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Food crop intercropping alternatives for replanting coconut farms destroyed by lethal yellowing disease

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Abstract

A two-year (2006-2008) study involving coconut - cassava and coconut - plantain as food crop intercropping alternatives for revamping the coconut industry of Ghana which has been hampered by Lethal Yellowing Disease (LYD) was conducted in eight locations in the Central and Western regions of Ghana. The locations were Antado, Kissi and Ayensudo in the Central Region and Tumentu, Nvuma, Aiyinase, Menzezor and Nuba in the Western Region. Both cassava as an intercrop in coconut production and integrated pest management of plantain in coconut-plantain intercrop studies were established in 2006. In each study, the experimental design was split plot with age of coconut (0-2 year old LYD tolerant hybrid 'MYD x VTT' and 40-45 year old 'WAT' coconut) as main plot and 5 cropping systems as subplots, with three replications. The objective was to develop biologically efficient and more profitable intercropping systems of coconut and food crops, mainly cassava and plantain. The study indicated that young coconut plantings may be intercropped with cassava with fertilizer application of 30 - 45 - 45 kg ha^{-1} N - P_2O_5 - K_2O or plantain using pared planting material treated with 15 ml l^{-1} chlorpyrifos insecticide (Dursban 4E) per litre of water. These coconut - food crop intercropping systems showed biological compatibility in that they did not affect the vegetative development of young coconut significantly ($P<0.05$), had minimal levels of major diseases and pests, produced high cassava yield (mean of 35.3 t ha^{-1}) and plantain yield (mean of 2.9 t ha^{-1}) and high economic returns with a value cost ratio of 5 for cassava. In mature coconut plantings, mean yield of cassava was 11.6 t ha^{-1} while plantain could not thrive due to adverse effect of competition for light and probably root competition. This was an indication of coconut age being a significant factor in food intercrop performance. Replanting of coconut with LYD tolerant hybrid could be boosted by intercropping with pared plantain planting material treated with chlorpyrifos insecticide and intercropping with cassava with minimum fertilizer application.

Key words: Cassava, chlorpyrifos, economic returns, fertilizer, plantain.

Introduction

The coconut industry of Ghana has been under a devastating threat by a Lethal Yellowing Disease (LYD) known locally as Cape St Paul Wilt Disease (CSPWD). The disease has destroyed a large area of coconut plantings estimated at 11,000 ha as at 2001 [3] and affected farmers are in untold economic hardships. Currently, the disease is being contained, however, fields already devastated need to be replanted with tolerant coconut varieties. In 1999, Malayan Yellow Dwarf cross Vanuatu Tall (MYD x VTT) coconut hybrid was recommended to the Coconut Sector Development Project (CSDP) for replanting of devastated coconut fields. The hybrid was identified in an earlier resistance screening work to have moderate tolerance to CSPWD and good agronomic characters. For successful management of MYD x VTT coconut hybrid, however, there was the need for suitable cropping systems involving the hybrid [2].

Intercropping is a major cropping system for coconut cultivation in coconut producing countries worldwide [9, 8]. In the Philippines, 60 to 70% of estimated 3.1 million hectares of coconut is intercropped with recommended crops including bananas and cassava [9]. Root and tuber crops are among the popular intercrops in all coconut growing countries because they constitute a major food source for the communities and require minimum inputs [10]. Plantain/banana intercrops are reported to be one of the most profitable coconut intercrops [10]. The suitability of food crop and non-food crop intercrop in coconut is also well established [1, 10, 14, 15] and attributed mainly to the complementary use of incident photosynthetic active radiation, soil nutrients and water. Better weed management in coconut - food crop intercrops has also been cited [12] as a key contributor to the higher productivity and greater economic returns from the coconut - food crop intercrops than mono - crop coconut.

According to a survey report [11], 99% of young coconut plantings in the coconut belt of southern Ghana were intercropped with food crops. However, farmers hardly apply fertilizers to food crop intercrops, unless vegetables were involved. Cassava intercrop was planted year to year in the same hole. Planting covered all interspaces up to the foot of coconut plantings, resulting in keen competition between coconut and intercrops. Plantain is usually

not intercropped with coconut in Ghana. As a crop, plantain suffers black sigatoka attack, nematode and weevil infestation leading to poor bunch yield. Consequently, a study involving 2 trials was initiated in 2006 to develop biologically efficient and more profitable intercropping systems of coconut and food crops, mainly cassava and plantain. The specific objectives were to 1) develop an integrated pest management (IPM) system for plantain intercrop in coconut, 2) determine optimum fertilizer regimes for cassava intercrop in coconut and 3) maximize financial returns from coconut - cassava intercropping system.

