Cowpea as a Potential Green Manure Crop in the Rain Forest Zone of Ghana

S. Agyenim Boateng
Soil Research Institute, Academy Post Office, Kwadaso-Kumasi, Ghana.
Email: sagyenimboateng@yahoo.com; soils@africaonline.com.gh
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Resumé

Boateng Agyenim, S. *Niébé Comme une Potentielle Culture de L'engrais Vert dans la Zone Forêt Dense Humide au Ghana.* L'usage du niébé comme culture de l'engrais vert n'est pas populaire parmi les paysans ghanéens. Néanmoins, il y a toujours la potentialité de l'usage. Une variété déterminée du Niébé était examinée pour deux ans dans la zone forêt dense humide sémi-caduque au Ghana. L'objectif était pour examiner le rendement du grain et les effets de l'engrais vert. Quatre traitements y compris le contrôle, l'engrais minéral à 51-30-30 kg, NPK ha^{-1}, l'engrais vert du niébé et l'engrais vert du niébé + 25 - 15 - 15 kg NPK ha^{-1} dans le RCBD de quatre réplications étaient employés. Les gousses étaient récoltées à la maturité physiologque pour le grain, alors que la feuille verte et la biomosse de la tige étaient coupeés et incorporeés dans le sol. Le maïs qui suivait l'engrais vert du niébé a produit le rendement d' à peu près 10.7 t ha^{-1} qui n'était pas différent de celui de l'engrais minéral. Un rendement moyen du maïs de 3.6 t ha^{-1} était obtenu des cultures de l'engrais vert en plus de rendement du niébé au dessus de 1.2 t ha^{-1}. Les parcelles de l'engrais minéral ont produit de même rendement du maïs. Une combinaison de l'engrais vert du niébé et un niveau moitié de l'engrais minéral ont produit d'une manière considérable un rendement plus élevé que l'engrais vert et l' engrais minéral uniques. L'engrais vert du niébé a peu amelioré le niveau des nutriments du sol. Les resultats suggèrent qu'on peut utiliser le niébé comme culture de l'engrais vert.

Mots-clés: Niébé, l'engrais vert, forêt dense humide, rendement du maïs, nutriments du sol.

Abstract

The use of cowpea as a green manure crop is not popular among Ghanaian farmers but the potential to use it exists. A determinate cowpea variety was tested for two years in the semi-deciduous rain forest zone of Ghana for grain yields and green manure effects. Four treatments consisting of control, mineral fertilizer at 51-30-30 kg NPK ha^{-1}, cowpea green manure and cowpea green manure + 25-15-15 kg NPK ha^{-1} in RCBD of four replications were employed. Pods were harvested at physiological maturity for grain, while the green leaf and stem biomass were cut and incorporated into the soil. The maize crop that followed the cowpea green manure produced stover yields of about 10.7 t ha^{-1} which was not different from that of the mineral fertilizer. A mean maize grain yield of 3.6 t ha^{-1} was obtained from the green manured plants in addition to cowpea grain yield of over 1.2 t ha^{-1}. The mineral fertilizer plots produced similar maize grain yield. A combination of cowpea green manure and half rate of the mineral fertilizer produced significantly greater maize stover and grain yields than sole green manure and sole mineral fertilizer. Cowpea green manure slightly improved the level of some soil nutrients. The results suggest that cowpea can be used as a green manure crop.

Keywords: Cowpea, green manure, rain forest, maize yields, soil nutrients.

Introduction

Cowpea (*Vigna unguiculata* L. Walp.), an annual legume, originated in Africa and is widely grown in Africa, Latin America, Southeast Asia and in the southern United States. The history of cowpea dates to ancient West African cereal farming, 5 to 6 thousand years ago, where it was closely associated with the cultivation of sorghum and pearl millet (Davis *et al.*, 2005).

Cowpea can be used at all stages of growth as a vegetable crop. The tender green leaves are an important food source in Africa and are prepared as a pot herb, like spinach. Immature snapped pods are used in the same way as snap beans, often being mixed with other foods. It is also consumed as a vegetable in parts of Asia and the Pacific. Green cowpea seeds are boiled as a fresh vegetable, or may be canned or frozen. Dry mature seeds are also suitable for boiling and canning.

