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Soil chemical properties and legume-cereal rotation benefits in an Ultisol in Nsukka, Southeastern Nigeria

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This research was conducted at the Department of Soil Science, University of Nigeria Teaching and Research Farm in 2008 and 2009 growing seasons. The objective was to evaluate the effects of edible grain legumes (cowpea and soybean) and velvet-bean/maize rotations on soil chemical properties and the contribution of these chemical properties to rotation benefit conferred on the maize by velvet-bean, cowpea and soybean. The experimental design was a factorial fitted into randomized complete block design comprising of four crop rotation systems, two nitrogen levels and two residue management options as factors replicated thrice making a total of 48 plots. Each year entailed two cropping sessions, first, the four crops (cowpea, soybean, velvet-bean and maize) were grown on separate plots and after harvest; maize was grown in all the plots to test for rotation effect. The result showed that the soil chemical properties nitrogen (N) and magnesium (Mg) were significantly higher in the legume-cereal rotations than in continuous maize in both years. Other chemical properties varied in the two years and between legume/maize and continuous maize rotations. Maize yield was significantly increased by velvet-bean/maize rotation in both years. Maize grain yields were also higher in cowpea/maize and soybean/maize rotations than in continuous maize but they were not significantly different. There was also significant rotation residue interaction effect with velvet-bean/maize rotation x residue having the highest maize yield. Regression analysis showed that 37 to 51% changes in maize yield were contributed by N, Mg and potassium (K).

Key words: Legume/cereal rotation, residue management, rotation benefit, soil chemical properties, maize yield.

INTRODUCTION

Legume/cereal rotation systems have been advocated as low input management strategy to increase cereal yields on acid sandy soils of sub-Saharan West Africa that are notoriously low in phosphorus (P) and nitrogen (N). Bationo et al. (1994) stated that continuous cropping of pearl millet resulted in lower yields across all nitrogen rates than when rotated with cowpea or groundnut in different agro-ecological zones. Burkert et al. (2001) noted that legume-induced increases in cereal total dry matter as recorded in the field experiments were site and crop specific, which is relatively consistent over years, but tended to grow over time. Despite increase in cereal

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yield, incorporation of green manure crops, which fix nitrogen and produce large quantities of residual biomass, also lead to soil improvement (Chikoye et al., 2002, Honlonkou et al., 1999), but these have had low adoption rate among farmers. The low adoption rates have been related to farmers` reluctance to invest land, labour and seeds into a technology that does not provide a direct return to their investment. As a result, grain and dual- purpose legumes, such as soybean and cowpea have the advantage of giving a more rapid return to investments. However, the nitrogen contribution of grain legumes to the soil may be less than that of green manure crops and grain legumes may be less beneficial for soil fertility improvement (Schultz et al., 2001; Giller et al., 1998). Annual grain legumes perform dual function. First, they are normally grown for grain production and secondly, some producers use them as green manure crops. Generally, most recognized benefit of a legume crop to a succeeding cereal is improvement in yield. This is known as rotation benefit. This benefit results from either improvement of N and non-N soil components, both known as other rotation benefits. Nitrogen rotation benefit is the yield advantage associated with extra soil N availability to a cereal crop succeeding a legume. For example, wheat following pea accumulated approximately 50 kg/ha more N compared to wheat in a wheat/wheat rotation (Evans et al., 1991). Non-N rotation benefit in a legume/cereal rotation is that portion of the yield increase not explained by extra N accumulated by a succeeding cereal crop or that portion of the yield advantage relative to a cereal-cereal rotation that cannot be accounted for by the addition of fertilizer N (Bullock, 1992).

There is an ongoing argument as to what these 'other rotation benefits' are. Notably, proper understanding of these other rotation benefits will lead to effective management and utilization of legume-cereal rotation systems for sustainable crop improvement. These 'other rotation benefits' have been attributed to chemical and biological factors such as enhanced P nutrition (Alvey et al., 2001), weed control (Tarawali et al., 1999) and reduction of soil-borne diseases and parasitic nematodes (Vargas-Ayala et al., 2000; Bagayoko et al., 2000). Presently, a fundamental and complete understanding of the beneficial rotation benefits is lacking and remains a scientific challenge and is necessary for proper utilization of legume-cereal rotation system.

