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Evaluation of Soil Nutrients under Maize Intercropping System Involving Cowpea *(Vigna unguiculata)*

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ABSTRACT

A field experiment was conducted at the Central Agricultural Station, Kwadaso, Ghana to examine soil fertility under different maize based cropping systems. Fertilizer application of NPK 90 - 60 - 60 kg/ha was compared with intercropping maize with cowpea and sole maize. The results showed no significant effects of intercropping on soil fertility in the short term. Though differences in nitrogen level among the cropping systems were insignificant, the level recorded under each system was high.

Keywords: Intercropping, Nutrient Management, Soil Fertility Maintenance, Monocropping

I. INTRODUCTION

The agriculture of Ghana is predominantly smallholder subsistence farming under rain-fed conditions. Maize has recently come up as the primary food crop mostly grown by small holder farmers in various cropping systems. The maize based cropping systems are mostly sole crop, intercrop between cowpea and cassava. Maize cowpea intercrop is done by farmers to restore soil fertility as well as deriving additional income, cassava is considered by most farmers as a food security crop in case of component crop failure.

Intercropping refers to the growing of two or more crop species simultaneously on the same field during a growing season (Ofori and Stern, 1987). It often results in a more efficient utilization of resources and causes more stable yields. It is also a method to reduce problems with weeds, plant pathogens and nitrogen losses (Dahlmann and Von Fragstein, 2006). In intercropping system, all the environmental resources are utilized to maximize crop production per unit area per unit time (Woolley and Davis, 1991). Vandermeer, (1989) and Zhang *et al.* (2003) claim that competition might be possible in intercropping systems and therefore calls for the need to select compatible crops (Seran and Brintha, 2009) for proper utilization of soil fertility. Ghosh et al. (2007) reported that inclusion of legumes in cereal cropping systems increases soil fertility and consequently the productivity of succeeding cereal crops. Intercropping of cereals with legumes has been popular in the tropics (Hauggaard-Nielsen et al., 2001; Tsubo *et al*., 2005) and rain-fed areas of the world (Agegnehu *et al*., 2006; Dhima *et al*., 2007) 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 benefit the associated cereal crop like maize by transferring part of fixed N to the maize because of the less N requirement of the legumes (Singh, 1983; Lupwayi and Kennedy, 2007). Legumes also provide a good canopy cover in the early stages to control soil loss through erosion especially on sloppy lands and also to control weeds (Khola *et al*., 1999).

However, Tulu (2002) indicated that different crops remove different amounts of mineral nutrients from the soil. In this regard, the practices of 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 by soil amendments aimed at nutrient management and soil fertility maintenance, the soil gets poor and productivity is drastically reduced. This is the normal trend in Ghana (Logah, 2009). Greater nutrient uptake by intercropping has been reported by several workers (Adu-Gyamfi *et al*., 1997; Sakala, 1998).

Intercropping of maize and cowpeas (*Vigna unguiculata*) is especially beneficial on nitrogen poor soils (Vesterager *et al*., 2008). As cowpeas obtain the majority of their nitrogen from the atmosphere, they do not compete with maize for soil nitrogen (Mongi et al., 1976). The addition of cowpea to the maize field provides an important protein supply for human and livestock consumption, improves soil fertility and structure, suppresses weeds, and insures against total crop failure (Mongi *et al*., 1976). Maize-cowpea intercropping increases the amount of soil nitrogen, phosphorus and potassium compared to monocrop of maize (Dahmardeh et al., 2010).

The objective of this study was to assess soil organic carbon (C), total nitrogen (N), available phosphorous and exchangeable potassium of soil under maize-cowpea (*Vigna unguiculata*) intercropping systems.

II. METHODS AND MATERIAL

A. Location and Climate

This study was conducted at the Central Agricultural Station of Soil Research Institute Kwadaso, Ghana. *The study site is located within the Semi-Deciduous Rainforest zone of Ghana.*

The area enjoys a bimodal rainfall pattern, the minor season (August to September) and the major season (March to July). The major season normally begins in March; reaches a peak in July and drops sharply in August whilst the minor season starts in September with the lowest occurring in late November. Thereafter, there is a long dry period from December to February during which negligible amounts of rain normally (below 10mm) are received (Sadick et al., 2015).

