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EVALUATION OF COCONUT-CITRUS INTERCROPPING SYSTEMS IN THE CONTEXT OF LETHAL YELLOWING DISEASE OF COCONUT IN GHANA

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ABSTRACT

Global coconut production is under the devastating threat of lethal yellowing diseases endemic in East and West Africa. The most practical solution to the disease problem lies in the development of resistant or tolerant coconut planting materials. Malayan Yellow Dwarf (MYD) crossed (x) Vanuatu Tall (VTT) coconut hybrid was identified in a resistance screening work to have moderate tolerance to the disease. Consequently, the hybrid was recommended for replanting of coconut fields devastated by lethal yellowing in Ghana. To stimulate a greater replanting effort however, there was the need to develop a more efficient coconut intercropping systems involving other economic tree crops that are capable of providing insurance against total crop failure and loss of income since the MYD x VTT coconut hybrid was only moderately tolerant to lethal yellowing. Four cropping systems involving the tolerant MYD x VTT coconut hybrid and Late Valencia sweet orange were evaluated in a randomized complete block design with three replicates. The cropping systems were: 1. Sole coconut (Coconut planted at 8.5m triangular spacing at 160 palms ha^{-1}) 2. Sole citrus (Citrus planted at 6m square spacing at 277 trees ha^{-1}) 3. Coconut-citrus intercrop I (Coconut planted at 9.5m triangular spacing at 128 palms ha^{-1} and intercropped with citrus at 100 trees ha^{-1}) 4. Coconut-citrus intercrop II (Coconut planted at 10.5m triangular spacing at 105 palms ha^{-1} and intercropped with citrus at 80 trees ha^{-1}). Citrus was planted at the convergence point of any two diagonal lines linked with four adjacent coconut palms. The MYD x VTT coconut hybrid planted at 9.5m triangular provided optimal spacing for citrus intercropping. The intercropping system did not hinder the optimal growth and yield of coconut or citrus. It enabled a more efficient use of land and generated higher productivity by fitting more trees (coconut/ citrus) to a unit area of land as compared with sole cropping. The cost-benefit ratio of the intercropping came next to sole coconut planting. Nevertheless, intercropping enjoyed 26% of fruit income as insurance against lethal yellowing disease while sole coconut planting had no insurance cover.

Key words: Coconut, Lethal yellowing, Citrus, Intercropping

INTRODUCTION

The lethal yellowing disease (LYD) of coconut constitutes the most important single threat to coconut production in the world including a number of African countries [1, 2, 3]. The disease is caused by phytoplasma and is endemic in East and West Africa. In East Africa, LYD is known collectively as Lethal Disease (LD) as opposed to West Africa where the disease is named differently as Cape St Paul Wilt in Ghana, Awka wilt in Nigeria, Kribi in Cameroon and Kaincope in Togo.

In Ghana, the disease has caused the Volta Region, where it was first observed in 1932 to lose its status as one of the three major coconut growing regions in the country. For the remaining two major coconut growing regions (Western and Central), the disease had devastated about 5,500 ha of coconut farms leading to economic hardships for thousands of farmers whose livelihood depends on the crop [4]. The spread of the disease still continues. Typical symptoms are pre-mature dropping of nuts, blackening or necrosis of inflorescence, yellowing or browning of leaves and topping over of crown leaving characteristic ‘telegraph poles’ in its trail.

The most practical solution to the disease problem lies in the development of resistant or tolerant coconut planting materials [5, 6]. The Malayan Yellow Dwarf (MYD) crossed (x) Vanuatu Tall (VTT) coconut hybrid was identified in an earlier resistance screening work to have moderate tolerance to the disease and good agronomic characteristics [1]. Consequently, the hybrid was recommended to the Coconut Sector Development Project of Ghana for replanting of coconut fields devastated by LYD [7].

To stimulate a greater replanting effort however, there was the need to develop a more efficient coconut intercropping systems involving other economic tree crops that are capable of providing insurance against total crop failure and loss of income [8] since the MYD x VTT coconut hybrid was only moderately tolerant to LYD. Sweet orange (*Citrus sinensis* L. Osbeck) was identified as one of the economic tree crops grown commercially and sometimes side by side with coconut in the coconut belt of Ghana. Other suitable tree crops include cocoa and rubber.

This work sought to develop a more efficient intercropping systems involving coconut and citrus with the following specific objectives: (1) to identify optimum spacing of coconut for intercropping with citrus (2) to assess the effect of intercropping on the performance of coconut and citrus and (3) to do agronomic and economic analysis of the coconut-citrus intercropping systems.