Materials and Methods

Experimental site and design: The study was carried out from 2006 to 2008 in 2 separate trials involving 8 farmer fields at different locations in the coconut belt of Western and Central Regions of Ghana. The locations were Antado, Kissi and Ayensudo in the Central Region and Tumentu, Nvuma, Aiyinase, Menzezor and Nuba in the Western Region. The 2 trials were coconut - cassava and coconut - plantain intercropping systems. Each trial was replicated twice in a split plot design with age of coconut as main plots: 0 - 2 year old (young coconut palms) and 40 - 45 year old (old coconut palms) and 5 cropping systems as subplots. The cropping systems for the coconut - cassava trial were: (i) Monocrop cassava without fertilizer, (ii) Monocrop coconut, (iii) Coconut + Non-fertilized cassava intercrop, (iv) Coconut + Fertilized cassava intercrop 30-45-45 kg ha^{-1} N-P_2O_5-K_2O (Fertilizer 1), (v) Coconut + Fertilized cassava intercrop 60-45-90 kg ha^{-1} N-P_2O_5-K_2O (Fertilizer 2). For coconut - plantain trial they were: (i) Monocrop plantain, (ii) Monocrop coconut, (iii) Coconut + Non - IPM plantain intercrop, (iv) Coconut + Dursban - treated plantain intercrop (IPM), (v) Coconut + plantain intercrop in *Pueraria phaseoloides* [(Roxb) Benth] cover crop. Main plot size was 74.0 m x 42.5 m and subplot was 42.5 m x 14.8 m.

Coconut plantings: The young coconut plantings were MYD x VTT coconut hybrid planted at 8.5 m triangular spacing with vertical inter-rows of 7.4 m wide. The old coconut plantings were West African Tall (WAT) variety planted rectangular with average spacing of 7.7 m between rows and 8.8 m within rows. The young coconut plantings were fertilized in the first year of the study but the old coconut plantings were not. Urea was applied at N 68 g $palm^{-1}$, triple superphosphate (TSP) at P_2O_5 92 g $palm^{-1}$, muriate of potash (MOP) at K_2O 180 g $palm^{-1}$ and magnesium sulphate ($MgSO_4$) at MgO 54 g $palm^{-1}$ for palms under one year old and twice the rate for two year-old palms.

Cassava and plantain intercrops: Cassava and plantain intercrops were planted in the vertical inter-rows of coconut palms. The cassava variety was 'CRI Agbelifia', a moderately branching type with maturity period of 15 months. Planting was spaced 1 m x 1 m but kept 1.7 m away from the palms to obtain 5 rows of cassava between 2 rows of coconut. Fertilizer treatments in the form of urea, TSP and MOP were split 50% and applied 4 and 12 weeks after planting. The application was done in bands on two sides of the cassava stands and buried. The plantain variety was 'Apantu' with a maturity period of 12 months. Planting was spaced 2 m between rows and 3 m within rows but kept 2.7 m away from the palms to obtain 2 rows of plantain between 2 rows of coconut. TSP was applied at 24 g P_2O_5 per hole during planting and followed by urea at N 46 g per plant, one month after planting (MAP). Planting material was pared to reduce associated pest, nematode and disease populations. For Dursban-treated plantain intercrop, pared planting material was dipped in a solution of 15 ml chlorpyrifos (Dursban 4E) per litre of water. Seeds of *P. phaseolides* were sown in the designated coconut - plantain intercrop plot at a rate of 12 kg ha^{-1} during planting of plantain.

Data collection: Growth of young coconut palms was assessed by collar girth measurement and leaf count. Yield and yield components of cassava and plantain were determined at harvest. Incidence and severity of major plantain diseases, namely Black Sigatoka disease (BSD) and Banana Streak Virus disease (BSVD), were assessed. Parameters determined were percent number of plants infected, percent number of leaves infected/total number of leaves of each plant and disease severity. Mean severity for BSD and BSVD was based on a 7-point scale (0-6) where 0 represented no apparent infection and 6 very severe infection. Tolerance was identified by a score 2.5 or below. For cassava, incidence and severity of major diseases, namely African Cassava Mosaic disease (ACMD), Cassava Bacterial Blight (CBB) and Cassava Anthracnose disease (CAD), were also assessed to determine percent number of plants infected for each treatment and disease severity. Mean disease severity was based on a 5-point scale of 1-5 where 1 represented no apparent infection and 5 very severe infection. Tolerance was determined by a score of 2 or below. Presence of tuber rot was determined at harvest. Weed types and populations were assessed using the quadrant methods. Weevil damage in plantain and effects of green mites and mealybugs in cassava were also assessed. Soils were sampled at planting in the 2 trials for analysis. Sampling was done at 0-20 cm and 20–40 cm depth.

