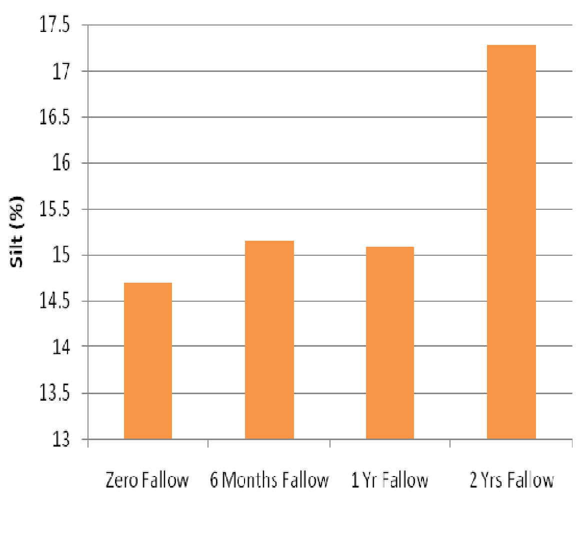

Fig 2: Silt content in *Chromolaena* fallow

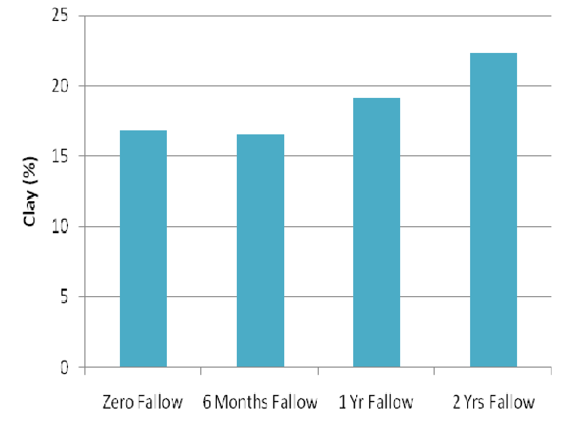

Fig 3: Clay content in *Chromolaena* fallow

Chemical Properties of Soils

The chemical properties of soils under the canopy of *C. odorata* of different fallow ages are shown in table 1. The soils of the area are slightly acidic with a pH range of 5.86 to 6.32. The slightly acidic nature of the soil is attributed to the high rainfall, which is sufficient to leach basic cations especially calcium from the surface horizons of the soils (Foth 2006; Abua et al., 2010). The content of pH however varied significantly among soils under *Chromolaena* fallows ($p<0.01$) (table 1). However, this proportion of pH may be said to be adequate in influencing positively the buildup of essential nutrients mostly Ca, Mg and P in the 1st and 2nd fallow soils (Hazelton and Murphy, 2007). The pH value obtained in this study agrees with the findings of Agbede (2008) that the pH in Nigeria derived savanna and forest soils falls with the range 4.5 - 7.5. The value obtained here also falls with the range of 6.13 in a similar study reported by Yahaya and Edicha (2010). The contents of OM and TN increased with the ages of *Chromolaena* fallow with the 2nd year fallow having the highest concentrations of 1.80% and 0.25% respectively. The increase in the contents of OM and TN in the 2nd year fallow is attributed to the increase in *C. odorata* cover. The increase in cover helps to reduce raindrop intensity and increases litter input which in situ decomposes to form nutrient (Aweto and Dikinya 2003; Offiong and Iwara, 2011). The OM and TN values obtained here also fall with the range of 1.83% and 0.35% in a similar study reported by Yahaya and Edicha (2010). The proportion of TN varied significantly across soils of *Chromolaena* fallows ($p<0.01$) (table 1).

