The Use of Pigeon Pea *(Cajanus cajan)* for Amelioration of Ultisols in Ghana

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Abstract

Pigeon pea, a multi-purpose species, is extensively used as food grain and green manure crop for soil fertility amelioration in local cropping systems. Recently, pigeon pea root exudates have been found to contain phenolic compounds (e.g. piscidic acid), which chelate Fe to free P in Fe bound P in soils for crop uptake. It is also reported that pigeon pea root exudates dissolve phosphate-containing rocks (e.g. phosphate rocks) to make P available for crop use. There are however, a few instances in West Africa where the use of pigeon pea has become unpopular among farmers due to its low and variable yield as well as its inability to redress soil fertility sufficiently in the long-term. In this study, the nutrient cycling, moisture storage of pigeon pea collections is reported.

Key words: pigeon pea, nutrient cycling, moisture storage

Introduction

Crop production in peasant cropping systems in the semi-arid areas of West Africa is generally constrained by low and uncertain rainfall, poor soil fertility (low nutrients content and structural degradation), lack of credit facilities to purchase inputs such as fertilizers and improved varieties (Weber *et al.*, 1996; Bationo *et al.*, 1993). Of these, phosphorus and nitrogen usually limit crop yields on farm fields. Under favourable soil and weather conditions, yields of improved maize ranged from 4.0 to 7.0 t ha^{-1} (Elemo *et al.*, 1990). However, yields of improved varieties in nutrient and moisture-stressed conditions, typical of farmers' circumstances ranged from 0.30 to 4.0 t ha^{-1} (Carsky *et al.*, 1998). Crop yields will continue to decline in so far as appropriate remedial measures are not put in place to conserve moisture and restore soil fertility (Mermut and Eswaran, 1987).

Scientists in West Africa and elsewhere in the tropics, have developed biological management practices which have the potential to address the problem of low soil productivity in the region (Peoples and Craswell, 1992; Sanchez and Salinas, 1981).

Corrective measures that have been developed by local and international research groups to address soil fertility related problems include:

1) the use of organic and inorganic mineral fertilizers (Smyth *et al.*, 1993; Manu *et al.*, 1988),
2) intercropping of cereals and legumes (Sanginga *et al.*, 1996),
3) legume based cropping systems e.g. herbaceous green manuring, agroforestry, improved fallow (Mafongoya *et al.*, 1997; Barnes, 1995)
4) crop residue mulch management (Tian *et al.*, 1993; Adeoye, 1984; De Vleeschauwer *et al.*, 1980);
5) the use of local rock phosphate (Ankomah *et al.*, 1995; Zapata and Axmann, 1991; Hammond *et al.*, 1986 and
6) integrated soil husbandry comprising a combination of the above (Mugwira and Mukurumbira, 1984).

These options were designed to increase nutrient use efficiency, make the environment less harmful as well as to reduce costs of production.

Pigeon pea, a multipurpose species, is extensively used as food grain and green manure crop for soil fertility amelioration in cropping systems (Adu-Gyamfi *et al.*, 1996; Tobita *et al.*, 1994). Pigeon pea root exudates have been found to contain phenolic compounds (e.g. piscidic acid), which chelate Fe to free P in Fe bound P in soils for crop uptake (ICRISAT, 1999). It has also been reported that pigeon pea root exudates dissolve phosphate-containing rocks (e.g. phosphate rocks) to make P available for crop use (Ae *et al.*, 1990). There are however, a few instances in West Africa where the use of pigeon pea has become unpopular among farmers due to its low and variable yield as well as its inability to redress soil fertility sufficiently in the long-term (Juo *et al.*, 1996).

The objective of the study is to validate the hypothesis that cultivation of pigeon pea results in nutrient contribution to the soil.

Methodology

Site characterisation

The field study was carried at the Soil Research Institute experimental field at Kwadaso, Kumasi (6°40'N, 1°4W; 255 m above sea level) (Soil Survey Staff, 1990) in the semi deciduous forest zone of Ghana. The mean annual rainfall in the area is 1473 mm per annum; the rainfall pattern is bimodal, the rainy season starts in March and ends in October, with a short dry spell in August with peaks in June and September. The soil is classified as Ferric Acrisol (FAO-UNESCO, 1990).

