Response of Pepper (*Capsicum frutescens*) to *Canavalia ensiformis* Green Manure in the Rain Forest Zone of Ghana

S. Agyenim Boateng[1†] and S. A. Peprah[2]
[1]Soil Research Institute, Academy Post Office, Kwadaso-Kumasi, Ghana.
[2]Crops Research Institute, P. O. Box 3785, Kwadaso-Kumasi, Ghana.
Received: July 2003 Accepted: September 2005

Resumé

Agyenim Boateng, S. & Peprah, S. A. *La Réaction du Piment (Capsicum frutescens) à Canavalia ensiformis. L' engrais végétal dans la zone forestière humide du Ghana.* La réaction du piment chaud (*Capsicum frutescens*) à *Canavalia ensiformis* (l'engrais végétal) a été étudié à Kwadaso dans la zone forestière humide du Ghana de 1997 à 1999. Le sol était haplic acrisol avec un pH de 4.9 P disponible et d'une teneur en. K de 0.14% 20.1 mg kg^{-1} et 42.20 mg kg^{-1} respectivement. Six traitements y compris *C. ensiformis* incorporation et paillis, chacun soit avec ou sans engrais minérale et deux series de contrôle (l'engrais minéral et absolu à un niveau de 51-30-30 kg NPK ha^{-1}) étaient ullisées en RCBD avec quatre reproductions. L'incorporation de *C. ensiformis* a augmenté la taille du piment de 10 mm par jour dans le premier mois. Le paillis de *C. ensiformis* n' a pas produit d'effet considérable sur la taille du piment. On n' a pas observé de réaction significative quand l'engrais était ajouté à ces traitenents rélatifs aux contrôles. *Canavalia ensiformis* incorporé a également produit une augmentation considérable dans la longueur de feuille mais pas dans la largeur de feuille. Les rendements des parcelles traitées avec l'engrais inorganique appliqué à 51-30-30 kg. NPK ha^{-1} étaient semblables à ceux des parcelles *C. ensiformis* incorporés produisant un rendenent frais moyen de 2 t ha^{-1} par rapport à 1.3 t ha^{-1} du contrôle. Les résultats montrent que *C. ensiformis* comme engrais végétal est également efficace comme l'engrais inorganique au taux ci-dessus augmentant le rendement du piment. *Canavalia ensiformis* comme paillis n'était pas aussi efficace comme l' engrais incorporé.

Mots clés: *Canavalia ensiformis*, l'engrais végétal, piment, forestière humide, nutriments du sol.

Abstract

The response of hot pepper (*Capsicum frutescens*) to *Canavalia ensiformis* green manure was studied at Kwadaso in the forest zone of Ghana from 1997 to 1999. The soil was a haplic acrisol with pH of 4.9, total N, available P and K contents of 0.14%, 20.1 mg kg^{-1} and 42.20 mg kg^{-1} respectively. Six treatments comprising *C. ensiformis* incorporation and mulch, each with and without mineral fertilizer and two sets of control (absolute and mineral fertilizer at a rate of 51-30-30 kg NPK ha^{-1}) were used in RCBD with four replicates. Incorporating *C. ensiformis* increased height of pepper by 10mm per day in the first month.

[†]*Corresponding author*

Canavalia ensiformis mulch did not produce significant effect on pepper height. No significant response was observed when fertilizer was added to these treatments relative to the controls. Incorporated *C. ensiformis* also produced significant increase in leaf length (0.58 mm per day) but not in leaf width. The yields from plots treated with inorganic fertilizer applied at 51-30-30 kg NPK ha^{-1} were similar to that from *C. ensiformis* incorporated plots producing an average fresh yield of about 2 t ha^{-1} compared with 1.3 t ha^{-1} from control. The results show that *C. ensiformis* as green manure is equally as effective as inorganic fertilizer at the above rate in increasing yield of pepper. *Canavalia ensiformis* as mulch was not as effective as incorporated manure.

Keywords: *Canavalia ensiformis,* green manure, pepper, rain forest, soil nutrients.