Therefore, this research evaluated the effects of edible grain legumes (cowpea and soybean) and velvet-bean rotations on soil chemical properties and effect of these chemical properties on rotation benefit conferred on the maize by the velvet-bean, cowpea and soybean. The specific objectives were to determine the effect of legume-cereal rotation on soil chemical properties, compare the beneficial effect of cowpea and soybean in relation to velvet-bean in contributing to rotation benefits in an integrated nutrient management and determine the contribution of the soil chemical properties to rotation benefit

MATERIALS AND METHODS

Site and soil description

Field experiments were conducted at the University of Nigeria, Nsukka Teaching and Research Farm, which is a derived savannah zone of Nigeria. Nsukka is located on Latitude 6^0 51′N and Longitude $7^0$24′E (Jungerius, 1964). It exhibits tropical wet (March to October) and dry (November to February) seasons with a mean annual rainfall of 1250 mm and a mean annual temperature of 26°C. The soil is degraded sandy clay and classified as Typicpaleustult belonging to Nkpologu series (Nwadialor, 1989). It is very deep, with dark reddish brown colour in the topsoil and red in subsoil. It is coarse to medium textured, granular in structure, acid in reaction and low in nutrient status. Its clay mineralogy is composed mainly of kaolinite and quartz (Akamigbo and Igwe, 1990).

Experimental design and treatments

This experiment was a rotation field trial. It was carried out in 2008 and 2009. The experimental design was factorial in randomized complete block design (RCBD), having three factors. Factor A was 4 crop rotation systems namely (velvet-bean/maize (VE/MA), cowpea/maize (CO/MA), soybean/maize (SO/MA) and maize/maize (MA/MA)), factor B was 2 nitrogen application levels (N at 0 kg ha^{-1} and N at 60 kg ha^{-1}, and factor C was 2 crop residue managements (Residue incorporated (RI) and Residue not incorporated (RN)) replicated three times making 48 plots. In each year, two cropping sessions were done, first was the cultivation of the legumes (velvet bean, cowpea and soybean) and maize as a reference crop. Second was the cultivation of maize in all the plots with and without residue incorporation and/or nitrogen application after harvesting the first crops.

The treatments were randomly applied to the plots using lettered papers. Hybrid maize seeds (*Zea mays* L.) cv Oba Super II, dual-purpose cowpea (*Vigna uniguiculata*) cv03k-374-4, early- duration soybean (*Glycine max)* cv TGX 1448 and velvet bean (*Mucuna pruriens*) were planted, three seeds per hole and thinned down to one seedling per hole after two weeks of germination. The planting spacing was 75 cm by 25 cm. The total area was 0.05 hectare. The main plot, subplot and sub-sub plots were 5 x 6 m, 2.5 x 6 m and 2.5 x 3 m, respectively. Weeding was done twice during the period. In 2008, the first and second planting took place on 23 June and September 5, respectively. The date for maize harvest was on 21 November whereas in 2009 the first and second cultivation took place on 8th June and 9th September, respectively. The plants were harvested at maturity in late November.

Data collection

At the onset of the experiment in 2008, representative soil samples were collected from 0 to 15 cm from the topsoil of the area and mixed together to obtain a composite sample. In addition, soil samples were collected at the end of each harvest. The entire soil samples were air-dried, sieved with 2 mm sieve and subjected to chemical soil analyses. Soil pH was measured potentiometrically in 1:2.5 soil to water ratio with the glass electrode pH meter (McLean, 1982); organic carbon (OC) by the Walkley and Black wet dichromate oxidation method (Nelson and Sommers, 1982), organic matter (OM) was calculated by multiplying organic carbon figure by the conventional "Van Berminelen factor" of 1.724; exchangeable

Table 1. The properties of soil of the location.

Parameter	UNN
Clay (%)	38.6
Silt (%)	17.6
Sand (%)	43.9
Textural class	Sandy clay
BD	1.10
pH	5.2
N (%)	0.11
OC (%)	0.86
OM (%)	1.48
P (mg kg^{-1})	6.48
Ca ($cmolkg^{-1}$)	0.8
Mg ($cmolkg^{-1}$)	0.6
K ($cmolkg^{-1}$)	0.09
Na ($cmolkg^{-1}$)	0.07
EA ($cmolkg^{-1}$)	1.4
ECEC ($cmolkg^{-1}$)	2.96
CEC ($cmolkg^{-1}$)	5.3
BS (%)	52.7
C/N	9.8

