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Potential pod production† and pod loss in cacao (*Theobroma cacao* L.)

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SUMMARY

The sequences of pod production and pod loss of various cultivars of cacao for a period of 12 months are presented. Physiological wilt and biotic damage accounted for up to 75% of all the cherelles lost per tree. Of these two factors, wilt caused by insects and diseases accounted for the greater part of the cherelle loss. Loss of mature pods due to biotic factors (insects, diseases and rodents) was found to be a factor of greater importance than cherelle wilt in the overall reduction of pod production. Suggestions are made for reducing the incidence of biotic damage to cacao pods and thus increasing yield.

It is a well known fact in all cocoa producing countries that only a small percentage of the potential pods of a cacao tree is ever harvested as healthy pods suitable for processing. Some of the potential pods are lost as cherelles in the earlier stages of pod development while others are lost due to biotic damage at later stages.

Cherelle wilt, physiological or biotic, is one of the factors believed to be responsible for the reduction of potential pods in cacao, but Hurd (1959, 1960, 1961) found no correlation between yield and cherelle wilt. Defloration of cacao trees, to reduce the total number of pods set, did not increase the yield. McKelvie (1956, 1960) reported that increasing or decreasing flower setting in cacao by controlled pollination had no effect on cherelle wilt, which accounted for between 70 and 90% loss of total potential pods per tree but did not correspondingly reduce the yield per acre.

McKelvie (1956, 1960), Murray (1953) and McDonald (1933) showed that the increase in cacao yield due to fertilizer application was a result of an increase in the production of cherelles per tree rather than a decrease in the amount of wilt.

In a survey of rodent damage to mature pods at Gambari Experimental Station, Western Nigeria, Everard (1964) found that in no month did damage exceed 19% of total pod production, while a corresponding figure of 2·3% was given by Taylor (1961) as the average national loss in Ghana. In a recent report on rodent and other vertebrate pests of cacao in Western Nigeria Everard (1968) stated that it is not economical to control a 5% or smaller pod loss due to rodents when yields are below 400 lb of dry cocoa beans per acre.

Johns and Gibberd (1951) estimated that between 15 000 and 30 000 tons of dry cocoa beans were lost annually in Nigeria due to the infection of pods by *Phytophthora*

† Potential pod production refers to the total number of harvested mature pods (healthy, diseased and damaged) and wilted cherelles excised, but does not include developing pods on the trees.

palmivora (Butl.) Butl. According to Hislop and Park (1962) the incidence of black pod is correlated with rainfall or high humidity. Thorold (1953, 1956) reported that, in order to reduce the loss due to black pod, attention must be given to both the level of yields and the rainfall conditions in areas of control, since there was a tendency for black pod percentages to be positively associated with the total number of pods produced.

This paper reports the results of two investigations on pod production and pod loss in various cacao cultivars.

MATERIALS AND METHODS

All cacao trees used for these trials were mature and at their peak of production and were sprayed at regular intervals against insects and black pod disease. Cherelles were defined as any developing young pods not more than 15 cm long. Wilted cherelles without any visible signs of damage caused by fungal pathogens or insects were classed as physiologically wilted, while cherelles showing damage caused by fungal pathogens, insects or both were classed as biotically wilted. In biotic wilt no attempts were made to establish which of the two factors was primarily responsible. Mature pods were defined as ripe pods ready for harvesting and processing, damaged pods as mature pods damaged by animals and diseased pods as mature pods infected with *Phytophthora palmivora* (black pod).

Both experiments reported in this paper were done between March 1968 and May 1969 at the Gambari Experimental Station of the Cocoa Research Institute of Nigeria, within an area of four square miles which is typical of one of the cacao-growing areas of western Nigeria.

The cultivars selected in the first experiment comprised 166 trees of F 3 Amazon, 100 trees of ICS 1, 64 trees of Kumba Criollo and 106 trees of N 38. Weekly observations were made on all the selected trees, and all cherelles showing the initial symptoms of wilt, physiological and biotic, were excised. These were then separated into the two categories of wilt and recorded for each tree and cultivar.

