

Shaded versus un-shaded cocoa: implications on litter fall, decomposition, soil fertility and cocoa pod development.

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Abstract

Traditionally, cocoa is grown in Ghana in conjunction with a diverse selection of trees that provide shade and habitat for a variety of wildlife forms thus enhancing biodiversity. In recent years, more cocoa plantations are being managed intensively and in full sun. A study was carried out to examine the implications of growing cocoa under different shade regimes provided by forest trees and in full sun on litter fall, decomposition of the litter, soil fertility and cocoa pod development over one year period in Ghana. Series of parallel transects of up to 1 km long and spaced 200m apart were laid through contiguous:

- (i) Cocoa farms with heavy overhead shade.
- (ii) Cocoa farms with medium overhead shade.
- (iii) Cocoa farms without overhead shade.
- (iv) Remnant native forest.

Shade regimes significantly ($p < 0.05$) influenced litter production in the cocoa farms. Cocoa litter production ranged from 3,096kg/ha to 5112kg/ha with the un-shaded cocoa farms recording significantly ($p < 0.05$) higher litter production than the shaded farms. Litter production from the shade trees ranged from 970kg/ha to 2080kg/ha with the heavy overhead shade producing the highest litter. The rates of decomposition of cocoa leaf litter were significantly ($p < 0.05$) faster in the shaded farms than in the un-shaded farms. About 61.2 and 64.6% of the initial mass of cocoa leaf litter in the heavy and medium shaded farms were lost during the initial six months of decomposition as opposed to 18.0% for the un-shaded farms. The pattern of the release of the nutrients related positively with the mass loss of the litter where litter from the shaded farms released more NPK during the period of decomposition. Cocoa cultivation generally decreased the organic C, total N, available P and exchangeable K contents of the soils when compared with the remnant native forest. The decrease in the nutrient concentrations in the soil was more pronounced in the un-shaded farms. Significantly ($p < 0.05$) higher total number of pods were recorded on trees in the un-shaded farms. Incidence of cherrille wilt on the farms ranged from 24 to 44% and was significantly ($p < 0.05$) higher in the un-shaded farms than in the shaded farms. It is concluded that shaded farms could enhance efficient nutrient cycling processes, improve the nutrient status of soils and reduce the stress on the development of cocoa pods.

Introduction

Cocoa represents a considerable share of the agriculture of most tropical countries and it is important in the economy of Ghana. Cocoa can be planted under thinned forest canopy, naturally regenerating or the canopy of artificially planted trees (Greenberg, 1998; N'Goran, 1998). Removing shade from cocoa has resulted in significant

increases in yield with a positive interaction between increased light and applied nutrient (Cunningham and Arnold, 1962). Cocoa production in major West African countries is now without shade and has expanded largely at the expense of primary forest. The absence of shade places significant ecological stress on the cocoa trees which become susceptible to pests attack (Entwistle and Yeodeowei, 1964). Cocoa is cultivated in areas identified as biodiversity hot spots (Myers *et al.*, 2000) and may represent a serious threat to biodiversity. There is little scientific evidence to quantify the environmental benefits of shaded cocoa, but it is regarded as environmentally preferable to many other forms of agriculture in tropical forest regions (Greenberg, 1998 ; Power and Flecker, 1998). Reitsma *et al.* (2001) and Estrada *et al* (1997) have both suggested that shaded cocoa could have positive environmental effect in landscapes already much impoverished by human activities. Murray (1975) has summarized most of the factors attendant with shade effects as reduction in diurnal variations in both soil and air temperatures, reduction in wind movement and improved mineral recycling. Santana and Cabala-Rosand (1982) reported that both the litter from the shade trees and cocoa make a considerable contribution to the cycling of nutrients particularly nitrogen in the plantations. The main losses of nitrogen, phosphorus and potassium from a cocoa plantation are through harvesting (Boyer, 1973; Omotoso, 1975; Thong and Ng, 1978). In an unfertilized cocoa farm the processes of litter decomposition, rain wash and rainfall are the main gains of N, P and K (Boyer, 1973; Ling, 1984).

