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Evaluation of Different Crop Covers as Improved Short-Term Fallow in the Improvement of Soil Fertility and Weed Control in the Southeastern Nigeria

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Abstract **– Decades of cropping without fallow have decreased soil fertility, reduced levels of soil organic matter, an invasion of noxious weeds and acidified soils. Weeds have invaded the land, forcing small-scale farmers to abandon their plots. Thus, achieving food security for a rapidly growing population will require intensification of food production on existing cropland through improving soil fertility and agronomic practices. In an attempt to improve on soil conservation and land management that are economically viable, ecologically sound, and socially acceptable, the study tend to evaluate different plant species in the rehabilitation of an ultisol of Ishiagu that has been under cultivation. Four treatments; (Mucuna, Cowpea and Maize), including the control were built into a randomized complete block design (RCBD) with three replications. Soil chemical properties tested were soil pH, organic carbon, total nitrogen exchangeable K^+, Mg^{2+}, Na^+ and Ca2+. Others were CEC; percent base saturation, exchangeable acidity and available phosphorus, while the weed weight was also measured. The results showed that soil pH, organic carbon and total nitrogen were significantly improved by legume covers better than maize cover and control. It was obtained that plots planted with legumes significantly ($P<0.05$) increased the exchangeable Mg^{2+}, Ca^{2+}, BS, CEC and available P relative to the maize and control plots. In addition, there was a significant higher reduction in weed suppression by the legume crop covers than maize cover and the control.**

Keywords **– Soil Degradation, Legume Cover Crop, Soil Fertility, Weed.**

I. Introduction

Poor soil fertility and land degradation are major limitations to food security in sub-Saharan Africa, placing many smallholder farmers in a vulnerable position. Smallholder farms size in Nigeria are usually cultivated continuously without adequate replenishment of soil nutrients [1, 2]. There is a wide range of technological options for improving soil conservation and land management that are economically viable, ecologically sound, and socially acceptable. These include inorganic fertilizers, crop residue management, green manure, composting, farmyard manure, agroforestry technologies, alley farming, planted fallow, cover crops, and cereal-legumes intercropping or rotation [3 - 8]

Diminishing soil fertility, reduced levels of soil organic matter, and acidified soils, labour constraints; food insecurity and higher poverty levels have necessitated alternative interventions such as intercropping legume cover crops into the cropping systems [9]. One of the most promising legume cover crops to improve soil fertility in intensified cropping systems is *Mucuna* fallow.

Legumes are grown as cover crops and serves as short term fallow species. They have proven to be an effective means of sustaining soil fertility [10]. They are cheap and can be used to complement animal manures. Legumes cover crops (LCC) when incorporated into the soil, improves soil organic matter and moisture retention, soil workability, retard erosion and suppress weeds [11].

Legume cover crops are efficient, low-cost source of nitrogen with considerable potential to improve soil fertility in intensified cropping systems [12 – 14; 8, 7]. They are also efficient in controlling noxious weeds such as *Imperata cylindrica*[15] and nut grass (*Cyperus rotundus*), two of the most difficult weeds to control in the tropics [14]. There are reports that *Mucuna* can be used for reducing nematode populations. *Mucuna* has also been used in cattle grazing, and can provide animal feed and human food [14; 16 – 18].

Therefore, the objective of the study was to investigate the effect of short-term effects of different crop covers on the level of rehabilitation on degraded ultisols of Ishiagu, Southeastern Nigeria. The study also aimed at determining the short-term effects of different plant species cover on field weed suppression and intensity on degraded ultisols of Ishiagu, Southeastern Nigeria.

II. Materials and Methods

2.1 Location of the Study Area

The experiment was conducted at the Research and Teaching Farm of the Federal College of Agriculture, Ishiagu in 2012 and 2013 cropping seasons. The area lies within latitude 05°56´N and longitude 07°41´E in the Derived Savannah Zone of Southeastern Nigeria. The mean annual rainfall for the area is 1350 mm, spread from April to October with average air temperature being 29°C.

The rainfall of Ishiagu between April and October with June having the highest rainfall of 430.4mm within the period of study (Table 1). The highest mean maximum air temperature was obtained in February and March (36 ^{0}C) with its lowest in October (30 ^{0}C). The relative humidity ranged from 36% in July to 97% in the month of September (Table 1).

The underlying geological material is shale with sand intrusions, locally classified as the Asu River Group. The soil is a hydromorphic Ultisol and has been classified as TypicHapludult[19]. The soil has moderate organic carbon (OC) concentration and is low in pH and cation exchange capacity, with Ca and Mg dominating the exchange complex site (Table 2).