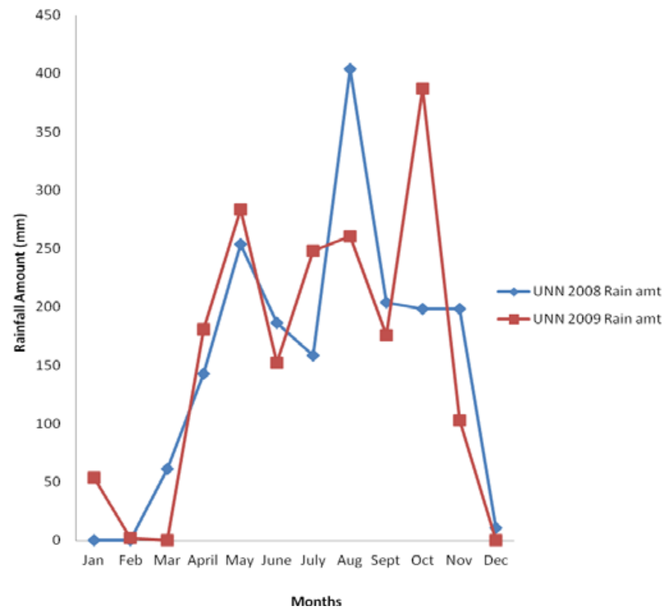

Figure 1. Rainfall amount for 2008 and 2009 at Moniya-Ibadan and UNN.

bases by extraction with neutral 1 N NH_4OAc. Potassium (K) in the extract was determined with flame photometer (Kundsen et al., 1982), Ca and Mg by atomic absorption spectrophotometer (L). Exchangeable acidity was determined by the KCl displacement method described by Page et al. (1982). Effective cation exchange capacity (ECEC) was obtained from the sum of the exchangeable bases and exchangeable acidity. Available P was extracted by Bray II method; the P concentration in the extract determined colorimetrically using the spectronic 70 spectrophotometer method (Page et al., 1982). Total N in soils was determined by the Micro-Kjeldahl digestion procedure (Bremner and Mulvaney, 1982).

Plant residue laboratory analysis

The residue for maize and velvet-bean were analyzed for total N, P, K, Ca, Mg and organic carbon. Total N was by the method of Bremner and Mulvaney (1982). For other analyses, 0.5 g of the residue was extracted with 20 ml concentrated nitric acid and allowed to stay overnight. It was then digested until blackish organic matter disappears. Then, 20 ml of H_2O_2 was added as digestion continued until white fumes appeared indicating complete digestion. Water was then added and filtered to 100 ml volume. The filtrate was used for determination of total P, K, Ca and Mg according to methods for soil sample determination as enumerated above. Maize crops were harvested maturity dried before shelling to obtain dry matter and grain yield. All plant samplings were done by cutting the shoot at soil level.

RESULTS AND DISCUSSION

Physicochemical properties of the soil at the beginning of the experiment are shown on Table 1. The pH of UNN soil is strongly acid (5.1) (USDA – SCS, 1994). The exchangeable Ca, Mg, K, Na, and cation exchange capacity of UNN soil were very low. Total N of 0.07% was very low (Landon, 1991) and available P was also low (6.48 mg/kg). The low nutrient content of UNN soils may have resulted from very high rainfall that leaches these nutrients with high temperatures, almost all the periods of the year. For instance, there was 404.15 mm of rainfall in 18 days in 2008 and in October 2009, there was 387.1 mm of rainfall in 17 days which were rather too high (Figure 1).

Chemical properties of the residues

Table 2 shows the chemical properties of the crop residues. Total N, P, Ca and Mg were higher in velvet-bean residue but total K and organic C were higher in maize residue. Therefore, velvet-bean residue contains more nutrients needed by crops for their growth and development. In addition, velvet-bean residue had lower C/N and C/P ratios, depicting easier degradation and earlier release of nutrients.

Soil chemical properties as affected by legume-cereal rotation, residue incorporation and nitrogen application

In 2008, Legume-cereal rotations significantly ($p < 0.05$) affected pH, OC, N, Ca, Mg, EA, ECEC, pH, OC and EA (Table 3) and pH, P, N, Ca, Mg, EA, pH, and EA in 2009. These soil chemical properties: N, Ca, Mg and ECEC

Table 2. Characteristics of organic wastes used in this study.

Parameter measured	Mucuna residue	Maize residue
Organic C (%)	5.8	6.7
Total N (%)	2.7	2.1
Total P (%)	2.6	2.2
Total K (%)	0.8	1.2
Total Ca (%)	0.4	0.2
Total Mg (%)	2.5	1.5
C/N	2.15	3.19
C/P	2.23	3.05

Table 3. Soil chemical Properties as affected by cropping system, residue application and N rates at the end of the experiment in UNN.