Mature pods (healthy, diseased and damaged) were harvested once every three weeks and recorded on an individual tree basis. From the records of mature pods harvested and the wilted cherelles for each month the potential pods per tree were calculated.

In the second experiment, the influence of fertilizers on pod production and pod loss was studied. In March 1968, 128 trees of Nanay 32 (Na 32) and 128 trees of Parinary 35 (Pa 35) were ring-dressed with triple superphosphate and urea at rates of 75 lb and 2½ cwt per acre respectively to raise the nutrient status of the soil which had not previously been fertilized. Both these clones were planted on the same plot in alternate rows.

All cherelles with symptoms of wilt were excised each month from each tree and recorded without classification into physiological or biotic, because distinction was difficult owing to the long sampling interval. Mature pods were harvested every two weeks, and records of healthy and diseased pods were taken to compile a monthly record.

RESULTS AND DISCUSSION

The mean potential pods and the mean pod loss, both physiological and biotic, of Kumba Criollo, N 38, ICS 1, and F 3 Amazon in various months are shown in Figure 1. The highest potential pods per tree of F 3 Amazon, ICS 1 and Kumba Criollo were recorded

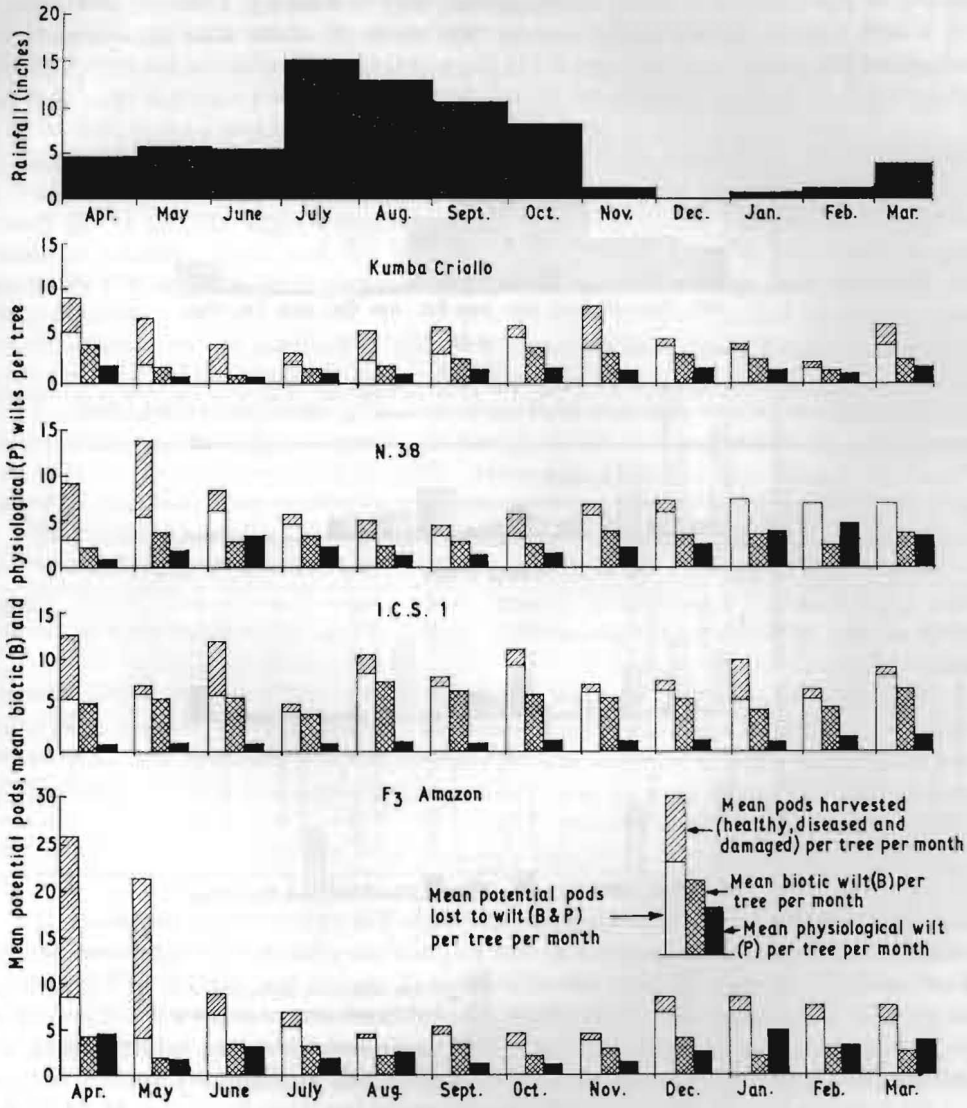

FIG. 1
Histograms showing the monthly rainfall pattern, mean potential pods, and biotic and physiological wilts per tree of Kumba Criollo, N 38, ICS 1 and F 3 Amazon cacao cultivars.

in April and those of N 38 in May. It seems that there is no significant correlation between the mean potential pods per tree and mean pod loss. The cultivars showed variations in the pod production pattern, but potential pods were generally fewer during the height of the rainy season (Fig. 1). In most months biotic damage was responsible for most of the cherelle loss. In the cultivar F 3 Amazon physiological wilt exceeded biotic damage from

January to April, while in N 38 this happened only in January, February and June. In ICS 1 and Kumba Criollo biotic damage was more prevalent than physiological wilt throughout the year.

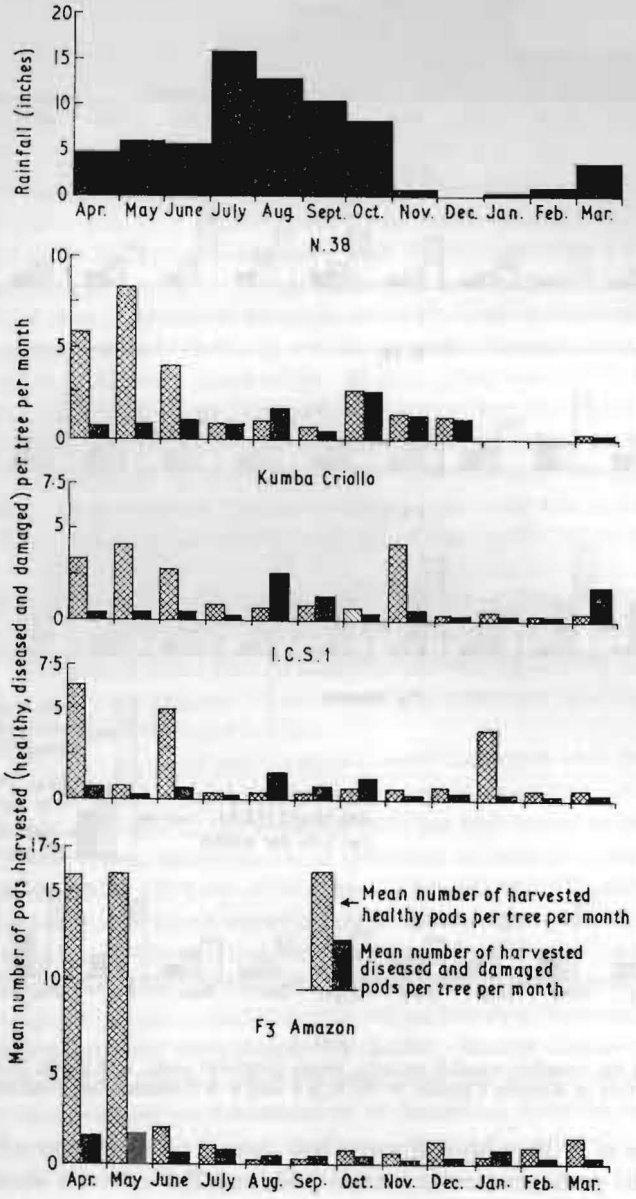

FIG. 2

Histograms showing the monthly rainfall pattern, the mean number of pods harvested (healthy, diseased and damaged) per tree of N 38, Kumba Criollo, ICS 1 and F 3 Amazon cacao cultivars.

