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Productivity of pigeonpea genotypes as influenced by palm bunch ash and NPK fertiliser application and their residual effects on maize yield

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ABSTRACT

A field study was undertaken in the semi-deciduous forest agro-ecological zone of Ghana to assess the impact of palm bunch ash (PBA) and phosphorus and potassium (PK) fertiliser application on yield and key agronomic traits of three early maturing pigeonpea genotypes (ICPL 87091, ICPL 88034 and ICPL 88039), their residual effect on soil chemical properties and a succeeding maize crop grown in rotation. The results indicated that neither the genotype nor fertilisation had any significant effects on the grain yield of the pigeonpea genotypes. The total dry matter yield was significantly influenced by both genotype and fertilisation with the genotype ICPL 88034 significantly producing the highest dry matter (7.29 t ha^{-1}) while ICPL 88039 produced the lowest dry matter (4.95 t ha^{-1}). The PBA-treated plots produced significant dry matter yield compared with the control. Application of PBA also increased the pH of the experimental field from 5.19 to 5.82, 40 weeks after application with increase in available P and exchangeable cations (K, Ca and Mg) content of the soils. Yield of maize planted on pigeonpea plots previously fertilised with PBA was increased by 25% relative to yield of maize planted to pigeonpea on control plots. The study suggests that in the oil palm growing areas in Ghana where soils are acidic, PBA which are found in abundance could be used as a liming material and as organic fertiliser supplement to improve the yield of staple food crops.

1. Introduction

The potential of the semi-deciduous agro-ecological zone of Ghana for the production of major staple crops such as plantain, maize and cassava are hampered by poor soil fertility especially nitrogen (N) and phosphorus (P). In the past, farmers in this area relied on the extended bush fallowing system for maintaining the fertility of their soils. However, population-induced pressure on land has reduced the fallow period (Ahn, 1961). This problem is further compounded by competition for the limited land between food and tree crops, particularly cocoa, citrus and oil palm to the detriment of food crop production. This has led to a situation where the limited land reserved for food crop production is continuously being cropped without application of nutrients resulting in nutrient mining. Although, mineral fertilisers could improve crop nutrition, fertiliser use in Ghana is limited, averaging 7.42 kg/hectare/year which are among the lowest in Sub-Saharan Africa (MoFA, 2010). This is due to prohibitive cost as a consequence of removal of government subsidies (Gerner et al., 1995; MoFA, 2010). This situation necessitates an alternative means of improving the productivity of the land so that farmers can cultivate on the same piece of land for a longer period without degrading the soil.

In smallholder farming systems in Ghana, legumes can play a complementary role as source of organic fertiliser. Research in many parts of sub-Saharan Africa including Ghana has shown that legumes have the potential to sustain soil fertility in smallholder farming systems (Hughes and Venema, 2005; Adjei-Nsiah, 2006, 2012b). Pigeonpea (*Cajanus cajan* L. Mills.) has been found to have a great potential in this respect because of its ability to recycle nutrients and tolerate wide environmental conditions and low soil fertility (Hughes and Venema, 2005). The grain can be used for food and for sale. Pigeonpea is well balanced nutritionally and is an excellent source of proteins (20–30%) (Deshbhratar et al., 2010).

In addition, pigeonpea improves N availability for subsequent crops. The net-nitrogen contribution however depends on the amount of nitrogen fixed and the proportion of plant N that is harvested. In Ghana, Adjei-Nsiah (2006) estimated that pigeonpea can contribute up to 200 kg N ha^{-1} over a period of 16 months through N-fixation. Positive effects of grain legumes on yields of cereals grown in rotation may also

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be due to other non-nitrogen effects such as breaking of cereal pest and disease cycles (Francis and Clegg, 1990), soil structure improvement (Peoples and Craswell, 1992), enhanced P-availability through secretion of enzymes and acids in the legume rhizosphere (Schlecht et al., 2006), and enhanced arbuscular mycorrhizal colonisation (Harinikumar and Bagyaraj, 1988).

Pigeonpea genotypes are generally grouped into extra short duration ($<$ 105 days), short duration ($\approx$105–145 days), medium ($\approx$146–199 days), and late maturing ($>$ 200 days) genotypes (van der Maesen, 1980). Shorter-duration lines frequently are determinate, although indeterminate growth habit occurs across maturity groups. All the available pigeonpea genotypes in Ghana are late maturing indeterminate types that mature in about 260 days (Adjei-Nsiah, 2006). Although, these genotypes produce copious biomass, the yields of these genotypes are very low ranging from 0.5 to 1.0 ton ha^{-1}. New genotypes developed by breeding programmes by the International Crop Research Institute of the Semi-Arid Tropics (ICRISAT) in India have short duration, high yielding and resistant to most soil-borne diseases compared with the local landraces. Pigeonpea genotypes that combine a reasonable grain yield with a large volume of leaf biomass could offer a useful compromise to meeting farmers' food security needs and improving soil fertility.