Introduction

Declining soil fertility is a challenge to crop production in developing countries (Kang *et al.*, 1990). Although high crop yield can be obtained with judicious use of inorganic fertilizer, agriculture with high chemical inputs has not been widely adopted in the humid and subhumid tropical Africa. Various factors that have contributed to the low use of fertilizer include scarcity of resources and its increasing costs (Tian *et al.*, 1993; Buckles *et al.*, 1998). Furthermore, heavy reliance on inorganic (mineral) fertilizers tends to favour economically those farmers with large hectarage (Meelu *et al.*, 1994). Other ways to remedy nutrient deficiency and declining soil productivity are to explore natural sources of fertilizers (Gyamfi *et al.*, 2001). Among the natural sources are farmyard manure, compost and green manures. The first two are relatively in limited supply. In Ghana, the relative abundance of farmyard manure is in the urban and peri-urban environs. Additionally, the use of farmyard manure and compost entail transportation and storage problems. The more readily available green manures, therefore, constitute a valuable potential source of N and organic manure (Meelu *et al.*, 1994).

The growth and incorporation of green leguminous crops in the soil (legume green manuring) is a potentially useful means of increasing soil fertility and crop yields. Evans *et al.* (1983) indicated that the use of green manure by small-scale farmers in developing countries would not only increase crop yield many folds, but would also improve physical properties of the soil with minimum environmental risk.

Canavalia ensiformis is one of the effective green manure crops in the rain forest and forest savanna transition zones of Ghana and is ranked second to *Mucuna pruriens* among a number of cover crop and green manure species preferred by farmers (Gyamfi *et al.*, 2001). *Canavalia ensiformis* has been used to increase maize yields as a cover

crop (SFSP, 2000) and as a green manure crop (Agyenim Boateng and Peprah, 2001). At savanna sites in Côte d'Ivoire, incorporation of *C. ensiformis* significantly increased rice yields (Becker and Johnson, 1998). Researchers working with farmers in eastern Uganda to develop alternatives for soil fertility management used *C. ensiformis* among others as green manures in short-term fallows (Fischler and Wortmann, 1997). In Brazil, applying *C. ensiformis* green manure minimized the decrease in base saturation in the plough layer, accumulating between 142 and 280 kg N ha^{-1} (Cahn *et al.*, 1993).

Responses of many crops to green manures have been extensively studied (Hariah and van Noordwijk, 1989; Giller and Wilson, 1991; Meelu *et al.*, 1994; Becker and Johnson, 1998; Agyenim Boateng and Peprah, 2001). However, few vegetable crops such as pepper have been tested with green manures in general and *C. ensiformis* in particular. The objective of this study was to evaluate the response of hot pepper (*Capsicum frutescens*) crop to *C. ensiformis* green manure in the forest zone of Ghana.

Materials and methods

The study was conducted at Kwadaso in the forest zone of Ghana from 1997 to 1999. The soil belongs to Akroso series, classified as Haplic Acrisol in the FAO/UNESCO (1974) classification system. *Canavalia ensiformis* was used as the green manure crop and hot pepper (*Capsicum frutescens*) was the test crop. The experiment was a randomized complete block design with four replications consisting of six treatments:

1. Control (absolute).
2. Mineral fertilizer at a rate of 51-30-30 kg NPK ha^{-1}.
3. *Canavalia ensiformis* incorporation (i.e. buried).
4. *Canavalia ensiformis* incorporation + one-half rate of mineral fertilizer (25-15-15 kg NPK ha^{-1}).
5. *Canavalia ensiformis* mulch (surface applied or non-incorporation).
6. *Canavalia ensiformis* mulch + one-half rate of mineral fertilizer (25-15-15 kg NPK ha^{-1}).