The mean numbers of healthy, diseased and damaged pods harvested per tree of F 3 Amazon, ICS 1, Criollo and N 38 cultivars are shown in Figure 2. The peak of production of healthy pods did not coincide with the height of the rainy season, but the largest number of diseased and damaged pods were harvested during this season. Diseased pods accounted for 75 to 80% of total pod loss at this period.

Pod production and pod loss of Na 32 and Pa 35 from April, 1968, to March 1969, are recorded in Table I. The highest number of cherelles alive per tree in Pa 35 was in January (25.0) and the highest number with wilt in July (21.9). For Na 32 the highest number of cherelles alive and the highest number wilted were in July and August respectively (Table II). In both clones the highest number of healthy pods harvested was in May (Fig. 3).

TABLE I

Mean number of cherelles alive (CA), cherelles wilted (CW), number of pods harvested (H), healthy pods (HP) and diseased pods (DP) per tree in clones Na 32 and Pa 35 from April, 1968, to March, 1969

Months	Clones									
	Pa 35					Na 32				
	CA	CW	H	HP	DP	CA	CW	H	HP	DP
April	4.7	6.1	0.8	0.5	0.3	1.7	6.8	20.3	15.1	5.2
May	5.9	3.7	3.7	2.1	1.6	5.2	4.1	26.2	16.2	10.0
June	17.9	13.4	0.7	0.6	0.1	11.1	8.2	5.4	3.3	2.1
July	18.2	21.9	0.2	0.0	0.2	13.9	12.6	1.0	0.5	0.5
August	7.3	19.8	0.2	0.0	0.2	7.6	14.5	0.3	0.0	0.3
September	7.3	18.1	0.5	0.2	0.3	6.4	13.1	1.1	0.6	0.5
October	9.2	12.6	0.4	0.1	0.3	5.9	11.0	0.3	0.1	0.2
November	9.0	12.8	0.1	0.0	0.1	6.2	11.0	0.1	0.0	0.1
December	23.5	8.4	1.2	1.1	0.1	10.4	7.3	1.5	1.0	0.5
January	25.0	6.3	1.7	1.6	0.1	12.1	5.5	2.8	1.9	0.9
February	22.8	6.7	0.5	0.3	0.2	9.8	8.2	2.7	1.8	0.9
March	6.7	5.5	0.6	0.4	0.2	2.1	8.5	9.4	7.8	1.6

The overall mean percentage wilt of cherelles in Pa 35 and Na 32 was 46.8 and 53.1, while the percentage of diseased pods was 21.8 and 26.4 respectively (Table II). It is evident that the peak of cherelle wilt did not coincide with the peak of cherelles alive; in Na 32 the two peaks were adjacent (July and August), but in Pa 35 they occurred in January and July. In both clones two peaks were observed for cherelles alive, one in June and July and the other between December and February. In Na 32 the peaks were of similar magnitude, while in Pa 35 the second peak was larger than the first.

The correlations between various factors affecting pod production of the four cultivars are presented in Table III. In none of the cultivars was there a significant correlation between biotic wilt and pods harvested. ICS 1 showed a significant negative correlation (—0.69) between physiological wilt and potential pods. Correlations between physiological wilt and biotic wilt (0.76), biotic wilt and potential pods (0.68), potential pods and pods harvested (0.78) were significant in Kumba Criollo. N 38 showed a significant negative correlation (—0.58) between physiological wilt and pods harvested and a positive correlation between pods harvested and potential pods (0.80). In all the cultivars, with the excep-