Cowpea seed is a nutritious component in the human diet, as well as a nutritious livestock feed. The protein in cowpea seed (23-33%) is rich in the amino acids, lysine and tryptophan, compared to cereal grains. However, it is deficient in methionine and cystine when compared to animal proteins. Therefore, cowpea seed is valued as a nutritional supplement to cereals and an extender of animal proteins (Davis *et al.*, 2005).

Used as a cover crop, cowpea suppresses weed, controls erosion and can encourage populations of beneficial insects to defend cash crops from insect pests (Valenzuela and Smith, 2002). Its drought tolerance makes it valuable in rain-fed agriculture or in unirrigated fallow fields. In soils low in phosphorus, the roots of cowpea develop effective mycorrhizal associations, improving the soil's available P content (Valenzuela and Smith, 2002). The roots of cowpea possess nodules which inhabit nitrogen-fixing bacteria and therefore the crop can enrich the soil with nitrogen. As a result, cowpea is often used as a rotational crop following heavy nitrogen feeder crops like maize and many vegetables.

Cowpea is also used as a green manure crop in many places including countries of South East Asia, Latin America, and United States of America and in some parts of Africa. However, in Ghana, its use in green manuring is minimal or non-existent (Agyenim Boateng, 1994). The crop is cultivated in the rain forest zone of Ghana chiefly for its leaves and grains for both human and animal consumption.

The acceptability and adoption of various green manure species by farmers in Ghana is a subject of great concern. Whereas the efficacy of most green manure crops in improving soil fertility and crop yields is obvious, many Ghanaian farmers are yet to embrace this modernized and improved age-old technology in their farming systems. They are not prepared to risk sacrificing one season or even part of a longer major season to growing and incorporating green manure crops into the soil without direct economic benefits (Agyenim Boateng, 1997).

It has therefore become necessary to look for species that play multiple roles of improving soil fertility and providing direct food grains at the same time among others. One of such species is cowpea. Some cultivars of cowpea that have the potential of being used as green manure as well as grain legume crops exist in the country.

When cowpea is used as a green manure crop, decomposition of the fresh biomass releases nitrogen into the soil within few weeks (Matthew *et al.*, 2004). Other nutrients are also released (Yagodin, 1984). The evolution of carbon dioxide during the decomposition of the biomass helps to increase the availability of phosphates in alkaline calcareous soils (Russel, 1973). Organic matter content of the soil may increase and the activities of soil micro-organisms are enhanced (Allison, 1973). Soil structure, water-holding capacity and water permeability of soils are improved (Valenzuela and Smith, 2002; Agyenim Boateng, 1997). All these have an overall effect of improving the fertility status of the soil resulting in good crop growth and increased yields. Cowpea, like other green manure crops, increases yield levels of various crops (Hariah and van Noordwijk, 1989; Giller and Wilson, 1991).

The objective of this study was to evaluate the possibility of using cowpea crop as a green manure crop in addition to its traditional role as a food grain crop in the rain forest zone of Ghana.

Materials and methods

The trial was conducted at Kwadaso near Kumasi in the Ashanti region of Ghana in 2000 and 2001. The study area lies within the semi-deciduous rain forest zone with bimodal rainfall pattern having an annual rainfall of between 1500 and 2000 mm. The soil at the site of trial belonged to the Akroso series, a Haplic Acrisol. A randomised complete block design with four replications was employed. Treatments were as follows:

1. Control (absolute) i.e. no application of green manure or mineral fertilizer;
2. Mineral fertilizer at 51-30-30 kg N-P-K ha^{-1} usual recommendation to maize farmers in this area designated as NPK;
3. Cowpea incorporated green biomass

of cowpea cut and buried in the soil as green manure designated as GM (green manure); and

4. Cowpea incorporated + 25-15-15 kg N-P-K ha^{-1} designated as GM + ½ NPK.

A plot size measured 6 m x 5 m. Two seeds of a determinate, 65 days to maturity cowpea (variety Bengpla) were sown 60 cm between rows and 20 cm within rows in the middle of the major season i.e. mid-June. Two manual weedings using the hoe were done according to weed occurrence and two insecticide applications using recommended insecticides were done according to pest build up. One pre-flowering insecticide using Karate at the rate of 15 g lamda-cyhalothrin per hectare was applied. The other application was done at post-flowering using dimethoate at the rate of 400 g ha^{-1}.