Statistical analysis: Data were analyzed by analysis of variance (ANOVA), using the general linear model (GLM) procedure of SAS[16].

Results and Discussion

Soil analysis: The soils at the outset of the studies (Table 1) were generally acidic (pH 5.0–6.1) and highly depleted of their nutrients. Available P was very low (0.4–5.7 mg kg^{-1}) at all the sites except Antado where P level was moderate (11.8 mg kg^{-1}). Bray extracted K and organic matter contents were slightly higher on the young coconut fields at Antado, Kissi, Ayensudo and Tumentu than at the old coconut fields at Nuba, Menzezor 1, Menzezor 2 and Nvuma. Most of the soils were sandy loam except at Kissi which was silty clay and Nuba which was loamy sand. The soils in the Central Region were Lixisols described as having low CEC, high base saturation, less leaching of bases, with possible increase of clay from top to subsoil. The young coconut plots were mainly located in the Central Region. In the Western Region, where the old coconut plots were located, soils were Ferrasols described as having sandy loam or finer particle size, CEC of 16 cmol (+) kg^{-1} clay or less and low base saturation due to excessive leaching [7].

Growth of young coconut: Coconut growth was measured by collar girth and leaf number. The intercropping systems had no significant ($p < 0.05$) effect on growth of young coconut palms at 4, 16 and 23 months after planting (MAP) (Fig. 1). Mean collar

Table 1. Chemical and physical properties of the top 20 cm soil at the onset of the study in 2006.

Study	Location	pH 2:1 H_2O	Available P mg kg^{-1}	Available K mg kg^{-1}	O. M gkg^{-1}		Sand	Silt	Clay	
							----------%---------			
				Young coconut						
Coconut-Cassava	Kissi	6.1	2.5	162.7	30.3		50.5	25.3	24.3	SiCL
	Antado	5.0	11.8	100.6	32.9		70.9	19.0	10.0	SL
				Old coconut						
	Menzezor 1	4.8	2.2	35.3	16.9		78.8	11.1	10.1	SL
	Nuba	5.0	5.7	31.2	14.8		82.3	7.5	10.3	LS
				Young coconut						
Coconut-plantain	Ayensudo	5.3	1.5	80.6	23.6		73.5	16.2	10.3	SL
	Tumentu	6.0	10.3	180.4	80.9		55.5	25.5	19.0	SiCL
				Old coconut						
	Menzizor 2	5.6	3.5	70.9	24.8	1.12	75.5	12.2	12.3	SL
	Nvuma	5.3	0.4	60.9	38.2	0.32	30.6	55.1	14.3	SiC

* SiCL=Silty clay loam; SL=sandy loam; LS= loamy sand; SiC= Silty Clay.

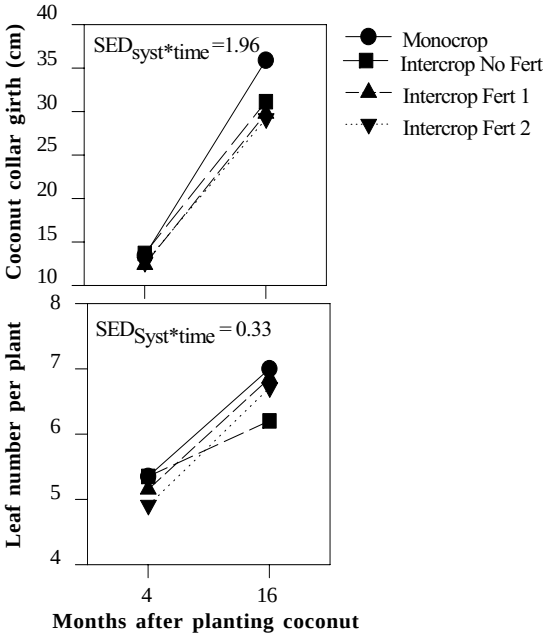

Figure 1. Coconut growth under various coconut-cassava cropping systems.

