ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF AGRONOMY

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Journal of Agronomy 5 (2): 362-368, 2006
ISSN 1812-5379

Influence of Cereal-legume Rotation on Soil Chemical Properties, Crop Yield and *Striga* Control

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Abstract: Integrated soil management with grain legumes was studied at two villages (Ugwan Shamaki) and Tashan Kaya) in Kaduna State, northern Guinea Savanna zone of Nigeria (190 day growing season). Impacts of one year rotation of Soybean and Cowpea on soil chemical properties were compared with sole maize and maize-cowpea mixture. All plots were *Striga* infested. Organic carbon decreased by 4 and 2% in maize after maize (SM) plots in Ugwan Shamaki and Tashan Kaya respectively. Sole soybean, SC and MC mixture increased organic carbon by 10, 2 and 23% in Ugwan Shamaki and 6, 4 and 16% in Tashan Kaya respectively. pH values were lowered in the order SM> MC>SS and SC. Exchangeable Ca, Mg and K remained unchanged or slightly increased. There was positive and significant association between pH and *Striga* parameters, while exchangeable bases had negative association with *Striga* parameters. Exchangeable K have positive and significant correlation with number of cobs at harvest (R = 0.68*), total cob weight (R = 0.61*) and maize grain yield (R = 0.64**) at Ugwan Shamaki. Maize yield increase from maize after Soybean were 150 and 301 kg over previous maize at Ugwan Shamaki and Tashan Kaya, respectively. Corresponding increases in Cowpea maize rotated plot in the two locations were 243 and 234 kg, respectively.

Key words: Cereal-legume, rotation, soil properties, *Striga*

INTRODUCTION

Maize (*Zea mays* L.) is currently replacing traditional crops such as sorghum and millet in the farming systems of West and Central Africa because of favourable environmental conditions and maize is grown both for cash and food (Jagtap, 1995). It is one of the two major crops in about 40% of the area under agricultural production in Sub Saharan Africa (Smith *et al.,* 1997). Length of the growing period is between five to six months and the rainfall pattern is uni-modal with peak a in August.

Because of favourable environmental conditions, it is possible to attain 80% productivity (Jagtab, 1995). Up to 8.0 t ha^{-1} can be obtained on farmers' field with an average of 5.5 t ha^{-1} (Smith, 1997). However, two major constraints to increasing maize yields in the Guinea savanna are poor soil fertility, resulting in P and N deficiencies and *Striga hermonthica* parasitism. Substantial yield losses (50-80%) have been reported on farmers' fields due to N deficiency and *Striga* infestation. This has resulted in the abandonment of farmlands in areas where these two stresses are evident.

Soil fertility regeneration and *Striga* control is archeived through traditional practice of long bush fallow systems after short periods of intensive cultivation. Increasing population pressure has resulted in a drastic shortening of the fallow periods necessary to restore soil fertility. Soil fertility can be maintained through the judicious use of inorganic fertilizers. Although farmers in this region know the importance and application of chemical fertilizers they are not widely used because of high cost and unavailability (Ibewiro *et al.*, 2000). Given this scenario, the integration of grain legumes into the cropping system has the potential to enhance yields of subsequent crops. This effect can largely be attributed to the improvement on soil fertility, especially N and the rotation effects such as the control of pest and diseases (Peoples *et al.*, 1995, Sanginga *et al.*, 2000). When legumes are used, N availability in the soil may be increased as a result of two effects: N sparing effect; that is the conservation of soil N through N_2 fixing legumes in comparism to non-fixing plants (Giller and Wilson, 1991) and priming effect; that is the enhanced mineralization of solid organic N during the decomposition of legumes residues (Jenkinson *et al.*, 1985). The effect of added legume N on subsequent crop yields regardless of the source of N, can however, be decreased by a number of factors. This includes N immobilization (Varco *et al.*, 1993), denitrification and volatilization

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(Sanginga, *et al*., 1995) as well as adverse effect of decomposition processes on soil fertility (Yamoah, *et al*., 1991). The interaction of legume N with fertilizer N supplied to subsequent crops can help to identify the role that improved N availability in the soil plays in contribution to the rotational effect following legumes (Giller and Wilson, 1991).

