African Journal of Environmental Science and Technology Vol. 3 (10), pp. 326-331, October, 2009
Available online at http://www.academicjournals.org/AJEST
DOI: 10.5897/AJEST09.028
ISSN 1996-0786 © 2009 Academic Journals

Full Length Research Paper

Effect of site characteristics on the productivity and economic returns from cassava legume intercropping in Ghana

J. O. Fening[1]*, T. Adjei Gyapong[2], F. Ababio[1] and E. Gaisie[1]

[1]Soil Research Institute, Academy Post Office, Kwadaso-Kumasi, Ghana.
[2]Department of Crop and Soil Sciences, Faculty of Agriculture. CANR, KNUST, Kumasi, Ghana.

Accepted 7 September, 2009

In a 2-year field study, cassava was intercropped with four legumes (cowpea, pigeon pea, soyabean and *Stylosanthes* at three locations with different soil and environmental conditions, to determine the effect of site characteristics on the agronomic and economic advantage of the intercrop. The trial was a factorial experiment in a split plot design with three replications. A cost benefit analysis was conducted for the trial on the different crop arrangements. Root yield of cassava in the mixed cassava legume treatment across location during the first year was significantly higher ($p < 0.05$) compared to the stripped treatment. Root yield of cassava cowpea mixed intercrop for example ranged from 38 to 88 t/ha. In the second year however, considerable variations were observed among the treatments with NPK treatment giving the highest yield of 84 t/ha. This influenced the overall economic net benefits and showed that the intercrop advantage depended on the interaction of component crops, the growth environment and to some extent agronomic manipulations, suggesting that the best combination of crops under a particular system of management in one environment with a particular set of climate and soil conditions may not necessarily be suitable in another environment.

Key words: Cassava, economic returns, intercropping, productivity.

INTRODUCTION

Several improved varieties of cassava have been introduced to the Ghanaian farmer in recent years through the Roots and Tuber Improvement Programme of the Ministry of Food and Agriculture, funded by the International Fund for Agricultural Development. Under optimal conditions these varieties can yield 30 t/ha and takes as much as 125, 30 and 150 Kg NPK/ha from the soil (Sys et al., 1993; Fening et al., 2005). This can deplete the soil of its nutrients and diminish the economics of the expansion drive in cassava production. To prevent this will require that some sustainable soil fertility measures that are practically cost effective and attractive to farmers are put in place, or else all the efforts in the development of these high yielding varieties will not be of much benefit to the farmer. The use of chemical fertilizers seems by far the most appreciated form of soil fertility restoration by the farmer. Its high cost however, limits its wide application by peasant farmers who constitute over 70%. Considerable increase in cassava production can also be achieved through the use of manure alone or in combination with mineral fertilizers (Fening et al., 2005). Sources of manure are however severely limited. Besides carting of manure to farm site, labour for application also increases the production cost. An alternative system of widespread practice in tropical agriculture is intercropping, where two or more crops are grown simultaneously on the same field and there are several types including mixed, row, strip and relay (Francis, 1986).

A lot of research efforts have been directed to intercropping methods that will increase the agronomic advantage by minimizing intercrop competition and enhancing complementary utilization of limited growth factors. Hildebrand (1976) suggested that the unit for measuring intercropping advantage must be meaningful to the farmer in such a way that it helps him to allocate

*Corresponding author. E-mal: kofifening@yahoo.com. Tel: 233 51 50353. Fax: 233 51 50308.

his limited resources among competing ones. Regardless of this, it is ultimately the farmer who selects what plant species will be intercropped and how each mixture will be managed. Farmers in Ghana allocate optimum space to cassava as a major economic crop in intercropping systems. Minor crops with relatively lower monetary value ha^{-1} such as pepper, okro, cocoyam, maize, cowpea and other vegetables are introduced in the early growth stage to complement in the utilization of growth resources. Although total productivity of an intercropping system can be greater, productivity of at least one or even both components can be influenced by the soil type or climatic conditions or both (Fukai and Trenbath, 1993). Understanding the effect of soil and climatic conditions on the yield components of intercropping systems will therefore be useful to crop improvement programmes, since it is necessary and obvious that yield reduction of component crops due to intercropping should be minimized.