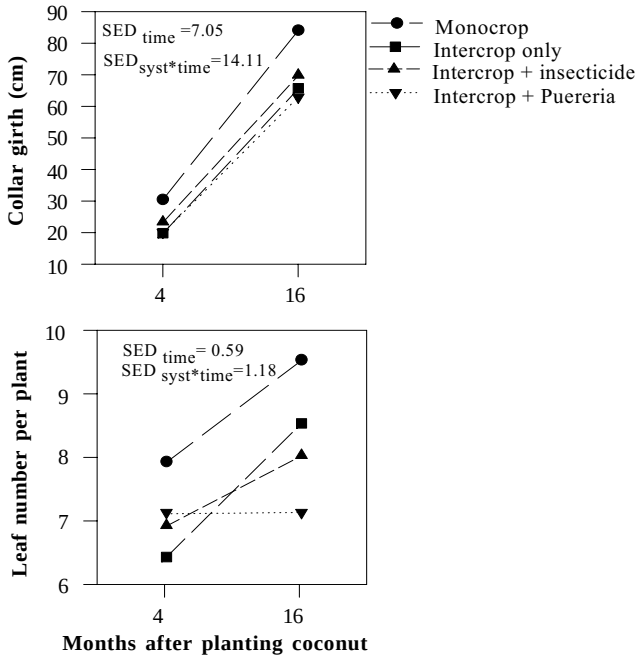

Figure 2. Coconut growth under various coconut - plantain cropping systems.

girth of intercropped coconut at 23 MAP (44.1 cm) was significantly ($p < 0.05$) higher than girth at 4 MAP (12.8 cm). Similarly, mean leaf number at 23 MAP (15.3) was significantly ($p < 0.05$) greater than leaf number at 4 MAP (5.2). Although increase in collar girth (G) and leaf number (Ln) in coconut monocrop (G = 42.5 cm, Ln = 11) were higher than intercropped coconut (G = 31.3 cm, Ln = 10), the differences were not significant ($p < 0.05$); indicating also that cropping system x time interaction was not significant ($p < 0.05$). Growth of coconut under plantain cropping systems followed the same trend as in cassava systems (Fig. 2). However, mean coconut plant size at the outset of the study was bigger due to the 2 year-old coconut planting used for the study at Ayensudo. The non-significant effect of the intercropping systems on growth of young coconut plantings was due to adequate spacing between coconut row and food crop row, fertilizer application to coconut and the less intensive intercropping system which was sufficient to prevent significant competition between coconut and food crops at this stage.

Cassava yield: There was no significant ($p < 0.05$) interaction between age of coconut and cropping system on fresh cassava root yield. Age of coconut was a significant ($p < 0.05$) factor with higher average fresh cassava root yield of 35.3 t ha^{-1} in young coconut fields compared to 11.6 t ha^{-1} in old coconut fields. Cropping system also had significant ($p < 0.05$) effect on fresh cassava yields (Fig. 3). Highest mean yields were recorded in cassava monocrop (29.0 t ha^{-1}) followed by cassava intercrop Fertilizer 1 (25.3 t ha^{-1}) and cassava intercrop Fertilizer 2 (22.1 t ha^{-1}) with least yield from cassava intercrop with no fertilizer (17.3 t ha^{-1}). The cassava yields under old coconut trees compare favourably with reported cassava root yields of 14.8-15.4 t ha^{-1} in 5-year old field trials fertilized with 80-80-80 kg ha^{-1} N-P_2O_5-K_2O [10]. Dry cassava root yield followed a similar trend as fresh root yield (Fig. 3) but with significant ($p < 0.05$) coconut age x cropping system interaction**.**

In the young coconut plots, cassava intercrop Fertilizer 1 had the highest tuber weight $plant^{-1}$. On the other hand, cassava intercrop Fertilizer 2 produced the highest tuber weight $plant^{-1}$ in