Groundnut, soybean and cowpea are grain legumes that are well adapted to the farming systems of the savannas. Farmers, therefore, prefer to intercrop or rotate these legumes with cereals. The amount of mulch as litter fall may be short of the recommended organic residues required to maintain soil fertility. However, contribution through N-fixation is an added advantage to the subsequent crop. Considering the present high costs of fertilizers, the recommended soil conservation and management strategy is maximum utilization and maintenance of available soil nutrients and reduced use of inorganic fertilizers. Rotation of these legumes with cereals can also reduce *Striga* infestation. The legumes act as trap-crops which cause suicidal germination of *Striga* seeds (Carsky *et al*., 2000). The objective of this study was to investigate the effect of a one-year legume-cereal rotation on soil chemical properties *Striga* control and crop yield on farmers' fields.

MATERIALS AND METHODS

On-farm trials were conducted in 2001 and 2002 at two villages (Ugwa Shamaki and Tashan Kaya) in Kaduna State, Northern Guinea Savanna (NGS) zone of Nigeria to demonstrate the use of host plant resistance, rotation and inter-cropping with legume trap-crops for *Striga* management. The villages are located on 690 m above sea level with mono-modal rainfall pattern. Annual Rainfall in the area averages 1050 mm. Maximum and minimum temperature averages are 20 and 35°C, respectively. The fields where the trials were established have been cropped for over 20 years with low fertilizer application rates and are severely infested with *Striga hermonthica.*

Treatments evaluated in 2001 were four cropping systems: *Striga* resistant sole maize, maize-cowpea inter-crop, sole cowpea and sole soybean. The promiscuous soybean (cultivar TGX 1448-2E) and cowpea (cultivar IT93K452-1) were reported to stimulate suicidal germination of *Striga* seeds moderately, mature early (60-65 days) and produce high biomass (Kureh, 1996). The demonstrations were established on 12 farmers' fields. Each farmer with six plots consisting of the sole *Striga* resistant maize, maize-cowpea inter-crop and two plots each of sole cowpea and sole soybean constitutes a replicate. The gross plot size was 20×20 m^2. In 2002, sole maize and maize-cowpea mixture plots were maintained as in 2001. However, one plot each of sole soybean and cowpea were rotated with maize, while the second plot of these legumes was maintained in order to test the effect of two year rotation in 2003.

Fields were prepared and ridged 75 cm apart using animal drawn plow or hand hoes. Maize was sown at the rate of 2 seeds per hill at an intra-row spacing of 50 cm giving a population density of 53,333 ha^{-1}. Soybean was drilled at a spacing of 5cm giving a population density of 444,444 ha^{-1} and cowpea was sown at a rate of 2 seeds per hill at an intra-row spacing of 30 cm giving a population density of 63,333 plants ha^{-1}. In the maize-cowpea inter-crop, two seeds of cowpea were sown in between two stands of maize. All crops were sown the same day. Maize plots were hoes weeded at 2 WAS and earthen up at 6 WAS, while the legume plots were hoes weeded at 3 and 6 WAS to control weeds. Fertilizer was applied to maize at the rate of 100 kg N ha^{-1}, 50 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1} using NPK (15:15:15) and urea. All the P and K and half of N were applied at 2 WAS, while the remaining N was top-dressed at 6 WAS. The legumes were fertilized at the rate of 20 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1} and 20 kg K_2O ha^{-1} using NPK (15:15:15) mixed with SSP. The cowpea was spread with cyperplus and benlate at the rate of 1 L ha^{-1} and 0.4 kg ha^{-1}, respectively, at flowering and podding to control disease and pests.

Representative soil samples from each farmer's field (1200 m^2) were taken by augering the topsoil (0-15 cm) before cultivation commenced. This was done to give the initial chemical and physical properties of the soil in each farmer's field. In 2002 soil samples were augered at the same depth from each of the six plots to evaluate changes due to treatments imposed. Prior to analysis, samples were air-dried, gently crushed and sieved with a 2 mm sieve. Particle size distribution analysis was done by the Bouyoucos (1951) method using sodium hexametaphosphate as the dispersant. pH of the soil were determined in 1:2.5 soil/water ratio and organic carbon by Walkley-Black method (Allison, 1965). Exchangeable bases were obtained by leaching soils with 1N NH_4OAc at pH 7.0. Total N was determined by the micro-kjeldhal method. Available P was extracted with Bray No. 1 solution and the P in solution determined using the ascorbic acid method (Wantanabe and Olsen, 1965).