MATERIALS AND METHODS

The study was undertaken between 2003 and 2005 under rain fed conditions at three sites, Kwadaso, (6° 40' N, 1° 40' W) in the forest zone, Mampong (7° 2.5' N, 1° 22' W) in the forest savanna transition zone, and Wenchi (7° 44' N 2° 7' W) in the guinea savanna zone. Annual precipitation for Kwadaso is 1450 mm with peaks in June and September. Mampong and Wenchi receive between 1300- 1400 mm and 1100 – 1200 mm respectively. The test legumes were cowpea (*Vigna unguiculata* L) soybean (*Glycine max*) Pigeon pea (*Cajanus cajan*), and *Stylosanthes guinensis*. These legumes are commonly grown by farmers for food and for improving the fertility of the soil.

Composite top soil (0-15 cm) samples were taken from each experimental site at the beginning and end of the study. In each plot, soil was collected and bulked from three locations, air dried and sieved to pass through a 2-mm mesh. Soil pH was determined in H_2O (glass electrode method), organic carbon (the dichromate-oxidation method of Walkley-Black (1934) and total N by the method of Keeney and Nelson (1982). Available P and K by Bray 1 (Bray and Kurtz, 1945). The exchangeable bases were determined in neutral ammonium acetate (Anderson and Ingram, 1993). Calcium and magnesium were determined by titration with 0.02 N EDTA and sodium and potassium in neutral ammonium acetate extract by flame photometry. Exchangeable acidity (Al + H) (cmol (+)/kg soil) was determined by titration in 1.0 N potassium chloride extract. Particle size analysis was determined by the pipette method (Gee and Bauder, 1986). Soil bulk density was determined with a metal core sampler (Blake and Harte, 1986).

The trial was a factorial experiment in a split plot design with three replications. There were two factors; (i) Legumes cowpea (*V. unguiculata* L. var. Amantin), soyabean (*G. max* L. var. Bengbla), pigeon pea (*C. cajan*) and *S. guianensis* L.), and (ii) Crop management (strip and mixed intercropping). Main plot size was 20 x 12 m and subplots 20 x 6 m with strips of 5 x 6 m. Cassava variety (TEK bankye), duration 12 months was the main crop and the legumes strip-intercropped or mixed-cropped. Each crop strip was rotated with the associated intercrop in a 1-year rotation cycle. Cassava was planted at a spacing of 1 x 1m. During the second year NPK (60-40-40) treatment was imposed on the sole cassava plots. Soybean and *Stylosanthes* were drilled along rows spaced at 75 cm apart and thinned to 5 cm apart within rows. On the strips samples for harvestable yields were taken from the middle strip (5 x 4m). In the mixed intercropped, cassava legume row spacing was 0.5 m while legume - legume spacing was 1 m apart. The intra row spacing was 1 m for pigeon pea, 20 cm for cowpea and 10 cm for soybean and *Stylosanthes.* Yields of cassava roots (fresh weight) were measured at harvest. Harvested pods of the legumes were air dried and hand shelled and grains oven dried to 15 % moisture content.

A partial budget analysis for the various yields was conducted following the procedure of Alimi and Manyong (2000). The budget for the different treatments was based on marketable output with yields adjusted by 20% to allow for field losses under farmers' conditions. Farm gate prices were used for the inputs, planting materials, mineral fertilizer and insecticides. No consideration was given to the economic benefits related to residual soil fertility.

Data analysis

The data for the soil chemical properties were averaged and standard deviation computed. The yields of cowpea and soybean were summed over two seasons to obtain the time equivalent of a single crop of cassava and pigeon pea. Analysis of variance was conducted on data obtained using SAS (SAS Institute Inc, 1995) and significant means were separated using Duncan's New Multiple Range Test.

