

STUDIES ON OIL PALM BASED CROPPING SYSTEMS IN GHANA



By

BERNARD NARH NUERTEY

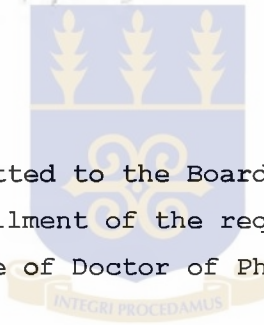


STUDIES ON OIL PALM BASED CROPPING SYSTEMS
IN GHANA

By

BERNARD NARH NUERTEY

Thesis submitted to the Board of Graduate Studies, in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy in crop science.



OCTOBER, 1999



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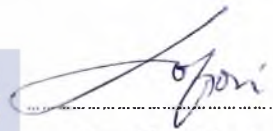


DECLARATION


I certify that the field work related to this thesis "Studies on oil palm based cropping systems in Ghana" was carried out by me, Bernard Narh Nuerterey, of the Department of Crop Science, U.G at the Oil Palm Research Institute, Kusi in Ghana. This thesis has never been presented on any occasion at any University for the award of a degree.




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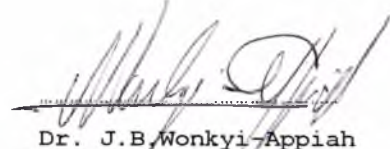


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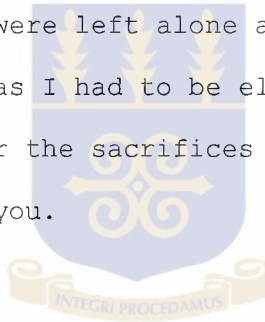
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DEDICATION



Dedicated to my wife Betty, and children - Ama,
Nelie, Nana, Galina and Luda.

On many occasions, you were left alone at home
without my protection, as I had to be elsewhere for
this work. Thank you for the sacrifices made. And may
the almighty God bless you.



ACKNOWLEDGEMENTS

I wish to thank the following people and organisations for their roles played in the preparation of this thesis:

My supervisors at the Department of Crop Science, Legon, Dr K. Ofori and Prof. E. V. Doku for their suggestions, constructive criticisms and encouragement in my course of studies;

My institutional supervisor Dr J. B. Wonkyi-Appiah. The Heads and staff of the Crop Science Department Legon, and the Agronomy Division of the Oil Palm Research Institute, C.S.I.R Kade;

Mr. W.A. Asante of Crop Science Department and Mr. Wilson Dogbe of Savana Agricultural Research Institute for assisting in the statistical analysis of data. Mr. F.M. Tetteh, of Soil Research Institute for carrying out the chemical analysis of the soil/leaf samples.

Mr./Mrs Okyere Mensuo for providing me with accommodation during my stay in Accra for these study;

Mr. A.K. Nantwi, for allowing me the use of his personal library;

The Oil Palm Research Institute, Kade of the CSIR for granting me the study leave to undertake these studies.

Finally, I am thankful to all those who typed the various manuscripts which gave form to this thesis.

May almighty God bless you all. Amen.



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ABSTRACT

A survey was conducted in 1994 to gather information on the practice of intercropping food crops in oil palm on small-scale farms in the oil palm zones of southern Ghana. The objective was to identify and study intercropping systems used in oil palm production. Data was collected by interviewing a total of 72 oil palm farmers from the oil palm growing regions, (Eastern, Central, Western, Ashanti, Brong-Ahafo, and Volta) at their farm locations. The responses indicated that the small-scale oil palm farmers in Ghana commonly intercrop oil palm with maize, cassava and plantain especially during the first three years of the crop. The three staple crops, maize, cassava and plantain were intercropped in oil palm between 1994 and 1997 at the Oil Palm Research Institute, Kusi, Ghana to assess their effects on the growth, development and yields of oil palm. Intercropping was compared to the standard system of cover cropping oil palm with pueraria.



Nutrient dynamics, soil moisture retention, and solar interception by the oil palm were also examined.

The performances of the food crops were also assessed as well as the ability of the cropping systems to control weeds was assessed. An economic analysis was also carried out.

There were seven treatments, consisting of:

- (i) sole oil palm with pueraria cover crop;
- (ii) oil palm + maize + cassava;
- (iii) oil palm + maize + plantain,
- (iv) oil palm + maize + maize;
- (v-vii) sole crops of maize, cassava and plantain respectively.

These were arranged in a randomized complete block design and replicated four times.

Intercropping oil palm with maize, cassava and plantain had no adverse effect on the growth, development and yield of the oil palm. The Oil palm + maize + maize intercrop and oil palm cover-cropped with pueraria positively influenced soil moisture retention, nutrient uptake and accumulation and light interception by the oil palm more than what pertained with oil palm + maize + cassava and oil palm + maize + plantain.



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Yields of the intercropped food crops compared favourably with yields of these crops when solely cropped.

The sole oil palm with pueraria cover crop and oil palm + maize + maize association controlled weeds better than the oil palm + maize + cassava and oil palm + maize + plantain associations. Intercropping oil palm with maize, cassava and plantain was found to be economically beneficial to the small-scale oil palm farmer.





CHAPTER ONE

1.0: INTRODUCTION

The oil palm industry has developed over the last two decades into a huge and important industry, which comes next only to Cocoa in the agricultural sector of Ghana's economy. Small-scale farmers who occupy about 70% of the estimated total area of 145,500 hectares under oil palm (Anonymous, 1989; Anonymous, 1990) dominate Oil Palm cultivation in Ghana. The development estates account for the remaining 30% of the oil palm production area. In Ghana, oil palm is cultivated as a monocrop by the development estates and their affiliated small holders as well as out-growers.

The practice of the development estates has been to inter plant the oil palm rows with Pueraria sp, a leguminous cover crop. The leguminous cover crop is expected to conserve soil moisture, suppress weed growth and control soil erosion. It also improves soil fertility by fixing atmospheric nitrogen into a form for use by plants.



There is also evidence that the leguminous cover crop may compete with the oil palm and may do so more than even intercropped food crops (Hartley 1988).

In spite of the many benefits of the leguminous cover crop, the small scale farmers do not plant them under the oil palm. This is partly due to lack of immediate economic returns accruing from them. They instead, intercrop the oil palm with food and other cash crops for three to four years. Integration of food and tree crop farming has become necessary also because most of the areas around the large estates (BOPP, TOPP, etc.) which were once exporting food crops have become net deficit areas. Some farmers are therefore forced to remove palm fronds to create space for intercrop food crops.

The standard 8.8-m triangular spacing used for oil palm provides wide spaces between the young palms. There is therefore considerable waste of solar radiation and weed problems from transplanting to canopy closure which takes between three and five years. (Chee et al., 1992).

Farmers may seem justified then by grng food and/or cash crops between oil palm trees until canopy closure. The question to which solution needed be found is whether intercropping of food crops in establishing oil palm is more beneficial than sole cropping in small holdings or otherwise. The type of crop used as intercrop changes from one locality to another depending on the food culture of the people.

There is no information on the compatibility of all these food crops grown in association with the oil palm with respect to the use of resources for growth and development.

The objectives of this study therefore were:

- (i) to identify the food crops commonly intercropped with oil palms in Ghana;
- (ii) to assess the effects of these food crops when intercropped with oil palm on the growth, development and yield of the oil palm;
- (iii) to assess the performance of food crops intercropped in oil palm;



- (iv) to assess the effects of the intercropped food crops on the use of nutrients, water and light by the oil palm;
- (v) to study the effects of the intercropped food crops on weed suppression and control; and
- (vi) to evaluate the economics of intercropping food crops with oil palm.

CHAPTER TWO

2.0: LITERATURE REVIEW

2.1: The physiology of growth and development of oil Palm

Oil palm productivity is influenced by the total dry matter production of each palm. Dry matter production is highly dependent on the photosynthetic rate of the palm (Dolmat, 1996).

2.1.1 The role of leaves in dry matter accumulation Of plants

Various concepts are used to characterise the role of leaves in dry matter accumulation in relation to growth analysis of plants.

(i) Leaf area (LA): This is the area of the leaf surface. Usually used to quantify the photosynthetic component. Leaf area expansion is initially more related to air temperature (Milthorpe, 1959), subsequently, LA expansion is more responsive to solar radiation (Blackman and Black, 1959). Nutrient deficiency reduces growth in general and leaf area in particular. Corley and Mok (1972) showed that N & K increases LA. Restriction in water supply was demonstrated to affect leaf expansion (Boyers 1970; Acevedo et al. 1971). A range of techniques for measuring the area of leaves is available and has been described by Bleasdale (1973). Leaf development can be plotted with time and related to dry matter production.