Data collected and statistical analysis: Data collected include plant count at harvest, *Striga* shoot count (infestation) number of maize plants infested (incidence), crop damage severity, crop vigor, number and weight of cobs, grain yield and changes in soil chemical properties.

Differences in soil chemical properties due to treatments were determined using ANOVA. Relationship between soil properties and *Striga* and crop characters were compared in a correlation coefficient matrix.

RESULTS

Initial soil properties: The soils of both locations were Alfisols. Organic carbon, total N and available P content of both villages were in the low range class based on the USDA-SCS (1999) classification. Mean organic carbon, total N and available P were slightly higher at Tashan Kaya than Ugwa Shamaki. Initial soil pH varied from strongly acidic (5.40) in Ugwan Shamaki to moderately acidic (5.80) in Tashan Kaya. Exchangeable calcium (Ca) content of both locations were low, while mean exchangeable magnesium (Mg) and potassium (K) for both locations were medium and high respectively (Table 1).

Treatment effects on soil properties: The mean values of soil properties presented in Table 2 showed that treatment effect was only significant on the organic carbon content and soil pH at Ugwan Shamaki.

Table 1: Initial chemical properties of soils of Ugwan Shamaki and Tashan Kaya, Nigeria (2001)

Soil parameter	Ugwan Shamaki	Tashan Kaya
pH 0.01 M $CaCl_2$	5.40	5.80
Organic carbon (g kg^{-1})	0.48	0.50
Total nitrogen (g kg^{-1})	0.02	0.03
Available P (mg kg^{-1})	3.75	5.10
Exchangeable Ca (Cmol kg^{-1})	1.56	1.75
Exchangeable Mg (Cmol kg^{-1})	1.21	1.05
Exchangeable K (Cmol kg^{-1})	0.25	0.28

Organic carbon content declined (4%) in plots that had maize after maize. Sole soybean and sole cowpea and maize-cowpea inter-crop increased organic carbon by 10, 2 and 23%, respectively. Treatments significantly decreased soil pH. Drop in pH varied from 4% for sole soybean and sole cowpea, 5% for maize-cowpea intercrop and 6% for sole maize plots, respectively.

Unlike organic carbon and soil pH, all treatments had either no effect or positive effect on total N, available P and exchangeable bases. Treatment effects were not significant on soil chemical properties at Tashan Kaya (Table 3).

Increase in available P was more tremendous compared to organic carbon and total N. Initial P content in Ugwa Shamaki was small (3.75 mg kg^{-1} compared to 12.02 mg kg^{-1} observed for maize-cowpea inter-crop plot. Similarly, Bray P content was increased from 5.1 to 8.26 mg kg^{-1} in maize-cowpea inter-crop in Tashan Kaya.

Treatment effects on maize yield: Maize grain production in the four cropping patterns varied significantly in the two villages (Table 4). Maize grain yield varied from 758 to 1528 kg ha^{-1} in Ugwan Shamaki and from 795 to 1481 kg ha^{-1} in Tashan Kaya, respectively. Maize grain yield after sole soybean and cowpea were significantly higher than for maize grown after maize. Highest yield (1528 kg ha^{-1}) was obtained in maize after cowpea in Ugwan Shamaki and in maize after soybean (1481kg ha^{-1}) in Tashan Kaya. In both locations maize-cowpea intercrop produced the lowest maize grain yield. Yield increase associated with growing maze after soybean compared to maize after maize were 12 and 37% in Ugwan

Table 2: Effect of one-year rotation on some chemical properties at Ugwan Shamaki, Nigeria

	Soil parameters					
Treatments	OC (g kg^{-1})	pH 0.01 M $CaCl_2$	Av, P (mg kg^{-1})	Exch. Ca (cmol kg^{-1})	Exch. Mg (cmol kg^{-1})	Exch. K (cmol kg^{-1})
Sole maize (SM)	0.46	5.10	8.73	1.59	1.21	0.28
Sole soybean (SS)	0.53	5.20	10.73	1.28	1.23	0.25
Sole cowpea (SC)	0.49	5.20	10.75	1.39	1.23	0.25
Maize/cowpea (MC)	0.59	5.15	12.02	1.74	1.24	0.26
RMSE	7.62	0.18	7.62	0.42	0.22	0.10
CV	11.67	3.41	75.76	27.79	20.47	36.35
R-Square	0.65	0.80	0.29	0.51	0.28	0.28
F-Ratio	4.30	2.51	0.36	1.90	0.94	0.49