The content of cation exchange capacity (CEC) in soils of *C. odorata* increased steadily with the age of fallow, meaning that the more the fallow history, the more nutrients are added to the soil. CEC is the relative measure of the nutrient-holding capacity of a soil, and its content progressively increases in the soils with the highest values of 7.94 Meq/100g and 8.52 Meq/100g obtained in the 1st and 2nd fallows respectively. It thereafter decreased and increased considerably. The proportion of CEC varied across soils of *Chromolaena* fallows ($p<0.01$). The increase in CEC in the 1st and 2ndyear fallows is attributed to the increase in density of *C. odorata* plants which rapidly decomposes to add nutrient in the soil. The value of CEC obtained for soils under *C. odorata* according to Hazelton and Murphy (2007) is rated as low; which implies that the soils have a low resistance to changes in soil chemistry that are caused by land use (agricultural activities). The content of Av. P varied significantly across soils of *Chromolaena* fallows ($p<0.01$). The rapid increase of Av. P in the 2 yr fallow is attributed to the high production of litter which probably is enhanced by the density of *C.*

odorata plants. Also, the increase in P as well as other essential nutrients may be attributed to the increase in pH to a level that favourably influences nutrient availability in the soil (Brady and Weil 2005; Osemwota 2010; Iwara *et al*., 2011). In general, the upward trend of OM, total nitrogen, CEC and P in soils under the canopy of *C. odorata* may be attributed to the increase in *Chromolaena* cover as well as the number of *Chromolaena* plants.

Table 1 Chemical properties of soils[a]

Soil properties	Zero Fallow	6 Months Fallow	1 Yr Fallow	2 Yrs Fallow	F-values
pH	5.86±0.05	5.95±0.04	6.05±0.09	6.32±0.09	7.590*
OM (%)	0.99±0.03	1.18±0.06	1.55±0.12	1.80±0.11	17.497*
TN (%)	0.16±0.01	0.15±0.01	0.18±0.01	0.25±0.01	13.331*
Av. P (PPM)	3.23±0.07	3.64±0.09	4.61±0.20	5.35±0.13	51.173*
CEC (Meq/100g)	3.52±0.10	5.58±0.09	7.94±0.09	8.52±0.11	563.332*
Ca (Meq/100g)	0.32±0.08	0.29±0.03	1.14±0.01	1.21±0.01	130.801*
Mg (Meq/100g)	0.54±0.03	0.53±0.03	1.14±0.01	1.26±0.03	200.064*
Na (Meq/100g)	0.10±0.01	0.13±0.01	0.17±0.01	0.20±0.20	15.519*
K (Meq/100g)	3.40±0.32	4.05±0.05	4.67±0.11	4.74±0.12	11.885*

[a]values are means ± standard errors.
* Difference between means is significant at 1% alpha level.

Moreover, the proportion of exchangeable bases (Ca, Mg, Na and K) varied substantially across fallow soils of *C. odorata*. Exchangeable bases relate information on the ability of the soil to sustain plant growth as well as retain nutrients show that their proportions in soils under the canopy *C. odorata* increase progressively with the age of fallow. The amounts of exchangeable calcium (Ca) and exchangeable magnesium (Mg) increase substantially with the age of *C. odorata*; the values of Ca and Mg ranged from 0.29 to 1.21Meq/100g and 0.53 to 1.26Meq/100g respectively. Also the levels of Na and K gradually increase with fallow history of *C. odorata*. The amounts of Na and K ranged from 0.10 to 0.20Meq/100g and 3.40 t0 4.74Meq/100g respectively. There were significant variations in the contents of Ca, Mg, Na and K among soils of *Chromolaena* fallows ($p<0.01$). The accretion of Ca, Mg and K in the old *C. odorata* fallow (2 yr fallow plots) is attributed to the increment in pH to a level of nutrient availability as well as the rapid mineralization of nutrient through the decomposition of litter. The Pearson's correlation matrix in table 2 indicates that the pH levels (5.86 to 6.32.) has high, positive and significant relationships with OM, TN, Av. P, Na, Silt and Clay ($p<0.05$). This implies that the pH level obtained for soils under the canopy of *C. odorata* mostly in the later year of fallow (2[nd]yr fallow) significantly increase the contents of these elements in the soil (Ukpong, 1994, Iwara *et al*., 2011).