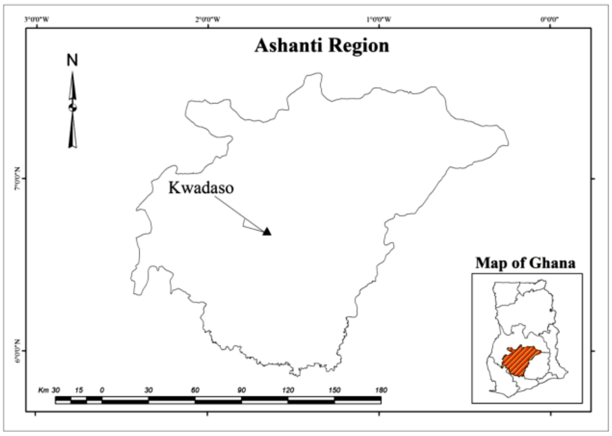

Figure 1. Location of the Study Area (Sadick et al., 2015).

Mean monthly temperatures remain high throughout the year only falling around 24o C in August. February and March are the hottest (nearly 28^{o}C) recorded months. Absolute minimum temperatures of around 20^{o}C are usually recorded in December and January with absolute maximum temperature of about 33^{o}C occurring in February and March(Sadick et al., 2015).

The soil falls within the Kumasi Series and it was a well-drained loamy sand textured soil, easy to cultivate.

B. Treatments / Experimental Design

The treatments used were maize, which was the main crop, and selected leguminous crop which was cowpea. The treatment combinations were maize only (T0) and maize + cowpea (T1). The crops cultivars used were, Dorke SR (maize) and Soronko (cowpea). These were obtained from the Crop Research Institute (CRI) at Fumesua near Kumasi. These varieties are early maturing (90-95 days). The experiment was a randomized complete block design (RCBD) with three replications.

C. Land Preparation

The vegetation on the land was slashed manually and the land later ploughed and harrowed to a fine tilth. The field was then lined and pegged to demarcate it into blocks and plots. The total field area was of dimension 4.5 m x 7 m. The maize was planted intercropped with cowpea. The field consisted of 2 blocks with 2 plots each. The plot area measured 2 m x 3 m. Spacing between blocks was 1 m and 0.5 m between plots as shown in Figure 2

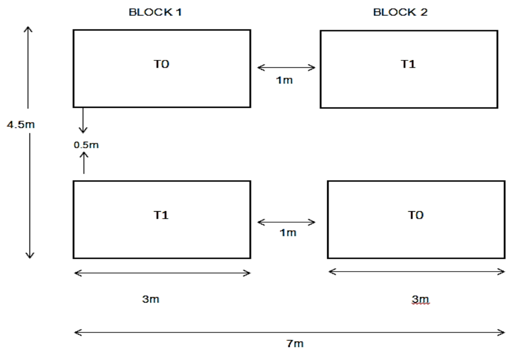

Figure 2. Layout of plot showing treatments allocation (not drawn to scale). T0: maize only and T1: maize + cowpea

D. Initial Soil Sampling

Soils were randomly collected from the field at a 0-15 cm depth. Twelve samples were obtained with an auger from the field and bulked to obtain the final sample. The sample were analysed at the Soil Research Institute Laboratory. Parameters determined were organic carbon, total nitrogen, available phosphorus, exchangeable calcium, magnesium, potassium and sodium, soil pH and soil texture.

E. Planting and Thinning

The test crop was maize sown 2 seeds per hill at a spacing of 90 cm × 40 cm. Cowpea was sown 2 seeds per hill at 20 cm between maize rows.

F. Fertilizer Application

Figure 3. Field experiment showing cowpea intercropped with maize at the study area

Fertilizer application was done in two splits. By side placement, 60-60-60 kg/ha NPK 15-15-15 was applied three weeks after sowing and 30 kg/ha sulphate of ammonia was applied seven weeks after sowing.

G. Weed Control

Weeding was done manually with a hoe and a cutlass just before amendment and two weeks afterwards. And watering was done 40 days after planting (DAP) with a watering can when the natural rains stopped for a while. Pest and disease incidence were not much encountered during the growing stage of the crop. Their incidence was only observed during the tasselling stage. Pests and animal encountered were birds, stem borers, corn ear worms and cotton stainers. Pesticide (25 Emulsifiable Concentrate Lambda) was used to control pests.