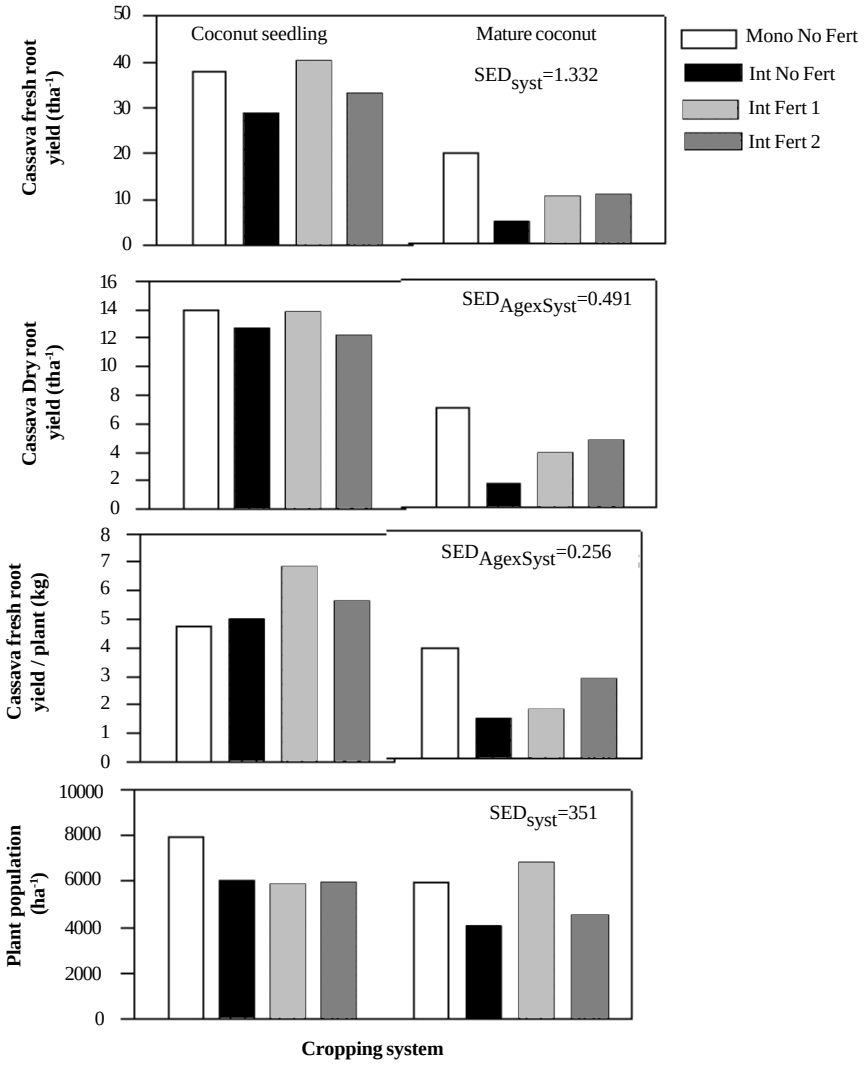

Figure 3. Cassava root yield and plant population at harvest under various cropping systems.

the old coconut plots. It was apparent in the old coconut plots that when no fertilizer was applied, cassava yield plant^{-1} for cassava intercrop was higher than cassava monocrop. The overall lower yield for cassava intercrop, however, could be attributed to an estimated 35% reduction in the population of cassava intercrop due to space occupied by coconut palms. However, with fertilizer application, the reduced plant population was compensated for by the greater increase in tuber weight plant^{-1}. There was no significant ($p < 0.05$) interaction between age and cropping system on root weight plant^{-1}. Age of coconut was a significant factor for root weight plant^{-1} with cassava intercrop in young coconut plantings producing higher root weight plant^{-1}. Similarly, in the young coconut plots, there was 24% reduction in root yield of cassava intercrop due to a corresponding 25% reduction in plant density. However, this was more than compensated for by application of fertilizer. Cassava intercrop Fertilizer 1 (30-45-45 kg ha^{-1} N-P_2O_5-K_2O) resulted in 39% tuber yield increase over cassava intercrop with no fertilizer.

Plantain growth, flowering and yield: At 7 MAP, there were significant ($p < 0.05$) coconut age x cropping systems interactions for plant height, number of leaves and pseudostem girth (Tables 2-4).

Dursban-treated plantain in young coconut was significantly taller with greater leaf number and bigger pseudostem girth than the other interactions. It was, however, similar to plantains under No IPM in the young coconut. Generally in the young coconut, intercropped plantain was about 12% taller in height and 10% bigger in girth than the monocrop plantain. In contrast, in the old coconut, intercropped plantain was about 25% shorter in height and 20% smaller in girth than the monocrop plantain. There was also a reduction in leaf number such that the intercropped plantain had about 25% less leaves than the monocrop plantain. The implication was that there was competition in the old coconut between the plantain and coconut while in the young coconut there was lack of it. A possible source of competition might be light because less than 50% of the fractional light was intercepted by the plantain in the old coconut (Table 5). Generally, more than 60% of incident light was intercepted by the coconut in both the young and old fields.

Plantain flowering started 9 MAP and was early in the young coconut than in the old one. In the young coconut, plantain flowering was similar under all the IPM treatments. However, under the mature coconut flowering of the monocropped plantain was delayed by almost two months (Fig. 4). There were differences in the number of plants harvested under the various IPM treatments in the young as well as the old. The Dursban-treated plantain produced the highest number of harvested plants followed by the No IPM treatment (Intercrop only) (Fig. 5). The pattern was the same in bunch weight. Consequently, the highest mean yield, 2.9 Mg ha^{-1}, was obtained from the Dursban-treated plantain (Fig. 6). This yield was 163% greater than that of the monocropped plantain. Furthermore, the No IPM treatment (intercrop only) produced yield that was 64% higher than the monocropped plantain. Across IPM treatments, plantain yield was better in the young than old coconut. The low yield in the old coconut could be the resultant effect of shading which prolonged vegetative phase with adverse effects on the yield. The Dursban-treated plantain also produced the highest percentage of flowered first and second ratoon plants, an indication of the extended bunch production over time.