RESULTS AND DISCUSSION

Chemical properties of soils

A summary of the analytical results on the chemical characteristics of the soils of the three sites is presented in Table 1.The soil pH was moderately acid to acid at all the site, ranging from 5.6 to 6.0. Soil organic carbon content was in the range of 1 – 2% at Kwadaso becoming occasionally high (> 2 %) in some plot. At Mampong the values were medium averaging 1.5 %, while at Wenchi, the levels were generally low with values below 1%. Total nitrogen levels ranged from low (0.6%) at Wenchi to medium (0.15) at Kwadaso. Cation exchange capacity (CEC) was low to medium at Kwadaso and Mampong but generally low at Wenchi. Exchangeable calcium (Ca^{++}) was generally low, while that of magnesium (Mg^{+}) was generally high in all the soils. Available potassium was observed to be high in all the soils with levels above 50 mg kg^{-1} soil. The soils at Kwadaso and Mampong - Haplic Lixisol and Chromic Lixisols (FAO, 1998) respectively had no physical limitations. The soils at Wenchi, was a Plinthosol (FAO, 1998) and had weak fine granular topsoil containing few ferruginized sandstone fragments, few fine and medium angular quartz gravels and common hard iron and manganese concretions. The prevailing nutrient levels and physical conditions were not a limitation for growth of cassava and the legumes (Sys et al., 1993), however for sustainable crop production they will require some management practices.

Cassava root yield

Sole cassava root yield at all the sites was high during the first year (Table 2a), which confirms the assertion of Sys et al. (1993), that cassava usually gives higher root yields on freshly cultivated fields which provide optimum

Table 1. Selected Chemical properties of soils at the three sites

Location	PH (H_2O) 1:01	Organic Carbon (%)	Total Nitrogen (%)	Exchangeable basic cations (cmol+ kg^{-1} soil)				TEB (cmol+kg^{-1} soil)	Exch acidity (cmol+kg^{-1} soil)	ECEC (cmol+/ kg soil)	Base Saturation	Available Bray,s (mg kg^{-1} soil)	
				Ca^{++}	Mg^{++}	K^{+}	Na^{+}		Al^{+++} + H^{+}			P	K
Kwadaso	5.99[1] (0.17)[2]	1.89 (0.21)	0.15 (0.01)	7.52 (1.33)	1.42 (0.21)	0.62 (0.09)	0.19 (0.04)	9.75 (1.46)	0.10 (0.01)	9.85 (1.46)	98.91 (0.27)	25.07 (9.54)	128.97 (31.57)
Mampong	5.77 (0.20)	1.54 (0.17)	0.14 (0.02)	6.88 (1.08)	1.90 (0.42)	0.37 (0.06)	0.08 (0.02)	9.32 (1.22)	0.06 (0.03)	9.31 (1.18)	99.34 (0.49)	5.42 (2.71)	185.00 (106.74)
Wenchi	5.61 (0.16)	0.70 (0.20)	0.06 (0.02)	3.26 (0.39)	1.12 (0.55)	0.10 (0.03)	0.06 (0.03)	4.54 (0.70)	0.07 (0.03)	4.61 (0.70)	98.48 (0.76)	6.37 (2.07)	56.76 (26.12)

[1]Value represent averages.
[2] Values in brackets indicate standard deviations

Table 2a. Cassava root yields (t/ha).

Year	2004			
Treatment	**Kwadaso**	**Mampong**	**Wenchi**	**Main plot treatment (mean)**
Stylosanthes mixed	34.43	7.63	10.33	17.47
Stylosanthes strip	34.13	20.77	24.43	26.44
Soya mixed	68.13	30.27	39.07	45.82
Soya strip	32.47	19.83	19.00	23.77
Cowpea mixed	88.73	38.10	48.23	58.36
Cowpea strip	36.50	19.70	27.57	27.92
Pigeon pea mixed	51.367	15.267	22.37	29.67
Pigeon pea strip	34.27	19.80	18.27	24.11
Control	85.30	44.07	52.67	60.68
Sub plot treatment (mean)	54.93	27.24	29.93	
Lsd (0.05)	3.37	3.33	3.07	3.29
Std Error	4.26	2.65	2.40	1.63
CV (%)	4.14	7.14	6.09	8.21

Table 2b. Cassava root yields (t/ha).