At 50% flowering, nodule counts were done. Four plants per plot were uprooted, washed off soil particles and air-dried. The number of nodules per plant was counted and weighed. The weights of active nodules, denoted by internal pink colour, were also taken. At physiological maturity, the yellow but semi-dry cowpea pods were harvested, dried, weighed and threshed. The still green stover, made up of leaves and stems were immediately cut at soil level, chopped up and then incorporated into the soil. Samples of stover and grain were taken and oven-dried at 70C to a constant weight and dry biomass and grain yield respectively were determined. The samples were then ground and analyzed for total N concentration using Kjeldahl method (Brermner, 1965). Nitrogen accumulation was calculated as a product of biomass and N concentration.

Maize (variety Abeleehi) as test crop was sown after one week of incorporation of the cowpea biomass. The mineral fertilizers were applied in the form of 15-15-15 NPK one week after sowing the maize as basal application, and in the form of sulphate of ammonia five weeks later as top-dress. Weeds were controlled as and when it was found necessary. No other pest or disease problem was encountered in the maize trial. The maize was allowed to grow to maturity and then harvested and measured for stover and grain yields. A harvest index was determined according to the proposition below:

Harvest Index = Economic Yield x (Biological Yield)$^{-1}$

where,
Economic yield refers to grain yield and biological yield refers to total above-ground biomass yield.

The soil was sampled (top 20 cm) just before sowing cowpea, after harvesting cowpea and after harvesting maize. Soil samples were air-dried, crushed and passed through a 2-mm sieve. Soil analyses were done at the laboratory of Soil Research Institute in Kumasi. The following parameters were measured: soil pH (soil : water ratio,1 : 2.5), organic carbon (Walkley and Black, 1934), total nitrogen using Kjeldahl's method (Bremner, 1965), available phosphorus (Bray and Kurtz, 1945) and available potassium (flame photometer). Soil sampling and analyses were done only in the first year.

Data were statistically analyzed using the MSTAT statistical package (MSTATC, 1988).

Results and Discussion

Chemical properties of the soil

Table 1 shows some chemical properties of the soil at the site before sowing cowpea, after harvesting cowpea and after harvesting maize. The inherent fertility status of the soil was generally low, except available P which was medium, as indicated by the chemical properties. The soil was very strongly acidic and the addition of the green manure slightly changed the pH from 4.9 to 5.1, a strongly acid state. Although the change was not much it showed a promising tendency that green manures have the potential of improving acidic soils (Yagodin, 1984). Continued application over a period of time is likely to bring about a significant positive change.

With the incorporation of the cowpea green manure into the soil, total nitrogen level increased by about 15% against the backdrop that maize, being a heavy feeder on nitrogen, was grown on the soil. This change is significant since green manures are primarily used as a source of nitrogen (Quintana, 1987; M-Samann and Kotschi, 1994; Allison, 1973). Available phosphorus and potassium slightly increased (by 5% and 7% respectively). Organic carbon level was maintained. Increases in these nutrients may be expected when repeated additions are made (Agboola and Fayemi, 1972; Buanec and Jacob, 1981).

Some characteristics of the cowpea

A few characteristics of the cowpea used in the study are presented in Table 2. For both years, the number of nodules was quite high compared with that obtained from other cowpea cultivars by some investigators. For example, Frimpong and Safo (2003) obtained values between 40 and 50. The nodule weight was comparable to figures from Frimpong and Safo (2003) and was much higher than values obtained for groundnut (0.1 g) and pigeon pea (0.2 g) reported by Giller and Wilson (1991) but lower than that of mucuna (0.9 g) reported by Agyenim Boateng (1999).

The above-ground biomass was high compared to values between 2.06 and 2.43 t ha^{-1} reported by Dogbe *et al.* (2002). Odhiambo (2004) found that the biomass produced by two cowpea varieties in South Africa for two continuous seasons ranged between 2.0 and 4.0 t ha^{-1}. Depending on planting date, Muza (1996) noted that cowpea produced 4.7 t ha^{-1} above ground

Table 1. Some chemical properties of the soil (0-20 cm) at the site at specified stages of the experiment (2000).