Soil sampling

Composite samples from the 0-20 cm depth were taken from the experimental sites following the method of Anderson and Ingram, (1993) The samples were transported to the laboratory at the Soil Research Institute, Kumasi and air-dried. Un-decomposed plant materials were sorted out and the samples crushed to pass a 2-mm sieve. The sieved soil samples were stored in thick polythene bags for laboratory analyses.

Soil analyses

Soil Particle size distribution was determined by the modified Bouyoucos hydrometer method as described by Day (1965). Soil pH was determined in distilled water using a Glass electrode-calomel electrode (McLean, 1982), MV Pracitronic pH meter at a soil solution ratio of 1:1. Organic carbon was determined by the method of Bremner (1965) and soil available phosphorus was by Bray 1. Exchangeable Ca and Mg in the extract were determined by an atomic absorption spectrophotometer. The K and Na were determined by flame photometry. The effective cation exchange capacity (ECEC) was calculated as the sum of the exchangeable potassium, calcium, magnesium and sodium. All analyses were carried out in duplicate.

Pot experiment

Three seeds of each collection of pigeon pea were sown into pots containing 5.0 kg soil. The treatments were replicated four times and pots were arranged in a completely randomized design. Seedlings were thinned to two per pot one week after germination. The moisture contents in the pots were kept at filled capacity throughout the experimental period with demineralized water. Plants were harvested 36 days after planting and the above-ground plant material as well as the below-ground material washed in distilled water. Harvested plant materials were oven-dried and weighed.

Establishment of pigeon pea for field study

The study site was a three- year fallow field with *Chromolaena odorata* as the dominant weed. The site was hand cleared with cutlass and the thick biomass was burnt thereafter.

Nine (9) pigeon pea cultivars of 90 % germination were planted on 13th June 2000 at two seeds per hill. The collections were:

1) 82/492;
2) 82/472;
3) GJ 93/207;
4) 82/137;
5) 82/021;
6) 82/433;
7) 82/491;
8) 82/486 and
9) 82/481.

These collections represent local pigeon pea germplasm from Ghana collected by the Plant Genetic and Research centre (PGRC, Bunso of the Council for Scientific and Industrial Research, (CSIR). The collections belong to the family Papilionaceae and the scientific name is *Cajanus cajan* and the common name is pigeon pea. The locations where collections were made are shown in Table 28.1.

Table 28.1: Some basic information of the pigeon pea cultivars

Collection number	Locality	Vernacular name	Source of sample
82/492	Gomoa Akropong	*Adua*	Field
82/472	Ejura	*Asedua*	Field
GJ 93/207	Tanoboase	*Akye*	Farm store
82/137	Kwahu Tafo	*Adua*	Farm store
82/021	Norre	*Adua*	Farm store
82/433	Bonuntong	*Adua*	Farm store
82/491	Aboabo	*Ase*	Farm store
82/486	Ayere	*Ase*	Farm store
82/481	Kontonso	*Ase*	Farm store

Experimental design for the field study.

The experimental design was a randomised complete block with four replications. Plot size was 4 m x 4 m and the distance between plants were 1 m apart.

Trial maintenance

Efforts were made to ensure 100 % seed establishment by refilling withered seedlings. Weeding was done mechanically with a hoe as often as was necessary.

N and P were applied at the rate of 50 kg N ha^{-1} and 20 kg P ha^{-1} respectively, to each treatment four weeks after planting.

Results and Discussion

Table 28.1 shows locations in Ghana where pigeon pea commonly grown were collected. The locations indicate the adaptability of the crop across the major agro-ecological zones of the country. The collections vary in seed colour and have benefited very little from morphological characterisation.

Table 28.2: Shoot and root dry matter yield of pigeon pea collections.