Parameter	pH	OC (%)	N (%)	P (mg/kg)	Ca	Mg	K (cmol/kg)	EA	ECEC
Cropping systems				2008					
Velvetbean/Maize	4.51	0.98	0.107	13.87	0.83	0.59	0.24	1.08	2.86
Cowpea/maize	4.51	1.19	0.098	15.32	0.73	0.54	0.18	0.86	2.42
Soybean/Maize	4.45	0.99	0.097	13.46	0.70	0.50	0.22	1.00	2.52
Maize/maize	4.7	1.01	0.070	14.32	0.63	0.47	0.21	0.92	2.33
LSD (0.05)	0.08**	0.11**	0.01**	ns	0.08**	0.05**	ns	0.14*	0.18**
N application									
Zero N	4.52	1.02	0.09	14.07	0.70	0.51	0.24	0.90	2.45
60 Kg/ha N	4.57	1.07	0.1	14.42	0.74	0.54	0.19	1.04	2.61
LSD (0.05)	ns	ns	ns	ns	ns	ns	ns	0.1*	0.13**
Residue addition									
Zero Residue	4.55	1.04	0.087	13.33	0.70	0.49	0.22	1.02	2.54
Residue addition	4.54	1.05	0.098	15.17	0.74	0.56	0.21	0.91	2.52
LSD (0.05)	ns	ns	0.007**	ns	ns	0.03**	ns	0.1*	ns
Cropping systems				2009					
Velvetbean/Maize	4.59	0.95	0.070	13.01	0.99	0.22	0.16	1.28	2.75
Cowpea/maize	4.45	0.99	0.063	13.17	1.21	0.26	0.14	0.93	2.67
Soybean/Maize	4.61	0.94	0.063	15.64	1.15	0.24	0.14	1.16	2.80
Maize/maize	4.41	0.89	0.045	10.23	1.00	0.19	0.14	1.21	2.67
LSD (0.05)	0.16*	ns	0.007**	3.42*	0.17*	0.03**	ns	0.1**	ns
N application									
Zero N	4.50	0.93	0.058	13.09	1.08	0.23	0.13	1.07	2.65
60Kg/ha N	4.53	0.95	0.062	12.93	1.09	0.23	0.15	1.22	2.81
LSD (0.05)	ns	ns	ns	ns	ns	ns	ns	0.07**	0.12**
Residue addition									
Zero Residue	4.56	0.93	0.056	13.19	1.10	0.22	0.14	1.20	2.78
Residue addition	4.46	0.94	0.065	12.83	1.08	0.24	0.15	1.09	2.68
LSD (0.05)	ns	ns	0.005**	ns	ns	ns	ns	0.07**	ns

ns = not significant, * = significant at 5%, ** = significant at 1%

Table 4. Interaction effect between cropping system and residue application at UNN.

Cropping system x Residue	pH	OC (%)	N (%)	P (mg/kg)	Ca	Mg	K (cmol/kg)	EA	ECEC
2008									
Va/Ma X R	4.6	1.02	0.11	13.89	0.80	0.61	0.22	0.90	2.63
Cp/Ma X R	4.5	1.18	0.10	16.32	0.77	0.57	0.20	0.90	2.55
Sb/Ma X R	4.5	0.96	0.11	14.72	0.69	0.53	0.20	1.00	2.52
Ma/Ma X R	4.7	1.01	0.08	15.74	0.70	0.51	0.22	0.86	2.39
Va/Ma X NR	4.6	0.94	0.10	13.89	0.85	0.57	0.26	1.27	3.09
Cp/Ma X NR	4.5	1.19	0.10	14.32	0.68	0.51	0.17	0.82	2.29
Sb/Ma X NR	4.4	1.01	0.09	12.19	0.69	0.46	0.24	1.00	2.52
Ma/Ma X NR	4.8	1.01	0.06	12.90	0.56	0.43	0.20	0.97	2.28
Lsd (0.05)	0.1*	ns	ns	ns	0.12**	ns	ns	0.19*	0.25**
2009									
Va/Ma X R	4.4	0.98	0.08	13.6	1.1	0.3	0.18	1.0	2.6
Cp/Ma X R	4.3	0.95	0.07	17.6	1.1	0.3	0.13	1.0	2.7
Sb/Ma X R	4.6	0.93	0.07	14.6	1.0	0.2	0.15	1.2	2.6
Ma/Ma X R	4.6	0.91	0.05	11.2	1.1	0.2	0.13	1.2	2.7
Va/Ma X NR	4.4	0.92	0.07	14.8	0.9	0.2	0.14	1.5	2.9
Cp/Ma X NR	4.6	0.98	0.06	14.4	1.3	0.3	0.15	1.0	2.7
Sb/Ma X NR	4.6	0.95	0.06	16.7	1.3	0.3	0.13	1.2	3.0
Ma/Ma X NR	4.6	0.90	0.04	9.3	0.9	0.2	0.14	1.3	2.6
Lsd (0.05)	ns	ns	0.01**	ns	0.24**	0.05**	0.03**	0.21**	0.29*