(ii) Net Assimilation Rate (NAR): It is defined as the rate of increase in plant dry weight per unit leaf area over a given period (Gregory, 1926). NAR expresses growth in terms of foliar surface and therefore allows us

to see if any treatments make the leaves more efficient or if the efficiency merely changes with time. NAR declines with leaf age (Watson, 1947; Hernandez-Gil and Schaedle, 1973) limited by solar radiation (Blackman and Black, 1959) and governed by temperature (Gregory, 1926 and Milthrope, 1959).

(iii) Leaf Area Index (LAI): Defined as the ratio of leaf area to ground area covered (Watson, 1947 and Harper, 1983). LAI varies according to leaf orientation (Pearce et al., 1967). Kriedemann and Smart, (1971) demonstrated that vertically oriented foliage makes good use of both diffuse and direct sunlight and can therefore achieve greater LAI. Corley and Mok, (1972) showed that high N levels give rise to faster LAI development. Similar effects have been observed with irrigation. (Ochs and Vanderwegen, 1969). High values of LAI may not necessarily be desirable because the lower leaves in the canopy are shaded and their efficiency is reduced. LAI values usually fall between 1 and 8. There is normally restriction in growth of some crops when LAI declines rapidly.



(iv) Leaf area duration (LAD): This is a measure of persistence of the leaf canopy. If leaf area index is plotted against time, the area under the curve is a measure of the duration of the leaves. Corley (1973) has suggested that provided leaves are not removed by pruning, their life depend in part on the intensity of light reaching them through the canopy.

(v) Crop growth rate (CGR): The rate of increase of dry matter production per unit of time. Growth rates can be compared at different times in the season for different treatments. CGR is affected by a range of factors including temperature (Milthrope, 1959), radiation levels, (Blackman and Black, 1959), water (Acevedo et al. 1971) and nutrient supply (Corley and Mok, 1972) the type and age of the plant (Watson, 1947) These factors affect the size and efficiency of the leaf canopy and hence the ability of the crop to convert solar energy into useful growth.



2.1.2 DRY MATTER ACCUMULATION AND DISTRIBUTION IN oil PALM

The dry matter produced is used for both vegetative and reproductive growth. In the oil palm, vegetative growth assumes priority over the reproductive growth (Hartley, 1988). Thus the requirements of vegetative growth must necessarily be satisfied before dry matter is diverted into fruit production.

For economic production of the oil palm therefore it is imperative that management practices which would enhance the availability of such factors influencing vegetative growth and development of the oil palm are adopted.

2.2: Factors influencing growth and development of

Oil palm

Many factors affect the rate of photosynthesis of the palm. These are predominantly climatic, edaphic and agronomic practices.

2.2.1: Climatic factors

Oil palm is now grown in most tropical countries where the climate is favourable. Differences in climatic factors affect productivity. Rainfall, temperature and light intensity are the main climatic factors, which affect the growth and development of the oil palm.



2.2.1.1: Rainfall and water balance

The annual rainfall distribution relative to potential evapotranspiration with the buffering effect of soil water reserves defines the water available for plants (Surre, 1968). In the Sub-region of West Africa, the seasonality of rainfall and the long drought which lasts 2 to 4 months in a year result in huge water deficits. The amount and distribution of rainfall and therefore soil moisture availability influence leaf production. There is evidence that within West Africa, annual leaf production is low in areas with rainfall of 1250 mm and below.

Broekmans (1957) showed that in Nigeria palms of the same genetic origin gave varied averages of leaf Production when planted in areas with varied annual rainfall. At Umuahia, with an annual rainfall of 2108 mm, the average annual leaf production was 23.1. While at Ibadan, with an annual rainfall of 1219 mm, the yearly mean leaf production was 20.5 in the adult palm.

De Berchoux and Quency (1980) noted that stem growth was fastest in plantations sited where water supply was



satisfactory against slowest stem growth on plantations sited where there was limited water supply.

Quency and de Taffin (1981) observed that the insufficient water supply in West Africa mainly affects the sex ratio of the palms and thus determines the number of bunches produced.

Olivin (1968) found good correlation between the mean annual water deficit and the average production level. Surre(1968) and IRHO, (1969) also reported direct relationships between the magnitude of water deficit estimates and bunch yield. Desmarest (1967) and IRHO (1967) demonstrated that, in the Cote d'Ivoire yields of fresh fruit bunches could be raised by irrigation from 7.5 T Ha^{-1} to 26t/ha .

This was collaborated by the work of Ochs and vander Wegen (1969) who also reported yield increases of 13 T ha^{-1} by applying irrigation in the Cote d'Ivoire.

Rees (1989) thought irrigation may not be economically feasible considering the large areas involved in oil palm cultivation and the cost of the necessary equipment coupled with their maintenance costs.



Therefore husbandry practices that conserve soil moisture might be the best option.

2.2.1.2: Temperature

There are indications that temperatures below 20°C for any extended period are generally deleterious to oil palms (Hartley, 1988). Henry (1957) showed that growth of young seedlings at 25°C is seven times and at 20°C three times as rapid as at 17.5°C. There is little definitive information on temperature effects on growth and development of oil palm.

Rees (1989) attributed this lack of information to the fact that field temperatures are not controllable and therefore renders work on temperature effects only academic. He however agreed that the knowledge on temperature fluctuations could be an important consideration when siting new plantations.

Hartley (1988) found temperature differences to be the most distinguishing climatic factor between Yangambi, Zaire and the Far East. Yangambi had a minimum of between 19.3°C and 20.3°C while the Far East had a minimum of 23°C. The former had a lower yield than the latter.



2.2.1.3: Light use for oil palm growth and

Development

Another environmental factor which has a large influence on the photosynthetic output of the oil palm tree is light.

Solar radiation is often measured as sunshine hours only. From several observations, Hartley (1988) inferred the importance of solar radiation for growth and bunch production of the oil palm.

Corley (1973) showed that the number of leaves produced depends on the light intensity reaching the oldest leaves of the canopy.

Thus, under heavy shade, the growth of the leaves is very much depressed. Milthorpe (1956) showed that yield of crops depends largely on the rate of development and maintenance of leaf surface.

In the oil palm where each frond axil subtends only one inflorescence, the rate of frond production sets an upper limit to the rate of inflorescence production. Bunch production therefore depends on the number and size



of fronds and the proportion of them providing inflorescence.

Shading adult palm reduces the production of female inflorescence. Sparnaaij, (1960) demonstrated this by pruning the leaves of adjacent palms to increase the production of female inflorescence. A positive though not strong correlation has been found between sunshine data in the preceding 12 months and yield some 28 months later (Hartley, 1988).

In countries such as Nigeria and Ghana and other West African countries with marked seasonal differences in hours of sunshine, the differentiation of female inflorescence as shown by the sex ratio at flowering two years later, is much higher during the months with many hours of sunshine than during the months with few (Broekmans, 1957).

The exact requirements, either in terms of radiation or sunshine hours for optimum yield are unknown. Records however kept for some high oil palm production areas in terms of annual averages of daily sun-hours range from



over 6 hours in parts of Malaysia, Zaire and Brazil, to 4.6 hours in Nigeria and even lower in Cameroun (Hartley 1988).

Rees (1988) reported on the seasonal radiation distribution at the Nigerian Institute for Oil Palm Research (NIFOR) which has three wet-season months of only 2.3 and 2.4 hours compared with the lowest monthly value in Kuala Lumpur of 4.9 hours.

At NIFOR, the total incident light (PAR) was $2.43 \times 10^9 \text{ Jui}^{-2} \text{ annum}^{-1}$ unevenly distributed so that the highest monthly value was about 1.4 times higher than that of the lowest month. The annual totals for some sites in Malaysia are higher than this.

Corley et al (1971) and Corley (1973) observed incident light (PAR) for Layang-layang and coastal West Malaysia as value of $2.55 \times 10^9 \text{ Jui}^{-2} \text{ annum}^{-1}$ and $3.2 \times 10^9 \text{ Jui}^{-2}$ for Layang - layang and Coastal West Malaysia annum^{-1} respectively.

Rees (1962), Rees and Tinker (1963) measured intercepted light by adult palms in Nigeria and indicated that the proportion intercepted was 87% at a leaf area index of

4.9, some 13% was not trapped and therefore lost. This may be due to the wide spacing of the oil palm.