In Ghana, the bulk of cocoa is produced in unfertilized farms where litter from both cocoa and shade trees could play a central role in the supply of nutrients to the crop. Considering the current cocoa farming practices where the farms are established in areas of felled trees it is important to examine the implications of growing cocoa under different shade regimes in relation to the sustainable cocoa farming concept. This paper reports on the effect of different shade regimes provided by forest trees and in full sun on litter fall, decomposition of the litter, soil fertility and cocoa pod development.

Materials and methods

Sites description

The project is situated in Adjeikrom in the Eastern Region of Ghana between latitudes 6° and 6°30' north and longitudes 0° and 0°30' west. The research sites were grouped into four different land use types namely:

- a) Shaded cocoa farms with 15 – 18 forest trees/ha, classified as medium shade.
- b) Shaded cocoa farms with 22 – 30 forest trees/ha, classified as heavy shade
- c) Un-shaded cocoa.
- d) Remnant native forest

Establishment of permanent transects

A series of up to 1 km parallel permanent transects were established 200m apart through each land use type. The position of each transect was determined using Global Positioning Satellite (GPS) meter. Cocoa plots were demarcated at 10m x 10m (5 metres on either side of transect) at 40m intervals along each permanent transect.

Litter sampling

Litter fall in the cocoa ecosystems was collected by means of traps with a dimension of 1.0 x 1.0 x 0.2m raised 50 cm above the ground. Three traps were set on each transect in the three cocoa ecosystems. The litter traps were emptied bi-weekly and

bulked at the end of each month for 12 months. All litter collected were sorted into shade tree leaves, cocoa leaves, twigs, flowers and pods. Each sample was dried weighed and analysed for N, P and K using standard methods.

Litter decomposition

Based on the average moisture content of freshly fallen cocoa leaf litter, litter bags of nylon measuring 20 x 20cm with a 5mm mesh were loosely packed with leaf litter equivalent to 20g oven dry weight and placed on the plantation floor. The litter bags were collected at bi-monthly intervals for a total of 6 collection dates over a one-year period. The contents of the bags were weighed and prepared for chemical analysis of N, P and K to determine the transfer of the nutrients to the plantation floor.

Soil sampling

Soil samples were taken from 0 – 15 cm soil layer in all the land use types. The samples were air dried, sieved and prepared for analysis of pH, organic carbon, total nitrogen, available phosphorus and exchangeable potassium. Soil insects were also identified in the litter layer and in the top soil.

Cocoa productivity

The total number of cocoa trees per plot was counted. A census of pods on the individual trees within each of the 10m x 10m plots was carried out. Data was collected on the total number of healthy small cocoa pods (less than 4cm long), medium pods (greater than 4cm and less than 10cm long) and larger pods (greater than 10cm long). The number of cherelle wilt and number of pods showing signs of insect, rodent or disease damage were also recorded.

Results and discussion

Litter fall, decomposition and nutrient release.

Figure 1 shows the quantities of both cocoa and shade tree litter produced over 12 month period in the cocoa farms. Litter from cocoa trees ranged from 3.0 to 5.1 tonnes/ha with the un-shaded cocoa farms recording significantly ($p < 0.05$) the highest quantity. The results suggest that the direct effect of the solar radiation on the leaves perhaps increased leaf abscission in the un-shaded. Shade tree litter ranged from 0.9 to 2.0 tonnes/ha with heavy shaded cocoa farms recording the highest litter fall.