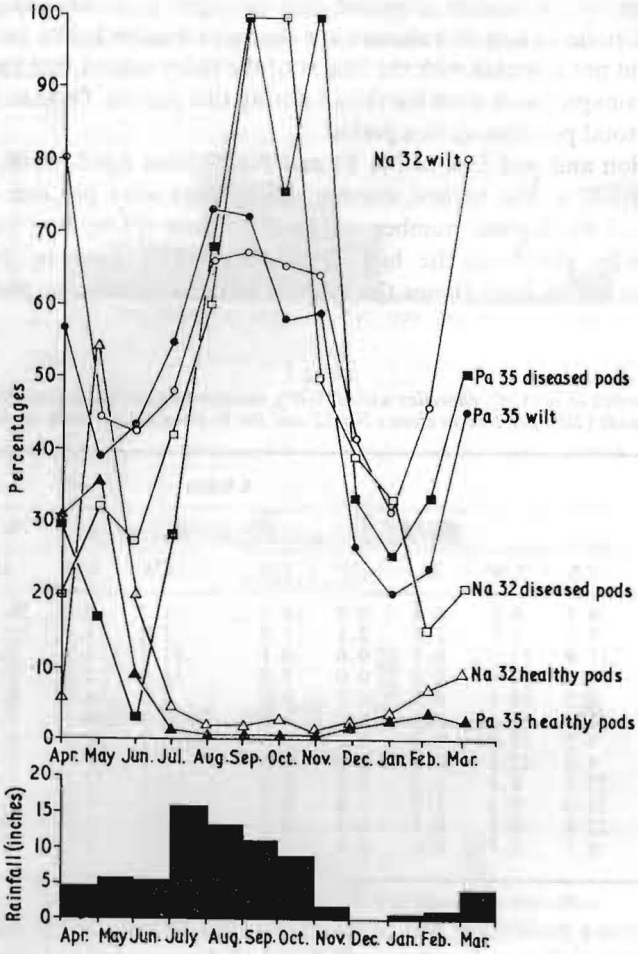

FIG. 3
The monthly percentage wilt, harvested mature healthy and diseased pods of Na 32 and Pa 35 cacao clones. Rainfall histogram is inserted.

tion of ICS 1, there was a highly significant positive correlation between pods harvested and potential pods.

Cherelle wilt, physiological and biotic, is not of major importance in pod production and loss in cacao. If the loss of mature pods due to biotic factors can be controlled effectively, pod production should rise by about 50%. Fertilizer application to mature cacao trees, while not reducing the overall wilt, may also increase yields, but the economic aspects of such practice need to be studied.

There is also an urgent need for effective fungicides and insecticides with good binders which will retain them on the pods and trees during the rainy season. Good pest and disease control in plantations will improve yields, and maintaining a wide perimeter between

TABLE II

Mean number of healthy pods harvested per tree per clone per year during (a) 1967/68 and (b) 1968/69, and mean number of diseased pods harvested during 1968/69

Months		April		May		June		July	
Clones		Pa 35	Na 32	Pa 35	Na 32	Pa 35	Na 32	Pa 35	Na 32
Mean No. of healthy pods harvested per tree	(a)	0.5	15.1	2.1	16.2	0.6	3.3	0.0	0.5
	(b)	0.7	21.2	7.4	21.0	3.2	5.8	0.5	0.7
Mean No. of diseased pods harvested per tree		0.3	5.2	1.6	10.0	0.1	2.1	0.2	0.5

Months		August		September		October		November	
Clones		Pa 35	Na 32	Pa 35	Na 32	Pa 35	Na 32	Pa 35	Na 32
Mean No. of healthy pods harvested per tree	(a)	0.0	0.0	0.2	0.6	0.1	0.1	0.0	0.0
	(b)	0.1	0.2	0.0	0.0	0.1	0.0	0.0	0.1
Mean No. of diseased pods harvested per tree		0.2	0.3	0.3	0.5	0.3	0.2	0.1	0.1