2.2.2: Soil factors affecting the growth, development And yield of the oil palm

Besides the inherent fertility of the soil, mineral nutrient absorption by the oil palm is highly dependent on such soil physical properties as aeration, moisture status and soil pH (Jacquemard, 1998).

2.2.2.1: Soil physical factors

According to Hartley (1988) for optimum oil palm production, the soil must be deep and loamy with a well-developed structure. Soil should have a loose friable consistency and must be without impervious layers in the top 1.5 meters. Drainage must be good to ensure aeration. The soil must however be capable of holding ample moisture for the oil palm (Olivin, 1968; Ochs and Olivin, (1969).

Growth and development of the oil palm is impaired on soils with high water table especially the young plants which cannot tolerate stagnant water. Heavy, badly

drained soils and coarse sandy soils, which are easily depleted of moisture, are not suitable. Dolmat et al. (1982) and Rasmussen et al., (1981) showed that peat soils could be suitable provided they are well drained and deep enough to provide sufficient anchorage for the root system of the oil palm. In areas with marked dry seasons like some parts of West Africa, Olivin and Ochs (1978) postulated that a soil of good water holding capacity and of good moisture retention is valuable.

vander Vossen (1969) observed that the oil palm best flourishes in areas of acid soils with pH between 4 and 6.

2.2.2.2: Mineral nutrient requirement

The oil palm needs large quantities of nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg) which are important for both vegetative and fruit production (Dolmat, 1996).

These nutrient requirements of the oil palm vary with age (Foster and Chang, 1977), variety (Poon ET al., 1970), level of production and management practices which among

others include planting density and cover management (Hartley 1988).

Yield potential of the environment also dictates nutrient requirement. Therefore when yield is restricted by such factors as inadequate rainfall, shallow soil depth and poor drainage, nutrient requirement is also depressed (Foster et al., 1985). The natural nutrient supply of any soil is only of limited capacity. Extra supplies in the form of fertilisers are practically always needed. These are applied from the very first year of planting in the field.

Soil analysis indicates the quantity of elements at the disposal of the palm. Soil nutrient supply capacity indices are shown in Table 2.1. Fertiliser is applied to bring the soil nutrient supply capacity from low to the high profile as and when necessary.



Table 2.1: Soil Nutrient Availability Indices

Nutrient	High	Medium	Low
N (Total)%	> 0.2	0.1 - 0.2	0 - 0.1
P (available) (mg/kg Soil)	> 20	10 - 20	0 - 10
K (available) (mg/kg Soil)	>100	50 - 100	0 - 50
Organic Matter Content (%)	> 3	1.5 - 3	≤ 1.5

Foliar analysis identifies and quantifies the deficiency of individual nutrients so that fertiliser adjustments can be calculated.

The leaf nutrient concentrations are indicative of the nutrient status of the palm trees. Critical leaf nutrient levels are presented in Table 2.2. Below or above these sufficiency levels, fertiliser use needs to be increased or withheld.



Table 2.2: Critical Levels of Oil Palm Leaf Nutrient Status

AREAS	N	P	K	Ca	Mg	Sources
Ivory Coast & Benin	2.50	0.15	1.00	0.60	0.24	IRHO (1960)
Nigeria	2.50	0.16	1.00	-	0.28	WIFOR (1956)
Malaysia	2.40	0.15	1.00	0.60	0.24	Ollagnier(1963)

2.3: Oil palm cropping systems

Two broad types of cropping systems are identified with the production of oil palm in Ghana. The oil palm is either cultivated as a monocrop with various cover crops and/or in association with food crops (Sparnaaij, 1991).

2.3.1: Monocrop oil palm with leguminous cover crops

Oil palm is cultivated as a monocrop by the development estates and their affiliated small holders as well as out-growers. The practice of these development estates has been to inter plant the oil palm in inter rows with leguminous cover crops. These cover crops include *Pueraria phaseoloides*, *Pueraria javanica*, *Calapogonium mucunoides*, *Calapogonium caesuleum*, *Centrosema pubescens* and *Mucuna cochichinensis* (Hartley, 1988). The natural

plant cover consisting of broad leaves and grasses persists as weeds where no effort is made to incorporate the leguminous cover crops. Gray and Hew (1968) and Tan and Ng (1973) have established that leguminous covers are beneficial to the oil palm as compared to the other inter row covers such as grasses.

Legume covers are established during the planting of the oil palm and their benefits are numerous. They enrich the soil with organic matter and improve the nutrient status especially Nitrogen. Foster (1976) observed that legume cover is beneficial to a tree crop in the initial years because it does not compete with it for the soil nitrogen while in the fourth to sixth year, the legume cover releases considerable amount of nitrogen and organic matter to the soil as it dies out. The total N supplied by a legume crop to an oil palm plantation is equivalent to 3 to 4 kg of ammonium sulphate applied per palm per year for three years (Hartley, 1988). Broughton (1976) found that leguminous covers increased oil palm leaf contents of N, P and Mn over those obtained with other types of covers.



Tan and Ng (1981) and Hew and Tam (1972) made similar observations.

There is also the added control of soil erosion and water run-off especially in hilly terrain as well as the improvement of soil physical properties. Leguminous cover crops are sown before planting of the oil palm and therefore provide some protection to the bare soil against erosion by reducing the impact of the heavy rains, which erode the topsoil.

Zaharah et al (1986) and Agamuthu and Broughton (1985) showed evidence that Pueraria phaseoloides contributed about 150 kg N per hectare per year to oil palm plantations. Chemara (1968) discovered that the presence of a leguminous cover more effectively raised the leaf N concentration in young oil palms than the application of 2 kg of ammonium sulphate per palm per year.

Song and Yap (1976) postulated that the reduction in soil erosion are due in part to improved aggregation of the soil particles and increased water infiltration rates. This they claimed resulted from the increased readily decomposable organic matter added to the soil by



the legume cover. In addition, the extensive root system of legumes acts as a permeable barrier thus reducing the rate of run-off. Agamuthu and Broughton (1985) estimated the leaching losses under legume covers to be 63 kg N per hectare per year less than the losses under other plant covers.

Soil moisture is conserved from reduced by evaporation as the legume cover protects the soil surface from the direct effect of sunlight.

One good method to suppress noxious weeds such as Chromolaena odorata especially during the immature phase is to grow the legume cover crop in the inter rows. Vigorous and luxuriant weed growth poses a serious competition to the main crop. Rajaratnam et al., (1977) reported of competition for nutrients between the oil palm and weeds. Gray and Hews (1968) reported yield reductions due to weeds of 6% to 20% in a mature oil palm. Teo et al (1991) observed an increase in yield of about 11.8% when a noxious weed, Ischaemun muticum was totally removed.

There are however some negative effects of cover crops on the oil palm. Ochs and Daniel (1976) observed

that in drier climates legume covers can cause a decrease in yields of oil palm due probably to competition with the crop for water during the dry season.

Aya and Lucas (1977) considered the initial poor establishment of legumes a hindrance to the control of erosion and viewed the subsequent vigorous growth as providing strong competition for water and nutrients.

2.3.2: Intercropping oil palm with food crops

Andrews and Kassam (1976) defined intercropping as growing two or more crops simultaneously on the same field. Crop intensification is said to be both in time and space dimensions. The practice of intercropping is common among small-scale farmers in tropical Africa especially West Africa (Onochie, 1977).

The oil palm is grown as cash crop by these category of farmers who also intercrop it with food crops (Hartley, 1988). Crop combinations are many and varied. These combinations depend on the food culture of the area. Other factors such as climate, soil, age of palm and socio-economic determine the choice of crops grown.

2.3.3: Influence of climate on choice of intercrop

Oil palm is generally grown in the forest belt in West Africa. The area is characterised by bimodal rainfall amounting to or more than 2000 mm. The growing period is more than 200 days extending from March/April to October/November. Food production in this area is based on associations of maize, cassava, plantains, cocoyams and vegetables that are the dominant staples (Okigbo and Greenland, 1976, Steiner, 1982). These are also the crops mainly intercropped with oil palm in combinations determined only by the farmer.

Onwubuya et al., (1988) noted that Nigerian peasant farmers pruned oil palm groves to the spear leaf in order to allow sufficient light for food crops. The same is practised in Ghana.

On the plantations, the small-scale farmers intercrop oil palm with food crops but this is limited to the early stages when the oil palms have not yet developed a closed canopy. This is because the majority of the food crops grown as intercrops with oil palm such

as maize, plantain and cassava are not suited to growing under shade except cocoyam (Hartley, 1988).