MATERIALS & METHODS

Study location

The study was carried out from 2002 to 2008 in the coconut belt of southern Ghana at three locations namely; Agona - Nkwanta; Ayensudo - Enyenase and Aburansa. Annual rainfall of the locations varies from 1200-1500 mm and is distributed bi-modally with the major peak in June-July and a minor peak in September -

October. Soils at the locations (Table 1) were suitable for coconut and citrus production except that fertilizer application was necessary.

Experimental design

Four cropping systems involving MYD x VTT coconut hybrid and Late Valencia sweet orange on rough lemon root stock were randomly assigned to four distinct plots of size 0.65 acres at each of the three locations to obtain a randomized complete block design with three replicates. The cropping systems were: 1. Sole coconut (Coconut planted at 8.5m triangular spacing at 160 palms ha^{-1}) 2. Sole citrus (Citrus planted at 6m square spacing at 277 trees ha^{-1}) 3. Coconut-citrus intercrop I (Coconut planted at 9.5m triangular spacing at 128 palms ha^{-1} and intercropped with citrus at 100 trees ha^{-1}) 4. Coconut-citrus intercrop II (Coconut planted at 10.5m triangular spacing at 105 palms ha^{-1} and intercropped with citrus at 80 trees ha^{-1}). Citrus was planted at the convergence point of any two diagonal lines linked with four adjacent coconut palms.

Food crop intercropping

Intercropping tree crops with staple food crops before canopy closure is a very important practice by farmers. Consequently, available interspaces between the coconut and citrus were uniformly intercropped with cassava, followed by maize and vegetable within the first three years of the trial. Food crops were planted 1 m away from either coconut or citrus in year one and 1.5 m away in years two and three to minimize competition between the test trees and food crops.

Fertilizer application

Urea was applied as source of N; Muriate of potash as source of K_2O; Magnesium Sulphate as source of MgO and triple superphosphate as source of P_2O_5. Coconut was given 276g N; 204g P_2O_5; 1,440g K_2O and 240g MgO per palm in three annual split applications. For citrus fertilization, 184g N; 132g P_2O_5 and 720g K_2O were applied per tree in three annual splits.

Data collection and derivation

Growth of coconut was assessed at six-monthly intervals by measurement of collar girth at soil level and count of newly emerged leaves. Nuts in bunches of leaf ranks 14, 19 and 24 were counted and their mean multiplied by 12 to estimate nut load $palm^{-1}$ yr^{-1} [9]. Growth of citrus was determined at six-monthly intervals by measurement of plant height, stem girth and canopy width. Height was measured from bud-union level to shoot apex. Girth was taken at 5 cm above bud-union level. Canopy width was measured in the North-South and East-West directions and their mean calculated. Following the procedure of [10], canopy volume was derived as:

$$\frac{4}{3}\pi\,[plant\ height]\,[canopy\ radius]^2$$

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Fruit yield per hectare was estimated from fruit count per tree and mean fruit weight. Land Equivalent Ratio (LER) was estimated using the procedure of [11]:

$$LER = \left[\frac{Pcoconut}{Mcoconut} + \frac{Pcitrus}{Mcitrus}\right]$$

Where:

Pcoconut = Intercropped yield of coconut
Pcitrus = Intercropped yield of citrus
Mcoconut = Monocropped yield of coconut
Mcitrus = Monocropped yield of citrus

Statistical analysis

GenStat Discovery (Edition 3) software was used for statistical analysis. Data were subjected to Two-Way Analysis of Variance (in Randomized Blocks) to be able to factor time into the analysis of repeated measures. Means were separated by Least Significant Difference (LSD).

Economic analysis

The economic analysis of the cropping systems was assessed by evaluating the net income, cost-benefit ratio and insurance against lethal yellowing disease (LYD). The net income was obtained by deducting input cost from gross income. The cost-benefit ratio was determined by dividing gross income by input cost. Insurance against LYD was estimated by expressing citrus income as a percentage of the total fruit (coconut + citrus) income.

RESULTS

Growth and yield performance of citrus

Growth of late Valencia sweet orange as measured by rate of increase of plant height, stem girth, canopy radius and canopy volume went through exponential, stabilization and decline phases. Increase in growth parameters was highly significant ($P<0.01$) between sampling times but between the cropping systems there were no significant ($P>0.05$) differences except for plant height (Table 2). Height of late Valencia came up significantly ($P< 0.05$) taller in coconut-citrus intercrop II (452.4 cm) compared with coconut-citrus intercrop I (420.5 cm) at 54 months after planting.

