Reflections on Yields from Hybrid Cocoa Varieties in Ghana

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In Ghana, Upper Amazon × Amelonado hybrids (4, 5, 6, 8) have been adopted for use in replanting schemes in the belief that they are superior to Amelonado. In a study on trends in cocoa production, the International Cocoa Organisation deduced that at maturity (15–19 years), the maximum sustained yield of Amelonado was 443 kg/ha whereas hybrids would give 841 kg/ha after seven years. The latter figure was taken from the 1970 report on the Eastern Region Cocoa Project, prepared by the International Bank for Reconstruction and Development; but the IBRD did not describe how the figure was derived. There is no published yield data from hybrids on farms and in trials yields vary by a factor of two or more depending on:

Season.
Site.
The assumptions made in calculating the yields.
The estimates of pod values used.

The purpose of this article is to discuss how best to arrive at accurate yield figures in cocoa variety trials and to attempt to quantify the yield advantage of hybrids over Amelonado.

Trials with Hybrid Varieties

In the present article, "the hybrids" refers to the new varieties developed in Ghana during the fifties (6). The 8th Progeny Trial Area (P.T.A.) at Tafo (9) was planted in 1952 at 2·4 m square spacing with 36 tree plots; the trial included eight plots of Amelonado, four of Amelonado × Amazon hybrids and eight of local-Trinitario × Amazon hybrids. In the trial the better hybrids consistently outyielded Amelonado, although blackpod losses were lower on the Amelonado. Once the trial was mature the yields of all the genetic types fluctuated together and there was no evidence that the yields of the hybrids reached a peak and then declined relative to Amelonado in the later years. The 9th P.T.A., also at Tafo, was planted in 1954 in thinned forest, the spacing was 3·05 m square and there were five replicates. The Series III experiment (4) was planted at Tafo in 1963 in plot D13 on clear felled land with ten replicates of fifteen Amazon hybrids in twenty tree plots and a spacing of 3·05 m square. Over the last five years two Series II hybrids, which were included as controls, were slightly lower in net yield than the average for the whole trial. Three Series II trials were planted in 1956, each included eight hybrid progenies and 36 tree plots at 2·4 m spacings, with four replicates at Apedwa and Asikuma and three replicates at Pankese, but with no perimeter guard trees. During 1975 a large swollen-shoot outbreak was cut out of the Apedwa trial, but otherwise the trails were intact. The Apedwa Series II trial is adjacent to a 4·86 ha plot of Amelonado which was planted in 1954 at 1·52 m spacing and thinned once by eye. Between 1970 and 1976 shade levels over the trial and the Amelonado were comparable. The 13th and 14th P.T.A.s (11), mainly with inter-Amazon hybrids, were planted at Apedwa in 1974 under thinned forest shade in dense bush which had previously carried scattered cocoa. Amelonado was planted throughout the trial areas for simultaneous calibration.

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Establishment Ability

A number of experiments in Ghana have compared the performance of hybrids and Amelonado under experimental conditions. The earliest of these was the Trinidad Introductions plot at Tafo, where it was quickly apparent that Pound's Upper Amazon selections were easier to establish, faster growing and earlier into bearing than Amelonado. Later trials have consistently reproduced this result. For example, the 13th and 14th P.T.A.s experienced two protracted dry seasons and mortality in the Amelonado was several tmes greater than in the hybrids which were under test:

	% Mortality by March, 1976	
	Amelonado	*Hybrids*
13th P.T.A.	27·9	8·9
14th P.T.A.	21·3	4·0

When considering results from experiments with hybrids and Amelonado it should be borne in mind that in one trial area it is difficult to find a combination of management methods which perfectly suit the two types. Normally the Amelonado has been grown at a closer spacing and shade levels have favoured the hybrids. More important, the trials were usually on old cocoa land, which was clear-felled in advance and replanted while the temporary shade remained sparse. Under such conditions the hybrids have an even greater advantage, whereas if the plantings had followed the traditional practice of thinning old forest land, the difference might have been less marked. From this it follows that in older cocoa growing areas of Ghana replantings should always be made with the new vigorous types. After swollen-shoot control farms are often exposed and the soil degraded and under such conditions Amelonado can be very difficult to re-establish.