2.3.4: Soil conditions and choice of intercrop

Wilson and Ademiran (1976) observed that cassava is an important staple of the tropical rain forest zone because it is very tolerant to low soil pH, low soil fertility and low moisture regimes, which characterise the tropical rain forest zone. Maize and plantain are also dominant components adapted to the small-scale farmers' situation in these zones as they grow well on freely drained soils (IITA, 1977).

2.3.5: Socio-economic factors and choice Of intercrops

Socio-economic factors have also been shown to influence the decision of small-scale farmer to practice intercropping. Norman (1974) established that personal tastes, tradition and religious convictions condition social factors. Getalum (1977) emphasised the fact that in Ethiopia crop production is for home use and food that habits are based on ethnic differences, cultural biases

and education as well as religious convictions. Economic factors however are based on magnitude of inputs and outputs, dependability of returns, prices and ease of transport.

Bradfield (1986) stressed those transportation facilities and costs are other major factors affecting the feasibility of crop production in a given area. Quite typically if roads are either unavailable or passable only at certain seasons of the year, farmers may adopt the cropping systems of crops that mature during the dry seasons of the year when the roads are passable.

If there are no roads at all, the farmers usually opt for A combination of subsistence crops.

His taste and what crop brings in maximum revenue to sustain his family until his palms mature (Norman 1974) guide the small-scale farmer's decision among others.

2.4: Growth and yield of intercropped oil palm

In the West African sub-region especially in Ghana, most small-scale farmers intercrop their oil palm with food crops during the early years of establishment.



Various studies have shown that tree crops can be successfully grown in association with food crops before their canopies are fully developed.

Sparnaaij (1957) in Nigeria reported that intercropping of oil palm with maize, cassava and plantain during the early years of tree establishment generally had no adverse effect on the growth and yield of the palm.

It has also been reported in Indonesia that growing food crops in association with rubber and oil palm do not have adverse effect on the young rubber or oil palm (Tan, 1960; Srepadyo and Tan, 1968). The findings of Onwubuya and Eneh (1987) and Nigeria Institute for Oil Palm Research (NIFOR, 1988) also agree with Sparnaaij (1957) that intercropping oil palm with food crops generally has no adverse effect on the growth and development of the oil palm. They observed that more leaves were produced per palm in the intercropped treatments than in the treatment with cassava.

Mean height, girth and sex ratio of oil palm were also highest in the combination with maize.

Results from the work of Ofo et al., (1988) also confirmed some of the earlier findings. Cropping system involving cassava had significantly lower number of leaves, smaller girths and shorter palms than the rest involving maize, melon and maize + melon combinations. The palms grown with a mixture of legumes also had low numbers of leaves, shorter trees and small girths. Oil palm intercropped with maize, melon and maize + melon also produced a significantly higher sex ratio (ratio of female to total inflorescence) than any of the crop combinations in which cassava and sole cropped oil palm with legume was involved.

Christian (1959) in Ghana showed that leguminous covers might be more competitive with palms than intercropped food crops.

Work at NIFOR (1988) showed results of soil studies, which indicated decreases with time in soil, pH and which significantly, increased. Hartley (1988) also reported of increased adverse effects of palm shade on intercropped food crops with time as light interception by the oil palm increased.

2.5 Growth and yield of food crops intercropped with oil palm

Hartley, (1988) observed that in oil palm shading and competition for light are the major factors for yield suppression of food crops by oil palm and other tree crops. The extent of shading and radiation distribution within canopies varies with tree species and is related to tree growth stage (Rosenberg, 1974, and Vandermeer, 1989),

Work on intercropping has shown that yield advantages can be achieved as reported by Wilson and Agboola (1979) for cassava + maize and Onwubuya and Eneh (1987) for oil palm and some annual crops.

Ofoh et al., (1988) by intercropping some food crops with oil palm found that irrespective of the cropping system there were no significant differences in the yields of the food crops. However yields from the sole cropped maize, cassava and melon were highest.

CHAPTER THREE

3.0: MATERIALS AND METHODS

3.1: A survey of oil palm based cropping Systems in Ghana

A survey of oil palm-based cropping system was carried out to identify and study intercropping systems used in oil palm production. It was also necessary to understand the socio-economic background of farmers and to relate such information to their practices.

The objective was to identify food crops suitable for intercropping with oil palm. It was also to provide to relevant information for designing agronomic trials aimed at improving and sustaining oil palm production within the socio-economic context of the small-scale farmer.

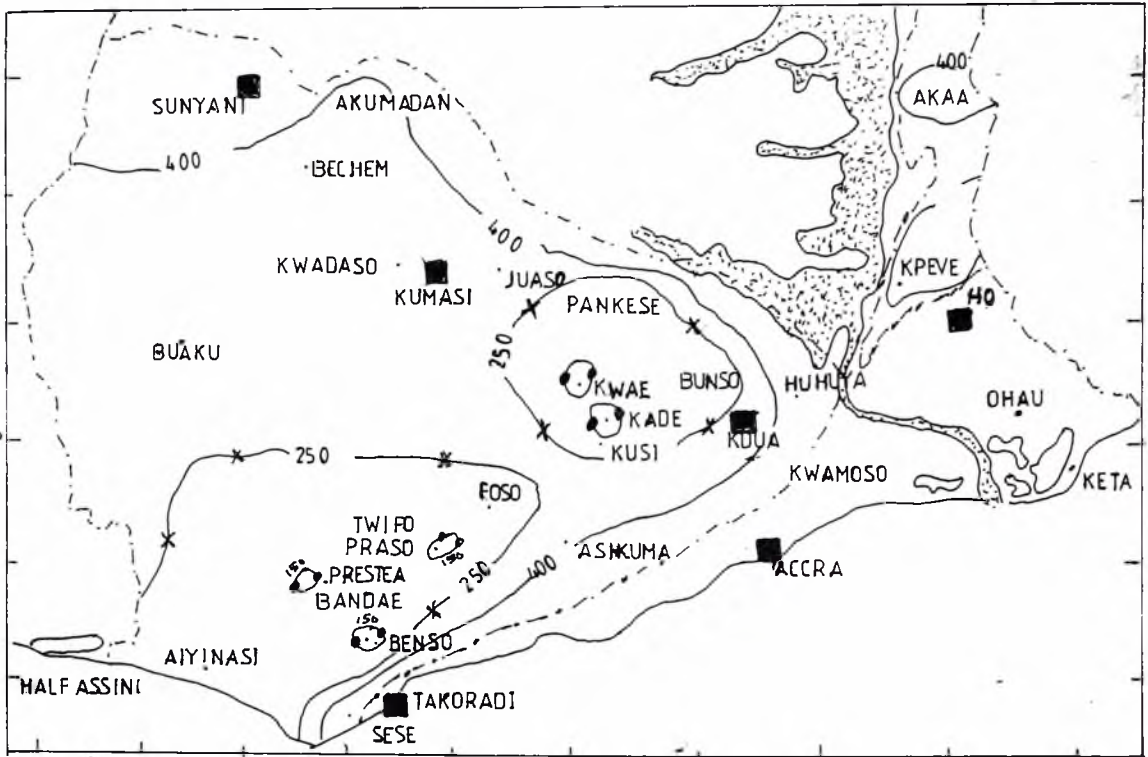
Climatic conditions confine economic oil palm cultivation to the lowland tropical rain forest and moist semi-deciduous forest zone in the southern part of Ghana.

van der Vossen (1969) using values of mean annual water deficit delineated this area into three climatic zones for economic oil palm cultivation (figure 3.1).

These areas described by van der Vossen (1969) cover six regions, namely Eastern, Ashanti, Western, Central, Brong Ahafo and Volta (Figure 3.1). Farm visits were carried out in these six-oil palm-producing regions. In each region, two districts were selected. Each district was divided into two sub-districts and three farms were visited in each sub-district.

Farmers were interviewed using a detailed questionnaire. Questions were on agronomic practices, age of farmers, and their level of education, type of dependants and income from oil palm and food intercrops. Agronomic questions centred on land preparation, time of intercropping, duration of intercropping, plant population, choice of food intercrop, intercropping pattern, time of canopy closure, yield of food intercrop and oil palm yield. Other questions were on the age of farm, size of farm and variety of oil palm grown.

Fig.3.1: Areas climatically suitable for oil palm production in the forest zone of Ghana.



