Correlation Studies on some Chupon—Main Stem Characters of Virus Infected Mature Cocoa Trees

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INTRODUCTION

SWOLLEN shoot disease of cocoa is a virus disease found in Western Nigeria. This disease is one of the most important factors limiting the yields of cocoa trees. Cutting out of infected trees is still used to keep the disease under control but not in the Areas of Mass Infection (AMI), which encompass much of Ibadan and Abeokuta provinces, where control measures and inspection have been abandoned. The AMI make up one seventh of the cocoa growing areas of Western Nigeria and contain some of the best available cocoa soils (Thresh, 1959). As no curative control measures have yet been found for this virus disease, experiments were designed to find out how to improve management techniques in order to get the best out of such virus infected farms. Thresh (1960) had earlier shown that the condition of cocoa trees in naturally infected farms was more closely related to the effects of mirid damage and the associated canopy dieback caused by *Calonectria rigidiuscula* (Berk & Br) Sacc., than it was to swollen — shoot infection. Longworth (1963) also showed that by encouraging the growth of chupons on virus infected cocoa trees whose main stems had been affected by dieback as a result of mirid damage, good canopy can be restored if regular maintenance, which include spraying with gamma-benzene hexachloride against mirids and removal of weeds, is done. He further showed that there was a significant positive correlation between canopy condition and yield. The present study is designed to throw more light on chupon contribution to the performance of virus infected cocoa trees which were being rehabilitated after suffering a set back due to dieback.

MATERIALS AND METHODS

Yield, stem and chupon girth, canopy and tree condition were observed in an experiment carried out in a randomly planted Amelonado cocoa farm referred to as Koroboto II in an earlier publication by Longworth (1963). This swollen shoot diseased cocoa farm, which is about 40 years old, is located in the Area of Mass Infection in Ibadan Province. Longworth (1963) had earlier reported that most of the trees infected at the outset were in poor condition and that mirid damage and dieback were present throughout the farm and that there was an extensive undergrowth of weeds and shrubs which was removed in 1954. The report added that as from 1956, trees were sprayed with gamma-benzene hexachoride and mirid attack was completely checked. The trees made a striking recovery, and some of those whose canopy was completely destroyed produced new chupons which restored the canopy. The number of chupons growing on the trees varied from one to seven; this being determined by the space created by the poor condition of the main stems which were already dying-back as a result of mirid damage. In this experiment, a chupon is an off-shoot arising from 6 to 9 inches from the base of the main stem of the original cocoa tree.

A detailed study of the various factors affecting the performance of the main stems of the cocoa trees and their chupons was made between November 1964 and October 1965.

Tree condition:

During the experimental period, the condition of the original main stems of the cocoa trees was classified into dead, dying and living. Those dead had been completely killed by die-back and in most cases had chupons which contributed to the canopy. Those dying were in a poor condition with little or no canopy as a result of die-back. The living ones were those which had not been seriously affected by mirid damage. These had invariably a fair to good canopy.

Yield:

Although yields of all the trees had been recorded individually since August 1954, yields were separated into those from the main stem and those from chupons during the experiment. In addition, the pods harvested were grouped into black-pods, fermentable, rodent-damaged and total pods. Harvesting of pods was done twice monthly. In all subsequent calculations total number of pods is used as this is found to have a highly significant positive correlation ($r = 0.66$) with the number of fermentable pods.

Canopy Score:

The canopies of the main stem and chupons were scored separately for each tree wherever possible, especially either where the main stem was dead and only chupons remained, or where the main stem had no chupons. Wherever the main stem and chupons existed, a total joint score was given per tree unit, but the contribution of main stem and chupon was determined by assigning proportionate percentage canopy score. This therefore enabled the spliting of the score in order to correctly determine the contribution to the total canopy of the main stem and chupon. Scores of 1 to 5 were given: 1 was for the best canopy and 5 was for the worst (Thresh, 1957).

Girth:

The girth of the main stems and individual chupons were separately taken in inches at a point 6 inches from the ground level at the end of our observations in October 1965. Wherever there are two or more branching stems per tree or where the main stem is dead and chupon girths have to be used in place of main stem girth, two estimates of girth for each tree have been tried. In method 1, the mean girth of all the stems or chupons is used; while in method 2, the sum of all the stem (chupon) girths divided by the square root of the number of stems (chupons) is used (Pearce, 1956).