H. Final Soil Sampling

Final soil sampling was done two weeks after application of sulphate of ammonia. Soil samples were taken at the depth of 0 - 15 cm from the bases of five plants selected randomly from each plot. These were bulked to get one sample for each plot. For the intercrop plots, samples were taken between the maize and legumes rows. In total, twelve samples were taken. Soil parameters determined were organic carbon, total nitrogen, and available phosphorus, exchangeable cations which are calcium, magnesium, potassium and sodium, soil pH and soil texture.

I. Determination of Physico-chemical Properties of the Soil

The physico-chemical properties of the soil samples were determined using routine methods as described by Allison (1960) and Ibitoye (2006). The physiochemical parameters used for this study were pH, organic carbon, exchangeable cations, total nitrogen, available phosphorus and particle size distribution.

III. RESULTS AND DISCUSSION

A. Initial Soil Properties

Initial soil analysis was carried out to assess the soil fertility status at the study area before the conduct of the experiment. The results of the initial soil analysis are presented in Table 1 below.

Soil organic carbon and total nitrogen contents were 1.42 % and 0.10 % respectively. Available phosphorus recorded was < 5 mg/kg soil whilst soil exchangeable Ca and Mg were < 3 cmol/kg soil. The soil was moderately acidic with a pH value of 5.63. The results for particle size distribution indicated that the soil of the study site was of the textural class - loamy sand.

The initial soil organic carbon content was low. According to Metson (1961), a productive soil should have an organic carbon content of 2.3%. Total nitrogen was low according to the rating by Bruce and Rayment (1982). The low organic carbon and total nitrogen was by virtue of high temperatures resulting in rapid organic carbon decomposition coupled with a generally low input of organic material at the study area. Organic matter is closely associated with the nutrient status of soils because it contributes much to the soil CEC (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).
According to the ratings of Metson (1961), exchangeable bases recorded in this study were generally low. The low exchangeable bases were due to the organic carbon content of the soil. Generally, the fertility status of the soil at the study site before the experiment was low.

B. Soil Properties under the Cropping System

Nitrogen and phosphorus contents were high (Table 2) and showed an increment from the initial values. This was as a result of the NPK fertilizer applied to the respective plots. High P could also be attributed to the very slow diffusion and immobilization of the applied P (Prasad and Power, 1997). Logah (2009) recorded high phosphorus levels under cropping systems following organic and inorganic soil amendments.

Intercropping of legumes and cereals is an old practice in tropical agriculture. Snaydon and Harris (1979) found legume-cereal as the most popular intercropping system in the tropics and Kamanga et al. (2010) reported that maize-legume intercropping resulted in high productivity. Intercropping maize with legume is able to reduce the amount of nutrients taken from the soil as compared to a maize monocrop (Adu-Gyamfi et al., 2007). In the absence of nitrogen fertilizer, intercropped legumes will fix nitrogen from the atmosphere and not compete with maize for nitrogen resources (Adu-Gyamfi et al., 2007). The mixture of nitrogen fixing crop and non-fixing crop gives greater productivity than monocropping (Seran and Brintha, 2009). Banik and Sharma (2009) reported that cereal-legume intercropping systems were superior to monocropping.

TABLE I. INITIAL SOIL PROPERTIES AT THE STUDY SITE

Soil Properties	Value
Organic Carbon (%)	1.42
Total Nitrogen (%)	0.10
Available Phosphorus (mg/kg soil)	4.95
Exchangeable calcium (cmol/kg soil)	2.20
Exchangeable magnesium (cmol/kg soil)	1.40
Exchangeable potassium (cmol/kg soil)	0.13
Exchangeable sodium (cmol/kg soil)	0.17
Soil pH	5.63
Soil texture	Loamy sand

TABLE II. SOIL PROPERTIES OF THE STUDY AREA AFTER INTERCROPPING AND FERTILIZER APPLICATION

Soil nutrient	Maize+Cowpea	Sole Maize
Organic carbon (%)	1.75	1.86
Total Nitrogen (%)	0.32	0.30
Available Phosphorus (mg/kg)	31.00	20.00
Calcium (cmol/kg soil)	5.78	5.52
Magnesium (cmol/kg soil)	2.68	3.16
Potassium (cmol/kg soil)	0.66	0.63
Sodium (cmol/kg soil)	0.14	0.16

IV.CONCLUSION

The main purpose of this study was to evaluate soil properties under various maize based intercropping systems. Generally, the intercropping systems had no significant effects on soil fertility in the short term.

Though differences in nitrogen level among the cropping systems were insignificant, the level recorded under each system was high.

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