- KEY
- - - - - LIMIT OF THE FOREST ZONE
 - 150 --- 150 MEAN ANNUAL WATER DEFICIT (mm) OPTIMUM RAINFALL FOR OIL PALM PRODUCTION
 - 250 --- 250 MEAN ANNUAL WATER DEFICIT (mm) FAVOURABLE RAINFALL AREA FOR OIL PALM PRODUCTION
 - 400 --- 400 MEAN ANNUAL WATER DEFICIT (mm) SUITABLE RAINFALL AREA FOR OIL PALM PRODUCTION
 - REGIONAL CAPITAL

Source: van der Vossen (1969)

3.2: Physiological and agronomic studies on Oil palm based cropping systems

3.2.1: Experimental Site

The experiment was conducted from 1994 to 1997 at the Oil Palm Research Institute (OPRI), Kusi (06.00N, 001.45W), which is about 450 meters above sea level.

The experimental area was fairly flat but gently sloping in the North-South and East-West directions. The natural vegetation of the area is semi-deciduous forest type.

The original vegetation was cleared in 1967 and planted to oil palm, which was felled in 1991. A regrowth of bush dominated by *Chromolaena odorata* and relics of *Pueraria phaseoloides* and *Carica papaya* was the vegetation cleared for this experiment. Soils in the experimental area are sedentary. The soils of the Nzema series (Acrtdol, FAO) occur in upper to middle slopes and colluvial soils of the Kokofu series on the lower parts (Asiamah and Senayah, 1991).

The area is in a zone characterised by relatively high



Rainfall which falls in two seasons. The major rainy season occurs from April to July. The minor rainy season begins in September to the end of October or mid-November. Average annual rainfall is about 1425 mm.

3.2.2: Experimental treatments, design and crop Management

The experiment was consisted of 7 treatments arranged in a randomised complete block design with 4 replications. The planting material was tenera (D x P ex OPRI). 12 months old seedlings were transplanted in the field in April 1994. Each plot measured 35.2 x 22.7 m and had 12 seedlings. Planting was done at a spacing of 8.8 m triangular or the equivalent of 148 palms per hectare.

The treatments were as follows:

(i). oil palm + pueraria: oil palm interrows were seeded with a leguminous cover crop, Pueraria phaseoloides . The cover crop was seeded at 0.5 kg per plot in April 1994 after transplanting of the seedlings. This is standard estate practice, which served as the main control in this experiment (plate 3.1)

(ii). Oil palm + maize + cassava: oil palm interrows were cropped with maize and cassava during the major seasons.

Maize (var. Okomaso ex CRI) was planted on 20th April 1994, at 0.7m x 0.5m with three seeds per stand but thinned to two at one week after emergence resulting in a plant population of 3780 per plot.

There were 27 rows per plot. The cassava, a mixture of Nzema, and Ankra was planted on 6th May 1994, about two weeks after emergence of maize and spaced at 1m within rows thus giving a plant population of 945 plants/ha. Maize and cassava rows were spatially arranged on the same row as oil palm and in rows 0.7m, 1.4m, 2.1m and 2.8 metres equidistant away from the palm row. The maize was harvested on 24th August. Cassava was harvested in March the following year. The cycle was repeated every year for the three years of experimentation (plate 3.2.)

(iii). oil palm + maize + plantain: the oil palm interrows were cropped with maize and plantain in the major season in 1994. The maize was planted and

harvested in the same manner and time as in the previous treatment and at the same plant population.

The plantain, false horn variety 'Apantu pa', was planted at 3 m triangular in the interrows of the oil palm thus giving 88 plants per plot or ha^{-1} .

The nearest plantain rows with reference to the oil palm rows were 1.2 m equidistant away from the oil palm rows. After the first cycle maize, the plantain was maintained up to the first Raton crop ending January 1997

(Plate 3.3)

(iv). Oil Palm + Maize + Maize: oil palm interrows were cropped with maize in the major season and followed by maize in the minor season. Major season maize was planted on 20th April and harvested on 24th August as for treatment (ii). The minor season maize was planted on 6th September 1994 and harvested on 3rd January 1995.

Spacing and plant population for both major and minor season maize was the same as in treatment (ii).

The cycle was also repeated every year for the three years of experimentation 1994, 1995 and 1996 (plate 3.4)

(v). Sole crop of maize, cassava and plantain were also grown as controls on similar plot sizes and were planted and harvested in the same way as those in the Associations.

Fertilizer was applied to oil palm seedlings six months after transplanting, and thereafter, in September every year. Nitrogen was applied at 42g, P at 48g and K at 250g per tree (Anon, 1988). No fertilizer was applied to the food crops (maize, cassava and plantain.)

The food crop plots were weeded two times in a season. The leguminous plots in treatment 1 were slashed and a circle of 1m around the palm was clean-weeded every three months. Plantain was mulched with chopped dried weeds at the pre-harvesting period. The pseudostem and leaves were used for mulching after harvesting.



Plate 3.1: Oil Palm with Pueraria Cover Crop (T₁)



Plate 3.2: Oil Palm Intercropped with cassava (T₂)



Plate 3.3: Oil Palm intercropped with plantain (T₃)



Plate 3.4: Oil Palm intercropped with maize (T₄)

3.2.3: Data Collection

3.2.3.1: Rainfall Data

Temperature and rainfall data were collected for the site. Monthly and annual water deficits were calculated from the rainfall data using the formula:

$$D = R + P - Pe$$

Where D = water deficit; R = theoretical soil moisture reserve at the end of the previous month;

P = precipitation or rainfall for the month;

Pe = potential evapotranspiration for the month

(Surre, 1968).

3.2.3.2: Growth, development and yield of oil palm

(i) Leaf area per palm (LA)

LA = b (n X LW). Where n = number of leaflets;

Lw = mean of length x mid - width for a sample of the largest leaflets, and b, the correction factor = 0,55

(Hardon et al; 1969).

(ii) Leaf area index (LAI)

Having estimated the leaf area (LA) of a palm, it was related to the ground area. LAI was thus estimated:

$$\text{LAI} = \frac{\text{Leaf area}}{\text{Ground area}}$$

(iii) Frond dry weight (FDW)

A non-destructive method as described by Corley (1971) was used to estimate this parameter which also allows for estimation of Dry matter production rates. A pair of callipers was used to measure the width and depth of petiole, that is the point of insertion of the lowest leaflet. The values obtained were put into a formula to estimate the FDW (Corley 1971) thus:

$$\text{FDW} = 0.1026 \text{ width} \times \text{depth} + 0.2362 \text{ (Kg)}$$

(iv) Rate of leaf production (RLP)

Six months after transplanting the oil palm seedlings to the field, leaf number one, which is the youngest fully expanded leaf was identified and tagged. All functional

leaves were then counted up to the tagged leaf. Subsequent counts were made at six - monthly intervals. After the identification and tagging of leaf No.1, the leaves between the current and the previous reference leaves were counted. The total number of leaves counted was related to time for the growth rate of leaf production. The calculation was thus:

$$\text{RLP} = \frac{N_2 - N_1}{T_2 - T_1}$$

Where N_2 , N_1 were total leaf counted at the periods T_2 , T_1 respectively.

(v) Sex ratio

Male and female inflorescences produced on the palms were counted at bi-weekly intervals. Counted inflorescence was marked to avoid re-counting.

Sex ratio was then calculated from the floral production data obtained using the formula of Corley et al. (1971):

$$\text{Sex ratio} = \frac{\text{No of female inflorescence}}{\text{Total inflorescence (Male + Female)}}$$

Flowering started in August 1995 and it was monitored up to December 1997.

(vi) Yield of oil palm.

Weekly individual yield recording was carried out as soon as palms came into bearing. The weights and numbers of the fresh fruit bunches (FFB) harvested were recorded for individual palms at each harvesting round. The data obtained was used to estimate yield per hectare.

3.2.3.3: Nutrient dynamics, soil moisture retention and solar interception by the oil palm.

(I) Soil fertility status

To assess the dynamics of soil nutrient accumulation, soil sampling was undertaken before land clearing and after every cropping cycle at 0 - 15 cm and 15 - 30 cm depths. 4 soil samples each from plots having a common treatment were bulked and mixed to form a composite. Sub-samples of the composite were air dried, ground and passed through a 2-mm mesh sieve for analysis.

Soil pH was determined in a 1:1 soil and water suspension using a pH meter with glass electrode.

Organic-Carbon was determined by the Walkey-Black dichromate method. Total nitrogen was determined by the

Kjedjahl method. Available phosphorus was determined by the Bray's No.1 method and potassium by flame photometry.

(ii) Leaf nutrient dynamics

To determine the dynamics of oil palm nutrient uptake, leaf samples of the oil palm lamina from the central leaflets of leaf No.17 were taken at six-monthly interval.