Sampling period	*pH (H_2O)*	*Total N*	*Organic C*	*Available P*	*Available K*
		----------%----------		------------ppm------------	
Before sowing cowpea					
	4.9	0.13	1.02	14.45	30.05
After harvesting cowpea					
Control plots	4.8	0.12	0.07	10.02	26.68
Cowpea plots	5.0	0.14	0.09	11.20	29.00
After harvesting maize					
Control plots	4.7	0.08	0.06	9.78	24.25
Mineral fertilizer plots	4.8	0.15	0.08	15.30	31.98
Cowpea plots	5.1	0.15	1.02	15.17	32.15
Cowpea + Min fertilizer plots	5.0	0.14	1.02	15.88	32.95

Values were from bulked samples of treatments.

biomass in one of four sites among legume green manure crops planted four weeks after 50% maize emergence; the other sites produced below 1.2 t ha^{-1}.

The grain weight obtained was between 61% and 68% of the yield potential of 1.8 t ha^{-1} (GGDP, 1992). Frimpong and Safo (2003) obtained 1.96 t ha^{-1} grain weight from a medium maturing cowpea variety. Kang and Nangju (1983) reported 1.04 t ha^{-1} cowpea seed weight from control plots where no P was added and values of 1.5 t ha^{-1} and above from plots with P additions.

The thousand-grain weight obtained here was in conformity with the reported value of 16 g 100^{-1} seeds (GGDP, 1992) which is equivalent to 160 g 1000^{-1} seeds.

N accumulation in biomass and grain

Estimates of nitrogen accumulated in the vegetative and reproductive structures of cowpea are presented in Table 2b. The crop accumulated between 120 and 130 kg N ha^{-1} in its leaves and stems, and between 24.5 and 27 kg N ha^{-1} in the seeds and empty pods. By incorporating the biomass into the soil, an amount of 120 - 130 kg N ha^{-1} was estimated to have been added to the soil by the crop. And by harvesting the pods and grains, an estimated amount of 24.5 - 27 kg N ha^{-1} had been taken away. The N uptake by the crop in the first year was 144.5 kg ha^{-1} and 157.0 kg ha^{-1} in the second year of which 83% was returned to the soil in each year.

Duke (1981) stated that cowpea above-

Table 2A. Plant population and some characteristics of the cowpea used in the study.

Parameter	*Value* 2000	2001
Plant population (number of plants ha^{-1})	166,660	163,470
Nodulation (mean of four plants):		
number of nodules per plant	88	65
number of effective nodules per plant	61	43
weight of effective nodules per plant (g)	0.45	0.40
Biomass (dry) produced (t ha^{-1})	5.0	4.8
Pod weight(t ha^{-1})	1.20	1.31
Grain weight (t ha^{-1})	1.10	1.22
Thousand-grain weight (g)	155	158

ground N content ranges globally from 73-354 kg ha^{-1}, with a mean of 198 kg ha^{-1}. Peaceful Valley (1988) estimated only as much as 89.6 kg ha^{-1}. In Davis, California, Klein (1990), cited by UC (undated), found the following nitrogen contents in some cowpea cultivars (in kg N ha^{-1}): 'California Blackeye # 46, 151.4; 'California Blackeye #3, 152.8; 'Chinese Red,' 142.5; 'Spotted Purple Hull,' 146.2. Thus, the N content of the cowpea used in this study compared very well with that of other cowpea varieties elsewhere.

Stover yields of maize

The largest maize stover weight of 12 t ha^{-1} was produced by the GM + ½ NPK treatment followed by the GM and the NPK in that order (Table 3). All the treatments statistically out-yielded the control signifying the importance of fertilizing or manuring the soil for maize cultivation. Cowpea as a green manure produced comparable maize stover yields as the mineral fertilizer. This implies that cowpea green manure can be a suitable substitute or alternative to mineral fertilizer in maize production in the rain forest zone of Ghana. In a related study, Agyenim Boateng (1999) found that mucuna green manure could be a suitable alternative to mineral fertilizer rate of 60-40-40 kg NPK ha^{-1} in the semi-deciduous rain forest zone of Ghana.