In addition, the result further implies that the present level of pH of soil under the canopy of C. *odorata* favours the substantial increase in Mg, Ca, K, and CEC contents, even though, the increase is insignificant ($p>0.05$), while its value tends to have a negative relationship with sand (-0.93, $p>0.05$). This is evident as the sandy nature of the soil mostly in the inception of fallow (zero fallow) and 6 months fallow makes the soil acidic as a result of the leaching of basic cations especially calcium from the surface horizons (Foth 2006; Hazelton and Murphy, 2007; Abua *et al*., 2010). This is so because at this early stage, the *Chromolaena* plant is not dense in number and has not developed a dense cover to suppress the direct impact of raindrops, leading to the leaching of cations from the soil surface.

The result also depicts that high positive and significant associations are found between OM and the contents of Av. P, Mg, Na and CEC, while a negative and significant association is found between OM and sand. OM is also observed to have high positive and insignificant relationships with TN, Ca, K, silt and clay. However, these insignificant and low associations among the parameters mentioned above reveal that the elements may have been influenced by similar climatic and biotic factors. Furthermore, the result in table 2 reveals that soil properties are positively/negatively and significantly/insignificantly correlated with one another, which may imply that the elements are influenced by similar climatic and biotic factors that influence the buildup of nutrients in the soil.

Table 2 Pearson's correlation matrix of soil properties under the canopy of *C. odorata*

	pH	OM	TN	Av. P	Mg	Ca	Na	K	CEC	Sand	Silt	Clay
pH	1.00											
OM	0.96*	1.00										
TN	0.96*	0.88	1.00									
Av. P	0.96*	0.99+	0.90	1.00								
Mg	0.87	0.96*	0.84	0.96*	1.00							
Ca	0.84	0.95	0.81	0.94	0.99+	1.00						
Na	0.95*	0.99+	0.86	0.99+	0.94	0.93	1.00					
K	0.84	0.95	0.69	0.93	0.90	0.90	0.96*	1.00				
CEC	0.88	0.97*	0.74	0.96*	0.93	0.92	0.98*	0.99+	1.00			
Sand	-0.93	-0-98*	-0.90	-0.99*	-0.99+	-0.98*	-0.97*	-0.90	-0.93	1.00		
Silt	0.96*	0.83	0.95	0.85	0.71	0.66	0.83	0.66	0.71	-0.80		
Clay	0.97*	0.94	0.98*	0.96*	0.93	0.90	0.93	0.79	0.84	-0.97*	0.90	1.00

*. Correlation is significant at 0.05 level (2- tailed)
+. Correlation is significant at 0.01 level (2-tailed)

Conclusion/Recommendations

The present study has clearly shown that *C. odorata*, a plant of secondary succession has significant effect on the buildup of nutrients in the soil. This is evident as the contents of soil properties under the canopy of *C. odorata* progressively increase with the age of fallow, which perhaps is affected by the increase in *Chromolaena*plant and cover. These attributes help in nutrient accretion in the soil by minimizing the loss of nutrients through leaching. It also shows that *Chromolaena* plant can produce more litter as well as provide the needed temperature for bacteria, fungi, micro-fauna and other soil microbes that facilitate organic matter decomposition, thereby helping to add nutrient to the soil. The study therefore reveals that *C. odorata* significantly influence the buildup of nutrients in the soil. The pH level obtained for soils under the canopy of *C. odorata* especially in the 2ndyr fallow considerably favours the increase in the contents of elements in the soil. The study therefore shows that *Chromolaena* attenuates the acidity of its substrate, as the pH of the underlying soils tends towards neutrality with increase in age of fallow. This means that *Chromolaena* minimizes the acid forming effects of certain elements in the soil.

However, the generally low levels of exchangeable bases under the canopy of *C. odorata* reflect a low fertility status of soils in the area which could be blamed on the scope of the study which is limited to *C. odorata* fallow of 2 years. As these cations could increase to a recommended level if the fallow period was increased above 2 years. In order to improve soil fertility, *C.* plantshould be planted along with staple crops to help minimize nutrient loss, and also, fallows with *C.* plantshould be allowed for a reasonable number of years to facilitate nutrient accretion before cultivation. Finally, future studies on *Chromolaena*should concentrate on the characteristics of *Chromolaena*at different fallow periods of 10 years and above as well as compare the soil properties under *Chromolaena*plant with soils of a mature forest. This will help give a thorough understanding of the impact of *Chromolaena*on soil under its canopy and the relationships that exist between them.

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