The leaf samples were cleaned with cotton wool and distilled water, oven-dried at 60° C for 72 hours, ground and analysed for N, P and K. Nitrogen was determined by the kjeldahl's method, Phosphorus by the vanado-molybdate method and potassium by flame photometry.

(iii) Soil moisture status during the dry season

To assess which cropping system had best conserved soil moisture, especially during the dry season, soil moisture status was determined monthly over the dry season, November - March. Soil samples were taken at the depths of 0 - 15cm and 15 - 30cm. Sampling dates were delayed for at least six rainless days whenever the rains fell on

sampling dates. Soil samples were collected in aluminium cans, which were covered immediately. The samples were then weighed before and after oven drying at 80°C for 48 hours. Gravimetric soil water content (%) as mass of water (g) related to mass of oven dry soil (g) and multiplied by 100.

(iv) Light interception by the oil palm

To study the influence of the various cropping systems on light interception by the oil palm canopies, two tube *solarimeters* were used. Each *solarimeter* was connected to a *Microvolt integrator* (NV^2). One tube *solarimeter* was installed above the canopy of the palm about one meter above leaf No.1 (plate 3.5) and the other were placed directly beneath the canopy (plate 3.6). The tubes were installed and set or reset on the plots at 0930 hours. Daily readings were taken hourly from 1030 hrs to 1530 hrs. Measurements from the two *solarimeters* were used to estimate percentage interception of solar irradiance by the oil palm. Solar irradiance above canopy was used as basis for comparison.



Plate 3.5 Tube Solarimeter installed above the Canopy of oil palm (arrowed)



Plate 3.6 Tube Solarimeter installed beneath the canopy of the oil palm (arrowed)



3.2.3.4: The performance of food crops intercropped with oil palm.

3.2.3.4.1 Maize

Data on growth, development and yield of maize were taken monthly until the maize was harvested.

A maize row were arranged on the same row as oil palm and coded 0, and on rows 0.7 m, 1.4 m, 2.1 m and 2.8 metres equidistant away from the palm row.

(i). Leaf Area (LA) Per Plant

Thirty plants were randomly selected and tagged in each plot. The length and the greatest width of leaves on these plants were measured at each sampling time. Maize leaf area was then estimated from the quotient of the leaf length and the greatest width multiplied by the constant 0.75 (Moll and Krampath, 1977). The formula was thus:

$$LA = \text{Length} \times \text{width} \times 0.75.$$

(ii). Rate Of Leaf Production (RLP)

At each sampling time all functional leaves on each tagged plant were counted. The total number of leaves counted at the different time periods was used to estimate RLP.

$$\text{RLP} = \frac{N_2 - N_1}{T_2 - T_1}$$

Where N_2 , N_1 were total leaves counted at the periods T_2 , T_1 respectively.

(iii). Plant Height

The heights of the thirty-tagged plants in each plot were taken monthly. Height was taken from the ground level to the tallest leaf tip and mean height per plant calculated.

(iv). Grain Yield

Rows in each plot were harvested separately. Yield parameters recorded were 1000 seed weight and grain yield per unit area.



3.2.3.4.2 Tuber yield of intercropped cassava

Like the maize, the various rows of cassava were harvested separately. The fresh tuber weights were recorded for each plot. Growth and development measurements of cassava could not be taken due to the mixed population of cassava varieties planted. While some plants were short and branched profusely so close to the soil level (i.e. Nzema var.) others were tall and almost did not branch (i.e. Ankra var.).

The two varieties grown and identified were however supposed to have same yield potential of 25t ha⁻¹.

3.2.3.4.3 Growth, development and yield of plantain

Growth and development measurements started at three Months after planting of plantain and thereafter continued monthly until flowering. Ten plants per plot were randomly selected for measurements. The Data collected were:

(i). Plant height at flowering

Height of the plants was taken from soil level to the point where the peduncle emerged from the pseudostem.

(ii). Girth of the pseudostem

The girth of the pseudostem was measured at a height of 1 m from ground level using a measuring tape.

(iii). Rate of leaf production (RLP)

This was determined as described for maize using leaf production over time.

$$\text{RPL} = \frac{N_2 - N_1}{T_2 - T_1}$$

Where N_2, N_1 were total leaves counted at the periods T_2, T_1 respectively.

(iv). Leaf area (LA) per plant

Plantain leaf area was determined as the product of the leaf length and the greatest width multiplied by the constant 0.81.

(v). Type and rate of wind damage

The type and incidence of lodging were assessed from weekly counts of lodged plantain suckers and especially after rains.

Counted lodged plantain suckers were immediately cut into pieces and disposed of as mulching material which ensured avoidance of duplication of counts. Cumulated count of lodging was recorded for each plot.

(vi). Yield and components of yield

At harvesting, bunches were weighed and the number of hands per bunch as well as the number of fingers per hand and peduncle weight were recorded. Finger weight was also recorded. The total fruit weight was obtained as the bunch weight minus the peduncle weight. Yield of plantain between February 1995 and January 1996 was recorded for 1995. Bunches harvested between February 1996 and February 1997 was entered for 1996

3.2.3.5: Weed growth and succession

Weed samples were taken on the eve of each weeding exercise. Weed species and their intensities were recorded with a quadrat of 100 cm x 50 cm. The average over two locations randomly selected in each plot was

determined. The quadrat was placed and weeds within it were cut, identified and sorted into species.

They were then oven-dried for 48 hours at 80^oc for dry weight determination. The data was used to study the weed control efficiency by the various systems between 1995 and 1996. Relative weediness(DW) of species was calculated as follows:

$$DW = \frac{\text{Treatment's species Weed Dry Weight} \times 100}{\text{Total Treatment Weeds Dry Weight}}$$

3.2.3.6: Agroeconomic analysis of intercropping

Food crops with oil palm.

The cost benefit analysis of intercropping food crops with oil palm was by comparing production cost and revenue for sole oil palm with that of intercropped oil palm. Records were kept of cost of inputs, equipments and labour used for the experiment. Labour cost at the period of study was used as well as the current market prices of produce.

(i) Production Costs of the cropping systems

Total cost was calculated as $X = a + b + c + d + e$.

Where variables a,b,c,d and e were:

a - cost of planting materials/seeds

b - labour cost throughout the cropping cycle

c - harvesting costs

d - storage costs, if there were any and

e - marketing costs

(ii) Value of produce (V)

The economic yields of the oil palm and food crops were multiplied by the mean market prices for the three years to give value in monetary terms. The computation was:

$$V = pa^{Y_a} + pb^{Y_b}$$

Where p_a , p_b are constants measuring the value in monetary terms of unit amounts of A and B, assuming that quality of produce remains same and that there was no change in cost price.

(iii) Net returns (Benefits)

All costs were deducted from the revenue and the resulting Net Returns for oil palm 'with' and 'without' intercropping compared.

$$\text{BENEFITS} = \text{REVENUE} - \text{COSTS}$$

(iv). Economic assessments

The cost benefit ratio, which is the return per cash invested, was calculated by relating Gross Income to Total cost of production or cash invested. This was obtained from the formula:

$$\text{Cost benefit ratio} = \frac{\text{Gross Return}}{\text{Total cost of cultivation}}$$

The income equivalent Ratio (IER) which is the relative land area under sole crops, that is required to produce the incomes achieved in intercropping was extrapolated using the sole oil palm with pueraria cover crop as the basis of comparison.

CHAPTER FOUR

4.0: RESULTS

4.1: Features of oil palm based cropping systems in Ghana

4.1.1: Age distribution of oil palm farmers

Over 70% of oil palm farmers studied were aged between 30 and 60 years old (Table 4.1). In the Western and Central regions, about 90% of the oil palm farmers were in this category. About 22% of the farmers were over 60 years Old. Farmers under 30 years rarely planted oil palm.

4.1.2. Level of education of farmer

Eighty-one percent of the respondents had some formal education (Table 4.2). Fifty percent of those interviewed had only primary school education, and only 3.5% went beyond Secondary School.

4.1.3. Composition of dependants

On the national scene, the mean age of dependants, above 18 years was highest and the least was recorded for those

below 10 years (Table 4.1). Over 40% of the dependants were above 18 years, except for Central region.