2.2 Field Methods

Four treatments replicated three times were built into a randomized complete block design (RCBD). The treatments were; Mucuna plant, Cowpea plant, Maize plant and plots with no plant as control. The Mucuna and cowpea seeds were planted at a spacing of 30 cm X 30 cm, while maize seeds were planted at a spacing of 25cm X 75cm. the study was conducted in two seasons, 2012 and 2013 cropping seasons using the same field, plots and treatments (crop covers).

2.3 Agronomic Practices

The area was cleared, ploughed, harrowed and ridged with a tractor operated implement after which the test crops were planted at two weeks after land preparation. Weed weight determination was carried out at 2 weeks interval from date of planting. This was done by hand-pulling of the weeds in each plot, after which the soils attached to the roots of the weeds are carefully removed by shaking the weeds. The hand-pulled weeds are gathered together plot by plot and their weight taken. The weights (kg) of weed gathered from each plot were weighed with weighing balance from 2 – 14 WAP.

2.4 Collection of Soil Samples and Laboratory Analysis

A composite soil sample from different representative field location was collected from the experimental site, with soil auger at a depth of 0 – 20 cm for initial soil characteristics.

At the harvest, another soil samples were collected from each of the plots to determine the changes that occurred due to treatments application.

The soil samples were air-dried and sieved with 2 mm sieve. Soil fractions less than 2 mm from individual samples were then analyzed using the following methods; Particle size distribution of less than 2 mm fine earth fractions was measured by the hydrometer method as described by Gee and Bauder[20]. Soil pH was measured in a 1:2.5 soil:0.1 M KCl suspensions [21]. The soil OC was determined by the Walkley and Black method described by Nelson and Sommers[22]. Total nitrogen was determined by semi-micro kjeldahl digestion method using sulphuric acid and $CuSO_4$ and Na_2SO_4 catalyst mixture [23]. Sodium (Na) and potassium (K) were determined from ammonium acetate leachate using the auto-electric flame photometer. Calcium (Ca) and magnesium (Mg) were determined using the complexometer titration method as described by Thomas [24]. CEC was determined by the method described by Thomas [26], while exchangeable acidity (EA) was measured using the method of McLean [24]. The available phosphorous was determined by the Bray 11 method [25]. Base saturation was determined by calculation as the percentage ration of total exchangeable bases to effective cation exchange capacity, using the procedure outlined in Tropical Soil Biology and Fertility Mannual [26].

2.5 Data Analysis:

Data analysis was performed using GENSTAT 3 7.2 Edition.Treatment means were separated and compared using Least Significant Difference (LSD) and all inferences were made at 5% Level of probability.

III. Results and Discussion

3.1 Initial Soil Characteristics

The result of the pre-planting soil properties shows that the soil texture was sandy loam and the pH of the soil is moderately acidic. The soil was however low in total nitrogen according to Obigbesam [27], who reported total nitrogen less than 0.10% and exchangeable K less than 0.15m/kg were classified as low availability.

3.2 Effect of legumes cover crop on soil pH, organic carbon (OC) and total nitrogen (TN).

The results (Table 3) showed that there was significant difference among the plants species on the improvement of the soil pH for the two years of study. The result indicated that pH measured in water was statistically ($p < 0.05$) improved higher by all the plant species, over the control plots that gave the least pH value within the periods. The values ranged from 4.40 - 5.93 and 4.27 – 6.40, in the first and second year, respectively. It was obtained that among the plant species; plots with *mucuna* legume specie statistically ($p < 0.05$) improved the pH higher than the maize plots (Table 3). The result reveals that both *mucuna* and cowpea legume species did significantly perform the same in the pH improvement for the periods. The result shows that there was a very significant trend of pH improvement in the second year compared to the first year of study in the legume covered plots.

It was also obtained that legume covers significantly ($p < 0.05$) affected soil organic carbon (SOC) pool higher compared to maize cover in the field within the periods of experiment. The results (Table 3) indicated that *mucuna* legume cover significantly ($p < 0.05$) increased the accumulation of soil organic carbon better in the first year of study than the cowpea and maize covers. It was also observed that in the second year, both legume covers performed statistically the same, and were significantly higher than the maize and the control plots. Generally, all the plots with plant covers significantly ($p < 0.05$) increased the soil organic carbon pool higher than the control plot for the two years of study. The values ranged from 0.213- 0.460% in the first year and 0.18 – 0.58% in the second year.

