

Cocoa research in West Irian (West New Guinea)¹

J. RUINARD

Formerly Director of the Agricultural Research Station at Manokwari,
West New Guinea

Contents

SUMMARY

1. INTRODUCTION
2. PLANTING MATERIAL FOR THE FARMERS
3. BREEDING AND SELECTION
 - 3.1. Aims and purposes
 - 3.2. Pollination technique
 - 3.3. Selection technique
 - 3.4. Compatibility and incompatibility
 - 3.5. Material, methods and results
 - 3.5.1. *Manokwari selections and their progeny*
 - 3.5.2. *Wageningen seedlings*
 - 3.5.3. *Keravat selections and their progeny*
 - 3.5.4. *ICS selections*
 - 3.5.5. *Amelonado cocoa*
 - 3.5.6. *Cross KA 5-104 × Amelonado*
 - 3.5.7. *Cross KA 2-106 × Wa 12*
 - 3.5.8. *Cross SCA 6 × ICS 1*
 - 3.5.9. *Conclusions*
4. DISEASES AND PESTS
5. CULTIVATION
 - 5.1. Provision of ground cover and shade
 - 5.1.1. *Ground-cover crops*
 - 5.1.2. *Temporary shade crops*
 - 5.1.3. *Permanent shade trees*
 - 5.2. The problem of shade
 - 5.3. The manuring of cocoa
 - 5.4. Spacing
 - 5.5. Seedlings, cuttings and budded cocoa
 - 5.6. Effect of stocks on scions
6. CURING AND STORAGE
 - 6.1. Fermentation
 - 6.2. Drying
 - 6.3. Storage

ACKNOWLEDGEMENTS

REFERENCES

¹ After the transfer of sovereignty of West New Guinea to Indonesia by the Netherlands Government the name was changed to West Irian.
Received for publication 28th September, 1963.

Summary

The present article is a review of research work undertaken in West Irian up to the end of 1962 on behalf of the cultivation of cocoa in that area.

Breeding and selection were the chief subjects of this research work. Thanks to pre-war imports from Indonesia, which were afterwards supplemented by shipments from Australian New Guinea and the Netherlands, ample starting material was available. Particularly noticeable was the early start of production and the high yield level of both the imported material and the crosses made from it. During the research work a remarkable case was revealed of cross-compatibility between self-incompatible Trinitario clones.

Cocoa plantations in West Irian are not seriously affected by pests and diseases. Up to now it has been possible to keep the country free from the most important, e.g. swollen shoot and cocoa moth. From a preliminary trial at Manokwari we gained the impression that here too shade trees are less necessary than is believed.

Other studies in our research programme related to plant spacing, the effect of stocks on scions, and the processing and storage of cocoa.

1. Introduction

Prior to 1950 the only export crops of any importance in West Irian were the coconut and the Papua nutmeg (*Myristica argentea* WARB.). The former was chiefly cultivated in the Radja Ampat (a small group of islands to the west of the main island) and the latter solely in the Fakfak region. During the succeeding years the ambitious programme of agricultural development focussed attention on cocoa, this being a crop for which only a moderate degree of soil fertility is required, which thrives best in a warm, humid climate without marked periods of drought; besides plantation maintenance, harvesting and manufacture do not require a great amount of labour. Having regard to these factors, cocoa appeared to be excellently suited for large areas of West Irian, and in addition world cocoa prices were favourable during this period.

Cocoa cultivation was first introduced to the native population in 1953. In the first instance the Government's efforts were confined to extension work, supplemented with such material assistance as the provision of machinery for clearing forest, agricultural implements and planting material, but owing to various causes the results were not always up to expectation. Maintenance of the new plantations was often below standard, and the area planted with cocoa was not extended as rapidly as was desired. Consequently in 1960 a second method was introduced in addition to that followed hitherto. The new method has now become an unqualified success, the essence of it being that the construction of roads for opening up certain areas and the preparation of plantations in these areas and their planting with food crops and cocoa were undertaken simultaneously, the manual labour involved being done by the future smallholders for a generous wage. The intention was that they should repay part of their earnings after their cocoa had been brought into production.

Owing to the political pressure to which West Irian was exposed, neither Dutch nor foreign companies were enthusiastic about starting cocoa estates. The only step in this direction was taken by a combine of Dutch companies which in 1955 opened a small experimental cocoa estate near Ransiki. Despite the excellent results attained the experiment was abandoned in 1960.

There were a few Dutch colonists, mostly from Indonesia, who grew cocoa on a some-

what larger scale than most native farmers, but their share of the total cocoa acreage was only a few per cent.

At the end of 1962 the area planted with cocoa in West Irian was 1.350 ha; other perennial crops were coconut 16.000 ha, Papua nutmeg 2.000 ha, common nutmeg (*Myristica fragrans* HOUTT.) 850 ha, rubber 60 ha, and coffee 80 ha. Of these 1.350 ha 350 were from four to nine years old, 650 ha from one to three years old, and 350 ha less than one year old. The annual area scheduled for additional planting was 1.000 ha. As much as 55 % of the area planted with cocoa was in Japen/Waropen, 20 % in Manokwari and Ransiki, 10 % in Sentani, 10 % in Genjem and 5 % in Sarmi. During recent years there was a rapid increase in cocoa exports; whereas they only amounted to 25 tons in 1959, they had grown to 52 tons by 1960 and as much as 82 tons in 1961.

The chief aim of the cocoa investigation was to create facilities for improved and more economic cocoa cultivation under the given conditions, so that it had an extremely practical basis. Up to 1958 the investigation was carried out by the Government, and afterwards by the Manokwari Agricultural Research Station, which was administered by the Institute for Agricultural Research in Netherlands New Guinea. This Institute ended its work a short time ago when the government of West New Guinea was transferred to Indonesia.