* = Significant at 5%, ** highly significant at 1%, ns- not significant. Va-velvet-bean, CP- cowpea, SB- soybean MA- maize, R- Residue addition NR- no residue addition

were higher in the legume-cereal rotations than in continuous maize in 2008 with velvet-bean/maize rotation having significantly higher values. Velvet-bean/maize rotation had 0.107% N, 0.83 cmol kg^{-1} Ca, 0.59 $cmolkg^{-1}$ Mg and 2.86 $cmolkg^{-1}$ ECEC, followed by cowpea-maize (0.098% N, 0.73 $cmolkg^{-1}$ Ca, 0.54 $cmolkg^{-1}$ Mg and 2.42 $cmolkg^{-1}$), soybean-maize rotations (0.097% N, 0.70 $cmolkg^{-1}$Ca, 0.50 $cmolkg^{-1}$ Mg and 2.52 $cmolkg^{-1}$ ECEC) with maize having the least values (0.070% N, 0.63 $cmolkg^{-1}$ Ca, 0.47 cmol kg^{-1} Mg and 2.33 cmol kg^{-1} ECEC). Continuous maize had the highest pH of 4.7 and soybean-maize rotation, the least value of 4.45. Organic C and EA varied among the legume-cereal rotations and continuous maize. Organic C was highest in cowpea-maize rotation (1.19%) and the least was velvet-bean-maize rotation (0.98%), soybean-maize had 0.99% OC and continuous maize 1.01%. Similar trend was observed in EA with the least value obtained from cowpea-maize rotation (0.86 $cmolkg^{-1}$) and the highest value in velvet-bean-maize rotation (1.08 $cmolkg^{-1}$). Similar result was obtained in 2009 but pH, avail P and Mg were higher in legume/maize rotations but Ca and ECEC varied.

Nitrogen application affected significantly EA and ECEC, with N application having higher values (1.04, 1.22 and 2.61, 2.81 $cmolkg^{-1}$) than no application (0.90, 1.07 and 2.45, 2.65 $cmolkg^{-1}$) in both years. Residue addition significantly affected N, Mg and EA, with residue addition having higher values than no addition except for EA, which was higher in no addition of residue. This was also the case in 2009. The interaction between cropping system and residue incorporation (Table 4) shows that the Legume x residue highly increased soil N, Ca and Mg than maize residue. In addition, for N specifically, legume-cereal rotations gave higher soil N than continuous maize whether there was addition of residue or not. The legume-cereal X legume residue interaction improved most of these parameters over continuous maize X maize residue interaction.

The lower pH in the legume/cereal rotation in soils in 2008 agrees with the findings of Helyar and Porter (1989), which states that the presence of legumes in agricultural system influences soil acidity through the N and C cycles. Legumes increase soil organic N through N-fixation, and subsequent oxidation of organic N followed by NO_3 leaching is the main acidifying process (Helyar, 1976). Secondly, the excretion of H^+ from legume roots, due to the uptake of more cations than anions (Haynes, 1983), is another reason for accelerated acidification associated with legume growth. At Tarlee site, the results show that the wheat-lupin rotation gave the highest acidification rate. Tang et al. (1998) have shown that the total acid excretion by the roots of some

Table 5. Dry matter (t/ha) and grain yield (t/ha) as affected by cropping system, residue application and N rates.