The (Table3) showed that there was significant ($p < 0.05$) difference among the plant species including the control on the improvement of the soil Total Nitrogen (TN %). The result indicated that the TN was statistically improved higher by *mucuna* and cowpea legumes over the control for the two years. It was obtained that only *mucuna* legume cover performed better statistically ($p < 0.05$) than the maize plant within the two years period of experiment. The values ranged from 0.048- 0.126% and 0.052 – 0.187% in the first and second year of study, respectively. It was indeed obtained that legume cover crops have efficient and low-cost source of nitrogen with considerable potential to improve soil fertility in intensified cropping systems [12 -14; 8, 7]. The high values in the soil chemical properties observed in the plants planted with legumes relative to the control and maize plots could be due to higher level of organic matter from litter fall which increased the soil organic carbon, pH, nitrogen, soil aggregate stability and hence other properties. The improvement in these properties may lead to increased crop growth and development.

3.3 Effects of crop species cover on the exchangeable bases (sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^+))

The results (Tables 4) indicated that different crop species cover improved the exchangeable bases significantly ($p < 0.05$) higher than the control except in exchangeable sodium in the first year. The results (Table 4) showed that maize and control plots in the first year significantly ($P< 0.05$) increased the exchangeable sodium higher than plots with cowpea legume covers. In the second year, plots with maize and *mucuna* cover significantly improved the exchangeable Na^+ higher than the control.

Table 4 equally revealed that the legume crop species cover did significantly ($P< 0.05$) affected the exchangeable potassium K^+ positively higher than the maize and control plots. It was observed that the highest statistical exchangeable K^+ was obtained in cowpea plots for the two years of study, while the control plots recorded the least value for exchangeable K. The values ranged from 0.34 – 0.50 $cmol_ckg^{-1}$ in the first year and 0.31 – 0.59 in the second year.

There was a significant ($P < 0.05$) difference on exchangeable calcium among the treatments as shown in (Table 4). The results (Table 4) indicated that exchangeable calcium was significantly ($p < 0.05$) improved better in plots planted with *mucuna* and cowpea than in maize plots within the periods, while control had the least exchangeable calcium. It was obtained that plots with plant covers including the maize plots significantly ($P < 0.05$) increased the exchangeable Ca higher than the control plots for the two years of study. The values ranged from 2.00 – 3.90 $cmol_ckg^{-1}$ and 1.33 – 4.40 $cmol_ckg^{-1}$.

The results (Table 5) showed that there was also significant difference among the plant species on the improvement of the soil exchangeable Mg^+. The result indicated that the exchangeable Mg^+ was statistically ($P < 0.05$) influenced better by the legume species cover than maize plots. Generally, all the plant species cover significantly ($P < 0.05$) improved the exchangeable magnesium better than the control for the two years of study. The values ranged from 0.53 – 1.90 $cmol_ckg^{-1}$ and 0.91 – 2.47 $cmol_ckg^{-1}$ for the 1st and 2nd year of the experiment.

3.4 Effects of plant species cover on cation exchange capacity (CEC), Base saturation (BS) Exchangeable acidity and Available phosphorus (P)

The result (Table 5) showed that there was significant ($P < 0.05$) difference on CEC due to different plant species influence for the two years. It was obtained that *mucuna* and cowpea plots had the highest significance ($P < 0.05$) value increase on the CEC, as the control plots gave the least CEC values in the first and second year of study. The results showed that all the plots with plant species did improve the soil CEC higher than the control. The values varied from 14.60 – 28.7 $cmol_ckg^{-1}$and 12.24 – 32.34 $cmol_ckg^{-1}$ in the 1st and 2nd year of study, respectively. The result agrees with the submission that, legumes are grown as cover crops and serve as short-term fallow species. They have proven to be an effective means of sustaining soil fertility [10]. They are cheap and can be used to complement animal manures.

It was obtained (Table 5) that there was significant ($P < 0.05$) difference among the plants species on the improvement of Base saturation of the studied soil. The result revealed that *mucuna* plot in the first year of experiment had the highest significant ($P < 0.05$) improvement on the base saturation followed by cowpea covered plots while the control recorded the least base saturation. In the second year, both cowpea and *mucuna* plots performed statistically alike, and their values were significantly ($p < 0.05$) higher than maize and control plots. It was also obtained that plots with maize cover did statistically better than the control plot. The values ranged from 18.78 – 47 83% in the 1st year and 19.38 – 51.67% in the 2nd year.