RESULTS

Distribution of Chupons:

Because of the manner in which chupons have been allowed to grow, one would expect the dying trees to have more chupons on the average than the vigorously living trees on which not many chupons are allowed in view of their vigour and hence wider canopies. The observed difference in the mean number of chupons per tree for the dying and the living trees is however not significant (Table 1). When the chi-square test is applied to table 1, the growth of chupon seems quite independent of the tree condition, [$(\text{chi-square})_{(2)} = 2.021$, $P > 0.05$], and the overall percentage (47) of trees without chupons does not deviate significantly from 50 per cent suggesting a 50 : 50 chance of a virus infected tree having or not having chupons. Trees with more than 3 chupons are very few and it would appear that in general, not many chupons are required to restore the canopy.

Table 1. Number of trees in the different classes

	Main stem condition			
	Dead	*Dying*	*Living*	*Total*
Without chupon	137	8	291	436
With chupon	116 +	13	262	391
Total	253	21	553	827
Mean no. of* chupons/tree		2.4	1.7	

+ One tree (no. 318) is left out in subsequent calculations because of recording error.
* trees with chupons only.

Yield:

Table 2 gives the yields for the 1964/65 season arranged according to the number of chupons. It is obvious from this table that chupons are making worthwhile contribution to yields. For trees with two or more chupons, the chupon yield exceeds the main stem yield. While the mean yield per chupon decreases with increase in the number of chupons, the performance of the individual tree in terms of yield per tree tends to improve with the number of chupons. The increase appears most marked in trees with three, four and five chupons (Table 2).

The positive significant correlation between yield and the number of chupons (Table 3) would lead one to think of a linear yield-number of chupons relationship. This however appears to hold in the range of zero to four chupons (Table 2). As trees without main stems tend to yield much less than those with main stems (Table 2), if a new correlation coefficient is calculated for trees with main stems, the resulting correlation is found to be more significant than the first one. This might be due to the fact that for all trees with a given number of chupons, the proportion of trees without main stem varies as the number of chupons varies (Table 4a). Subdivision of the total chi-square into components (see Table 4b) [Cochran, 1954], shows that this proportion is significantly higher for trees with one chupon than for others, whilst the variations among the others are not significant. This probably explains why the average chupon contribution to yield is higher than the main stem contribution in trees with more than one chupon and less in trees with one chupon.

Girth:

The effect of including trees without main stems is most pronounced with the girth results. Since chupon girths are necessarily smaller than main stem girths, using chupon girths in place of missing stems seems to result in underestimate of mean girth per tree (Table 5). This is more so when the chupon mean is used (method 1) in place of main stem than for the other method, and the underestimation, measured by the difference in the girth means appears to be largest for trees with more than one chupon where the proportion of trees without main stems is largest (Table 4). Although the use of method 2 brings about slight differences in girth correlations over method 1, the only character with which girth is significantly correlated is yield. The absence of any correlation between girth and number of chupons seems to suggest that growth of chupons may not inhibit trunk girth development. The mean girth per chupon however, shows a significant downward trend with increase in number of chupons ($r = -0.172^*$).

Canopy:

The canopy score appears to improve with the number of chupons (Table 6). The major contribution of chupons to canopy score is also well illustrated in this table and it can be seen that the main stem contribution to canopy decreases with increase in the number of chupons. The trend in canopy score with number of chupons is confirmed by the significant correlation

Table 2. Yield expressed in number of pods

Number of chupons	*Number of trees*	*Main stem yield*	*Chupon yield*	*Total yield*	*Mean yield per tree (all trees)*	*Mean yield per tree (excluding trees without main stem)*	*Mean Yield per Chupon*
0	299	4549	—	4549	15.2	15.2	—
1	231	2240	1366	3606	15.6	18.2	5.9
2	92	533	1021	1553	16.9	18.4	5.5
3	37	289	526	815	22.0	27.3	4.7
4	18	227	277	504	28.0	34.0	3.8
5	6	37	109	146	24.3	22.8	3.6
6	5	34	48	82	16.4	27.0	1.6
7*	1	—	—	—	—	—	—

Mean yield for 115 trees without main stem = 11.4 pods/tree
Mean yield for 573 trees with main stem = 17.4 pods/tree
S.E. of yield per tree = 15.4 pods
* not included in subsequent calculations.

