ECOLOGICAL CONSIDERATIONS IN THE SELECTION OF LEGUMINOUS PLANTS AS COVER CROPS ON THE VERTISOLS OF THE ACCRA PLAINS IN GHANA

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ABSTRACT
Experiments were conducted in 2003 and 2004 to select leguminous cover crops for the Accra plains ecology in Ghana, based on the ability to withstand drought, produce enough biomass and fix nitrogen. In a randomised complete block design, Crotalaria ochroleuca, Stylosanthes hamata, Stylosanthes guianensis, Aeschenomene histrix, Chamaecrista rotundifolia, Sesbania sesban and Leucena leucocephala were grown and plant residues incorporated into the soil. Other treatments were recommended inorganic fertilizer application and no fertilization (control). Maize was planted on all plots and data collected on biomass of leguminous residues and also shoot biomass, cob weight and grain yield of maize. Soil samples were taken and analysed for pH, organic carbon and nitrogen (N). The leguminous plant materials were also analysed for N, phosphorus (P) and potassium (K). Annual rainfalls of 2003 and 2004 were low and dry matter yields of some leguminous plants (e.g. Aeschenomene histrix and Chamaecrista rotundifolia) were consequently low. Also, Crotalaria ochroleuca, Leucena leucocephala, Sesbania sesban and Chamaecrista rotundifolia had higher percentage of N per unit dry weight than the other leguminous plants (3.1, 3.1, 2.8 and 2.8, respectively). In the major rainy season of 2004, maize after Sesbania sesban had higher total dry matter, cob weight and grain yield than observed in the unfertilized control and were comparable to those of the inorganic fertilizer application. Grain yields were 2.4, 0.9 and 3.5 t ha^{-1}, respectively. In the minor season, crop growth and yield were much lower in all the treatments due to low rainfall. By virtue of its high vegetative growth and nitrogen fixation, Sesbania sesban was selected as suitable cover crop for the Accra plains.

INTRODUCTION
The Accra plains of Ghana and the other savanna ecologies have low soil organic matter (OM) content because of the annual bush fires and slower rate of vegetative growth and decomposition, due to low rainfall (700-1100 mm). Organic matter provides benefits to the soil and the subsequent crop in many different ways. It improves the physical condition of the soil by improving soil tilth, stability of soil aggregates, water infiltration, air diffusion, and by reducing soil crusting. The addition of organic matter increases the population of soil microbes and earthworms, which in turn contribute to efficient nutrient cycling and improvement in soil structure. Organic matter also increases nutrient retention in the root zone.

Cover crops can be leguminous or non-leguminous. They add and capture soil N that might otherwise be lost through leaching. They reduce erosion, runoff and potential pollution of surface waters; and also impact on insect and disease life cycles and suppress nematode populations and weed growth. Land does not need to be taken out of production in order to incorporate cover crops into cropping systems. In dryer ecologies like deserts and semiarid environments, cover crops minimise the effect of the excessive heat on the soil. Leguminous cover crops produce organic matter that is rich in nitrogen (N) and provide a significant source of N for subsequent crops.

Acquaye (1986) observed that soil fertility is closely associated with OM content of the soil, which was determined to be 1-2% (0-15 cm depth) in savanna soils, compared with 4.5-6% in forest soils. The lack of OM in the Vertisols of the Accra plains reflects negatively on the physical and chemical properties of the soils. Organic matter improves soil moisture holding capacity of soil, as observed by Kang *et al.* (1985) and Agyenim-Boateng (1997).

This study has been conducted to select suitable leguminous cover crops for the Accra plains ecology, based on ability to withstand drought, produce enough biomass and fix substantial quantities of nitrogen. Most of the legumes studied are grown as forage legumes elsewhere. Leucaena performs well in a wide range of rainfall environments, from 650 mm to 3,000 mm (Brewbaker *et al*., 1985). Its dry matter productivity has been observed to vary with soil fertility and rainfall and ranges from 3 – 30 t ha^{-1} $year^{-1}$, being low in dry environments and increasing linearly from 800 to 1,500 mm. Leucaena is very drought tolerant and deep rooted, with roots extending to 5 m to exploit underground water (Brewbaker *et al*., 1972). *Chamaecrista rotundifolia* cv. Wynn has been identified as a promising forage legume for sub -humid Nigeria, with average annual rainfall of 1,413 mm (Tarawali, 1995). Dry matter yield of 0.72-7.96 t ha^{-1} was attained. Aeschynomene grows best in moist fertile soils, being more tolerant of extremely wet conditions than of drought and mostly planted in areas receiving at least 1000 mm per year rain (Vendramini *et al*., 2010). Dry matter yield of 5 t ha^{-1} is commonly observed but 10-15 t ha^{-1} is achievable from more productive ecotypes (Tropical Forages, 2010). *Stylosanthes guianensis* and *Stylosanthes hamata* are grown as forage crops in the sub-humid ecology of Nigeria and dry matter yields of 2.8 t ha^{-1} and 3.5 t ha^{-1}, respectively, have been observed (Peters *et al*., 1994).