The results (Table 5) showed that there was a significant difference among the plant species on exchangeable acidity in both years of study. The result indicated that the exchangeable acidity was statistically reduced better by the plant species compared to the control. It was recorded that among the plant species, maize plant significantly increased the exchangeable acidity higher for the two years of the experiment. The result observed that while the highest significant reduction of exchangeable acidity (EA) was obtained from *mucuna* plots in the first year, cowpea and *mucuna* plots drastically reduced the EA of the soil significantly ($p < 0.05$) in the second year. The values ranged from 1.93 – 3.53 $cmol_ckg^{-1}$ and 3.88 – 1.77 $cmol_ckg^{-1}$ in the 1st and 2nd year of study, respectively.

The results (Table 5) equally revealed that the treatments did significantly ($P<0.05$) affected the soil available phosphorus for the two years of study. It was observed that the two legume species (*mucuna* and cowpea) covers gave the highest significant available phosphorous values within the studied periods. The values varied from 5.66 – 22.17 mg/kg in the first year and 6.66 – 31.77 mg/kg.

3.5 Effect of legumes cover crop on weed weight (kg) weeks after planting (WAP).

The results (Table 6) showed that there were significant (P<0.05) differences among the treatments as they affected the weed weight or density at various stages of the crop growth for the two years of study. At 2 weeks after planting (WAP), there was a significant (P<0.05) difference on the weed weight due to different plant species. It was obtained that control plots with no plants had the highest significance (P<0.05) increase on the weed weight throughout the weeks in the first and second year. This was followed by plots planted with maize, except on week 4 after planting where it decreased the weed weight significantly lower for the two years. The results (Table 6) showed that at week 4 and 8 after planting in the first year, plots with cowpea gave the least mean values of weed weight compared to *mucuna* cover plots. However, plots with *muccuna* legume cover drastically reduced the weed weight significantly (P<0.05) higher than plots with cowpea cover at 6, 10 and 14 WAP in the first year and 14 WAP in the second year better than cowpea cover plots. The results are in agreement with the submission that *mucuna* is efficient in controlling noxious weeds such as *Imperata cylindrical* [15] and nut grass (*Cyperus rotundus*), two of the most difficult weeds to control in the tropics [14]. The general relative significant (p < 0.05) reduction in weed weight by the legume cover crops over the maize and control plots was in agreement with the submission of Blackshaw, *et al.* [28] that legume cover crops suppress weeds both during growth and death. In addition to competition-based or physical weed suppression certain cover crops are known to suppressed weed through allelopathy [29].

3.6 Important relationships among the soil properties and weed weight

Table 7 and 8 showed the correlation coefficients among the soil properties and weed weight for the two years of study. It was observed that the soil pH significantly (p < 0.05 and p < 0.01) correlated with organic carbon, exchangeable potassium, cation exchange capacity and available phosphorous in the first year of study (Table 7). The soil pH (Table 7) was also observed to strongly correlate significantly (p < 0.05) with total nitrogen, exchangeable calcium and magnesium, including the percent base saturation in the first year. On the other hand, the soil pH had a significant (p < 0.05) negative correlation with the exchangeable acidity and weed weight in the first year. In addition, the weed weight (Table 7) negatively significantly (p < 0.05 and p < 0.01) correlated with the soil pH, organic carbon, total nitrogen, exchangeable potassium, calcium and magnesium; cation exchange capacity, percent base saturation and available phosphorous. These results (Table 7) implied that for the field weed intensity to be reduced; there must be relative increase in the availability of the above mentioned soil elements, as increase in these elements will bring about increased performance of crops which will improve the vegetative cover, hence, smoldering of weed in the field.

In the second year of the experiment (Table 8), pH has positive significant (p < 0.05 and p < 0.01) correlation with exchangeable magnesium and cation exchange capacity. It was also observed that the soil pH significantly (p < 0.05) correlated with total nitrogen, organic carbon, exchangeable calcium, base saturation and available phosphorous. The result (Table 8) shows that weed weight though not significant, had negative strong correlation with the soil pH, organic carbon, total nitrogen, exchangeable sodium, potassium, calcium and magnesium; cation exchange capacity, percent base saturation and available phosphorous. The result indicated that an increase in the weed intensity of a field might lead to a decrease in the availability of the ten soil elements mentioned. Therefore, there is a need to reduce weed intensity in the field if the soil nutrients availability is to be maintained at particular time.