Insects, diseases, nematodes and weeds: In the weeds assessment, it was visually observed that in the old coconut plantations, weeds tended to be more of grasses and ferns and were only present in the Western region. Broad leaf weeds, *Chromolaena odarata*, *Spigelia anthelmia*, *Heliotrophium indicum*, *Digitaria* spp. and *Bracharia* spp. were observed in all locations. *Ageratum conyzoides* and *Euphorbia heterophylla* identified at Ayensudo (young coconut field) are alternate hosts to the nematodes *Meloidogyne* spp., *Pratylenchus* spp. and *Paratrichodorus* spp. *Commelina* spp. identified at Nuba and Antado and *Seteria* spp. identified at Kissi (both young and old coconut fields) are alternate hosts to the nematode *Meloidogyne* spp. The above named weeds

Table 2. Plant height of plantain in cropping systems and in young and old coconut at 7 MAP.

	Coconut age		
Cropping system	Young	Old	Mean
Pueraria-plantain	122.5	81.3	101.9
Dursban-plantain	156.4	96.1	126.2
No IPM-plantain	143.6	86.6	115.1
Monocrop plantain	125.9	117.3	121.6
Mean	137.1	95.32	
LSD (p=0.05)	Coconut age (CA) = 21.84 ; Cropping system (CS)= 30.89; CO x CS = 20.05		

Table 3. Number of leaves of plantain in cropping systems and in young and old coconut at 7 MAP.

	Coconut age		
Cropping system	Young	Old	Mean
Pueraria-plantain	6.1	5.1	5.6
Dursban-plantain	7.8	5.8	6.8
No IPM-plantain	7.4	5.0	6.2
Monocrop plantain	7.2	7.1	7.2
Mean	7.1	5.7	
LSD (p=0.05)	Coconut age (CA) = 0.99; Cropping system (CS) = 1.41; CO x CS = 0.91		

Table 4. Pseudostem girth of plantain in cropping systems and in young and old coconut at 7 MAP.

	Coconut age		
Cropping system	Young	Old	Mean
Pueraria-plantain	31.2	20.7	25.9
Dursban-plantain	38.4	23.3	30.8
No IPM-plantain	35.5	21.6	28.6
Monocrop plantain	31.8	27.3	
Mean	34.2	23.2	
LSD (p=0.05)	Coconut age (CA) = 4.35; Cropping system (CS)= 6.15; CO x CS = 3.99		

must therefore be contained to avoid spread of nematodes in these locations. Weevils, which cause considerable damage to plantains were either absent or had extremely low numbers in the plantain study in all the locations assessed in the Western and Central regions. Incidence of green mites and mealybug, the major insect pests of cassava in Ghana, were very low in all the coconut - cassava systems across age of coconut and locations. In the coconut - cassava cropping systems, incidence and severity of the major diseases were either absent or very low for all the treatments across age of coconut and locations (Table 6) and no significant differences between treatments implying that Glemo Duade, the improved cassava variety used at the four locations, could be intercropped with both young and matured coconut without any adverse effects on the pathosystem. With regards to the cassava tubers, rots of fungal and bacterial origin were identified, however, incidence was very low for all the treatments across locations (mean of 1.3%) also implying that fertilizer application on cassava do not have any adverse pathological effects on the tubers as speculated. At seven months after planting plantain, Black Sigatoka disease was identified on plantain for all the treatments across age of coconut and locations (Table 7). Banana streak virus disease was identified in only one location Nvuma and it was identified only on two plants. However, looking

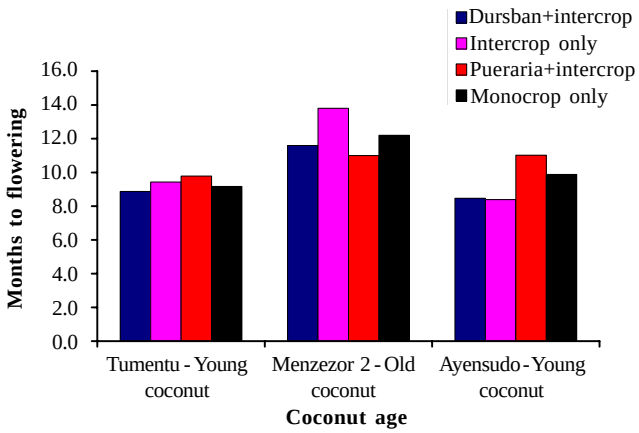

Figure 4. Effect of age of coconut on months to flowering of plantain in coconut-plantain system.