Months		December		January		February		March	
Clones		Pa 35	Na 32	Pa 35	Na 32	Pa 35	Na 32	Pa 35	Na 32
Mean No. of healthy pods harvested per tree	(a)	1.1	1.0	1.6	1.9	0.3	1.8	0.4	7.8
	(b)	0.2	0.8	0.3	1.8	0.4	5.1	0.2	6.0
Mean No. of diseased pods harvested per tree		0.1	0.5	0.1	0.9	0.2	0.9	0.2	1.6

TABLE III

Various correlations between physiological wilt (PW), biotic wilt (BW), mean number of pods harvested (PH) and potential pods (PP) in four cacao cultivars

Cultivars / Correlations	PW with BW	PW with PH	PW with PP	BW with PH	BW with PP	PW with PP
ICS 1	0.04	—0.29	—0.69*	—0.11	0.34	0.55
F3 Amazon	0.12	0.13	0.33	0.20	0.33	0.97***
Kumba Criollo	0.76**	—0.24	0.38	0.10	0.68*	0.78**
N 38	0.15	—0.58*	0.01	0.06	0.33	0.80**

* Significant at 5% level, ** significant at 1% level, *** significant at 0.1% level.

plantations and uncleared forest will reduce the incidence of rodent damage. Finally, prompt harvesting of ripe pods will reduce the loss of mature pods due to black pod disease.

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REFERENCES

EVERARD, C. O. R. (1964). Some aspects of vertebrate damage to cocoa in West Africa. *Proc. Conf. Mirids, Ibadan, 1964*, 114–19.

EVERARD, C. O. R. (1968). *A report on the rodent and other vertebrate pests of cocoa in Western Nigeria.* Ministry of Agriculture and Natural Resources Research Division, Ibadan, pp. 123.

HISLOP, E. C., and PARK, P. O. (1962). Studies on the chemical control of *Phytophthora palmivora* (Butl.) Butl. on *Theobroma cacao* L. in Nigeria. III. Field trials. *Ann. appl. Biol.*, **50,** 77–88.

HURD, R. G. (1959). Physiology of fruiting; factors influencing yield in cacao. *Rep. W. Afr. Cocoa Res. Inst. 1957–58*, 51–2.

HURD, R. (1960). Cherelle wilt in the Trinidad introductions. *Rep. W. Afr. Cocoa Res. Inst. 1958–59*, 44.

HURD, R. (1961). Cherelle wilt in the shade and manurial trial. *Rep. W. Afr. Cocoa Res. Inst. 1959–60*, 58.

JOHNS, R., and GIBBERD, A. V. (1951). A review of the cocoa industry of Nigeria. *Rep. Cocoa Conf. Lond., 1951*, 135–43.

MCDONALD, J. A. (1933). An environmental study of the cacao tree. *Rep. Cacao Res., I.C.T.A., 1932*, 41–9.

MCKELVIE, A. D. (1956). Cherelle wilt in cacao. I. Pod development and its relation to wilt. *J. exp. Bot.*, **7,** 252–63.

MCKELVIE, A. D. (1960). Cherelle wilt of cacao. II. Wilt in relation to yield. *J. exp. Bot.*, **11,** 413–24.

MURRAY, D. B. (1953). The effect of mineral injections and hormone sprays on flower setting and fruit development in cacao. I. *Rep. Cacao Res., I.C.T.A., 1952*, 22–6.

TAYLOR, K. D. (1961). *An investigation of damage to West African cocoa by vertebrate pests.* (Unpublished). Ministry of Agriculture and Natural Resources, Ibadan.

THOROLD, C. A. (1953). The control of black-pod disease of cocoa in the Western Region of Nigeria. *Rep. Cocoa Conf., Lond., 1953*, 108–15.

THOROLD, C. A. (1956). Observations on cacao pod production in relation to the incidence of black-pod disease caused by *Phytophthora palmivora. J. hort. Sci.*, **31,** 149–55.

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