Pigeonpea like other legumes makes very little demand on soil nitrogen but requires moderate amount of P and K for growth and yield. However, increasing K and P through mineral fertiliser application is difficult as these fertilisers are not readily available in rural markets, and smallholder farmers hardly apply mineral fertilisers to legumes. Most soils in the forest parts of southern Ghana are also acidic due to the nature of the parent material, high intensity of rainfall regime and associated leaching of nutrients (Adu-Dapaah et al., 1994; Obiri-Nyarko, 2012). This often results in a situation where most of the major nutrients become unavailable for plants uptake. Palm bunch ash (PBA) has been found to have high pH and contains varying amounts of other nutrients such as calcium (Ca), magnesium (Mg), potassium (K) and phosphorus (P) (Safo et al., 1997; Adjei-Nsiah, 2012a). This makes PBA a suitable material for reducing soil pH and raising the levels of other nutrients for uptake by crop plants.

In southern Ghana, where this study was undertaken, there is abundance of PBA generated through the burning of empty fruit bunches of oil palm which is 'an agro by-product' from small and medium scale processing of palm fruits into palm oil. Although, PBA could be used in the preparation of soap due to its high potassium content, it is currently not being utilised for any purpose resulting in several heaps of ashes in the area.

We evaluated the response of three early maturing pigeonpea genotypes to PBA and PK fertiliser application and their effect on soil physico-chemical properties of an acid soil in the semi-deciduous forest zone of Ghana. We also assessed the residual effect of the pigeonpea fertilisation on the growth and yield of a succeeding maize crop grown in rotation.

2. Materials and methods

2.1. Study site

The current study was undertaken at the Forest and Horticultural Crops Research Centre, Kade which lies within latitude 6°09′ and 6°06′ N and longitude 0°55′ and 0°49′ W in the Kwaebibrim district of the Eastern region of Ghana. The centre which is located in the semi-deciduous forest agro-ecological zone of Ghana is 135.9 m above sea level. The study site is characterised by a bi-modal rainfall pattern with peaks in June and October and a short break in August and a dry period from December to March. The total annual rainfall during the experimental period was 1677.9 mm. The soils at the experimental site which are mainly forest Ochrosol derived from precambium phyllitic rocks are deep, well-drained and are generally classified as Acrisols in the FAO-UNESCO Revised Legend (Ahn, 1961; FAO-UNESCO, 1998). The physico-chemical properties of the surface soil of the experimental plots are presented in Table 1.

Table 1
Physico-chemical properties of 0–20 cm layer of soil and PBA used for the experiment.

Soil Property	Soil	PBA
pH (1:1.25 H_2O)	5.09	10.89
Total Nitrogen (%)	0.24	0.08
Organic matter (%)	4.20	
Organic carbon (%)		0.55
Available P (mg kg^{-1} soil)	6.81	269.57
Sand	36	
Silt	53	
Clay	11	
Exchangeable cations		
Calcium (Ca^{++})	3.56	34.93
Potassium (K^{+})	1.00	582.77
Magnesium (Mg^{++})	1.32	29.08

2.2. Experimental layout

The experimental plot which was dominated by *Chromolaena odorata* had been fallowed for 1 year. The *C. odorata* was initially cleared by slashing with a cutlass. Four weeks later, herbicide (glyphosate; 36% active ingredients) was applied at the rate of 2.5 L per hectare. Prior to clearing the field, surface soil (0–20 cm) and PBA samples were collected from the experimental site and analysed for both chemical and physical properties (Table 1).

2.3. Pigeonpea agronomic practices and field management

Three pigeonpea genotypes namely ICPL 87091, ICPL 88034 and ICPL 88039 obtained from the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) in India were planted between 14 and 15 June 2011. Treatments were randomised within four replicates. The pigeonpea was planted at 1 × 0.5 m at three seeds per hill. Two weeks later, pigeonpea was thinned to 1 seed per stand. The plot size was 12 × 8 m with 3 m paths between plots and replicates. Two weeks after planting, the pigeonpea plots were divided into three sub-plots with the treatments: 2 ton ha^{-1} PBA (4.8 kg $plot^{-1}$), 20 kg ha^{-1} PK (30–20) (48 g $plot^{-1}$) and control (without PK). Each sub-plot consisted of three rows of pigeonpea each measuring 8 m long leaving one row as border between treatments. The PBA and the PK-fertiliser were ring-applied around the plant and worked into the soil. Weeds were manually controlled at 3 weeks after planting and subsequently at 8, 13 and 21 weeks after planting (WAP). Insecticide (containing cypermethrin and dimethoate) was applied at 6 weeks after planting and at flowering to control insects.

2.3.1. Pigeonpea nodule assessment

At flowering, ten plants were randomly selected and tagged for growth and nodulation assessments. To prevent loss of some of the nodules to the soil, the sampled plants were carefully dug out together with a ball of earth around them. The plants together with the soil were placed in plastic buckets and sent to the laboratory. The number of nodules on each plant was recorded after careful search of the nodules was done on each plant and fresh weight taken by weighing them on an electronic scale. The nodules of each plant were put into labelled envelopes and oven-dried at 70 °C for 48 h. After assessing the nodules, each plant was separated into tops and roots and each portion chopped into pieces and placed in paper bags and oven-dried at 70 °C for 48 h to constant weight.

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