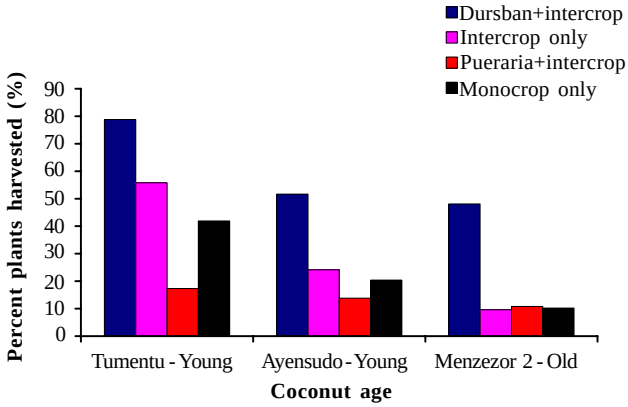

Figure 5. Percent mother plants harvested under different IPM systems in young and old coconut.

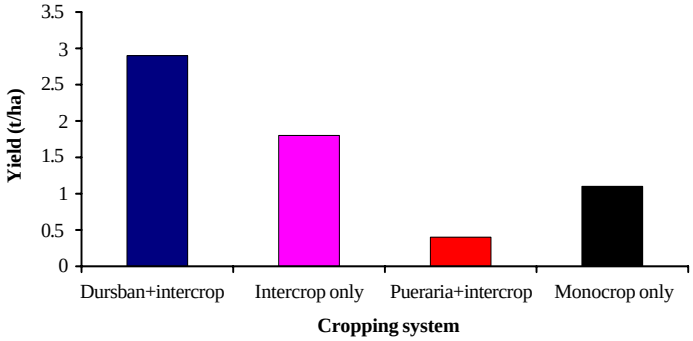

Figure 6. Bunch yield of plantain under various coconut-plantain cropping systems.

at the % mean number of leaves infected with BSD/total number of leaves for each plant across locations, it was observed that plants whose suckers were treated with chlorpyrifos (Dursban 4E) had the least Sigatoka infection (Table 7) while those which were not subjected to any IPM had the highest Sigatoka infection. Though there were no significant differences between treatments, chemical treatment which resulted in least Sigatoka infection contributed to higher bunch yields of the crops (Fig. 6). Looking at the mean disease severity, where plants subjected to the different treatments all showed tolerance to BSD, there is an indication that plantain could successfully be intercropped with coconut without any adverse effects on the pathosystem and there is a bonus effect when the crop is subjected to an integrated pest management system.

Table 5. Fractional light interception by plantain in coconut – plantain intercrop.

	Pueraria-plantain	Dursban-plantain	No IPM-plantain	Monocrop plantain	Monocrop coconut	S.E
Young coconut fields						
Ayensudo	0.6	0.59	0.54	0.50	0.65	0.025
Tumentu	0.39	0.66	0.58	0.68	0.61	0.022
Old coconut fields						
Menzezor 2	0.35	0.49	0.43	0.35	0.75	0.086
Nvuma	0.46	0.51	0.49	0.59	0.68	0.039

Table 6. Effect of major diseases on cassava in the intercrop and monocrop systems across locations in the Western and Central regions.

Cropping system/ Fertilizer application rate to cassava kg ha^{-1} N-P_2O_5-K_2O	ACMD		CAD		CBB	
	% infection	Mean severity	% infection	Mean severity	% infection	Mean severity
Monocrop cassava, No Fertilizer	0.00	1.00	1.22±0.37	1.50±0.15	0.00	1.00
Intercrop No Fertilizer	0.00	1.00	0.90±0.29	1.50±0.15	0.00	1.00
Intercrop Fertilizer 1	0.00	1.00	0.90±0.35	1.50±0.15	0.00	1.00
Intercrop Fertilizer 2	0.00	1.00	1.53±0.57	1.75±0.13	0.00	1.00
P	-	-	0.656	0.538	-	-

Table 7. Effect of black sigatoka on plantain in the intercrop and monocrop systems across locations in the Western and Central regions.