Cropping system did not have significant ($P>0.05$) effect on fruit weight per tree but it had significant ($P<0.05$) influence on fruit yield per hectare (Table 3). Fruit yield per hectare averaged over 2 years was significantly ($P<0.05$) greater in the sole citrus compared to the intercropping systems. Fruit yield of late Valencia in coconut-citrus intercrop I did not differ significantly ($P>0.05$) from that of coconut-citrus intercrop II (Table 4).

Growth and yield performance of coconut

Like late Valencia sweet orange, growth of MYD x VTT coconut hybrid as measured by rate of increase of collar girth underwent exponential, stabilization and decline stages. Cumulative leaf number increased progressively over the study period. Increase in collar girth and cumulative leaf number was highly significant (P<0.01) between sampling times. Cropping system affected collar girth of coconut significantly (P<0.05) but not cumulative leaf number (Table 5). Collar girth of coconut grew significantly (P<0.05) larger in coconut-citrus intercrop II (93.7 cm) relative to coconut-citrus intercrop I (75.4 cm) after 30 months in the field.

Cropping system did not have significant (P>0.05) effect on nut load per tree but it had significant (P<0.01) influence on nut yield per hectare (Table 6). Nut yield per hectare averaged over two years was significantly (P<0.05) greater in the sole coconut compared to the intercropping systems. Nut yield of coconut in coconut-citrus intercrop I did not differ significantly (P>0.05) from that of coconut-citrus intercrop II (Table 7).

Agronomic and economic analysis

Coconut-citrus intercrop I had the greatest land equivalent ratio (LER) with the least LER observed under coconut-citrus intercrop II. A 7% less land was required under coconut-citrus intercrop I to produce the same quantity of coconut and citrus yields as under the sole cropping (Table 8). Net income per hectare was highest for sole coconut which generated 71.2%, 62.4% and 16.7% more income than sole citrus, coconut-citrus intercrop II and intercrop I, respectively. Similarly, cost-benefit ratio was highest for sole coconut, followed closely by coconut-citrus intercrop I, coconut-citrus intercrop II and sole citrus. While coconut-citrus intercrops I and II respectively enjoy 26.1% and 21.9% of their fruit incomes as insurance against the lethal yellowing disease, sole coconut had no insurance cover (Table 9).

DISCUSSION

Growth and yield performance of coconut and citrus

Growth of citrus and coconut in the cropping systems followed a normal biological growth pattern [12]. The exponential phase was in conformity with the juvenile stage when vegetative growth occurred at increased rates to accumulate maximum dry matter and to attain optimum leaf area index. The stabilization phase probably occurred at the time of optimum leaf area index and maximum dry matter accumulation. The decline phase was probably indicative of floral initiation when the greater sink strength of floral structures accumulated more assimilates relative to vegetative structures. The progressive increase in cumulative leaf number of coconut was in conformity with the known emergence of 12 leaves per year in coconut [9] barring any growth limitation.

Relative to the sole crops the intercropping systems (coconut-citrus intercrops I and II) did not hinder the optimum growth of either MYD x VTT coconut hybrid or late Valencia sweet orange. This might indicate coconut-citrus compatibility and buttress the practice of intercropping as the major cropping system for coconut cultivation worldwide [13, 14, 15]. The wider spatial arrangement of coconut-citrus intercrop II tends to stimulate taller height in citrus and larger collar girth in coconut compared to coconut-citrus intercrop I. This might be attributed to lower plant population in coconut-citrus intercrop II which probably led to better availability of growth resources such as light, water and nutrients [16, 17].

Like the growth of citrus and coconut, the intercropping systems did not adversely affect fruit weight of citrus or nut load of coconut per tree. On per hectare basis therefore differences in citrus or coconut yield between the cropping systems could be attributed mainly to variation in coconut or citrus density per hectare.

The long term effects of the intercropping systems on yield of coconut and citrus need to be established since at this stage (6 years after planting) yield was only preliminary. The possibility of shading effect in the future particularly in coconut-citrus intercrop I, the promising intercropping system, cannot be ruled out. Shading effect, if permitted, could cause several problems including delayed ripening, reduced yields and poor fruit quality of citrus [18]. Consequently, this study needs to be continued to monitor the effect of shading (if any) on fruit yield and quality.