Yield Estimation in Trials

Use of different methods of calculating yields from trials can lead to markedly divergent results, the main variables being:

Estimates of pod sizes.
Allowances for possible interaction between progenies.
Whether or not adjustments are made for spoilt pods.

It is not normally the practice in trials to separately ferment and dry all the cocoa obtained from each treatment at every harvest. Instead, for each treatment estimates are made of "pod values" (sometimes referred to as "pod indices") the numbers of pods required to yield a unit of dry cocoa. From these values and the numbers of pods harvested from each treatment an estimate of dry bean yield is obtained. Bean sizes and bean numbers vary markedly between progenies as well as through the season (Table 1), suggesting that accurate yield estimation requires determination of pod values for each progeny at every harvest, which is now the regular practice with cocoa breeding trials on the station at Tafo (10).

TABLE 1

Pod and bean characters in the 8th P.T.A. 1974/75

	Conversion ratio	*Pod value in kg*	*Bean weight in gm*
Range between progenies (mean over season)	35·81–44·97	17·93–34·98	0·89–1·43
Range within progenies (through the season)			
Amelonado	29·09–40·81	19·61–25·02	1·07–1·32
WAE 5	32·39–43·42	19·98–25·73	1·19–1·26
WE 3	30·65–40·12	31·22–39·57	0·81–0·98

Having estimated the dry weight of cocoa, corrections are sometimes made to allow for possible encroachment of one treatment onto another (7). However, most progeny trials with cocoa are concerned with assessment of the progenies for farmers' use as a mixture, so this consideration does not necessarily apply (12). But if an experiment does not have perimeter guard rows, there is a stronger case for the use of core plot data, because trees adjacent to empty areas exploit the space and thus occupy more land than their nominal spacing would indicate. Sometimes additional adjustments are made for pods which are lost to disease, squirrel damage, insect attack, etc., these lead to estimates of "potential" yields. The effect of this and the use of whole and core plots on the Apedwa Series II trial, which has no guard trees, are shown in Table 2.

TABLE 2

Yields from the Series II Trial at Apedwa in kg dry cocoa/hectare

	Whole plots		*Core plots*	
	potential	*net*	*potential*	*net*
1971/72	1117	622	974	521
1972/73	1038	712	917	615
1973/74	683	465	606	402
1974/75	553	337	480	266
1975/76	938	776	828	680

+FGKA.

It would seem preferable if net yields from breeding trials were most widely quoted, since the farmer is interested in the return from the cocoa he actually sells at the buying station and not in what has been lost. Moreover, the difference between actual and potential yields is not always clearly understood particularly by readers who are unfamiliar with the problems inherent in estimation of yields from progeny trials with cocoa but who may wish to use published data for other purposes. There is a natural tendency to quote potential yields because the figures are often large, but, as the Apedwa data shows, this can be misleading.

Yields obtained from Variety Trials

Yields and levels of blackpod losses in some of the breeding experiments are shown in Tables 3 and 4. Blackpod losses were estimated from the diseased pods which were harvested when unripe as well as those from which some useable cocoa was obtained. Pods which ripened prematurely and contained no useable cocoa were excluded from the total of diseased pods, except at Asikuma from 1970–74. The yields were calculated as above, except in the Series II trials where they were derived from the wet weights of cocoa recorded and the wet to dry weight conversion ratios determined at Tafo during the same season. In calculating the yields from the Apedwa Amelonado plot a pod value of 26/kg was assumed. All of the data from the Tafo and Asikuma experiments and the Apedwa Series II trial were collected by plant breeding staff. Over the last five years the Pankese experiment and the Apedwa Amelonado were visited regularly and there is no cause to doubt the reliability of the yield estimates.