Treatment	Dry matter (t/ha)		Grain yield (t/ha)	
	2008	2009	2008	2009
Cropping systems				
Velvet-bean/Maize	32.17	31.34	1.85	2.04
Cowpea/maize	10.86	9.49	0.55	0.65
Soybean/Maize	9.17	10.82	0.62	0.57
Maize/maize	9.20	8.20	0.52	0.52
LSD (0.05)	2.59**	2.90**	0.16**	0.06**
Nitrogen application (N)				
Zero N	10.46	12.63	0.62	0.81
60Kg/ha N	20.23	17.30	1.15	1.08
LSD (0.05)	1.83**	2.05**	0.12**	0.04**
Residue				
Zero Residue	10.59	11.42	0.51	0.67
Residue addition	20.11	18.50	1.26	1.22
LSD (0.05)	1.83**	2.05**	0.12**	0.04**

* Significant at 5%, highly significant at 1%, ns- not significant

Table 6. Interaction effect of cropping system and residue application.

Treatment interaction	Dry matter (t/ha)		Grain yield (t/ha)	
	2008	2009	2008	2009
Velvet-bean/Maize *Residue	40.28	37.36	2.61	2.79
Velvet-bean/Maize*Zero Res	24.06	25.31	1.09	1.29
Cowpea/maize*Residue	14.98	12.44	0.79	0.86
Cowpea/maize*Zero Residue	6.73	6.54	0.32	0.44
Soybean/Maize*Residue	11.50	14.64	0.76	0.66
Soybean/Maize*ZeroRes	6.84	7.00	0.47	0.47
Maize/Maize*Res	13.66	9.57	0.90	0.55
Maize/Maize*ZRes	4.73	6.84	0.14	0.49
LSD(0.05)	3.37**	3.60*	0.19**	0.16**

* Significant at 5% ** highly significant at 1%, ns- not significant.

pasture legumes correlated with the total shoot content of excess cations, and this was associated with a decrease in soil exchangeable base cations. In addition, higher nutrient in legume-cereal rotation over continuous maize agrees with the work of Alvey et al. (2001); Muhr et al. (1999) that mineral nutrition of the soil is increased by the legume because of higher solubilization of the occluded nutrients.

Effect of the treatments on maize yield

Table 5 shows the effects of cropping systems, residue additions and N applications on maize yield. Comparing the cropping systems, velvet-bean/maize rotation produced significantly higher maize grain yields (1.85 tha^{-1} in 2008, 2.04 tha^{-1} in 2009), which was statistically different from all other rotations. Velvet-bean/maize rotation is notable in significant improvement in subsequent maize yield (Buerkert et al., 2001). In 2008, cowpea/maize and soybean/maize rotations were significantly the same with continuous maize yield but in 2009, cowpea/maize was significantly higher than continuous maize in increasing maize yield but soybean/maize rotation did not increase maize yield significantly. The generally non-significant maize yield produced in soybean and cowpea/maize rotations were because of the poor growth due to the heavy rainfall during the first cultivation in which these legumes were grown. However, the yields were still generally higher than maize/maize rotations. Velvet-bean grew very well even under heavy rainfall, so produced significant higher maize yield in rotation.

Interactions between cropping systems and residue addition significantly affected the subsequent maize yield (Table 6). Velvet-bean residue was superior to all other

Table 7. Maize yield improvement of legume/maize over maize/maize (Rotation benefit).

Treatment	2008 (%)	2009 (%)
Velvet-bean/maize	255	293
Cowpea/maize	5.7	25
Soybean/maize	19	9.6
Velvet-bean/Maize *Res	192	350
Cowpea/maize*Res	NA	115
Soybean/Maize*Residue	NA	17

Table 8. Regression equation and R^2 of significant soil factors of legume/cereal rotations.

Year	Yield parameter	R^2	Regression equation
2008	Dry matter	0.51	Y= -46.75 + 211.41N + 81.02 Mg
	Grain yield	0.44	Y= -2.82 + 15.21N + 4.37 Mg
2009	Dry matter	0.37	-23.86 + 349.41 N + 124 K
	Grain yield	0.41	-1.97 + 23.06 N + 10.65 K

N = nitrogen, Mg = magnesium, K=potassium.

residue in increasing maize yield. Table 7 shows the overall contribution of the cropping systems and their residue on rotation benefit. Velvet-bean/maize rotation had over 100% increases in maize yield in relation to continuous maize rotation. Cowpea/maize rotation had about zero to 33% increase and soybean/maize rotation had about zero to 43%.

Percentage contribution of non-N rotation benefit vis-à-vis soil chemical properties to maize yield increase

Table 8 shows the Regression coefficient (R^2) and regression equation of the second maize yield and soil chemical properties in legume-cereal rotations. In 2008, 51, 44% changes in dry matter and grain yield were contributed by N (8%) and Mg (43%) and N (34%) and Mg (10%), respectively, while in 2009, 37 and 41% changes in dry matter and grain yield were contributed by N (6%) and K (31%) and N (5%) and K (36%), respectively.