Apart from the potential of cover crops to enrich the nitrogen status of soils through nitrogen fixation, they transform atmospheric CO_2 into soil organic carbon in a process referred to by Ramesh and Chandrasekaran (2004) as carbon sequestration. This, to some extent, controls excess atmospheric CO_2.

MATERIALS AND METHODS

The experiment was conducted at the Agricultural Research Center, Kpong, University of Ghana. The design was randomised complete block, with four replications and plot size 6 m x 4 m. The treatments included seven leguminous plants and two other treatments, namely: *Crotalaria ochroleuca, Stylosanthes hamata, Stylosanthes guianensis, Aeschenomene histrix, Chamaecrista rotundifolia, Sesbania sesban, Leucena leucocephala*, recommended inorganic fertilizer application and no fertilization (control). The inorganic fertilizer and no fertilization (control) were left to fallow at the time of growing the leguminous plants.

The leguminous plants were planted on 12th May 2003 and grown over the major and minor rainy seasons of 2003; the seeds were drilled in 60 cm rows, at rates of 60 kg ha^{-1} (Garrity, 1989, unpublished). At the beginning of the minor rainy season, the perennial plants, *Sesbania sesban* and *Leucena leucocephala* were pruned (on 5th September, 2003), to enable regrowth, and the residue spread as mulch on the soil surface. The annual plants, *Crotalaria ochroleuca*, *Chamaecrista rotundifolia* and *Aeschenomene histrix* had set seed and were similarly pruned and spread as mulch. Shattered seeds were allowed to re-grow, as occurs in natural fallows. In all the leguminous plots, two 1 m x 1 m samples were randomly taken for measurement of biomass. At the end of the minor season (on 30th December 2003), biomass samples of the re-grown leguminous plants were again taken, the plants chopped up with machete and the residues incorporated into the soil with hoe. A sub-sample of 1 kg fresh weight was taken and dried in an oven at 75 °C for 48 hours for chemical analysis.

Maize (*Zea mais* var Obatanpa) was planted on all plots in the major rainy season (on 18th April, 2004). Planting was at a spacing of 80 cm x 40 cm, with three seeds per hole but thinned to two plants after germination, to give a planting density of 62,500 plants ha^{-1}. Twenty days after planting the maize, basal NPK 15-15 -15 fertilizer was applied, in the plots earmarked for inorganic fertilizer treatment, at a rate of 250 kg ha^{-1}. This was followed with top dressing of sulphate of ammonia, 50 days after planting the maize, at a rate of 150 kg ha^{-1}. Weeds were controlled by hoe, from day 35 to 40 after planting maize. After harvest of the major season maize crop, maize was again planted on the same plots (on 10th September, 2004) to study the residual effect of the earlier incorporated leguminous crops and the inorganic fertilizer application.

Data collected included biomass of incorporated leguminous plants (in the major and minor seasons of 2003) and also shoot biomass (Dry matter), cob weight and grain yield of the maize crop (in major and minor seasons 2004). Soil sampling for chemical analysis was done at 0 – 20 cm depth, after harvesting the initial maize crop. The chemical analyses included: soil pH (1:2.5, soil:water), as done by McLean (1982); organic carbon by the Walkley and Black wet digestion method (Nelson and Sommers, 1982); nitrogen by micro-Kjedahl digestion method (Bremner and Mulvanay, 1982); available phosphorus and potassium were extracted by Bray and Kurtz-1 method; and phosphorus was determined colorimetrically and potassium by flame photometry. The leguminous plant materials were also analysed for N, P and K.