Each plot measuring 8 m x 8 m was planted first using *C. ensiformis* at a spacing of 50 cm x 30 cm at the beginning of the rainy season. The plants were allowed to grow to the flowering stage (42 days after planting) when they were cut and applied either by incorporating into the soil or left on the plots as mulch (i.e. non-incorporation). The fresh biomass was weighed with a spring balance (average weight was 16 t ha^{-1}) and was incorporated with a hand hoe on the same day it was cut. One week after incorporation, three-week old pepper seedlings (var 'Legon red') were transplanted in to the plots at a spacing of 90 cm and 60 cm between and within rows respectively. The mineral fertilizer was applied at the rate of 51-

30-30 kg NPK ha^{-1}; 30 kg ha^{-1} of N, P and K in the form of 15-15-15 NPK compound fertilizer as basal at 7 days after transplanting (DAT) and 21 kg N from sulphate of ammonia (21% N) as topdress at 6 weeks after transplanting (WAT).

Initial and final soil samples were taken before incorporation of the *C. ensiformis* and at the last harvest of the pepper. Soil samples taken from a depth of 0 - 20 cm, were bulked by treatment. All samples were dried, crushed and passed through a 2-mm sieve. The soil parameters determined using methods outlined by Anderson and Ingram (1998) were: pH, total N, organic matter, available P, and K. The growth parameters of the pepper taken in course of growth were plant stand, plant height, basal diameter (girth) of the stem, leaf length and width. Leaf length and width were not measured three months after transplanting since most of the leaves had senesced and dropped. At harvest, ripened fruits were picked, counted and weighed. Both growth and yield parameters were taken from plot sample size of 6 m x 5.4 m. The results were analyzed by using a two-way analysis of variance (ANOVA).

Results and Discussion

Soil chemical properties

The chemical properties of the soil taken are presented in Table 1. The results indicate that the soil is very acidic (pH 4.9) with low fertility levels. Slight improvements in the chemical properties of the soil following the application of *C. ensiformis* were observed. Although not statistically analyzed, the trend indicates that the increase in N levels by *C. ensiformis* (23-30% over control), especially when combined with inorganic fertilizer (30-38.5%), should be noted. These

Table 1. Some chemical properties of the soil (top 0-20 cm).

Time of sampling	*pH (H_2O)*	*Organic matter (%)*	*Total N (%)*	*Available P(mg kg^{-1})*	*K(mg kg^{-1})*
Before *C. ensiformis* establishment	4.9	1.91	0.14	20.10	42.20
At pepper harvest:					
Absolute control	4.8	1.54	0.13	18.10	41.90
Inorganic fertilizer	4.9	1.61	0.16	23.45	39.00
C. ensiformis incorporation	5.1	1.94	0.17	24.25	43.10
C. ensiformis incorporation + fertilizer	5.0	1.96	0.18	26.00	42.60
C. ensiformis mulch	5.0	1.98	0.16	32.25	45.80
C. ensiformis mulch + fertilizer	4.9	1.94	0.17	33.40	46.50

Values were from bulked treatment of samples.

increases might have come from additions through nitrogen fixation and nutrient release during decomposition of biomass. Although N fixation was not measured in this study, *C. ensiformis* is known to fix atmospheric N in the range of 142 and 280 kg N ha^{-1} in tropical soils (Cahn *et al.*, 1993; Hamdi, 1982). Nodulation count of the legume taken at flowering showed that between 31 and 49 nodules per plant were effective. These values are quite high when compared with those of cowpea (Kolawale *et al.*, 2000) and greater than those of *Mucuna pruriens* (Sanginga *et al.*, 1996; Agyenim Boateng, 1997).

The levels of organic matter increase by the green manure crop, especially when applied as mulch, albeit without statistical analysis (Table 1) are important since tropical soils are known to decrease in organic matter once the vegetative cover is removed. There is the need for repeated applications of green manure in order to maintain high levels of organic matter. Agboola and Fayemi (1972) reported that improving or maintaining the levels of organic matter in tropical soils require repeated applications of green manure over a period of time. According to Ranganathan *et al.* (1980) and Agboola and Corey (1973), desirable C contents of tropical lowlands can be achieved only through planned management of humus. Available P and K also recorded some increases probably through phosphorus assimilation during growth and mineralisation during decomposition as noted by Kotschi and Muller-Samann (1994). Agboola and Fayemi (1972) concluded that legumes were able to keep phosphorus in an available state, protecting it from mineral fixation.

