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Assessment of Soil Nutrients under Maize Intercropping System Involving Soybean

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ABSTRACT

This study was conducted to examine the influence of soybean – maize intercropping on soil fertility. Maize was grown sole and as an intercrop with soybean and NPK 90 - 60 - 60 kg/ha fertilizer was used. Soil samples were collected and analysed before the experiment was installed and after the experiment. Results indicated that the soil was moderately slightly acid (pH =5.63), low total nitrogen (0.1%) and very low available phosphorus (4.95 mg/kg). After the experiment results revealed that soil variables which increased were the organic carbon (0.15%), phosphorus (5.25 mg/kg), calcium (0.54 cmol (+)/kg), and sodium (0.06 cmol (+)/kg) and those decreased were the total nitrogen (0.02%), magnesium (0.54 cmol (+)/kg) and potassium (0.12 cmol (+)/kg). Furthermore, correlation analysis indicated that organic carbon and available phosphorus correlated positively with all other parameters. Nitrogen correlated positively with calcium (r =0.9747, P =0.1434), potassium (r =0.9884, P =0.0972) and magnesium (r =0.9716, P =0.1521), organic carbon (r =0.8811, P =0.3136) and phosphorus (r =0.9512, P =0.1997). However, nitrogen and potassium were negatively correlated. Based on the findings of this study it is recommended that long term experimentation with multiple replicates in which NPK would be applied in varying rates and nutrients omissions while giving option for sole soybean in a continuous cropping is the best option. This would help to ascertain the usefulness of soybean in supplementing nutrient N gap in the soil when included in the maize cropping systems.

Keywords: Intercropping, soil fertility.

INTRODUCTION

Intercropping involves the growing of two or more crop species simultaneously on the same field during the same growing season (Ofori and Stern, 1987). It always results in a more efficient utilization of growth resources among component crops and causes more stable yields (Bargali et al 2014; 2009; Mishra et al 2011). Intercropping mostly serves to reduce problems associated with weeds, plant pathogens and nitrogen losses (Dahlmann and Von Fragstein, 2006). All the environmental resources are utilized to maximize crop production per unit area per unit time under intercropping systems (Woolley and Davis, 1991). According to Vandermeer, (1989) and Zhang et al. (2003), competition might be possible in intercropping systems and this therefore calls for the need to select compatible crops (Seran and Brintha, 2009) for proper utilization of soil fertility (Bargali et al 2015; Bargali and Bargali 2016).

Ghosh et al. (2007) reported that inclusion of nitrogen fixing legumes in cereal cropping systems increases soil fertility and consequently the productivity of subsequent crops. Intercropping of cereals with legumes has been popular in the tropics (Hauggaard-Nielsen et al., 2001; Tsubo et al., 2005) and in the rain-fed areas of the world (Agegnehu et al., 2006; Dhima et al., 2007). This has been largely due to its advantages for soil conservation (Anil et al., 1998), weed control (Poggio, 2005; Banik et al., 2006), lodging resistance (Anil et al., 1998) and yield increment (Anil et al., 1998; Chen et al., 2004). Intercropped legumes add value the associated cereal crop like maize by transferring part of fixed N to the maize because of the low N requirements of the legumes (Singh, 1983; Lupwayi and Kennedy, 2007). Legumes also give good canopy cover in the early stages to control soil loss through erosion especially on sloppy lands and control weeds (Khola et al., 1999).

However, Tulu (2002), indicated that different crops remove different amounts of mineral nutrients from the soil. In this situation, intercropping deplete the soil of essential plant nutrients in varying quantities depending on the nutrient demand of crops (Logah, 2009). If the nutrient removal rate is not balanced through soil amendments aimed at nutrient management and maintenance of soil fertility, the soil becomes poor and its productivity drops. This trend of degraded soils is witnessed in Ghana where high nutrient uptake by intercropping has been reported in many studies (Adu-Gyamfi et al., 1997; Sakala, 1998; Logah, 2009).

Asafo-Adjei et al. (2001) depicted that soybean has a high N fixation capacity such that greater than 60% nitrogen is derived from atmosphere. The N-fixing ability of soybean has long been hypothesized as an explanation for the soybean N credit. Brophy and Heichel (1989) reported that soybean plant can release some of its symbiotically-fixed N during the same growing season.

Martin et al. (1990) indicated that transfer of N from soybean to intercropped maize plants showed higher level of inorganic N in the soil.

West and Griffith (1992) observed that maize yield increased by 26% in maize-soybean strip intercropping. In maize/soybean intercropping system, Dalal (1977) observed that grain yield of soybean was very greatly reduced when it was planted with maize. Intercropping soybean and maize reduces the yield of the former crop considerably, but has little influence on that of the latter (Hiebsch, 1981; Chui and Shibbles, 1984). According to Francis et al. (1986), the total maize yield in strip intercropping with soybean was between 10 and 40 % higher than maize in pure stand, while soybean yields were reduced between 10 and 30 % because of competition for light, water and nutrients. According to Ennin et al. (2002), intercropping maize and soybean reduced both maize and soybean grain yields. Therefore, this study is designed to assess the physico-chemical properties of soil under maize intercropping system involving soybean.