IV. Conclusion

Results from the study have shown that legume plant species improved the soil chemical properties of the studied soil more than maize. Consequently, plots with plant covers were observed to have improved the soil chemical properties relative to the control. It is therefore concluded that farmers should use any of the available legume studied to improve their soil properties and ensure sustainability in the soil fertility under intensive farming within a short period.

It can be maintained in these days that fallow after cropping is no longer possible because of modern development activities. If adoption of farming system that will provide agro-forestry or fallowing, especially with legumes through rotation and organic farming, soil fertility and productivity will eventually improve.

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APPENDIX

Table 1: Details of Meteorological Data of Ishiagu Located in the Derived Savanna (January to October 2013).

Months	Mean Rainfall (mm)	Mean Monthly Temperature (^{0}C) Max.	Min.	Relative humidity (%)
January	0.0	34	24	74
February	39.6	36	25	63
March	84.8	36	24	60
April	144.3	35	26	48
May	302.7	34	24	48
June	430.4	33	24	40
July	210.0	32	24	36
August	246.2	31	24	66
September	232.1	32	24	97
October	286.6	30	24	64

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Table 2: Initial properties of the soil

Soil properties	Values
Clay	7
Silt	3
Sand	63
Fine sand	27
Texture	Sandy loam
pH (H_2O)	4.8
Organic carbon (%)	0.23
Total nitrogen (%)	0.070
Exchangeable bases ($cmol_c kg^{-1}$)	
Sodium (Na)	0.76
Potassium (K)	0.42
Calcium (Ca)	2.0
Magnesium (Mg)	1.4
Cation exchange capacity CEC ($cmol_c kg^{-1}$)	16.40
Exchangeable acidity ($cmol_c kg^{-1}$)	2.2
Available phosphorous ($mgkg^{-1}$)	12.72
Base saturation (%)	20.40

Table 3: Effect of legumes cover crop on soil pH, organic carbon and Total nitrogen

	pH	Organic carbon (%)	Total nitrogen (%)
Year 1			
Cowpea	5.50	0.377	0.095
Muccuna	5.93	0.460	0.126
Maize	5.23	0.317	0.074
Control	4.40	0.213	0.048
LSD $_{(0.05)}$	**0.4553**	**0.05492**	**0.04500**
Year 2			
Cowpea	6.23	0.58	0.152
Muccuna	6.40	0.53	0.187
Maize	5.30	0.36	0.085
Control	4.27	0.18	0.052
LSD $_{(0.05)}$	**0.3811**	**0.0954**	**0.0800**

Table 4: Effect of legumes cover crop on exchangeable sodium (Na), exchangeable potassium (K) and exchangeable calcium (Ca^+).

	Exch. Na $cmol_c kg^{-1}$	**Exch. K $cmol_c kg^{-1}$**	**Exch. Ca $cmol_c kg^{-1}$**	**Exch. Mg $cmol_c kg^{-1}$**
Year 1				
Cowpea	0.62	0.50	3.60	1.73
Mucuna	0.68	0.44	3.90	1.90
Maize	0.75	0.38	2.80	1.00
Control	0.74	0.34	2.00	0.53
LSD $_{(0.05)}$	**0.0856**	**0.0789**	**0.6292**	**0.307**
Year 2				
Cowpea	0.69	0.59	4.33	2.30
Mucuna	0.73	0.50	4.40	2.47
Maize	0.81	0.40	2.27	1.47
Control	0.64	0.31	1.33	0.91
LSD $_{(0.05)}$	**0.1042**	**0.0796**	**0.726**	**0.4150**

Table 5: Effect of legumes cover crop on soil exchangeable Mg^+, CEC and base saturation (BS).

Treatments	**CEC ($cmol_c kg^{-1}$)**	**BS (%)**	**EA ($cmol_c kg^{-1}$)**	**Avail. P (Mg/kg)**
Year 1				
Cowpea	27.4	39.52	2.40	20.16
Muccuna	28.7	47.83	1.93	22.17
Maize	18.9	30.90	2.93	10.62
Control	14.5	18.78	3.53	5.66
LSD $_{(0.05)}$	**4.006**	**6.222**	**0.5159**	**5.596**
Year 2				
Cowpea	29.61	51.67	1.85	30.31

Muccuna	32.34	48.73	1.77	31.77
Maize	21.15	31.85	2.63	12.98
Control	12.24	19.38	3.88	6.66
LSD ($_{0.05}$)	**4.107**	**4.359**	**0.4152**	**5.349**