Collection	Shoot Dry matter yield g pot^{-1}	Root dry matter yield g pot^{-1}
82/492	4.49	1.14
82/472	3.96	0.73
GJ 93/207	2.96	0.55
82/137	2.49	0.46
82/021	3.28	0.54
82/433	5.07	0.77
82/491	4.41	0.58
82/486	4.98	0.73
82/481	2.65	0.43
LSD (0.05)	NS	NS
S.E	1.16	0.22

The production of above-ground as well as below-ground biomass from the pot study did not differ significantly among the collections (Table 28.2). Again all the collections showed few tiny ineffective nodules at harvest.

Table 28.3: The effect of pigeon pea cultivation on some soil properties after one year of cultivation.

Soil properties	Uncultivated soil	Pigeon pea cultivated soil	Standard Error
pH 1:1 H_20	4.96	4.73	0.11
Organic carbon (%)	1.98	1.93	0.06
% Nitrogen	0.23	0.23	-
C/N ratio	8.5	8.5	0.16
Exchangeable calcium (ppm)	5.92	5.2	0.39
Exchangeable magnesium (ppm)	1.0	2.08	0.42
Exchangeable potassium (ppm)	0.16	0.17	0.01
Exchangeable sodium (ppm)	0.02	0.03	-
Total exchangeable bases	7.10	7.47	0.43
ECEC (C.mol/kg)	7.2	7.58	0.43
Available P (ppm)	2.99	2.21	0.28
Available K (ppm)	57.88	77.88	5.68
Bulk density (g/cm^3)	1.28	1.40	0.03
Moisture content(g/g)	16.1	20.43	1.44
% sand	38.37	41.13	1.44
% silt	38.88	46.25	1.57
% clay	20.00	15.38	1.15

Table 28.3 shows the properties of the 0-20 cm layer of soils under pigeon pea and in the uncultivated sites after one year of cultivation. The data indicated a decline in soil pH with cultivation. The mean organic carbon content of the pigeon pea sites is about 2.5 % lower than the mean of the uncultivated sites. There are no differences between the uncultivated soil and the cultivated soil with respect to the levels of total nitrogen and C/N ratio.

In general with the exception of exchangeable calcium which was almost 12 % more in the uncultivated site compared to the pigeon pea cultivated sites, exchangeable cations were higher in the pigeon pea cultivated sites than in the uncultivated sites. Exchangeable magnesium was more than 100 % higher in the pigeon pea cultivated sites compared to the uncultivated sites. Similarly, total exchangeable bases were about 5 % higher in the cultivated sites compared to the uncultivated sites. The cation exchange capacity of the pigeon pea cultivated sites increased by 5 % with respect to the uncultivated site within one (1) year. Also, available potassium increased by 25 % in the cultivated site. Available phosphorus, however, declined by almost 26 % in the cultivated sites with respect to the uncultivated site. The texture of the soil is loam in both the uncultivated and the cultivated sites. With the exception of percentage clay , pigeon pea cultivated site indicated a higher % particle size than the uncultivated sites. More moisture was stored under pigeon pea cultivated site which also showed a higher bulk density (1.40 g cm^{-3}), than the uncultivated site (1.28 g cm^{-3}).

The decrease in soil pH with cultivation could be attributed to erosion of the exposed sites prior to canopy closure of pigeon pea. It is possible that the amount of N derived from biological nitrogen fixation was utilised by the cultivated crop rather than soil N. Pigeon pea like all legumes, has a high phosphorus need and its performance can be affected by low soil P as is the case in most tropical soils. Under the present management of low fertilizer inputs, P shows a decline with cultivation. Soils under fallow however, had high levels of P. This is a reflection of the biological biochemical mineralization processes during which organic matter is mineralized. It is also a reflection of biocycling of P through deeper plant roots causing a relative enrichment in the topsoil (Barber, 1979).

Considering the fact that moisture storage improved under pigeon pea cultivated sites, the crop could be considered as a possible candidate in a moisture-stressed agro-ecological environment.

Conclusion

The one year study clearly demonstrated that there is a high potential for pigeon pea as a good vehicle for magnesium, potassium and sodium cycling in soils. The most valuable information for management decisions is the phosphorus mining under pigeon pea cultivation, where seed grain is harvested. Given the high cost of chemical fertilizers and the fact that most peasant farmers cannot afford their purchase, the need to test the efficiency of other sources such as phosphate rocks with pigeon pea based farming systems is great.

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