Table 3. Correlations between yield (y), canopy score (s), number of chupons (n) and girth (g)

(a) Using chupon mean in place of main stem girth (method 1)

	Canopy Score		*Number of chupons*		*Girth*	
	a	b	a	b	a	b
y	–0.161**	–0.170**	0.133**	0.192**	0.435**	0.478**
s			–0.217**	–0.225**	0.021	0.023
n					–0.030	–0.074

a = for all trees
b = Excluding trees without main stem
** = Significant at P = 0.01

(b) Using $\frac{\text{sum of chupon girth}}{\sqrt{\text{number of chupons}}}$, i.e. (method 2)

	Girth	
	a	b
y	0.508**	0.483**
s	0.026	0.036
n	–0.014	–0.053

a = for all trees
b = Excluding trees without main stem
** = Significant at P = 0.01

Table 4(a). Proportion of trees without main stem

	Number of chupons						
	1	2	3	4	5	6	*Total*
Total no. of trees	231	92	37	18	6	5	389
No. of trees without main stem	52	38	11	10	2	2	115
Proportion of trees without main stem	.2251	.4130	.2973	.5556	.3333	.4000	

Chi-square = 17.761, sig. at P = 0.01

Table 4(b). Subdivision of chi-square into components

Component	*df*	*Chi-square*
Total	5	17.762**
One chupon tree vs others	1	13.589**
Among others	4	4.173

Recomputed chi-square for among others = 3.6397

Table 5. Mean girth (in inches) per tree

Number of chupons	(*a*)			(*b*)			
	Mean girth per tree (all trees)	*Mean girth per tree (excluding trees without main stem)*	*Difference*	*Mean girth per tree (all trees)*	*Mean girth per tree (excluding trees without main stem)*	*Difference*	*Mean girth per chupon*
0	23.9	23.9	0.0	23.9	23.9	0.0	—
1	21.2	24.0	2.8	21.5	24.3	2.8	11.3
2	18.0	22.5	4.5	20.1	22.9	2.8	11.3
3	20.7	25.0	4.3	23.1	25.0	1.9	10.7
4	16.0	23.3	7.3	22.3	24.6	2.3	10.3
5	16.5	18.7	2.2	21.4	18.7	-2.7	10.8
6	13.1	16.0	2.9	18.3	16.0	-2.3	8.8

(a) Using chupon mean in place of main stem girth i.e. method 1
(b) Using $\frac{\text{sum of chupon girth}}{\sqrt{\text{number of chupons}}}$ in place of main stem girth i.e. method 2

Table 6. Canopy Score records

No. of chupons	*Mean Canopy score per tree*	*% Contribution per tree*	
		Main stem	*Chupons*
0	2.2		
1	2.0	48.8	51.2
2	1.8	29.6	70.4
3	1.8	30.9	69.1
4	1.6	22.5	77.5
5	1.3	13.3	86.7
6	1.2	18.0	82.0

between canopy score and number of chupons (Table 3). Because of this correlation, the effect of number of chupons on the yield-canopy score correlation is investigated by calculating the partial yield-canopy score correlation. This partial correlation (0.133) for trees with main stems is still significant thus confirming the result of Longworth (1963) who did not take number of chupons into consideration. There is no evidence of association between stem girth and canopy score.

DISCUSSION

Restoration of good canopy to mature virus infected cocoa trees damaged by *Calonectria* die-back consequent on mirid attack can be achieved by encouraging the growth of chupons. It therefore appears possible to rehabilitate a mirid devastated mature virus infected farm by the use of chupons. This investigation has shown that the growth of chupons is independent of the condition of the main stem, although from other work, it seemed that virus infected trees were less likely to regenerate chupons than uninfected ones if coppiced (Posnette and Todd, 1955; Thresh, 1958). Thresh and Lister (1960) have shown that when virus infected trees are coppiced, only half of them survive. The corresponding figure obtained here for uncoppiced trees is 47 per cent. Thus coppicing does not appear to improve survival rate and it would therefore appear reasonable that if a virus infected farm is to be rehabilitated by first coppicing the trees, chupons should be allowed to grow before the original main stems are removed. Since new chupons start bearing pods steadily from the third year onwards (Toxopeus, personal communication), it is suggested that the removal of the main stem should be delayed until that time. This will ensure a reasonable yield per stand for the farmer as trees with main stem have been shown to yield more than those without main stem in this study.