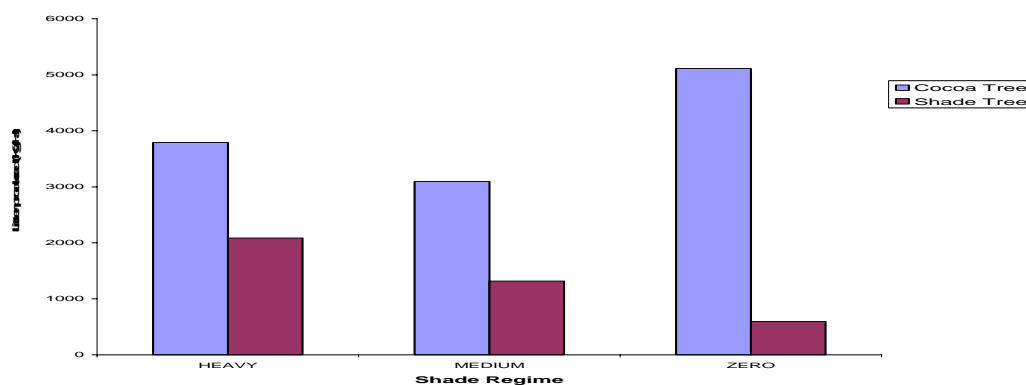


Fig. 1. Litter production under different shade regimes

The losses of dry matter during decomposition of the cocoa leaf litter are shown in Figure 2. After 6 months of decomposition, between 18 and 64% of the initial mass of the litter were lost. By the end of the 12 month period about 99% of the initial mass of the litter in the shaded cocoa farms had been lost whilst 86% was lost for the un-shaded farms. The results show that the litter from the shaded farms initially decomposed more rapidly than the litter from the un-shaded farms suggesting that decomposition rates might have been limited by some environmental factors. Meentemeyer (1978) have shown a good correlation between the actual evapotranspiration rate and decomposition rates. It is also possible that the higher population of decomposer organisms particularly insects in the shaded farms could be responsible for the differences observed. The mean population of insects in the litter layer and the top soil were 31.8, 32.6 and 3.6 for medium shade, heavy shade and un-shaded farms respectively. The curvature of the graphs for the litter from the shaded farms is similar to that for the decay of fresh plant residues in soils (Jenkinson and Ayanaba, 1977). This suggests that two factors were present which decayed according to first order kinetics but with different rates. The graph of the litter from the un-shaded farms show much less curvature which suggests that probably the microclimate of the farms had effects on the fraction that would otherwise have decayed quickly.

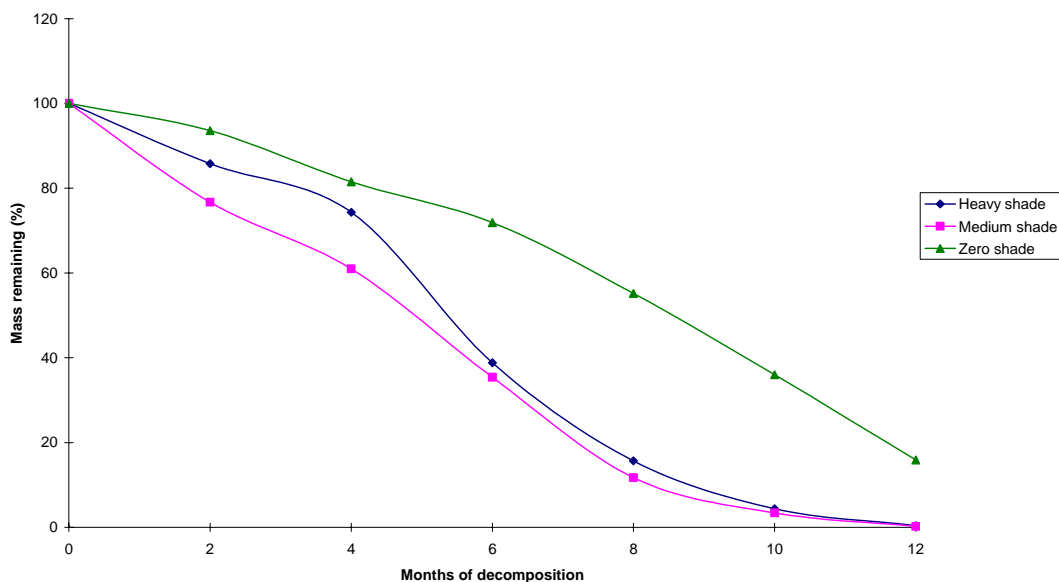


Fig. 2. Changes in the mass of cocoa leaf litter during decomposition

The release of NPK from the decomposing cocoa leaf litter over 12 month period are shown in Figures 3 to 5. The pattern of the release of the nutrients related positively with the mass loss of the litter where litter from the shaded cocoa farms released more nutrients during the period. After 12 months of decomposition, the percentages of the initial nutrients concentrations in the litter released were 75, 90, 85 for N, 66, 90, 92 for P and 88, 93, 93% for K for the un-shaded, heavy shaded and medium shaded cocoa respectively. The implication of these results is that the release of NPK from decomposing litter depends on the level of overhead shade which might indirectly influence the rate of litter fall and decomposition of the litter.