Year	2005			
Treatment	**Kwadaso**	**Mampong**	**Wenchi**	**Main plot treatment (mean)**
Stylosanthes mixed	31.17	39.17	41.87	37.40
Stylosanthes strip	47.00	34.00	40.00	40.33
Soya mixed	62.63	50.17	18.30	43.7
Soya strip	38.00	21.03	18.13	25.72
Cowpea mixed	64.23	30.23	19.07	37.84
Cowpea strip	38.00	32.33	34.00	34.78
Pigeon pea mixed	40.63	22.30	30.37	31.10
Pigeon pea strip	34.93	27.83	33.77	32.18
Control	53.00	36.83	16.00	35.28
NPK	84.00	57.00	33.00	58.00
Sub plot treatment (mean)	49.36	35.09	28.45	
Lsd (0.05)	5.65	5.61	5.48	5.10
Std Error	2.97	2.07	1.78	2.52
CV (%)	6.72	9.38	11.31	8.21

nutrient requirements. Cassava mixed intercropped with *Stylosanthes* and pigeon pea consistently resulted in lower cassava root yield at all the sites during the first year (Table 2a). This was evident by a more luxuriant growth of *Stylosanthes* and pigeon pea that out competed the cassava plants. Cassava mixed intercropped with soybean and cowpea resulted in a significantly ($p < 0.05$) higher root yield compared to stripped intercropped. May be the time period for further growth after the harvest of the first crops of cowpea and soyabean ensured good recovery and full use of available resources. On the other hand cassava stripped intercropped with *Stylosanthes* or pigeon pea yielded better probably because of reduced competition and improved spatial and temporal complementarity (Table 2a). The disparity may also indicate a substantial agronomic advantage of strip intercropping, which facilitates better field operations and enhance light energy utilizetion that translated into increase crop yield. Across locations the mixed legume treatments generally showed significantly higher cassava root yields compared to the stripped treatments with the exception of *Stylosanthes* (Table 2a). Grain yield of stripped soyabean, cowpea and pigeon pea consistently yielded better than the counterpart mixed-intercropped at all the sites probably because of agronomic advantage that guaranteed two croppings per annum as well as reduced competition with cassava.

Considerable variations were observed among the treatments during the second year and none of the treatments gave a consistent trend of intercrop advantage (Table 2b). At Kwadaso, NPK (60 – 40 – 40) gave the highest root yield (84 t/ha), followed by cassava - cowpea and soyabean mixed intercrop (64 t/ha), sole cassava, pigeon pea mixed then *Stylosanthes* mixed. At Mampong, root yield of cassava was in the order NPK > cassava soyabean mixed > sole cassava and *Stylosanthes* mixed > cassava cowpea mixed > cassava pigeon pea mixed. Root yield of cassava at Wenchi on the other hand followed the order *Stylosanthes* mixed > NPK and pigeon pea mixed > cowpea mixed > soyabean mixed and sole cassava. In the second year also the legume stripped treatments generally showed higher cassava root yields, even though in most cases the yields were not significantly different (Table 2b). At Kwadaso however, the mixed intercropped gave significant higher cassava root yields except that with *Stylosanthes*. Agronomic manipulation in favour of cassava in the cassava *Stylosanthes* and pigeon pea mixed intercrop improved the productivity of cassava only at Wenchi, probably because the physicochemical properties of the soil at Wenchi might have been improved by *Stylosanthes* and pigeon pea residues. That of *Stylosanthes* is worth noting because there was a four fold increment in root yield. Similar results have been reported by Ofori and Stern (1987), and Hiebsch and McCollum (1987). Root yield of sole cassava at Wenchi also showed a yield decline of over 50% which suggests that continuous cropping of cassava without soil fertility restoration interventions, should be discouraged. *Stylosanthes* strips showed a consistent higher cassava root yield at all the locations, suggesting that the preferred arrangement for cassava and *Stylosanthes* will be strip rotation intercrop. Grain yield of the legumes in the stripped intercrop was greater than the counterpart mixed-intercropped at all locations probably because of reduced competition and better utilization of resources (Tables 3a and 3b).