RESULTS

The annual rainfalls of 2003 and 2004 were low, compared with the long term average (Table 1). In both years, with exception of September 2004, the monthly rainfalls of June to October were much lower than expected. Crop growth was thus affected and dry matter yields of some leguminous plants were low. *Sesbania sesban, Leucena leucocephala, Stylosanthes hamata, Stylosanthes guianensis and Crotalaria ochroleuca* were able to withstand the drought better and thus had greater dry matter yield than *Chamaecrista rotundifolia* and *Aeschenomene histrix* (Table 2). *Chamaecrista rotundifolia* and *Aeschenomene histrix* were the most affected by drought and grew poorly. *Crotalaria ochroleuca, Leucena leucocephala, Sesbania sesban* and *Chamaecrista rotundifolia* had comparatively higher percentage N per unit dry matter than the other leguminous plants.

In the major rainy season of 2004, maize grown on plots with incorporated *Sesbania sesban, Stylosanthes hamata* and *Leucena leucocephala* had higher total dry matter of maize values than observed in the unfertilized control and was comparable to that of the recommended inorganic fertilizer application (Table 3). Cob weights in *Sesbania sesban* and *Stylosanthes hamata* had a similar trend. On the other hand, only *Sesbania sesban* gave grain yield that was significantly higher than that of the control and comparable to the recommended fertilizer application.

Crop growth and yield in the minor rainy season have been much lower in all the treatments than observed in the major season (Table 4). There were no differences in crop dry weights but cob weights were significantly higher in incorporated *Stylosanthes guianensis* and *Sesbania sesban* than in the control and similar to the inorganic fertilizer treatment. Soil nitrogen, organic carbon and pH contents did not differ between treatments (Table 5).

Table 1: Monthly Rainfall during the Period of Experiments

	2002 (mm)	2003 (mm)	2004 (mm)	Long-term average (mm) (1958-2010)
January	29.3	24.8	4.9	15.7
February	41.0	28.2	33.3	35.3
March	57.2	101.0	4.2	83.5
April	223.1	147.0	47.4	117.3
May	128.3	183.6	182.6	146.7
June	147.4	96.7	91.1	166.9
July	72.1	0.0	45.5	83.3
August	23.6	9.8	46.6	51.3
September	118.6	32.4	182.0	114.0
October	125.8	92.2	42.7	119.2
November	72.6	82.0	79.5	70.1
December	20.3	36.2	71.5	22.7
Annual Rainfall	**1059.3**	**833.9**	**831.3**	**1026.0**

Table 2: Dry Matter and Nutrient Content of Leguminous Plants

Leguminous Plants	**Dry Matter** ($t\ ha^{-1}$)	**N** (%)	**P** (%)	**K** (%)
Crotalaria ochroleuca	3.1	3.1	0.23	2.6
Stylosanthes hamata	4.5	2.1	0.19	1.8
Stylosanthes guianensis	3.4	2.0	0.18	1.7
Aeschenomene histrix	1.5	1.9	0.17	1.8
Chamaecrista rotundifolia	1.4	2.8	0.20	1.9
Sesbania sesban	5.3	2.8	0.27	2.3
Leucena leucocephala	4.2	3.1	0.24	2.2

Table 3: The Growth and Yield of Maize after Incorporation of Leguminous Plants in the Major Rainy Season of 2004

Leguminous Plants	**TDM** ($t\ ha^{-1}$)	**Cob weight** ($t\ ha^{-1}$)	**Grain weight** ($t\ ha^{-1}$)
Crotalaria ochroleuca	5.6	2.3	1.2
Stylosanthes hamata	11.9	4.9	1.5
Stylosanthes guianensis	9.1	3.5	1.4
Aeschenomene histrix	10.0	3.7	1.3
Chamaecrista rotundifolia	9.9	3.3	1.3
Sesbania sesban	18.3	8.1	2.4
Leucena leucocephala	10.4	4.1	2.0
Inorganic fertilizer	16.5	8.3	3.5
No fertilizer (control)	4.3	1.2	0.9
LSD	**5.8**	**3.5**	**1.5**

Table 4: The Residual Effect of Incorporated Leguminous Plants and Inorganic Fertilizer Application on Growth and Yield of the Minor Season, 2004 Maize Crop