Table 3: Effect of one-year rotation on some chemical properties at Tashan Kaya Nigeria (2001-2002)

	Soil parameters					
Treatments	OC (g kg^{-1})	pH 0.01 M $CaCl_2$	Av, P (mg kg^{-1})	Exch. Ca (cmol kg^{-1})	Exch. Mg (cmol kg^{-1})	Exch. K (cmol kg^{-1})
Sole maize (SM)	0.49	5.68	5.51	1.75	1.05	0.29
Sole soybean (SS)	0.53	5.73	6.18	2.63	1.26	0.28
Sole cowpea (SC)	0.52	5.73	5.14	1.75	1.15	0.30
Maize/cowpea (MC)	0.58	5.70	8.26	3.00	1.11	0.28
RMSE	0.11	0.52	4.57	0.98	0.25	0.08
CV	18.38	6.206	22.76	44.12	22.66	10.32
R-Square	0.69	0.56	0.51	0.72	0.67	0.56
F-Ratio	1.74	1.82	0.89	2.18	1.08	0.84

Shamaki and Tashan Kaya respectively. Accordingly, growing maize after cowpea increased yield by 19 and 22% over maize after maize in Ugwan Shamaki and Tashan Kaya respectively. Maize after soybean and cowpea gave yield increase of 89 and 102% more than in maize-cowpea intercrop in Ugwan Shamaki. The corresponding yield increases in Tashan Kaya were 86 and 65%, respectively.

Table 4: Effect of one-year rotation on maize grain yield at Ugwan Shamaki and Tashan Kaya, Nigeria (2002)

	Maize grain yield (kg ha^{-1})	
Treatments	Ugwan Shamaki	Tashan Kaya
Sole maize (SM)	1285	1078
Sole soybean (SS)	1435	1481
Sole cowpea (SC)	1528	1312
Maize/cowpea (MC)	0758	0795
RMSE	0179.44	0281.92
CV	0014.48	0024.16
R-Square	0000.92	0000.72
F-Ratio	0015.20	0005.46

Table 5: Correlation matrix of the some soil properties and yield of maize after one-year rotation at Ugwan Shamaki and Tashan Kaya, Nigeria (2002)

Ugwan Shamaki Soil parameter	Plant height	No. of cobs at harvest	Total cob weight at harvest	Grain yield
Organic carbon	0.04	0.12	0.01	0.18
Available P	0.02	0.14	0.06	0.28
pH	0.02	0.10	0.12	0.06
Exchangeable Ca	0.05	0.18	0.24	0.20
Exchangeable Ca	0.13	0.07	0.23	0.18
Exchangeable Ca	0.06	0.64*	0.61*	0.68**
Table r value	0.48			
Tashan Kaya				
Organic carbon	0.15	0.21	0.31	0.27
Available P	0.20	0.23	0.36	0.40
pH	0.19	0.08	0.13	0.06
Exchangeable Ca	0.09	0.02	0.19	0.14
Exchangeable Ca	0.19	0.28	0.41	0.40
Exchangeable Ca	0.21	0.52*	0.67**	0.65**
Table r-value	0.48			

*: Significant, **Highly signficant

Correlation studies

Soil properties and maize parameters: Among the soil properties evaluated, only exchangeable K showed significant and positive correlation with maize parameters (Table 5). At Ugwan Shamaki, exchangeable K was significant and positively associated with number of cobs (r = 0.64*), cob weight (r = 0.61) and maize grain yield (r = 0.68**). Corresponding values for the same parameters at Tashan Kaya were (r = 0.52*), (r = 0.67*) and (r = 0.65**) respectively. Other selected soil properties studied showed no significant relationship with maize parameters evaluated.

Soil properties and *Striga* parameters: Relationship between soil reaction and number of maize plants infected with *Striga* at 12 weeks after sowing and at harvest was positive and significant at Ugwan Shamaki. Only *Striga* shoot count at harvest had positive and significant relationship with soil reaction at Tashan Kaya.