Principal component analysis of the yield variants (soil chemical properties)

Looking at the yield varieties holistically in a multivariate analysis using PCA, a comparison between soil chemical properties after the legume/cereal rotation was done. In 2008, 69% variation in the database was dealt with in third PCs at the end of the legume/cereal rotation cropping. More so, in 2009, 60% variation was dealt with after the legume/cereal rotations. Notably, in PCA, the factors with higher weight (0.30 and above) controls more of the variation. Subsequently, in 2008 at the end of the legume/cereal rotations, N, Ca, Mg, EA, ECEC (first PC), pH, OC, N, K, EA (in second PC) and pH, P, Mg, Na (in the third PC) controlled the variations. In 2009 (Table 9), similar observations were made.

Conclusions

Based on the findings of this research, there was improvement of the soil chemical properties by legume/cereal rotation cropping systems. The soil properties significantly ($p < 5\%$) affected by the legume/cereal rotations were pH, OC, N, Ca, Mg, EA and ECEC in 2008 and pH, N, P, Ca, Mg and EA in 2009. Most of these properties were higher in legume/cereal plots than in continuous maize plots with velvet-bean/maize plots having higher values. Maize yield was also increased significantly by legume/cereal rotation over cereal/cereal rotation, thus the rotation benefit. Legume/cereal rotation conferred significant rotation benefit on the cereal component over cereal/cereal rotation. The extent of the rotation benefit depended on the type of leguminous crop. Overall rotation benefit ranged from 0% to over 200%. This rotation benefit resulted from N, P, Ca, Mg and K. The non-N factors were higher than the N rotation benefit except when residue was added. Edible legumes increased maize yield in rotation over continuous maize especially in the second year though velvet-bean was superior over them in increasing maize yield. Velvet-bean/maize rotation is therefore recommended though soybean and cowpea

Table 9. Principal component analysis of soil factors of legume/cereal rotation.

Soil properties	2008			2009		
	Prin1	Prin2	Prin3	Prin1	Prin2	Prin3
pH	-0.16	-0.31	0.56	0.21	0.32	-0.52
OC	-0.12	0.45	0.15	0.36	-0.08	0.24
N	0.39	0.36	-0.13	0.24	-0.08	0.60
P	-0.08	0.27	0.58	0.27	-0.14	-0.00
Ca	0.44	0.18	-0.17	0.49	-0.15	-0.34
Mg	0.34	0.38	0.31	0.50	-0.21	0.07
K	0.18	-0.39	-0.19	0.16	0.14	0.36
Na	0.26	-0.20	0.30	-0.14	-0.33	0.07
EA	0.34	-0.31	0.23	-0.10	0.67	0.25
ECEC	0.53	-0.19	0.11	0.41	0.47	-0.01
Eigval	3.07	2.09	1.19	2.88	1.72	1.56
Prop	0.31	0.21	0.12	0.28	0.17	0.15
Cum	0.31	0.52	0.63	0.28	0.45	0.60

can also be planted in rotation with maize instead of continuous cropping of maize but rotation benefit is not as much as in the case of velvet-bean/maize rotation.

Conflict of Interests

The author(s) have not declared any conflict of interests.

REFERENCES

Akamigbo FOR, Igwe CA (1990). Morphology, Geography, Genesis andTaxanomy of three soil series in Eastern Nigeria.Samaru J. Agric 7:33-48

Alvey S, Bagayoko M, Newmann G, Buerkert A (2001). Cereal/legume rotations affect chemical properties and biological activities in two West African soils. In:Plant and Soil 231: 45–54. Kluwer Academic Publisher, Netherlands.

Bagayoko M, Buerkert A, Lung G, Bationo A, Romheld V (2000). Cereal/legume rotation effects on cereal growth in Sudano- Sahelian West Africa: Soil mineral, mycorrhizae and nematodes. In: Plant and Soil, 218:103-116.

Bationo A, Ntare BR, Pierre D, Christianson BC (1994). Crop rotation effects and crop yield and soil productivity in the West Africa semi-Arid Tropics. Fert. Res.

Bremner JM, Mulvaney CS (1982). Total nitrogen p.595-624. In Page et al. (Ed.) Methods of Soil Analysis, Part 2 Agron. Monogr. 9. ASA and ASSA, Madison W.I.