Table 6: Effect of legumes cover crop on weed weight (Kg/plot)

Treatments	2 WAP	4 WAP	6 WAP	8 WAP	10 WAP	12 WAP	14 WAP
Year 1							
CP	2.1	2.0	2.0	1.5	2.0	1.6	1.5
MC	2.2	2.2	1.7	1.7	1.6	1.5	1.3
MZ	2.6	1.9	2.6	2.3	2.6	2.1	1.6
CT	5.3	5.4	5.6	5.4	4.9	4.6	4.3
LSD ($_{0.05}$)	**0.188**	**0.188**	**0.1732**	**0.145**	**0.176**	**0.186**	**0.192**
Year 2							
CP	2.30	2.03	2.07	1.70	1.70	1.60	2.17
MC	2.27	2.20	1.80	1.43	1.47	1.50	1.67
MZ	2.10	1.90	2.70	2.23	2.27	2.00	2.93
CT	2.80	5.17	3.67	4.37	4.93	4.93	4.93
LSD ($_{0.05}$)	**0.443**	**0.6593**	**1.107**	**0.3034**	**1.325**	**1.449**	**0.3753**

CP = cowpea, MC = mucuna, MZ = maize, CT = control

Table 7: Matrix of correlation coefficients for all the determined chemical properties of the ultisol and the weed weight of the studied site in the first year of study

	pH	**OC**	**TN**	**Ex. Na**	**Ex. K**	**Ex.Ca**	**Ex. Mg**	**CEC**	**BS**	**EA**	**Avail. P**	**Weed wt**
pH	_											
OC	.991**	_										
TN	.971*	.994**	_									
Ex. Na	-.588	-.616	-.611	_								
Ex. K	.759	.755	.726	-.953*	_							
Ex.Ca	.976*	.981*	.968*	-.747	.867	_						
Ex. Mg	.951*	.966*	.959*	-.799	.892	.995**	_	.				
CEC	.935	.953*	.947	-.826	.907	.990*	.999**	_				
BS	.989*	.998**	.991**	-.659	.792	.991**	.979*	.968*	_			
EA	-.982*	-.997**	-.994**	.675	-.795	-.990**	-.982*	-.973*	-.999**	_	*	
Avail. P	.938	.959*	.955*	-.815	.895	.990**	.999**	1.000**	.972*	-.978*	_	
WWt	-.940	-.887	-.834	.567	-.785	-.906	-.869	-.852	-.895	.875	-.848	_

* and ** stand for significant at P = 0.05 and P = 0.01, respectively, OC = soil organic carbon, TN = soil total nitrogen, Ex. Na = exchangeable sodium, Ex. K = exchangeable potassium, Ex. Ca = exchangeable calcium, Ex. Mg = magnesium, CEC = cation exchange capacity, BS = percent base saturation, EA = exchangeable acidity, P = available phosphorous, WWt = weed weight

Table 8: Matrix of correlation coefficients for all the determined chemical properties of the ultisol and the weed weight of the studied site in the second year of study

	pH	**OC**	**TN**	**Ex.Na**	**K**	**Ex.Ca**	**Mg**	**CEC**	**BS**	**EA**	**P**	**WWt**
pH	_											
OC	.983*	_										
TN	.964*	.922	_									
Ex. Na	.322	.257	.150	_								
Ex. K	.922	.977*	.852	.115	_							
Ex.Ca	.981*	.978*	.976*	.130	.945	_						
Ex. Mg	.992**	.974*	.986*	.210	.920	.995**	_					
CEC	.998**	.972*	.977*	.306	.905	.982*	.995**	_				
BS	.984*	.997**	.945	.194	.974*	.991**	.984*	.977*	_			
EA	-.994**	-.981*	-.930	-.409	-.918	-.957*	-.972*	-.987*	-.973*	_		
P	.972*	.965*	.982*	.092	.931	.999**	.993**	.976*	.983*	-.942	_	
WWt	-.944	-.921	-.840	-.607	-.835	-.864	-.896	-.933	-.897	.973*	-.841	_

* and ** stand for significant at P = 0.05 and P = 0.01, respectively, OC = soil organic carbon, TN = soil total nitrogen, Ex. Na = exchangeable sodium, Ex. K = exchangeable potassium, Ex. Ca = exchangeable calcium, Ex. Mg = magnesium, CEC = cation exchange capacity, BS = percent base saturation, EA = exchangeable acidity, P = available phosphorous, WWt = weed weight