MATERIALS AND METHOD

Description of the Experimental Site

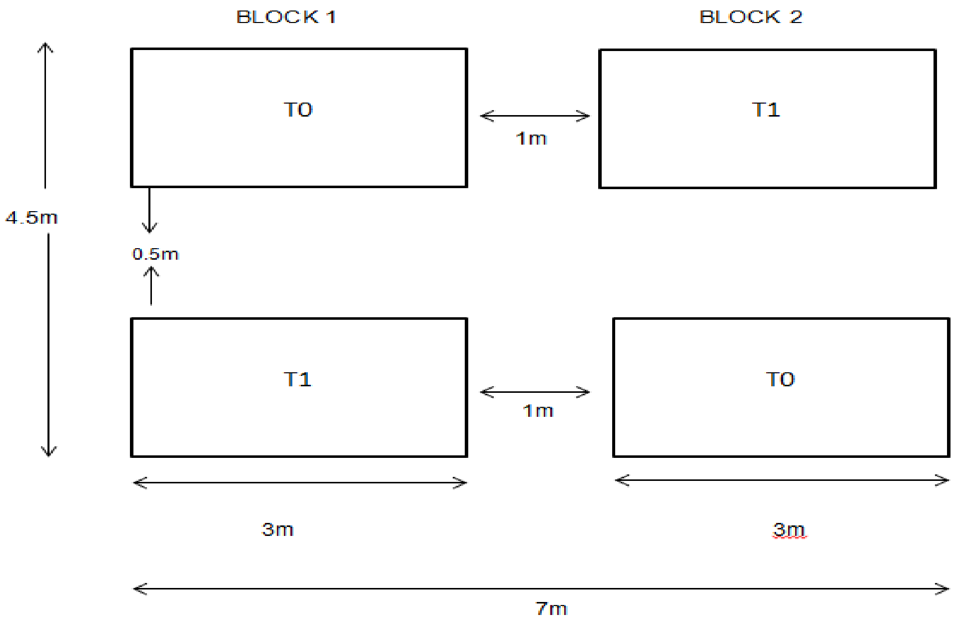
This study was conducted at the Plantation section of the Department of Crop and Soil Sciences, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi fig.1

Figure 1: *Location of the study area*

The study site is located within the Semi-deciduous rainforest zone of Ghana with a bimodal rainfall pattern, the short rainy season is August to September and the long rainy season is March to July. The soil falls within the Kumasi Series and it is a well-drained loamy sand textured soil and easy to cultivate.

Experimental Design

The treatments used were maize, which was the main crop and soybean. The treatment combinations were maize only (T0) and maize + soybean (T1). The crop cultivars used were Dorke SR (maize) and Nangbaar (soybean). These varieties are early maturing (90-95 days). The experiment was a randomized complete block design (RCBD) with two replications.



Sowing, thinning and fertilization

The test crop maize was sown 2 seeds per hole at a spacing of 90 cm × 40 cm and soybean 2 seeds per hole at a spacing of 20 cm within a role but between maize rows. Fertilizer application was done in two splits that are by side placement of 60-60-60 kg/ha NPK 15-15-15 applied three weeks after sowing and 30 kg/ha sulphate of ammonia was applied seven weeks after sowing.

Figure 2: *Field experiment showing soybean intercropped with maize at the study area*

Soil sampling and analysis
Composite soil samples were randomly collected from the field at a depth of 0-15 cm from 12 sampling spots before and after the onset of experiment. However, during post soil sampling soil samples were taken at the bases of five plants selected randomly from each plot and between the maize and soybean rows in the intercrops. Soils were analysed for organic carbon, total nitrogen, and available phosphorus, exchangeable calcium, magnesium, potassium and sodium, pH and soil texture as described by Allison (1960) and Ibitoye (2006).

RESULTS AND DISCUSSION

Effect of cropping systems on Soil Properties
Results of the initial and post experiment soil properties as determined by the cropping system are presented in Table 1.