TABLE 3

Blackpod losses (%) and net yields (kg/ha, whole plots) from selected progenies

		Trial									
		*9th P.T.A.***		*Apedwa*		*Asikuma*		*Pankese****			
Year	*Progeny**	*Disease*	*Yield*	*Disease*	*Yield*	*Disease*	*Yield*	*Disease*	*Yield*		
1972/73	F	9·5	733	14·1	931	26·2	539	17·8	1051		
	H	17·2	721	21·4	820	24·1	546	30·7	1112		
1973/74	F	6·2	378	12·3	646	34·3	398	12·0	513		
	H	13·9	945	28·4	893	38·7	452	40·7	553		
1974/75	F	10·3	711	12·3	525	13·0	777	22·7	933		
	H	11·0	821	28·4	361	12·4	671	45·8	825		
1975/76	F	4·2	721	8·0	791	17·2	945	12·4	1487		
	H	9·1	908	12·4	726	15·1	1172	20·6	1068		

*F=WE6 (T85/799×T79/501)., H=WAE11 (S84: E10/4/90×T85/799)

**Replicates 3–5 only

***Replicates 1–3 only.

TABLE 4

Pod disease losses (%) and net yields of dry cocoa from whole plots (kg/ha)

	1971/72		1972/73		1973/74		1974/75		1975/76	
Trial Area	*Disease*	*Yield*	*Disease*	*Yield*	*Disease*	*Yield*	*Disease*	*Yield*	*Disease*	*Yield*
8th P.T.A. at Tafo										
Amelonado	14·6	670	9·0	860	13·2	707	16·9	669	9·3	708
Amelonado × Amazon hybrid	12·0	1110	10·9	1627	14·1	1309	23·1	1167	10·6	1713
Local-Trinitario×Amazon hybrids	16·3	911	14·2	1153	20·7	838	31·2	670	14·5	1111
Series III Trial at Tafo	23·0	379	22·3	440	23·9	501	24·7	541	15·0	702
Series II Trial at Apedwa	31·3	622	24·9	712	21·2	465	34·1	336	12·4	776
Amelonado plot at Apedwa	22·9	355	7·4	569	7·2	459	7·9	527	2·3	449
Series II Trial at Asikuma	32·8	597	28·9	525	41·1	389	17·7	506	21·6	937
Series II Trial at Pankese	18·3	1068	30·0	919	29·4	488	43·9	721	22·6	1121

The results from one year of a single progeny trial take no account of site-to-site and year-to-year fluctuations in blackpod losses and yield and thus cannot be equated to possible returns on farms. The fluctuations can be large, as can be shown from the yields of two of our better hybrids grown at four sites and compared over four seasons (Table 3).

In the 8th P.T.A. (Table 4) the better hybrids have continued to heavily outyield the Amelonado, thus the mean yield of the hybrids over the last five years was 1114 kg/ha (weighted for the differing replication of the progenies) which is 54% higher than the Amelonado mean of 723 kg/ha. However, 1971/72 was the only season in the life of the trial when the losses from blackpod disease have been higher on the Amelonado than on the Amelonado × Amazon hybrids and it may be significant that the year was one in which early setting on self-compatible progenies at Tafo and Apedwa was very high. The Amelonado trees cropped unusually early during the blackpod epidemic, whereas, the largely self-incompatible hybrids cropped later and thus avoided infection. In more normal years Amelonado has a consistent advantage over hybrids for blackpod losses and it seems certain that this difference would be sharply accentuated if farmers harvest hybrids as irregularly as they do Amelonado. Supporting evidence for this view comes from the Apedwa plots where blackpod losses on the hybrids were much higher than on Amelonado.