Financial analysis

The results of gross margin analyses over the two cropping cycles (2003 –2004) showed that Kwadaso has com-

Table 3a. Legume grain yields (t/ha).

Year	2004			
Treatment	**Kwadaso**	**Mampong**	**Wenchi**	**Main treatment mean**
Stylosanthes mixed	0.00	0.00	0.00	0.00
Stylosanthes strip	0.00	0.00	0.00	0.00
Soya mixed	0.00	0.51	0.50	0.50
Soya strip	0.00	1.17	1.27	1.19
Cowpea mixed	0.20	0.30	0.20	0.23
Cowpea strip	1.00	0.80	0.90	0.90
Pigeon pea mixed	0.60	0.81	0.81	0.74
Pigeon pea strip	0.80	0.80	0.80	0.80
Control	0.00	0.00	0.00	0.00
NPK	0.00	0.00	0.00	0.00
Sub treatment (means)	0.42	0.44	0.45	
Lsd (0.05)	0.16	0.06	0.07	0.06
Std Error	0.08	0.03	0.02	0.03
CV (%)	22.39	7.71	5.78	10.20

Table 3b. Legume grain yields (t/ha).

Year	2005			
Treatment	**Kwadaso**	**Mampong**	**Wenchi**	**Main plot treatment (mean)**
Stylosanthes mixed	0.00	0.00	0.00	0.00
Stylosanthes strip	0.00	0.00	0.00	0.00
Soya mixed	0.40	0.00	0.40	0.27
Soya strip	1.05	0.93	0.60	0.86
Cowpea mixed	0.30	0.60	0.20	0.37
Cowpea strip	0.70	0.70	0.50	0.63
Pigeon pea mixed	0.90	0.30	0.70	0.63
Pigeon pea strip	0.72	0.69	0.70	0.70
Control	0.00	0.00	0.00	0.00
NPK	0.00	0.00	0.00	0.00
Sub plot treatment (means)	0.41	0.40	0.31	
Lsd (0.05)	0.06	0.07	0.07	0.03
Std Error	0.03	0.03	0.03	0.02
CV (%)	8.48	10.23	11.39	10.20

parative advantage for cassava production (Table 4). NPK treatment had the highest net benefit (US$ 1578.95), followed by cassava - cowpea and soya bean mixed intercrop (US$ 1400.00), then absolute control (US$ 1052.63). Cassava mixed intercropped with *Stylosanthes* showed the lowest (US$ 294.74) total net benefit. At Mampong cassava soyabean –mixed intercrop gave the highest net benefit of US$ 789.47, cassava soya strips US$ 652.63, NPK US$ 557.89 and absolute control US$ 336.84. The remaining treatments had net benefits lower than US$ 315.79. At Wenchi, net benefit was in the order cowpea and pigeon pea strip intercropped (US$ 463.16) > pigeon pea mixed and *Stylosanthes* strip (US$ 368.42) > *Stylosanthes* mixed US$ 336.84). Fertilizer (NPK) application in the second year did not give much net benefit (< US$ 105.26).

The variable responses obtained for the different intercrop arrangements makes blanket recommendations of cassava legume intercrop uneconomical. This indicates that intercrop productivity may depend on component crops, the growth environment that is climate and soil and to some extent agronomic manipulations.

The interaction of these factors should be optimized so that the limiting resource is utilized most effectively.

Table 4. Partial budget analyses of cassava – legume intercropping systems (2003 -2005) (US$).