Table 1: Soil properties before and after the maize/soybean experiment

Soil Parameter	SI-Unit	Before experiment	After experiment		Effect of soybean
			Maize +Soybean plot	Pure maize plot	
Organic carbon (O.C.)	%	1.42	1.81	1.66	0.15
Total nitrogen	%	0.1	0.26	0.28	-0.02
Available phosphorus	mg/kg	4.95	28.6	23.37	5.23
Exchangeable bases:	cmol(+)/kg				
- Calcium		2.2	6.23	5.69	0.54
- Magnesium		1.4	2.45	2.99	-0.54
- Potassium		0.13	0.47	0.59	-0.12
- Sodium		0.17	0.2	0.14	0.06
Soil pH		5.63	-	-	-
Soil textural class		Loamy sand	-	-	-

The soil was moderately acid with pH value of 5.63 63 (5.6 – 6.0) and available phosphorus was very low (< 6 mg/kg).
The initial soil organic carbon content was low and according to Metson (1961), a productive soil should have an organic carbon content of 2.3%. Total nitrogen was low base on the ratings compiled by Bruce and Rayment (1982). The low organic carbon and total nitrogen was by virtue of high temperature resulting in rapid organic carbon decomposition coupled with a low input of organic material to the soil of the study area. Organic matter is closely associated with the nutrient status of soils because it contributes much to the soil cation exchange capacity (Magdoff et al., 1985). It has been advocated that soil fertility replenishment in Africa should aim at an integrated nutrient management (Quansah, 1996; Swift, 1997; Sanchez et al., 1997; Quansah et al., 1997).
Based on the ratings given by Metson (1961), exchangeable bases recorded in this study area were generally low attributed to the low organic carbon of the soil. Generally, the findings of this study depict that fertility status of the soil before installation of experiment was low.
Furthermore, results indicated intercropping of maize with soybean caused increase in organic carbon (0.15%), phosphorus (5.25 mg/kg), calcium (0.54 cmol(+)/kg), and sodium (0.06 cmol(+)/kg) of the soil. The increase in available phosphorus was attributed largely to the addition of P from NPK. On the other hand, results revealed that in the maize-soybean intercrop some soil parameters which decreased compared to the pure maize were nitrogen (0.02%), magnesium (0.54 cmol(+)/kg) and potassium (0.12 cmol(+)/kg). The decrease in total nitrogen could be contributed to the high contents of nitrogen applied through NPK and SA, which probably did not favour N fixation by soybean. Similar findings were also reported by Adu-Gyamfi et al. (2007) who found that in the absence of nitrogen fertilizer intercropped legumes fixed nitrogen from the atmosphere and did not compete with maize for nitrogen resources.
In addition, decrease in nitrogen and potassium apart from being applied could be attributed to the nutrients imbalance across the NPK and SA combination. Decrease in magnesium could be attributed to dynamism of this nutrient in the same heterogeneity environment and increase in calcium content.
Previous study conducted by Prasad and Power (1997) indicated that high soil P could be attributed to the very slow diffusion and immobilization of the applied P. Logah (2009) recorded high phosphorus levels under cropping systems following organic and inorganic soil amendments.

Trends of soil nutrients as affected by cropping system

The trends of soil nutrients following fertilizer application in cropping systems is presented in Figure 3.
Results indicated high increase in soil phosphorus following application of NPK and the highest quantity (24 – 32 mg P/kg) was unveiled in maize-soybean intercrop plot, which was followed by phosphorus (19 – 26 mg P/kg) in a plot where pure maize was sown. Results also depicted that all nutrients were low before the onset of experimentation and were largest in the maize-soybean intercropped plot compared to the quantities recorded in pure maize plot. Exceptions were observed for magnesium in which pure maize outperformed maize-soybean intercrop and in sodium where pure maize plot was outperformed by the quantities obtained before experiment and in maize-soybean intercrop (Figure 3).