A detailed assessment of the Series III trial (8) showed that net yields have been very low; seven years after planting only 442 kg/ha and from the eighth to thirteenth year after planting an average of 513 kg/ha. In most years about half the pods did not yield fermentable cocoa, either because they were rotten following fungal infection (mainly blackpods) or the beans were caked. The latter is attributed to attack by *Bathycoelia thalassina*. Edwards (3), suggested that the low yields in the Series III trial and other plant breeding plots at Tafo were partially consequent upon exposure of the soil in the very early stages. As it is likely that many farm plantings with hybrids will be under similar conditions and not in newly cleared forest, the Series III rather than 8th P.T.A. yield levels may be a more reliable gauge of possible farmers' yields, under conditions comparable to those on the station at Tafo.

In the three Series II trials, losses from pod diseases have been serious even in years of normal rainfall and have been very high in wetter years (e.g. Pankese in 1974/75). Only in exceptionally dry years (Apedwa in 1975/76), were pod disease losses acceptably low. The marked increase in yield at Asikuma in 1975/76 is largely attributed to a lower level of infestation with *B. thalassina*.

The results from the Apedwa Amelonado plot are of particular interest because there are so few mature trials in which hybrids and Amelonado were compared, but it must be stressed that the comparison between this plot and the Series II trial has no statistical validity. The mean yield from the Amelonado over the last five years was 472 kg/ha, close to the ICO figure of 443 kg/ha whereas in the Series II trial the mean yield was 582 kg/ha, 23% higher than the [illegible] but blackpod losses were also much higher.

The Yield Potential from Hybrids on Farms

In all the trials the management practices followed those of local farmers thus all the plots were grown under shade and except for a single dressing on the 8th P.T.A. no fertilizers were used. Harvesting was done at three week intervals and routine capsid sprays were applied according to current recommendations and so the management was nearer to that of the best rather than the average farmer. All the trials were in good vegetative condition between 1970 and 1976 yet the yields must be judged disappointing, except for the 8th P.T.A. and the Pankese trial in some years.

Much thought has been given to the difficulties of interpreting results from formal progeny trials in terms of farmers' plantings (e.g. 1). It is generally accepted that for net yield and losses from blackpod disease different types of planting material would tend to rank in the same order when growing in trials or on farms under similar ecological conditions with similar management practices. Ideally all new progenies should be tested under a wide range of conditions by planting on cocoa stations and farms throughout the cocoa growing areas. The information gained would lead to reliable recommendations of varieties for particular areas and knowledge of the yields to be expected. In practice this is not possible because of the amount of work involved and new progenies are tested at very few sites. Under similar conditions it seems reasonable to expect that average yields will be higher in trials than on farms because often the latter are less well managed. The trials reported here are very small areas among Ghana's huge acreage and even allowing for the difficulties of extrapolating from trials to farms any conclusions must be tentative. Some early high yields from trials with hybrids lead to the hope that under farmers' management they would be markedly higher yielding than Amelonado and it is perhaps forgotten that Amelonado can be extremely high yielding with the appropriate management (2). As illustrated above there is now increasing recognition that blackpod disease is likely to be a more serious problem on the present hybrids than on Amelonado, furthermore most new plantings will be on old cocoa land under less than ideal conditions. The hybrids have a conclusive advantage over Amelonado in easier establishment and earlier bearing and in addition they are likely to prove to be higher yielding. The IBRD yield estimate for hybrids is 90% higher than the ICO figure for Amelonado and would seem too high, because in well managed trials hybrids are not consistently yielding 841 kg/ha and even in the 8th P.T.A. the advantage of the hybrids over Amelonado is much less than 90%. The 8th P.T.A. and the data from Apedwa suggest that an advantage of 25–50% is more likely, which, if the ICO yield estimate for Amelonado is accepted, leads to projected yields from hybrids in the range of 550–650 kg/ha, which are regularly achieved in the trials. This estimate can be more than a working hypothesis pending collection of yield data from farms planted with hybrids because the results from trials show that yields from hybrids vary widely both from site-to-site and from year-to-year and depend heavily on regular harvesting to minimise blackpod losses.

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