Table 4.1: Age of Farmers (%)

Region	Age of farmers (yr.)		
	< 30	30 - 60	> 60
Eastern	-	75	25
Aconite	-	80	20
Western	10	90	-
Central	-	88.9	11.1
B/Ahafo	-	62.5	37.5
Volta	-	60	40
Average	1.7	76.0	22.3

Table 4.2: Level of Formal Education (%)

Region	Level of education			
	No School	Primary school	Secondary school	Tertiary Level
Eastern	25	75	-	-
Ashanti	10	70	10	10
Western	20	40	40	-
Central	11.1	44.1	33.4	11.1
B/Ahafo	25	37.5	37.5	-
Volta	20	30	50	-
Average	18.8	49.5	28.5	3.5

Table 4.3: Composition of Dependants on Farm Revenue (%)

Region	Age of Dependants		
	< 10 yrs	10 - 18yrs	> 18 yrs
Eastern	25.8	25.8	48.4
Ashanti	22.9	35.5	41.6
Western	26.5	30.6	42.9
Central	37.3	33.6	29.1
Brong Ahafo	27.7	26.5	45.6
Volta	16.7	38.9	44.4
National Average	26.2	31.8	42.0



4.1.4: Income from oil palm produce

Table 4.4 shows the proportion of farm income from various oil palm produce. On the average, farmers generated about 38% of their income from sale of bunches. In the Volta region, however, palm oil generated the highest revenue of 32% followed by sale of 7 bunches (30.7%), kernel (16%), kernel oil (9.3%), palm wine (8%) and loose fruit (4%).

In the Western region about 55% of income from oil palm came from bunches and only 7% from palm oil. Between 22.7% and 54.9% of revenue was record from sale of bunches in the Eastern, Central, Western and Ashanti regions.

Table 4.4: Relative incomes from various oil palms Produce (%)

Region	Bunches	Fruits	Palm Oil	Kernel	Kernel Oil	Palm Wine
Eastern	22.7	25.0	22.7	9.0	9.0	4.5
Ashanti	34.4	31.2	23.6	-	-	-
Western	54.9	32.9	7.3	-	-	-
Central	41.3	21.2	21.7	-	9.3	-
Brong Ahafo	47.3	27.0	14.9	-	-	-
Volta	30.7	4.0	32.0	8.0	9.3	8.0
Mean	38.0	24.1	20.4	2.1	4.6	2.1

4.1.5: Income from food intercrops

Farm income from food intercrops is presented in Table 4.5. Maize, cassava and plantain in a declining order of importance are the major food crops used as intercrops in oil palms. They provide 32.0%, 30.5% and 16.1% of revenue to the farmer beside the oil palm produce.

The same trend is exhibited in the regions except in the Volta region where maize provided 5.8% more income than cassava.

Cocoyams, fruits, vegetables, yams and rice follow in declining order of importance as intercrops providing extra revenue to the farmers. Farmers indicated that consumption of these intercrops takes precedence over their sale for extra income.

Table 4.5: Relative Incomes from Food Intercrops (%)

Region	Maize	Cassava	Plantain	Cocoyam	Fruits	Vegetables	Yams	Rice
Eastern	32.6	32.6	11.6	7.0	9.2	7.0	-	-
Ashanti	29.3	26.0	23.6	7.3	3.3	8.9	1.6	-
Western	36.4	29.9	20.6	6.6	2.8	3.7	-	4.0
Central	32.0	27.1	17.3	3.3	10.2	1.0	5.1	3.7
B/Ahafo	28.0	27.1	15.9	9.3	-	5.6	10.3	-
Volta	33.9	39.7	7.53	4.9	6.1	4.1	3.8	-
Mean	32.0	30.4	16.7	6.4	5.3	5.1	3.5	1.3

4.1.6: Agronomic practices of farmers

Categorisation of farmers according to some agronomic practices is shown in Tables 4.6. and 4.7. The practices of farmers seemed to change little from region to region. No respondent planted his palms at a wider spacing than the recommended 8.8-m triangular (148 plants hectare⁻¹). Over 70% of the farmers in the Volta region planted denser than the 148 palms hectare⁻¹. (Table 4.6)

In the Brong Ahafo region, 33.3% planted denser than 148 plants hectare⁻¹. Between 77.8% and 90% of farmers in the Eastern, Ashanti, Western and Central regions planted at 148 palms hectare⁻¹.

All farmers interviewed except some in the Brong Ahafo and Volta regions planted the improved material, 'Tenera'. About 58% of respondents in the Volta Region planted unimproved 'Dura' materials collected as volunteer plants from other plantations and or tendered the natural oil palm grove.

All farmers visited during the survey had weed problems. Most of their farms especially, the younger ones were infested With Chromolaena odorata.

The most common among the weed control measures adopted was hand weeding followed by slashing (Table 4.7).

Less than 10% of the farmers interviewed used herbicides and this was mostly used to control weeds in maize intercrops.

Table 4.6: Frequency of planting materials and planting density used by farmers. (%)

Region	Planting density (plants/hectare)		Planting material	
	148	>148	Tenera	Dura
Eastern	80	20	100	-
Ashanti	90	10	100	-
Western	90	10	100	-
Central	77.8	22.2	100	-
Brong Ahafo	66.7	33.3	80	20
Volta	27.3	72.7	41.7	58.3
Mean	72.0	28.0	87.0	13.0

**Table 4.7: Frequency (%) of weed control methods
Adopted by farmers.**

Region	Weed Control Method		
	Weeding	Slashing	Herbicides
Eastern	50	25	25
Ashanti	76.9	7.7	15.4
Western	100	-	-
Central	66.7	22.2	11.1
Brong Ahafo	67.6	22.5	9.9
Volta	83.4	8.3	8.3
Mean	74.1	14.3	11.6

4.1.7: Duration of intercropping

The duration of intercropping food crops in oil palm is presented in (Table 4.8). In the Eastern, Ashanti, Western and Central regions, young palms were intercropped up to three years. Some farmers in the Central, Brong Ahafo and the Volta regions planted intercrops for six years.

Table 4.8: Distribution of farmers in terms of duration
of intercropping Food crops. (%)

Region	Intercropping Duration	
	1 - 3 yrs.	4 - 6 yrs.
Eastern	100	-
Ashanti	100	-
Western	100	-
Central	90	10
Brong Ahafo	16.7	83.3
Volta	66.7	33.3
National Mean	78.9	21.1

4.2: Physiological and agronomic studies on oil palm based cropping systems.

4.2.1: Weather during the Period of experimentation at Kusi.

The temperature, rainfall, and water deficit in the years of experimentation followed the same trend as the long-term area means. Mean monthly temperatures fluctuated between 22.6°C and 31.1°C, and the yearly mean was between 26.3°C and 26.9°C (Table 4.9).

The mean annual rainfall of the area is 1512 mm and was distributed in a bimodal pattern. The major rains fell between March and June and followed by a short dry season in July to August. The minor rains were in September and October.

The major dry season started from November to March. Rainfall pattern from 1994 to 1997 seemed to follow same trend. The wettest year was 1995 with a total rainfall of 1768 mm while 1996 was the driest year with 1306 mm rainfall (Table 4.10).

Monthly water deficits were recorded for January and February for 1994 through to 1996 and from January to

March in 1997. January to March is usually the driest period for the area (Table 4.11).

Comparatively, moisture retention of the soil during the period of experimentation was better than the average for the area.

Table 4.9: Mean Monthly Temperatures (°c) 1994 - 1997

Month	Area Mean	YEAR			
		1994	1995	1996	1997
January	28.2	25.5	26.1	26.3	26.9
February	26.9	27.8	27.8	27.8	27.9
March	27.8	27.2	26.7	27.7	28.0
April	27.5	27.7	27.7	27.6	24.7
May	27.1	26.6	27.2	27.1	26.4
June	26.2	26	31.1	26.0	26.2
July	22.6	24.9	25.3	25.5	25.1
August	24.9	25.0	25.4	26.1	25.2
September	25.8	25.4	26.1	27.5	26.6
October	26.3	26.5	26.5	26.5	27.4
November	26.8	26.9	26.9	27.1	26.9
December	26.1	25.9	25.9	26.5	26.7
Mean	26.4	26.3	26.9	26.7	26.5

Table 4.10: Monthly Amount of rainfall (mm) 1994 - 1997

Month	Area Mean	YEAR			
		1994	1995	1996	1997
January	22.5	91.6	24.4	8.4	8.6
February	40.5	8.9	9.9	36.1	30.5
March	135.9	128.1	153.6	224.2	45.7
April	167.8	211.2	285.0	89.1	238.7
May	214.6	199.3	247.3	201.3	150.3
June	211.3	164.9	252.4	213.4	314.6
July	119.7	81.5	133.9	148.4	91.8
August	94.8	59.2	175.4	95.5	66.9
September	145.1	170.3	148.9	52.5	88.9
October	187.3	180.1	162.0	115.2	150.0
November	121.8	164.5	119.0	49.5	118.0
December	50.8	0.0	56.1	72.4	56.7
Total	1512.1	1459.6	1767.9	1306.0	1360.7



Table 4.11: Monthly water deficit (mm) 1994 - 1997

Month	Area Mean	YEAR			
		1994	1995	1996	1997
January	102.4	0.0	75.6	36.5	141.4
February	115.0	134.4	140.1	113.9	119.5
March	31.5	21.9	0.0	0.0	30.5
April	6.1	0.0	0.0	0.0	0.0
May	3.5	0.0	0.0	0.0	0.0
June	0.0	0.0	0.0	0.0	0.0
July	0.7	0.0	0.0	0.0	0.0
August	25.2	0.0	0.0	0.0	0.0
September	8.9	0.0	0.0	0.0	0.0
October	7.6	0.0	0.0	0.0	0.0
November	9.2	0.0	0.0	0.0	0.0
December	20.4	0.0	0.0	0.0	0.0
Total	330.5	136.3	215.7	150.4	291.4

4.2.2: The effect of intercropped food crops

on growth, development and yield of oil palm.