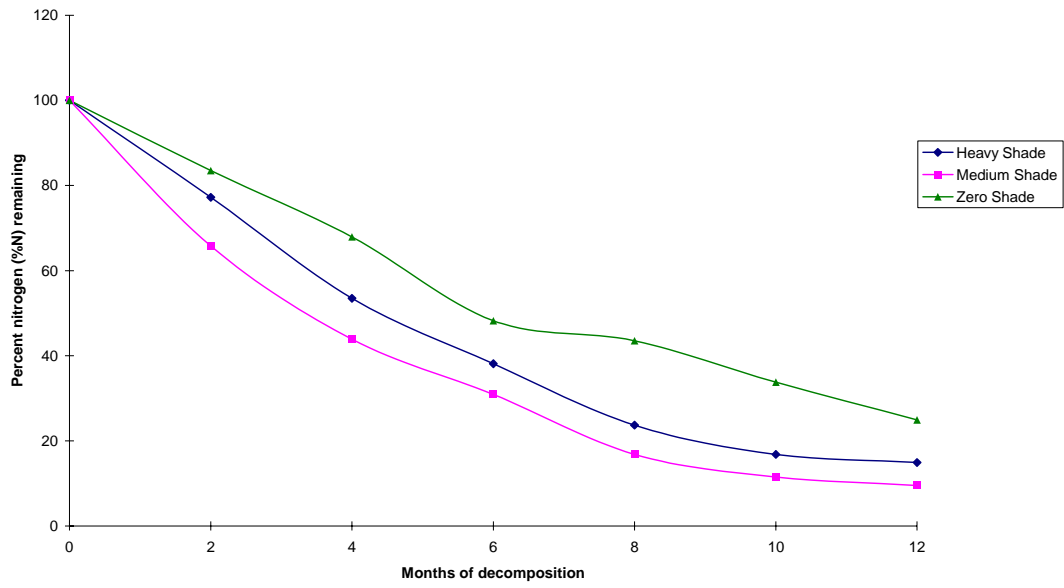


Fig. 3. Percent nitrogen remaining in decomposing cocoa leaf materials

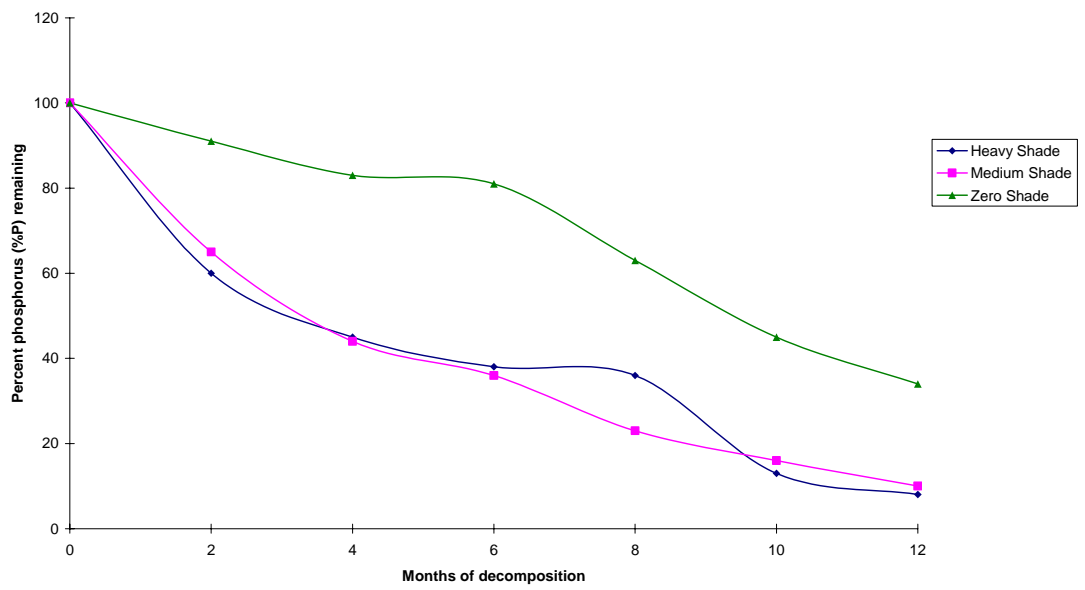


Fig. 4. Percent phosphorus remaining in decomposing cocoa leaf materials

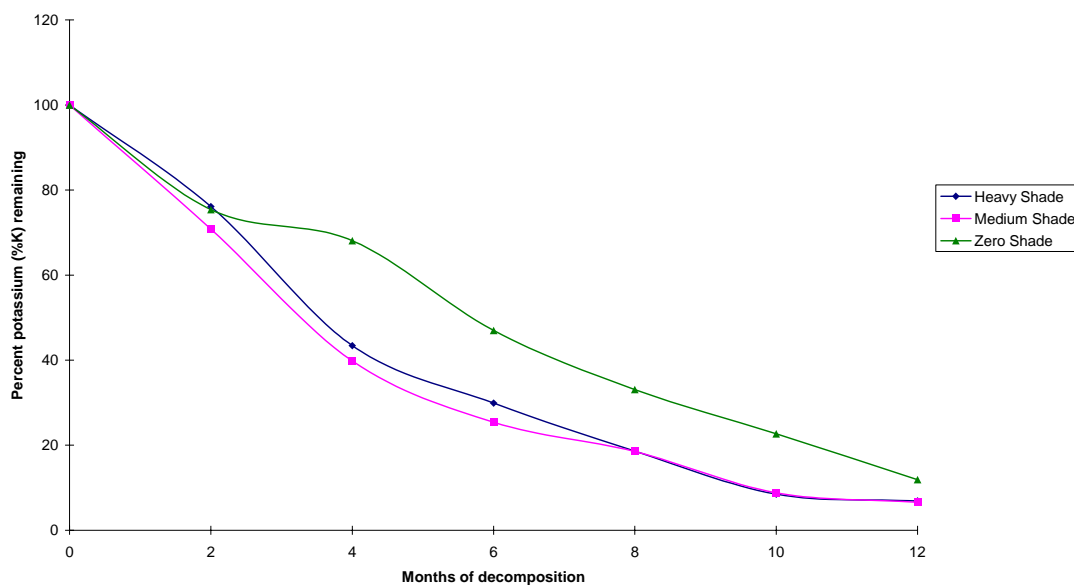


Fig. 5. Percent potassium remaining in decomposing cocoa leaf materials

Soil fertility

Table 1 presents data on the effect of land use type on some selected soil properties. Cocoa cultivation generally had significant influence on the soil properties. Soil pH was higher in the cocoa farms than in the remnant native forest. This could be attributable to the protection of the soil from erosion by the layer of partly decomposed cocoa leaf materials on the soil surface. Organic carbon content of soil in the remnant native forest was significantly ($p < 0.05$) higher than in the cocoa systems. This trend may be due to the greatest diversity of plant species with variable litter fall and decomposition rates found in remnant native forest. Ahenkorah *et al* (1974) reported a loss of 54000 kg humus ha⁻¹ within a 15 year period of continuous cocoa cropping. The lowest organic carbon content of soil under the un-shaded cocoa reflects on the slower rate of decomposition of cocoa litter in that system (Fig. 2). Total nitrogen and available P contents of soils significantly ($p < 0.05$) reduced in the un-shaded cocoa when compared with the remnant forest. Slower rate of decomposition of the litter to release the nutrients from the litter as well as increase in cocoa pod production could be responsible for the lower concentrations of nitrogen and available P in the soil in the un-shaded farms. The exchangeable K contents of soils were lower under the cocoa systems than in the remnant native forest although the differences were not significant. Ahenkorah (1974) noted that cocoa growing soils were well buffered against potassium depletion. Therefore the non-significant differences in the exchangeable K content of soils in the land use types could be due to the ability of the soil to replenish the lost potassium through cropping.