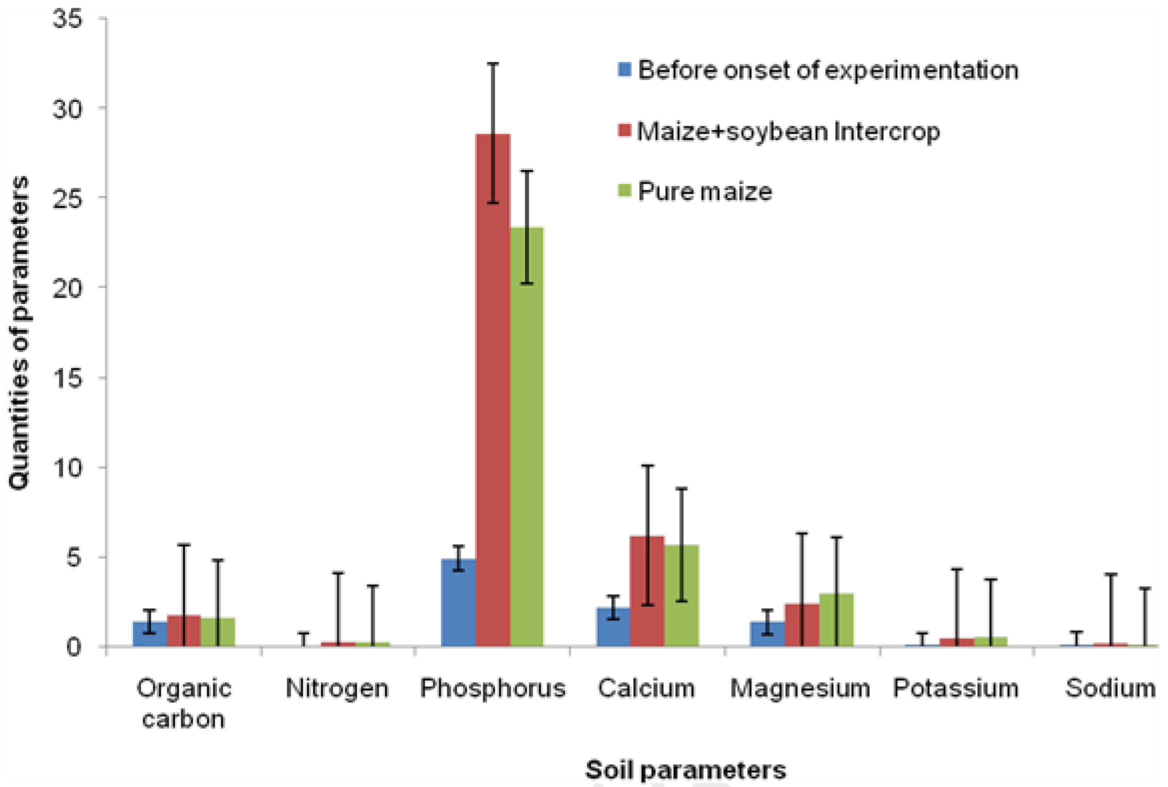


Figure 3: *Comparison of soil parameters in different cropping systems*

Application of NPK 90-60-60 is the same as applying equivalent of 25.8 kg P/ha (such that 0.43 × 60 = 25.8) derived from the fact that in NPK the P exists as an oxide (P_2O_5). According to Brady and Weil (2008), 25 kg P/ha is the recommended P application for the soil with very low available P (< 7 mg/kg soil), which is the case of the soil where this study was conducted (P is 4.95 mg/kg in Table 1). This was also the same as application of potassium equivalent to 49.8 kg K/ha based on K_2O composition nature in NPK (0.83 × 60 = 49.8). Nitrogen was also applied in two splits from NPK and from ammonium sulphate at differing stages of plant growth and definitely heterogeneity in the levels of soil moisture and temperature. This observation could have favoured high positive correlations of N, P and K with other soil parameters compared to the correlations among other parameters. This also indicates that increase in NPK in these soils could have been attributed to large rates applied and not, for example, N from fixation by soybean. The findings of this study justify the need for long term experimentation with multiple replicates in which NPK would be applied in varying rates and nutrients omissions while giving option for sole soybean in a continuous cropping. This would help to ascertain the usefulness of soybean in supplementing nutrient N gap in the soil when included in the maize cropping systems.

Correlations of soil parameters

Results of the correlations among soil parameters collected before installation of experiment and from plots where maize-soybean and pure maize were sown are presented in Table 2.

Table 2: *Correlations among soil parameters across the period of experiment*

	Soil parameter	1	2	3	4	5	6	7
1	Calcium	1						
2	Potassium	0.9294	1					
3	Magnesium	0.8942	0.9963	1				
4	Nitrogen	0.9747	0.9884	0.9716	1			
5	Sodium	0.1234	-0.252	-0.334	-0.101	1		
6	Organic carbon	0.9645	0.7989	0.7441	0.8811	0.3812	1	
7	Phosphorus	0.9961	0.8933	0.8512	0.9512	0.2105	0.984	1

Two-sided test of correlations different from zero

Results indicated that organic carbon and available phosphorus were positively correlated with all other assessed soil properties (Table 2). In addition, total N was positively correlated with Ca (r =0.9747, *P* =0.1434), K (r =0.9884, *P* =0.0972), Mg (r =0.9716, *P* =0.1521), organic carbon (r =0.8811, *P* =0.3136) and P (r =0.9512, *P* =0.1997). However, results revealed that total N was negatively correlated with exchangeable sodium (r =-0.1014, *P* =0.9354). Potassium also followed similar trend as that of total nitrogen in which only negatively correlation was observed with sodium (r =-0.252).

CONCLUSION

The study did not find significant influence of the maize-soybean intercropping on soil nutrients. However, this was largely masked by the high levels of NPK applied and the short period used to assess the effect of the cropping system. This was a single cropping season experiment, which indeed did not give enough time for the soybean plant to explore large soil mass, nitrogen build-up and transformations of other soil nutrients. Replicate trials of the same and the omissions of nutrients N, P and K also were not investigated in this study, which opens the door for further studies.

CONFLICT OF INTEREST

The authors have declared no conflict of interest.

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