Treatment	Kwadaso			Mampong			Wenchi		
	Total income	Total variable input cost	Net benefit	Total income	Total variable input cost	Net benefit	Total income	Total variable input cost	Net benefit
Stylo mixed	978.95	684.21	294.74	821.05	547.37	273.68	884.21	547.37	336.84
Soya mixed	2294.74	968.42	1336.84	1600.00	810.53	789.47	957.89	810.53	147.37
Cowpea mixed	2400.00	1010.53	1400.00	1136.84	852.63	284.21	968.42	852.63	115.79
Pigeon pea mixed	1494.74	684.21	810.53	715.79	547.37	168.42	926.32	547.37	168.42
Stylo strip	1315.79	694.74	621.05	842.11	610.53	231.58	989.47	610.53	368.42
Soya strip	1884.21	957.89	926.32	1557.89	894.74	652.63	1021.05	894.74	115.79
Cowpea strip	1800.00	989.47	810.53	1368.42	926.32	452.63	1357.89	905.26	452.63
Pigeon pea strip	1210.53	684.21	526.32	863.16	631.58	231.58	1094.74	631.58	463.16
Control	1905.26	852.63	1052.63	1126.32	789.47	336.84	800.00	789.47	21.05
NPK	2568.42	1000.00	1578.95	1494.74	936.84	557.89	1136.84	926.32	200.00

Exchange rate at time of experiment: 1US$ = ¢ 9500.

REFERENCES

Alimi T, Manyong VM (2000). Partial budget analysis for on-farm research. Int. Inst. Trop. Agric. Res. Guide 65.

Anderson JM, Ingram JSI (1993). Tropical Soil Biology and Fertility: A Handbook of Methods. CAB Int.; Wallingford, U.K.

Blake GR, Harte KH (1986). Bulk density. Physical and Mineralogical Methods of Soil Analysis. Part 1. In: Klute A, (eds) Agronomy Monograph No. 9. American Society Agronomy and Soil Science Society in America Madison, Wisconsin.

Bray RH, Kurtz LT (1945). Determination of total, organic and available forms of phosphorus in soils. Soil Sci. 59: 39-45.

FAO (1998). World reference base for soil resources. World Soil Resources Report 84. Rome: FAO.

Fening JO, Adjei Gyapong T, Ampontuah EO, Yeboah E, Gaisie E (2005). Fertilizing for profit: the case of cassava cultivation in Ghana. Trop. Sci. 45: 97 – 99.

Francis CS (1986). Introduction: distribution and importance of multiple cropping. In Francis C S (eds) Multiple Cropping Systems, New York, USA: Macmillan Publishing Company pp.1-10.

Fukai S, Trenbath BR (1993). Processes determining intercrop productivity and yield component crop. Field Crops Res. 34: 247 – 271.

Gee GW, Bauder JW (1986). Particle size analysis. Methods of Soil Analysis, Part 1: In Klute A, (eds) Physical and mineralogical Methods. Agronomy Monograph No. 9. America Society, Agronomy and Soil Science Society America, Madison, Wisconsin.

Hiebsch CK, McCollum RE (1987) Area – X- time equivalency ratio: A method for evaluating the productivity of intercrop. Agron. J. 79: 15 – 22.

Hildebrand PE (1976). Multiple cropping systems are dollars and "sense" agronomy. In: Stelly M S, Kral D M, Eisele L C, Nanseef J (eds.) Multiple Cropping. American Society of Agronomy (ASA) Special Publication number 27: 347-371.

Keeney DR, Nelson DW (1982). Nitrogen – Inorganic forms. Methods of soil analysis part-2. In Page AL, Miller RH, Keeney DR, (eds.) Madison, Wisconsin, USA: Am. Soc. Agron. pp. 643-698.

Ofori F, Stern WR (1987). Cereal-legume intercropping systems. Adv. Agron. 41: 41 -90.

SAS Institute (1995). SAS/Stat users Guide, version 6.1. SAS Institute, Cary, NC USA.

Sys CE, Van R, Debaveye J, Beernaert F (1993). Land Evaluation Part III. Crop requirements. Agric. publications No.7. General Administration for Dev. Co-operation, Brussels, Belgium.

Walkley A, Black IA (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic and titration method. Soil Sci. 37: 29-38.