However, a combination of green manure and mineral fertilizer may be more desired since GM + ½ NPK produced significantly more stover (over 12 t ha^{-1}) than either the sole mineral fertilizer or the sole green manure. This observation was in agreement with the findings of Agyenim Boateng (1999) who recommended a combination of mucuna green manure with 30-20-20 kg NPK ha^{-1}. There was a

Table 2B. Accumulation of nitrogen by the cowpea used in the study.

Parameter	*Level*	
	2000	*2001*
Biomass (kg ha^{-1})	5000	4800
N concentration in biomass (g kg^{-1})	26	25
N accumulation in biomass (kg ha^{-1})	130	120
Grain weight (kg ha^{-1})	1100	1220
N concentration in grain (g kg^{-1})	21	21
N accumulation in grain (kg ha^{-1})	23.1	25.6
Weight of empty pods (kg ha^{-1})	10.0	9.0
N concentration of empty pods (g kg^{-1})	8.0	8.0
N accumulation in empty pods (kg ha^{-1})	0.08	0.07

synergism of the two nutrient sources resulting in greater yields, making this treatment a preferred one. It lends credence to the popular integrated nutrient management technology.

Maize grain yields

Table 3 also shows grain yields of maize obtained following the imposition of the treatments. Both the organic and inorganic fertilizers and their combinations produced significantly greater grain yields than the control as was obtained for the stover yields. The yield values from cowpea green manure and the NPK fertilizer treatments were more than double of that from the control, while that from the GM + ½ NPK treatment more than tripled. The importance of fertilizing or manuring soils for maize cultivation is again underscored.

Although the inorganic fertilizer yielded more than the organic manure, it was not significantly different. Similarly, there was no significant difference between the fertilizers and their combination. Grain yield of 3.52 t ha^{-1} from the NPK and a yield value of 3.39 t ha^{-1} from the green manure were not statistically different from that of 4.11 t ha^{-1} from the GM + ½ NPK.

It can therefore be provisionally concluded that the cowpea green manure is a better alternative to the NPK rate used in the current study. That green manure is able to bring about improvement in crop yields as noted here has been reported by several investigators including Hariah and van Noordwijk (1989), Kang *et al.* (1981), Agyenim Boateng (1997; 1999), Fischler (1996) and Matthew *et al.* (2004).

The possibility of obtaining maize grain

Table 3. Effect of cowpea green manure on maize yields.

Treatments	*Maize stover weight*			*Maize grain weight*		
	------------	------------	--------------*t ha*$^{-1}$	------------	------------	------------
	2000	*2001*	*mean*	*2000*	*2001*	*mean*
Control	4.6	4.3	4.5	1.3	1.2	1.3
NPK fertilizer	9.8	10.6	10.2	3.5	3.7	3.6
Cowpea green manure	10.0	11.3	10.7	3.4	3.8	3.6
Cowpea green manure + 1/2 NPK	12.2	14.0	13.1	4.1	4.3	4.2
LSD ($p = 0.05$)	1.9	2.0	1.5	0.9	1.1	1.0

yields of over 3 t ha^{-1} when the stover of cowpea which has yielded over 1.0 t ha^{-1} grains was incorporated into the soil is commendable since it holds much promise for farmers in the country.

The harvest indices (Table 4) were medium indicating medium efficiency in redistribution of photosynthate from source i.e. green parts to sink i.e. the grains. Values from the fertilizer and manure treatments were significantly different from the control but not different from each other.

Table 4. Effect of cowpea green manure on harvest index of maize.

Treatments	*2000*	*2001*
Control	0.21	0.22
NPK fertilizer	0.27	0.26
Cowpea green manure	0.26	0.25
Cowpea green manure + ½ NPK	0.25	0.23
LSD ($p = 0.05$)	0.05	0.05

Conclusion

There is a great potential of using cowpea, particularly the determinate varieties like Bengpla, as a green manure crop in the rain forest zone of Ghana in addition to its traditional role of providing food for humans and animals. Cowpea green manure slightly increased the nitrogen, organic matter, and available phosphorus and potassium contents of the soil. The maize crop that followed the cowpea green manure produced stover yields of about 10.0 t ha^{-1} which was equivalent to that of the mineral fertilizer. A mean maize grain yield of 3.4 t ha^{-1} was obtained from the green manured plants in addition to cowpea grain yield of over 1.0 t ha^{-1}. The control plots produced only 1.25 t ha^{-1} maize grain.

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