Agronomic and economic analysis

Coconut-citrus intercrop I had the greatest land equivalent ratio; an indication of a more efficient land use and higher productivity under intercropping [19]. The 7% less land required under coconut-citrus intercrop I to produce the same quantity of coconut and citrus yields as under the sole cropping implied that more trees (coconut/ citrus) could be fitted to a unit area of land under intercropping. Apart from the high efficiency and productivity of coconut-citrus intercrop I, the 26.1% of fruit income enjoyed as insurance against the lethal yellowing disease could be a source of motivation for farmers who are skeptical to plant the improved coconut hybrid (MYD x VTT). The superior net income and cost-benefit ratio generated on per hectare basis by sole coconut followed by coconut-citrus intercrop I, coconut-citrus intercrop II and sole citrus was due to the higher farm gate price of coconut (four-fold higher than citrus). Any future improvement in the market trends of citrus relative to coconut could make the fruit income of the intercropping systems much better than sole coconut.

CONCLUSION

The six-year preliminary study showed that MYD x VTT coconut hybrid planted at 9.5m triangular offered optimal spacing for citrus intercropping at the convergence point of two diagonal lines linked with four adjacent coconut palms. The intercropping system did not hinder the optimal growth and yield of coconut or citrus. It enabled a more efficient use of land and generated higher productivity by fitting more trees (coconut/ citrus) to a unit area of land as compared with sole cropping. The cost-benefit ratio of the intercropping came next to sole coconut planting. Nevertheless, intercropping enjoyed 26% of fruit income as insurance against lethal yellowing disease while sole coconut planting had no insurance cover.

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Table 1: Some Chemical Properties of Soils at Experimental Locations in 2002

Location	(cm) Depth	(H_20) PH	------%------- N	O.M	$mgkg^{-1}$ Avail. P	---------$cmolkg^{-1}$---------- K	Ca	Mg
Agona	0-20	5.28	0.09	2.85	3.56	0.03	1.94	1.50
	20-40	5.02	0.07	2.14	1.74	0.02	1.44	1.20
Aburansa	0-20	6.05	0.16	3.86	3.53	0.10	5.25	2.95
	20-40	5.78	0.11	2.92	1.28	0.07	3.90	2.35
Enyenase	0-20	6.24	0.18	4.51	2.68	0.06	5.86	3.60
	20-40	6.06	0.11	3.12	1.29	0.03	4.06	2.83

Table 2: Two-Way Analysis of Variance of Growth Performance of Late Valencia Sweet Orange in Coconut-Citrus Intercropping Systems

Source of variation	Df	Sum of Square	Mean Square	Var Ratio	F Prob
Plant height					
Cropping system	2	2290.8	1145.4	3.33	0.046 *
Time	6	874078.8	145679.8	424.08	<0.001**
Cropping system. Time	12	1275.5	106.3	0.31	0.984 ns
Stem girth					
Cropping system	2	25.221	12.610	2.23	0.121 ns
Time	6	9745.193	1624.199	286.66	<0.001**
Cropping system. Time	12	35.192	2.933	0.52	0.891ns
Canopy radius					
Cropping system	2	319.3	159.6	1.45	0.256 ns
Time	3	69639.7	23213.2	210.74	<0.001**
Cropping system. Time	6	195.6	32.6	0.30	0.932ns
Canopy volume					
Cropping system	2	79.02	39.51	0.69	0.510 ns
Time	3	12954.00	4318.00	75.79	<0.001**
Cropping system. Time	6	72.54	12.09	0.21	0.969ns

*Significant at P ≤0.05 **Significant at P ≤0.01 ns Not Significant at P= 0.05

Df= Degrees of freedom Var= Variance Prob= Probability

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Table 3: Two-Way Analysis of Variance of Fruit Yield Performance of Late Valencia Sweet Orange in Coconut-Citrus Intercropping Systems

Source of variation	Df	Sum of Square	Mean Square	Var Ratio	F Prob
Fruit weight/ tree					
Cropping system	2	328.3	164.1	1.28	0.320^{ns}
Time	1	911.6	911.6	7.10	0.024*
Cropping system. Time	2	372.1	186.1	1.45	0.280^{ns}
Fruit weight/ ha					
Cropping system	2	159.99	79.99	4.50	0.040*
Time	1	38.43	38.43	2.16	0.172^{ns}
Cropping system. Time	2	44.53	22.26	1.25	0.327^{ns}