Buerkert A, Bagayoko M, Alvey S, Bationo A (2001). Causes of legume/cerealrotation effects in increasing cereal yields across the Sudanian, Sahelian and Guinean zone of West Africa. In: Plant and Soil 220:101-120.

Bullock DG (1992). Crop rotation. Crit. Rev. Plant Sci. 11:309-326.

Chikoye D, Manyong VM, Carsky RJ, Ekeleme F, Gbehounou G, Ahanchede A (2002). Response of spear grass (Imperata cylindrical) to cover crops integrated with hand weeding and chemical control in maize and cassava. Crop protection 21: 145 - 156

Evans J, Fettel NA, O'Connor GE, Walsgott DN, Mahoney J, Armstrong EL (1991). Wheat response after temperate crop legumes in south-eastern Australia. Aust. J. Agric. Res. 42(1):31–43.

Giller KE, Gilbert R, Mugwira LM, Muza L, Patel BK, Waddington SR (1998).Practial approaches to soil organic matter management for smallholder maize production in southern Africa. In soil fertility research for maize- based farming systems in Malawi and Zimbabwe, 139-153.

Haynes RJ (1983). Soil acidification induced by leguminous crops. Grass and Forage Science. 38:1-11.

Helyar KR (1976). Nitrogen cycling and soil acidifiation. J. Aust. Institute of AgriculturalScience. 42:21-221

Helyar KR, Porter WM (1989). Soil acidification, its measurement and the Processesinvolved. In: Robson A. D. (ed.). Soil Acidity and Plant Growth. Australia AcademicPress. p. 61-101

Honlonkou AN, Manyong VM, Tchetche N (1999). Farmers' perception and the dynamics of adoption of a resource management technology: the case of mucunafallow in southern Benin, West Africa. International Forestry Review 1:228-235.

Jungerius PD (1964). The soils.pp 1-22 In: Soil Survey Memoir No. 1. The Anambra- doRivers Area. Government Printers, Enugu.

Kundsen D, Peterson GA, Pratt PF (1982). Lithium, sodium and potassium,. In A.L. Page (ed.). Methods of Soil Analysis Part 1. Agron.Mongr. 9. ASA and SSA Madison, W.I. pp. 241-262

Landon JR (1991). Booker Tropical Soil Manual. A book for soil survey and landevaluation in the tropic and subtropics (ed.). John Wiley and Sons Inc, 605 Third Avenue, New York, USA. p. 474

McLean EO (1982). Soil pH and lime requirements. In: Page et al. (eds). Methods of Soil Analysis, Part II.Am Soc. Agron. 9, Madison, WI, USA.

Muhr L, Tarawali M, Peters SA, Schultze-Kraft R (1999). Forage legumes for improved fallows in agropastoral systems of sub-humid West Africa. II. Green manure production and decomposition after incorporation into the soil. Trop. Grassl. 33:234-244.

Nelson DW, Sommers LE (1982).Total C, organic C and organic matter.Methods of soil analysis.Part 2.Chemical and Microbiological Properties.ASA, Madison, WI pp. 359-580.

Nwadialor BE (1989). Soil landscape relationships in the Udi-Nsukka Plateau, Nigeria.Catena 16:111-120

Page AL, Miller RH, Keeney DR (1982). Methods of Soil Analysis.Part 2.Chemical and Microbiological Properties. Am. Soc. Agron. 9, Madison, WI, USA. 579 pp

Schultz S, Carsky RJ, Tarawali S (2001). Herbaceous legumes: the panacea for West African soil fertility problems? In: Tian G, Keatinge, JDH, Ishida F (eds). Sustaining soil fertility in West Africa. SSSA Special Publication No. 58, ASA, Madison, USA.

Tang C, McLay CDA, Barton L (1998). A comparison of proton excretion of twelvepasture legumes grown in nutrient solution.Austr. J. Exp. Agric. 37:563-570.

Tarawali G, Manyong VM, Carsky RJ, Vissoh PV, Osei-Bonsu P, Galiba N (1999). Adoption of improved fallows in West Arica: lessons from mucuna and stylo case studies. Agroforestry Systems 47:93-122.

USDA-SCS (1994). Definitions and abbreviations for soil description, West Technical Service Centre, Portland, Oregon, USA p. 67.
Vargas-Ayala R, Rodriguez-Kabana R, Morgan-Jones G, Mclnroy JA, Kloepper JW (2000). Shifts in soil microflora induced by velvet bean in cropping systems to control root-knot nematodes. Biol. Control 17:11-22.