Leguminous Plants	TDM *(t ha^{-1})*	Cob weight *(t ha^{-1})*	Grain weight *(t ha^{-1})*
Crotalaria ochroleuca	8.5	1.8	1.2
Stylosanthes hamata	8.1	2.2	1.0
Stylosanthes guianensis	13.8	3.8	1.8
Aeschenomene histrix	5.8	1.3	0.8
Chamaecrista rotundifolia	6.3	1.0	0.9
Sesbania sesban	13.3	3.7	1.2
Leucena leucocephala	8.5	2.2	1.3
Inorganic fertilizer	14.1	3.9	2.4
No fertilizer (control)	8.8	1.9	0.9
LSD	**5.4**	**1.6**	**.ns**

Table 5: Effect of Incorporation of Leguminous Plants on Chemical Properties of Soil at the end of Major Season, 2004 experiment

Leguminous Plants	pH	%C	%N
Crotalaria ochroleuca	7.4	1.45	0.11
Stylosanthes hamata	7.3	1.48	0.13
Stylosanthes guianensis	7.3	1.35	0.12
Aeschenomene histrix	7.4	1.30	0.11
Chamaecrista rotundifolia	7.3	1.47	0.12
Sesbania sesban	7.3	1.39	0.12
Leucena leucocephala	7.3	1.53	0.12
Inorganic fertilizer	7.3	1.51	0.12
No fertilization	7.4	1.48	0.11
LSD	**ns**	**.ns**	**ns**

DISCUSSION

Chamaecrista rotundifolia and *Aeschenomene histrix* had poor vegetative growth, compared with *Leucena leucocephala* and *Sesbania sesban*. *Stylosanthes hamata*, *Stylosanthes guianensis* and *Crotalaria ochroleuca* are smaller plants than *Leucena leucocephala* and *Sesbania sesban* and, therefore, had relatively lower biomass. A study conducted by Vendramini *et al*. (2010) showed that *Aeschenomene histrix* thrives best under very wet conditions and performs poorly when there is drought. Also, Peters *et al*. (1994) found that *Aeschenomene histrix* performed well and gave dry matter yield of 6 – 12 t ha^{-1} in the sub-humid ecology of Northern Nigeria, with annual rainfall ranging from 1205 – 1694 mm. On the other hand, the lower annual rainfalls of 833.9 and 831.3 mm in 2003 and 2004, respectively, in the Accra Plains, could not appreciably support the growth of the two cover crops (*Aeschenomene histrix* and *Chamaecrista rotundifolia*). In both years, rainfalls during the crop growing period (June – October) have been lower than expected.

The incorporated leguminous plant residues did not bring about significant maize growth and yield differences in some treatments, during the major and minor rainy seasons of 2004, due to the drought condition. Eghball *et al*. (1995) found in a long-term manure and fertilizer trial that, although management practices can reduce temporal grain yield variability in some crops, variations in environmental factors dominated the yearly maize grain yield regardless of soil fertility amendments. Wang *et al*. (2007) also found in long-term effects of various combinations of maize stover, cattle manure and N and P fertilizer applications on maize that grain yields and N, P, and K uptakes and N, P and K use efficiencies were greatly influenced by the amount of rain during the growing season and by soil water at sowing.

Sesbania sesban came up in both the major and minor rainy season experiments as a suitable green manure for maize production in the Accra Plains. *Chamaecrista rotundifolia* had similar nitrogen content as that of *Sesbania sesban* but had poor growth and dry matter accumulation due to the drought. It thus had less impact on maize growth and yield, thus indicating the importance of biomass in nitrogen accumulation in leguminous plants and their suitability as cover crops.

Studies by Asibuo and Osei-Bonsu (1999) showed that maize grown after legumes responded to fertilizer N, giving indication that the legumes could not supply the entire N required by maize for optimum yield and need supplementary applications from inorganic sources.

CONCLUSION

In both the major and minor season, 2004 maize crops, *Sesbania sesban* came up as a suitable green manure for maize production in the Accra plains. It has been found to have much vegetative growth and also high nitrogen content, compared with the other leguminous plants studied. On the other hand, *Chamaecrista rotundifolia* and *Aeschenomene histrix* grew poorly in the Accra plains ecology, which has a generally low rainfall that is not well distributed in some years. In order for leguminous plants to be effective as cover crops, they should be suitable for the ecology and be able to produce enough biomass and fix substantial quantities of nitrogen.

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