*Significant at P ≤0.05 **Significant at P ≤0.01 ^{ns} Not Significant at P= 0.05

Df= Degrees of freedom Var= Variance Prob= Probability

Table 4: Fruit yield of late Valencia sweet orange in coconut-citrus intercropping systems

Cropping System	Fruit Yield					
	----Yr. 5----		----Yr. 6----		-----Mean----	
	Fruit wt per tree (kg)	Fruit wt per ha (t)	Fruit wt per tree (kg)	Fruit wt per ha (t)	Fruit wt per tree (kg)	Fruit wt per ha (t)
Sole Citrus	18.9	5.27	45.6	12.63	32.3	8.95
Coconut-Citrus Intercrop I	32.6	3.27	37.9	3.80	35.3	3.54
Coconut-Citrus Intercrop II	19.7	1.57	30.4	2.43	25.1	2.00
LSD $_{0.05}$	*20.6*	*3.09*	*20.8*	*7.67*	*20.7*	*5.38*

wt = Weight

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Table 5: Two-Way Analysis of Variance of Growth Performance of MYD x VTT Coconut Hybrid in Coconut-Citrus Intercropping Systems

Source of variation	Df	Sum of Square	Mean Square	Var Ratio	F Prob
Collar girth					
Cropping system	2	2162.9	1081.4	9.28	<0.001**
Time	6	72222.9	12037.1	103.30	<0.001**
Cropping system. Time	12	635.8	53.0	0.45	0.929 ns
Cumulative leaf number					
Cropping system	2	15.746	7.873	1.34	0.274 ns
Time	6	11214.762	1869.127	317.10	<0.001**
Cropping system. Time	12	17.810	1.484	0.25	0.993ns

*Significant at P ≤0.05 **Significant at P ≤0.01 ns Not Significant at P= 0.05

Df= Degrees of freedom Var= Variance Prob= Probability

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Table 6: Two-Way Analysis of Variance of Nut Yield Performance of MYD x VTT Coconut Hybrid in Coconut-Citrus Intercropping Systems

Source of variation	Df	Sum of Square	Mean Square	Var Ratio	F Prob
Nut load/ palm					
Cropping system	2	2665.6	1332.8	2.56	0.138 ^{ns}
Time	1	662.7	662.7	1.27	0.292^{ns}
Cropping system. Time	2	629.0	314.5	0.60	0.570^{ns}
Nut yield/ ha					
Cropping system	2	284080159	-	15.18	0.002 **
Time	1	16956887	-	1.81	0.215^{ns}
Cropping system. Time	2	15556997	-	0.83	0.470^{ns}

*Significant at P ≤0.05 **Significant at P ≤0.01 ^{ns} Not Significant at P= 0.05

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Table 7: Nut yield of MYD x VTT coconut hybrid in coconut-citrus intercropping systems

Cropping System	Fruit Yield					
	----Yr. 5----		----Yr. 6----		-----Mean----	
	Nut yield per palm (nb)	**Nut yield per ha (nb)**	**Nut yield per palm (nb)**	**Nut yield per ha (nb)**	**Nut yield per palm (nb)**	**Nut yield per ha (nb)**
Sole Coconut	102	16,253	130	20,819	116	18,536
Coconut-Citrus Intercrop I	95	12,112	101	12,877	98	12,494
Coconut-Citrus Intercrop II	85	8,662	87	9,155	86	8,909
LSD $_{0.05}$	*43.2*	*4,073*	*45.6*	*5,760*	*44.4*	*4,916*

nb = number

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Table 8: Land equivalent ratio (LER) of coconut-citrus intercropping systems

Cropping system	Fruit yield/ ha (numbers) *(Averaged over years 5 and 6)*		LER
	Coconut	Citrus	
Sole coconut	18,536	-	1.00
Coconut-citrus intercrop I	12,495	17,620	1.07
Coconut-citrus intercrop II	8,909	10,020	0.70
Sole citrus	-	44,735	1.00

Table 9: Economic evaluation of coconut-citrus intercropping systems after six years

Cropping system	Input cost /ha (US$)	Gross income/ha (US$)	Net income/ha (US$)	Cost/ benefit ratio	Insurance against LYD
Sole coconut	351.68	2,008.04	1,656.36	5.7	0.0
Coconut-citrus intercrop I	315.77	1,736.67	1,420.90	5.5	26.1
Coconut-citrus intercrop II	319.51	1,355.12	1,035.61	4.2	21.9
Sole citrus	413.65	1,381.37	967.72	3.3	

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