The relatively greater values of the mulch treatments than the incorporation may be attributed to the relative slowness of release of nutrients from mulch materials since their decomposition is slower than incorporated materials. Most incorporated green manure materials decompose and mineralize to release their nutrients usually between 3 and 6 weeks (Arakeri *et al.*, 1962; Lalljee and D'costa, 1995) which may then be taken up by the pepper plant; some may be leached or rendered unavailable. All these processes would invariably reduce the level of the nutrients remaining in the soil after pepper harvest.

Growth response of pepper

The effects of *C. ensiformis* on some growth attributes of pepper are presented in Table 2 - Table 4. Table 2 shows that during the first month, general height growth increase was slow compared to during the last two months. Height response due to *C. ensiformis* incorporation with and without fertilizer was significantly different from the control and the inorganic fertilizer in the first month. There was, however, no difference between *C. ensiformis* with

Table 2. Effect of treatments on height of pepper at 38 and 98 days after treatment (DAT).

Treatment	*8 DAT (cm)*	*38 DAT (cm)*	*Height increase per day*	*98 DAT (cm)*	*Height increase per day*
Control	17.05a	18.50a	0.05	61ab	0.71
Inorganic fertilizer	17.88a	20.28a	0.08	70b	0.73
C. ensiformis incorporation	20.80a	24.13b	0.10	65ab	0.68
C. ensiformis incorporation + fertilizer	21.95a	25.80b	0.13	67b	0.69
C. ensiformis mulch	18.85a	21.08ab	0.08	58a	0.62
C. ensiformis mulch + fertilizer	17.45a	19.02a	0.05	66b	0.78
LSD (p =0.05)	5.10	4.98		8.0	

Means in the same column followed by different letters are significantly different.

and without fertilizer. There was marked improvement in height growth for all the treatments in the last two months. Sole inorganic fertilizer produced the tallest plants (70 cm) but was not statistically different from the others. The addition of inorganic fertilizer to *C. ensiformis* incorporation produced a negligible effect.

On the other hand, there was significant effect due to the inorganic fertilizer on *C. ensiformis* mulch which culminated in the largest growth increase in the last two months of growth. Without the inorganic fertilizer, the mulch alone registered the lowest values during this period. Agyenim Boateng (1999), working with *Mucuna pruriens* on maize, reported that there was no significant difference in height between green manured and mulched plants, except that the mulch alone produced shorter plants. He also reported that addition of inorganic fertilizer to *M. pruriens* green manure did not produce as significant change in height as the surface applied, which is consistent with the findings of the current study. Incorporated *C. ensiformis* produced significantly bigger girth growth than the control in the first month. After 90 days of growth, however, there was no significant difference among treatments, except the mulch (Table 3). A similar trend in the height growth increase of the mulch plus fertilizer treatment was also observed for the girth growth increase.

There was no clear difference in leaf width in the first month (Table 4). Differences, however, existed in the leaf length. Incorporation with and without fertilizer produced significantly longer leaves and correspondingly greater leaf growth increase than the control. The addition of inorganic fertilizer to both incorporation and mulch did not have any significant effect.

Table 3. Effect of treatments on girth of pepper at 38 and 98 days after treatment (DAT).

Treatments	*8 DAT (mm)*	*38 DAT (mm)*	*Girth increase per day (mm)*	*98 DAT (mm)*	*Girth increase per day (mm)*
Control	2.8	3.1 a	0.01	13.0 b	0.17
Inorganic fertilizer	2.8	3.6 ab	0.03	15.1 b	0.18
C. ensiformis incorporation	3.0	4.1 b	0.04	15.8 b	0.18
C. ensiformis incorp + inorg. fert.	3.2	3.8 ab	0.02	12.7 ab	0.17
C. ensiformis mulch	2.2	3.6 ab	0.05	11.0 a	0.11
C. ensiformis mulch + inorg. fert.	2.3	3.1 a	0.03	14.3 b	0.19
LSD (p=0.05)	0.8	0.8	3.2		

Means in the same column followed by different letters are significantly different.

Table 4. Effect of treatments on leaf length of pepper at 8 and 38 days after treatment (DAT).