4.2.2.1: Leaf area (LA) development

Table 4.12 shows oil palm leaf area as affected by cropping systems. Significant differences in leaf area among the various intercropped systems occurred only at 18 and 36 months after planting. Mean leaf area per palm at six months after planting was 4.65 m². This increased to 92.97 m² at thirty-six months after planting. Leaf area development was 95.3%, 124%, 88.3%, 33.4% and 80.4% at 12, 18, 24, 30 and 36 months after planting respectively. Highest increase in leaf area at 18 months after planting.

Leaf area was highest in the system with oil palm intercropped with maize in both major and minor season. The lowest LA development was for the system oil palm + maize + cassava (Table 4.12).

Table 4.12: Oil Palm Leaf area (m²) as affected by cropping systems

CROP COMBINATION ^a	Months after planting					
	6	12	18	24	30	36
Op + Pue	4.75	9.40	20.11	39.90	52.71	92.14
OP + Ma + Ca	3.88	7.75	16.05	33.10	45.64	81.50
OP + Ma + Pl	4.78	9.64	19.98	38.92	52.21	94.12
OP + Ma + Ma	5.17	9.54	26.48	73.70	55.54	104.13
LSD (P=0.05)	NS	NS	6.15	NS	NS	14.18
CV (%)	15.66	17.45	18.60	12.12	8.71	9.53

a: OP = Oil Palm; Ma = Maize; Ca = Cassava; Pl = Plantain and Pue = Pueraria.

4.2.2.2: Leaf area index (LAI)

The LAI of the oil palm also varied with the cropping Systems (Table 4.13). The lowest LAI was recorded for Oil palm + maize + cassava treatment.

The trend of attainment of LAI was similar to that of LA Development.

Table 4.13: Leaf Area Index in relation to
Cropping system.

CROP COMBINATION	Months after planting (MAP)					
	6	12	18	24	30	36
Op + Pue	0.04	0.08	0.17	0.32	0.43	0.77
OP + Ma + Ca	0.03	0.06	0.13	0.27	0.38	0.68
OP + Ma + Pl	0.04	0.08	0.16	0.32	0.42	0.77
OP + Ma + Ma	0.05	0.08	0.21	0.36	0.46	0.85
LSD (P=0.05) ^b	NS	NS	0.05	NS	NS	0.10
CV (%)	22.36	14.25	17.05	16.24	9.82	88.26

a: OP = Oil Palm; Pue = Pueraria; Ma = Maize;

Ca = Cassava and Pl = Plantain

NS = Not significant

4.2.2.3: Rate of Leaf production

Leaf production per month was significantly ($P < 0.05$) affected by the cropping systems but only during the first six months (Table 4.14).

Oil palm cover cropped with pueraria and oil palm in association with maize + maize had higher rates of leaf production than oil palm with cassava or plantain (Table 4.14).

Table 4.14: Leaf Production per month under various cropping systems

CROP COMBINATION ^a	Months after planting (MAP)					
	6	12	18	24	30	36
Op + Pue	1.5	2.0	2.5	3.2	3.9	5.0
OP + Ma + Ca	1.3	1.9	2.1	2.9	3.6	4.9
OP + Ma + Pl	1.4	1.9	2.4	3.0	3.5	4.9
OP + Ma + Ma	1.5	2.2	2.9	3.5	3.8	5.1
LSD (P=0.05)	0.2	NS	NS	NS	NS	NS
CV (%)	18.0	25.1	20.1	15.7	13.6	10.04

a: Op = Oil palm; Pue = Pueraria; Ma = Maize;

Ca = Cassava; Pl = Plantain and NS = not significant.

4.2.2.4: Frond dry weight

Table 4.15 shows frond dry weight (FDW) as affected by various cropping systems. The FDW of the oil palm was significantly affected by intercrop ($P < 0.05$). Rate of increase in FDW was highest in oil palm + maize + maize treatment and lowest in oil palm + maize + cassava. Differences in FDW of oil palm grown in association with the various intercrops were significant ($P < 0.05$) at all the sampling times.

Table 4.15: Frond Dry weight (kg) accumulation in relation to cropping systems

CROP COMBINATION ^a	Months after planting					
	6	12	18	24	30	36
Op + Pue	0.41	0.47	0.71	0.84	0.98	1.02
OP + Ma + Ca	0.37	0.44	0.66	0.76	0.89	0.92
OP + Ma + Ca	0.39	0.45	0.68	0.81	1.03	1.01
OP + Ma + Ma	0.38	0.48	0.72	0.84	1.04	1.06
LSD (P=0.05)	0.031	0.02	0.02	0.027	0.026	0.03
CV (%)	12.9	11.0	7.30	6.22	5.09	5.04

^a: Op = Oil palm; Pue = Pueraria; Ma = Maize; Ca = Cassava;

Pl = Plantain and NS = not significant.

4.2.2.5: Inflorescence production of oil palm

Table 4.16 shows inflorescence production by oil palm from 1995 to 1997. In 1995, only male inflorescences were produced. Sole cropped oil palm and oil palm intercropped with maize + maize produced higher number of male flowers than the combinations with plantain and cassava.

In 1996, female flower production was significantly ($P < 0.05$) affected by the various cropping systems. Again, sole - cropped oil palm with pueraria cover crop and oil palm intercropped with maize + maize produced higher number of female flowers than the combinations with plantain and cassava.

The sex ratio ranged from 42% in oil palm with maize + cassava to 65% in oil palm intercropped with maize in both seasons in 1996. A similar trend in sex ratio was maintained in 1997 as in 1996.

Table 4.16: Number of inflorescence per plot and sex ratio under various intercropping systems

Crop Combination	Number of Male Inflorescence			Number of Female inflore.		^b Sex Ratio (%)	
	1995	1996	1997	1996	1997	1996	1997
Op + Pue	34.5	100	30	146.1	53.2	59.4	63.9
OP + Ma + Ca	7.9	125	39.3	87.4	45.0	42.3	53.3
OP + Ma + Pl	9.0	92.5	38.2	100.7	55.0	52.1	59.0
OP + Ma + Ma	31.8	100.5	25.0	183.0	56.9	64.6	69.4
LSD (P=0.05)	NS	NS	NS	44.2	NS	NS	NS
CV (%)	71.0	23.4	26.5	20.4	27.3	14.9	15.12

a: Op = Oil Palm; Pue = Pueraria; Ma = Maize;

Ca = cassava; Pl = Plantain and NS = Not significant

b. No. of female inflorescence/No. of male + female
Inflorescences

4.2.2.6: Yield of the oil palm

In Table 4.17, the number of bunches per palm, single bunch weight and fresh fruit bunches per hectare are presented for the period August to December, 1996 and for the full year in 1997. Harvesting of fresh fruit

bunches (ffb) started in August 1996, some twenty-seven months after transplanting the oil palm seedlings to the field. Significant differences ($P < 0.05$) among the cropping systems were found for some yield parameters. Number of bunches produced per palm varied significantly ($P < 0.05$) among the intercrops for the five months in 1996 but differences were not significant for 1997.

The average of bunches produced per palm in 1996 was 2.4 for the oil palm + maize + maize treatment. This was about 70%, 74% and 20% higher than oil palm + maize + cassava, oil palm + maize + plantain and oil palm + pueraria respectively. A similar trend was obtained in 1997. There was very little variation in the average single bunch weight among the treatments. Thus the number of bunches produced per tree greatly influenced the yield of fresh fruit bunches.