Exchangeable Ca had negative and significant correlation with host damage severity at 12 weeks after sowing and at harvest at both locations. Similar result was observed for exchangeable Mg at Tashan Kaya. Mean exchangeable K was significant (-0.49*) and negatively correlated to *Striga* shoot count at Ugwan Shamaki. Similarly, mean exchangeable K was significantly and negatively correlated to host damage severity at 12 weeks after sowing (-0.48*) and at harvest

Table 6: Correlation matrix of some soil properties and *Striga* parameters in maize after one-year rotation at Ugwan Shamaki and Tashan Kaya, Nigeria 2002

Ugwa Shamaki soil parameters	SSC 12 WAS	NMPI 12WAS	HDS 12WAS	SSCH	NMPH	HDSH
Organic carbon	- 0.34	- 0.35	- 0.21	- 0.38	- 0.39	- 0.30
Available P	- 0.30	- 0.26	- 0.06	- 0.26	- 0.23	0.13
pH	0.40	- 0.49*	0.20	0.47	- 0.54*	0.39
Exchangeable Ca	- 0.25	- 0.25	- 0.50*	- 0.28	- 0.28	- 0.55*
Exchangeable Mg	- 0.21	- 0.12	- 0.06	- 0.27	0.12	- 0.15
Exchangeable K	- 0.31	- 0.29	- 0.13	- 0.49	0.29	0.15
Table r-value	0.48					
Tashan Kaya						
Organic carbon	- 0.20	- 0.22	- 0.24	- 0.25	0.06	- 0.38
Available P	- 0.34	- 0.35	- 0.16	0.03	0.26	- 0.22
pH	0.23	- 0.22	0.26	- 0.53*	0.30	0.36
Exchangeable Ca	- 0.07	-0.19	- 0.52*	- 0.35	- 0.22	- 0.56*
Exchangeable Mg	0.06	0.16	- 0.55*	- 0.30	- 0.20	- 0.60*
Exchangeable K	0.09	0.10	- 0.48	- 0.64**	- 0.24	- 0.58*
Table r-value	0.48					

SSC 12 WAS-*Striga* shoots count at 12 weeks after sowing, NMPI 12 WAS-Number of maize plants infected at 12 weeks after sowing, HDS12 WAS- Host damage severity at 12 weeks after planting, SSCH-*Striga* shoot counts at harvest, NMPIH-Number of maize plants infected at harvest, HDSH-Host damage severity at harvest, *: Significnt, **" Highly significant

(-0.58*) and *Striga* shoot count at harvest (-0.64**) at Tashan Kaya. Relationship between organic carbon levels and *Striga* parameters were negative but not significant at both locations (Table 6).

DISCUSSION

The slight differences in soil properties at the top 0-15 cm depth between the two locations were associated with their use. Soils from both locations were formed from basement complex of the precambian era, with some quartenary aeolian deposits (Harsptead, 1973). Based on the USDA, (1999) soil classification system, nutrient contents of all demonstration sites were within the low rating scale. The general interpretation is that low refers to nutrients levels where response to the respective nutrient is definite; medium refers to where there may be response and high to situations where response is not expected (Asadu and Nweke, 2000). These soils are generally considered as low fertility soils (Jones, 1975).

The higher and significant accumulation of organic carbon, in legume and maize-cowpea intercrop plots were attributed to high deposition of leaf litter (Weber, 1996). This is in addition to added nutrients (NPK) through mineralization of roots. Reduction in organic carbon levels in maize after maize plots highlights soil deterioration effect of such cropping practices. It is important to note that these soils have low activity clays (1:1 clay minerals) and soil fertility status is often associated with soil organic carbon content rather than clay content (Lal *et al*., 1975). Build up of soil organic carbon was positive in maize after soybean or cowpea plots and also in maize-cowpea intercrop. It is possible that the higher increase in available P compared to organic carbon and total N was due to slow mobility of P and also its higher residual effect in soils.

Reduction in soil pH was minimal in maize after soybean and cowpea plots compared to maize after maize and maize-cowpea intercrop due to the low N (20 kg N ha^{-1}) applied in legumes compared to maize (120 kg N ha^{-1}). Contribution of exchangeable bases from mineralization of fallen leaf litter and legumes roots was not enough to maintain acidity level. Both biomass and grain yield of legumes were however increased with application of 20 kg N ha^{-1} (data not shown). According to Agboola and Akinnifesi (1993), soil acidity is a major cause of low crop yields throughout the humid tropics and this has been associated with Al and Mn toxicity and deficiencies caused by imbalance among the basic cations. The absence of Al (0.98 g kg^{-1} dithionate Al) and Mn (2.0 g kg^{-1}) toxicity could have been responsible for the low reduction in yield even though pH decreased.