Treatment	Mean % plant infection	Mean % leaf infection / total leaves per plant	Mean disease severity
IPM	99.67±0.19	59.22±3.18	2.28±0.05
No IPM	99.88±0.11	64.50±3.08	2.39±0.09
Pueraria	99.61±0.27	62.17±4.07	2.25±0.06
Sole Plantain	100.0±0.00	59.75±4.00	2.36±0.06
P	0.36	0.718	0.443

Table 8. Costs in 2007, used in VCR calculations.

a) Field price of cassava /kg fresh weight : 0.033 GH
b) Cost of fertilizer

		30-45-45		60-45-90	
Type of fertilizer	Cost GH cedis / 50 kg bag	Quantity bags/ha	Cost GH cedis / ha	Quantity bags /ha	Cost GH cedis /ha
Urea	24	1	24	2	48
TSP	16	1.5	24	1.5	24
MOP	16	1	16	2	32
		Subtotal	64		104
		Transport	4		6
		Total	68		110

Economic analysis: The value cost ratio analysis was used to determine the profitability of using fertilizer on cassava in the coconut cassava intercrop. It is defined as ratio between the value of the additional crop yield and the cost of the additional fertilizer [4, 5] and is calculated as follows:

$$VCR = \frac{\text{Value of increased yield obtained}}{\text{Cost of additional fertilizer used}}$$

VCRs for F1 (30 - 45- 45) and F2 (60 - 45 - 90) were accordingly calculated with 2007 cassava and fertilizer prices shown in Table 8 as follows:

The results showed high and attractive VCR of 5 and 2.7 when the lower fertilizer rate of 30-45-45 kg ha^{-1} N-P_2O_5-K_2O was applied to cassava intercropped with young coconut and mature coconut, respectively (Table 9), with average VCR of 3.9. A VCR of 2 indicates a 100 percent return on the investment in fertilizer, and is the minimum value recommended to ensure profitability of fertilizer use [4, 5]. This study has shown that at the current fertilizer and cassava prices, application of fertilizer to cassava at 30-45-45 kg ha^{-1} N-P_2O_5-K_2O rate was very profitable when cassava was intercropped with either young coconut or mature coconut, with greater returns to investment in young coconut plantings. The higher fertilizer rate 60-45-90 kg ha^{-1} N-P_2O_5-K_2O was not profitable in the coconut - cassava intercropping system.

$$VCR_{F1} = \frac{(\text{Intercrop Cassava Yield}_{F1} - \text{Intercrop Cassava Yield}_{\text{No Fertilizer}}) \times \text{Unit cost of cassava}}{\text{Cost of fert}_{F1} + \text{Cost of transport}_{F1}}$$

$$VCR_{F2} = \frac{(\text{Intercrop Cassava Yield}_{F2} - \text{Intercrop Cassava Yield}_{\text{No Fertilizer}}) \times \text{Unit cost of cassava}}{\text{Cost of fert}_{F2} + \text{Cost of transport}_{F2}}$$

Table 9. Cassava fresh root yield and Value Cost Ratio (VCR) Analysis for fertilizer use in coconut-cassava intercropping systems 2007.

Cropping system/ Fertilizer application rate to cassava kg ha^{-1} N-P_2O_5-K_2O	Age of coconut				Average	
	Young coconut		Old coconut			
	Cassava yield kg ha^{-1}	VCR	Cassava yield kg ha^{-1}	VCR	Cassava yield kg ha^{-1}	VCR
Monocrop cassava, No Fertilizer	37,952.38		20,084.79		29,018.59	
Intercrop, No Fertilizer	29,890.60		4,750.64		17,320.62	
Intercrop + 30-45-45	40,186.61	5.0	10,386.10	2.7	25,286.36	3.9
Intercrop + 60-45-90	33,277.02	1.0	10,997.42	1.9	22,137.22	1.4

One ton of cassava can extract 4.91 kg N, 1.08 kg P, 5.83 kg K, 1.83 kg Ca and 0.79 kg Mg from the soil[13]. It has been reported that an application of N 100-112, P_2O_5 156 - 200 and K_2O 150 - 187 kg ha^{-1} could sustain high cassava root yields at 40 to 50 t ha^{-1} for over a decade [6]. Such fertilizer rates may not be profitable to the Ghanaian farmer due to the high and rising fertilizer prices. Supplementary organic sources such as cassava crop residue, cover crops, organic manure, coupled with adequate fertilizer application must be explored for an affordable and profitable integrated nutrient management system to maintain high cassava yields in coconut intercrops.

Conclusions

The study indicated that cassava intercrop fertilized with 30-45-45 kg ha^{-1} N-P_2O_5-K_2O in young coconut plantings generated high economic returns with a value cost ratio of 5. It also showed that integrated pest management system could be attained for plantain intercrop in coconut by intercropping young coconut with plantain using pared planting material treated with 15 ml l^{-1} chlorpyrifos insecticide (Dursban 4E). These coconut - food crop intercropping systems showed biological compatibility in that they did not affect the vegetative development of young coconut significantly ($p < 0.05$), had minimal levels of major disease and pest, produced high cassava yield (mean of 35.3 t ha^{-1}) and plantain yield (mean of 2.9 t ha^{-1}).

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