Treatments	*Leaf length (cm)*		*Difference*	*Leaf width (cm)*		*Difference*
	8 DAT	*38 DAT*	*in length (cm)*	*8 DAT*	*38 DAT*	*in width (cm)*
Control	4.26 a	5.32 a	1.06	2.05 a	2.91 a	0.86
Inorganic fertilizer	4.30 a	5.79 ab	1.48	2.19 ab	2.92 a	0.73
C. ensiformis incorporation	4.63 ab	6.36 b	1.73	2.32 ab	3.04 a	0.94
C. ensiformis incorp + inorg. fert.	5.27 b	6.54 b	1.59	2.70 b	3.40 a	0.69
C. ensiformis mulch	4.37 a	5.96 ab	1.26	2.29 ab	3.13 a	0.85
C. ensiformis mulch + inorg. fert.	4.22 a	5.51 ab	1.28	2.04 a	2.84 a	0.80
LSD ($p = 0.05$)	0.72	1.00		0.54	0.80	

Means in the same column followed by different letters are significantly different.

Yield response

Fresh yields of pepper fruits harvested are presented in Table 5. *Canavalia ensiformis* incorporation as well as inorganic fertilization increased the number and weight of fruits. The green manure was as effective as the inorganic fertilizer. Increase in fruit numbers by the incorporated green manure over control was about 36% and an additional 17% due to the added inorganic fertilizer. Significant fruit numbers were also obtained from *C. ensiformis* mulch combined with inorganic fertilizer, yielding nearly 50% higher than the control. Sole *C. ensiformis* mulch performed just as good as the control. As much as 39% increase due to the inorganic fertilizer effect was obtained.

The green manure increased pepper fruit weight by more than 0.6 t ha^{-1}(i.e. 50%) when alone and by about 1.0 t ha^{-1} in combination with fertilizer (75% increase). Many research workers have reported considerable increases in crop yields with green manure (Kang *et al.*, 1981; Ogbonna and Mabbayad, 1983; Hairiah and Noordwijk, 1989; Giller and Wilson, 1991; Meelu *et al.*, 1994). Specifically, *C. ensiformis* green manure has produced significant improvements in crop yields, particularly, maize (Carsky, 1989; Meelu *et al.*, 1994; Agyenim Boateng and Peprah, 2001). This effect is probably due to the N contribution, but the favourable effects of the organic matter addition and mobilization of other nutrients cannot be overlooked (Meelu *et al.*, 1994).

As in the case of the growth parameters, yield increase due to the effect of mulch was significant only when used in combination with inorganic fertilizer. The poor performance of *C. ensiformis* mulch on growth and yield of pepper may probably be due to late decomposition of the mulch material

Table 5. Effect of treatments on fresh yields of pepper at harvest.

Treatments	*Fruit number (No. ha^{-1})*	*Fruit weight (t ha^{-1})*
Control	777,448 a	1.29 a
Inorganic fertilizer	1,265,625 b	2.20 b
C. ensiformis incorporation	1,265,625 b	1.93 b
C. ensiformis incorp + inorg. fert.	1,237,031 b	2.25 b
C. ensiformis mulch	832,396 ab	1.58 a
C. ensiformis mulch + inorg. fert.	1,155,781 b	2.18 b
LSD	351,256	0.63

Means in the same column followed by different letters are significantly different.

hence, late mineralization of its nutrients and their subsequent uptake by the pepper crop as evidenced by relatively greater amounts of nutrients after crop harvest (Table 1). This observation implies that it may not be necessary to add inorganic fertilizer to *C. ensiformis* when used as green manure, whereas the addition of fertilizer should be considered when used as mulch in order to achieve comparatively greater yields of pepper. Further investigation to substantiate these findings is needed.

Conclusion

Incorporating *C. ensiformis* significantly increased height, girth and leaf length of pepper resulting in 50% increase in yield over control. The effect of the mulch was remarkable when used in combination with inorganic fertilizer. *Canavalia ensiformis* green manure was equally as effective as inorganic fertilizer in enhancing growth and improving fruit yield of hot pepper in the forest zone of Ghana.

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