The generally low changes in values of exchangeable Ca, Mg and K may not be surprising. This is because Ca and Mg are aboundant in savanna soils and crop requirement and uptake does not deplete them easily. Also, K is consumed luxuriantly and is returned to soil by simple processes of leaching and mineralization. Calcium, Mg and K are all constituents of added fertilizer (SSP and NPK). However, exchangeable Ca was greater in maize-cowpea intercrop as a result of added Ca through greater root and above grown organic residue mineralization of the crop mixture compared to the sole crops.

Only exchangeable K significantly correlated with maize yield parameters at the two locations. Potassium was the only exchangeable cation that was added in large quantity through inorganic fertilizer. This could have been responsible for the result obtained. The weak correlation between other soil chemical properties and maize yield parameters followed the known fact that very little correlation had been found between yield changes and measured soil changes (Sanchez, 1976). Carsky *et al*., (1998) also observed weak relationship between soil organic carbon and maize grain yield in farmer managed trials in the northern guinea savanna of Nigeria.

Rotation with soybean and cowpea increased maize grain yield compared with continuous maize (Table 4). Yield increase of maize after soybean was 150 and 301 kg over continuous maize at Ugwan Shamaki and Tashan Kaya, respectively. Yield increase of maize after cowpea was 243 and 234 kg at Ugwan Shamaki and Tashan Kaya, respectively. Yield increase from soybean and cowpea rotated plots was attributed to a combination of improved N supply and reduced *Striga hermontheca* parasitism. Similarly, Carsky *et al*., (1999) observed a 280 kg ha^{-1} yield increase in maize following legume rotation compared to maize following natural fallow. This was also attributed to improve N supply and reduced *Striga hermonthica*. Inter-cropping maize and cowpea that is a common practice in the northern guinea savanna reduced maize grain yield. This could be as a result of non-cooperative competition, since the cowpea variety used mature earlier than the maize. The cowpea variety also has fast vegetative growth and produce high amount of biomass. Varieties usually used for intercropping with maize are late maturing and are relayed with maize. The maize is planted first and is removed earlier, leaving the cowpea on the field. The cowpea and maize used in this trial were sown on the same day. However, from farmer's perspective, the moderate maize yield (757 and 795 kg) combined with additional income and or improve cropping system from the fast maturing cowpea grain was selected by the farmers as the most lucrative cropping combination. This is also in response to the falling prices of maize in northern Nigeria.

Soil pH has negative and significant correlation with *Striga* infection at 12 weeks after planting and at harvest in Ugwan Shamaki. Also, negative and significant relationship was observed between soil pH and *Striga* shoot count at harvest at Tashan Kaya. Since soil pH values decreased with treatments, this suggests that *Striga* infection may be increased in lower pH values. The full understanding of the possible interaction between soil pH and *Striga* infection of maize is a major research problem. The results of the correlation studies suggest that exchangeable bases may reduce *Striga* shoot count on maize and its subsequent damage to maize. This is an important observation if the effects could be attributed to only exchangeable bases. It is known that exchangeable bases increases plant resistance to diseases, the mechanism could be the same for *Striga* infection. The inclusion of Ca and Mg in some bulk blended fertilizers is an additional strategy for the multidimensional method of *Striga* control. The weak and negative correlation observed between organic carbon and *Striga* parameters may suggest less *Striga* damage to maize in high fertile soils (Carsky *et al*., 1998).

CONCLUSIONS

In the northern guinea savanna zone of West and Central Africa, soybean and cowpea rotation and inter-cropping maize with high biomas producing cowpea can be used to maintain or improve organic carbon, total N, available P and exchangeable bases levels in these soils. In addition to improvement in soil nutrient levels, rotation with soybean and cowpea reduced *Striga* infection of maize. Correlation study indicates that exchangeable bases have tendencies of depressing *Striga* infection. Yield of maize under *Striga* in ugwan Shamaki could be increased by as much as 11.67% if maize fields were rotated with soybean and by 18.91% if cowpea variety evaluated was included in the rotation. The corresponding increases in Tashan Kaya were 37.38 and 21.71%, respectively.

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