Table 1: Effect of land use types on selected soil properties (0-15cm depth)

SOIL PROPERTY	REMNANT FOREST	SHADED COCOA(MEDIUM)	SHADED COCOA(HEAVY)	UNSHADED COCOA	S. E. D
p ^H (1:2.5,H ₂ O)	5.1	6.4	6.3	6.3	n.s
% Carbon	4.0	2.8	2.4	1.7	0.6
% Nitrogen	0.46	0.33	0.24	0.19	0.08
Available P (µg/g)	24.1	22.4	15.5	9.9	2.68
Exchangeable K. (cmol/ ⁽⁺⁾)	0.20	0.15	0.10	0.10	n.s

Cocoa pod development

Table 2 presents data on cocoa pod production in the cocoa land use types. The mean number of pods ranged from 124.2 to 254.9 pods. The un-shaded cocoa farms yielded twice as much cocoa pods as in each of the shaded cocoa farms. Cunningham and Arnold (1962) observed that shade removal from cocoa resulted in significant increase in cocoa yield. The mean number of cherelles ranged from 67.2 to 126.5 with more cherelles in the un-shaded cocoa farms. The highest number of cherelles that were wilted was recorded in the un-shaded cocoa farms. Several reasons which include competition for nutrients and moisture have been identified as the causes for cherelle wilt (Murray, 1975). Under un-shaded cocoa conditions the leaves of the cocoa trees are directly exposed to the rays of the sun. Evapo- transpiration could be very high and could lead to moisture stress in the system. Of the three cocoa land use types studied, the un-shaded cocoa system is the least fertile (Table1). As a result of increased pod formation with the attendant rapid nutrient up take by the trees to support the high pod production coupled with the high moisture stress, incidence of cherelle wilt was highest in the un-shaded cocoa farms. Black pod incidence was higher in the heavy shaded cocoa farm probably because of the higher number of forest trees per ha as shade trees which invariably increased the humidity in the area making the pods more susceptible to the black pod infection. Higher rodent damage was observed in the un-shaded farms as a result of the absence of shade trees as habitat for rodents since the rodents used the cocoa trees as their habitats.

Table 2: Cocoa pod production in different cocoa systems. (Mean pod number).

Cocoa land use type	Small		Medium		Large			Total
	Healthy	Wilted	Healthy	Wilted	Healthy	Diseased	damaged	
	(Less than 4 cm long)		(4-10cm long)		(greater than 10cm long)			
Shade Cocoa (Medium)	19.3 ± 0.04	18.6 ± 0.05	18.0 ± 0.09	11.3 ± 0.03	43.0 ± 0.08	9.8 ± 0.03	4.2 ± 0.01	124.2
Shaded Cocoa (Heavy)	17.4 ± 0.06	27.5 ± 0.07	10.5 ± 0.01	23.8 ± 0.02	30.4 ± 0.06	21.9 ± 0.04	4.7 ± 0.03	136.2
Un-shaded Cocoa	8.9 ± 0.04	55.5 ± 0.03	12.1 ± 0.04	54.0 ± 0.01	97.8 ± 0.09	14.2 ± 0.02	64 ± 0.03	248.9
Total	45.6	101.6	40.6	89.1	171.2	45.9	15.3	509.3

Conclusion

The level of overhead shade provided by forest trees in cocoa farms significantly influences litter fall, decomposition of the litter, soil fertility and development of cocoa pods. Under un-shaded farms, litter fall is very high but the rates of litter decomposition are very slow compared to the shaded farms. Significantly higher nutrients particularly N and P are found in soils under shaded farms than in un-shaded farms probably because of efficient nutrient cycling process in the shaded farms. Incidence of cherville wilt is higher in un-shaded farms as a result of a likely higher moisture stress due to higher evapo-transpiration and the lower nutrient concentrations in the soils to support the higher crop yield. Shaded cocoa could therefore enhance efficient nutrient cycling processes, improve nutrient status of soils and promote healthy pod development.

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