Increase in yield was observed with increase in number of chupons (Table 2) up to 4 chupons and this was more obvious when the effect of dead main stems was removed. The relationship is possibly linear, but the break in the trend is probably due to the small number of trees with 5 to 6 chupons. From this investigation, it appears that not more than 4 chupons are needed on the main stem to obtain the best yield.

Jones and Maliphant (1958) suggested that the performance of cocoa trees was very much influenced by their initial size. Because of this and the tendency for chupon size to decrease with increase in number of chupons per tree, the smaller chupons should be removed from trees with many chupons since small chupons are unlikely to yield as well as the bigger ones in future. In addition, it would appear that canopy score is just as important as the girth of the chupons. It can be seen in Table 6 that the mean canopy score per tree improved with increase in number of chupons. The mean yield per tree, especially when trees without main stems are left out, increased with increase in number of chupons. Since the number of chupons affects the quality of the canopy (Table 6), it is suggested that both number of chupons and canopy score are important in determining the performance of a farm being rehabilitated by this method. Variations in number of chupons and canopy score are therefore likely to be reflected in the yields. A statistical method of controlling such variation in experimental work is to remove the effect of the extraneous source of variation by carrying out analysis of covariance of yield on these other variates which various writers have termed "calibrating variates". Among the more effective calibrating variates that have been suggested for use in cocoa work are initial plant size, previous yield and stem girth (Longworth and Freeman, 1963). It is here suggested that number of chupons and canopy score may be further useful calibrating variates. Canopy score could be used in all cacao growth studies, while number of chupons will apply only in rehabilitation using chupons.

In the Areas of Mass Infection, the problem of maintaining cocoa trees in satisfactory bearing will remain as long as the Western Nigeria government decides not to cut out virus infected cacao. One of the ways of rehabilitating such infected farms damaged by mirids is by the use of chupons. This investigation and those of others (Longworth, 1963) have shown that economic yields can still be obtained from such farms using this method of rehabilitation. One of the big disadvantages though, is that the variety of the old infected cocoa cannot be changed, and if such a variety is highly susceptible to virus attack, the *status quo* is maintained. The only way out may be to bud highly tolerant Amazon types on the young chupons of such susceptible varieties, but this might prove time consuming and expensive.

Although the two methods of estimating main stem girth by chupon girths do not have any appreciable effect on the results, it is not at all certain which is to be preferred in girth studies in cacao. Method 2 is being applied to apple trees where the branch girths are used. These branches normally exist alongside with the main trunks whilst in the present cocoa study, the main stems are not available and the chupons are likely to be younger than any corresponding branches which do not appear on cacao trees as they do on apples. It will therefore be necessary to make a more detailed study in order to determine the best measure to use.

SUMMARY AND CONCLUSIONS

Observations were made on the yield, stem and chupon girth, canopy and tree condition of mature, randomly planted, swollen-shoot-infected Amelonado cocoa trees in Ibadan Province, Western Nigeria. Harvesting of pods was done twice monthly and the total number of pods was used in all calculations. The canopies of the main stem and chupons were scored separately for each tree wherever possible, otherwise a joint score was given per tree unit, but the contribution of the main stem and chupon was determined by assigning proportionate percentage canopy score.

From the results, there was evidence of increase in yield per tree unit with increase in number of chupons, thicker girth and better canopy. The canopy improved as the number of chupons increased, but there was decrease in yield per chupon as number of chupons per stand increased. It was observed that chupons grew whether the main stems were dying or not and that some main stems died off without producing any chupons. It is suggested that the use of number of chupons and canopy score as additional calibrating variates to stem girth could bring about a reduction in variability of yield.

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