The present article gives a review of the chief objectives of the cocoa investigation and the results obtained to date. Generally speaking detailed points are not discussed; for these readers are referred to articles already published and to the reports which will appear in the near future.

2. Planting material for the farmers

Scattered cocoa trees, either solitary or in small groups, were still found during the post-1950 period; these were the remnants of small plantations established by colonists and cocoa estate companies before the second world war, and had been grown from seed imported from Indonesia. So far as is known, the trees were invariably Java cocoa, a Trinitario type of a marked Criollo character. The sole exceptions were six seedlings at Hollandia-Binnen which were progenies of a plantation of Amelonado cocoa in Celebes (Indonesia), originating from West Africa.

These remaining trees were far too few in number to make any important contribution to the supply of planting material for the renewed cultivation of cocoa, apart from the fact that their quality was doubtful. The Government therefore decided to import seed on a large scale from Australian New Guinea. By far the greater part of the present cocoa acreage in West Irian has been produced from or is descended from this seed, known as "Keravat bulk", which had already proved its value on the part of the island administered by Australia. This Keravat type is a Trinitario cocoa with a marked Forastero character.

It was only in the neighbourhood of Manokwari that plantations of any extent were established from seed of the Java type trees which were found locally. In this region there are also a few plantations for which use was made of seed of the Wageningen population, a seedling family to which further reference will be made below.

3. Breeding and selection

3.1. Aims and purposes

The use of imported seed was obviously only regarded as a temporary measure. At

a later stage its own breeding and selection work should provide West Irian with better material, more adapted to local conditions.

In general the chief aims of cocoa breeding and selection work are the reduction of production costs, increasing the yield both per unit of area and time, and improving the quality. It also depends on local conditions to which of these three factors priority is given.

The production-cost factor is not usually so very important on the family farm encountered in many development countries, since in cocoa cultivation these costs are chiefly determined by the amount of work done and the remuneration per unit of work. It will be manifest that these are only minor items on such family farms. On the other hand their importance can hardly be overestimated in estate agriculture. But increase in the yield and improvement of the quality are factors that may have a substantial influence on the financial results of the family farm, and obviously they have just as great an effect on the trading results of large estates.

It did not seem likely that estate plantations would offer any immediate prospects, so that the main emphasis of the research had to be placed on the needs of small-holdings. Another question that arose was whether quality was to be preferred to quantity, and if so, what were the types to which West Irian could most suitably turn? In this connection SPOON (1962) consulted a large number of cocoa-manufacturing companies. From the information supplied, supplemented by published evidence, he concluded that it would be unrealistic to aim at producing "fancy" or "fine" cocoa, for which there was only a small demand and no prospect of any increase. From the economic point of view high yields of a bulk product of a fairly good and above all constant quality were to be preferred.

This opinion gave its fiat to the policy of the preceding years in which emphasis was placed on quantity. This direction was taken following the pattern set by Australian New Guinea where such exceptionally good results had been achieved under similar conditions with the above-mentioned Keravat Trinitario. This type, which has a marked Forastero character, was found to be very sturdy in practice, the yields were good, the bean size was ample, and the quality of the market product was not inferior to cocoa from Ghana or Nigeria. Moreover the extreme sensitivity of the Criollo types (the chief sources of fancy cocoa) to numerous pests and diseases was sufficient to make them less attractive for native agriculture.

What is more, it was obvious from the first that since the smallholders were still in a very primitive state it would be better to provide them with seedlings for use as planting material than rooted cuttings or scions. Seedlings are generally sturdier, they grow more rapidly and require less maintenance, and moreover seedling plantations are not so subject to disastrous epidemics as mono- or biclonal plantations.

In view of these considerations it was decided that, at any rate in the first instance, the future breeding and selection work should be focussed on the production of high-yielding seedlings.

3.2. Pollination technique

As in other cocoa-research institutes, the usual practice was that flowers intended for pollination work were covered with glass or plastic tubes shortly before opening, the top of these tubes being sealed with bandage gauze or cheese cloth and the bottom being stuck to the bark of the stem or branch by means of plasticine. But the drawback of these tubes is that they cannot be used on thin branches, and moreover the plasticine does not adhere when the bark is moist. They were therefore

replaced by conical hoods of fine-mesh nylon gauze which were specially designed for this purpose and can be secured to the tree with pins (RUINARD, 1963).

3.3. Selection technique

The chief criteria in the selection of trees in a seedling plantation are considered to be their total wet-cocoa yield per annum and the average weight of the seeds. At first it was customary in West Irian to equate the total wet-cocoa yield of a tree with the product of the number of pods obtained in that year and the average pulp weight per pod. The latter figure, as also the average weight per bean, was derived from the results of analysing 20 pods per tree selected visually. But closer inspection revealed that these 20 pods usually differed so extensively from the "average" pod that the yield figures calculated bore no resemblance to the facts. Consequently another method was evolved which gives more accurate results. The essence of this method is that both the number of pods and their total weight are calculated at each harvest and for each tree. Moreover, during the year 20 pods are analysed per tree of which the weight is as close as possible to the average pod weight of the tree during the same year. The results of these analyses afford a good idea of the average weight per bean, while after the pulp-weight/pod-weight quotient of the analysed pods has been found, a reliable estimate of the total wet-cocoa yield is given by multiplying the quotient by the total weight of pods produced in that year (RUINARD, 1961a and 1964).

3.4. Compatibility and incompatibility

It is hardly possible to undertake cocoa-crossing work without being faced with questions of compatibility. They are part of a complex problem which has not yet been satisfactorily solved.

It was first thought that cocoa was only divided in two groups, *viz.* a self-compatible and a self-incompatible group. According to this theory all trees in the first group set fruit with their own pollen and when crossed with each other, and also when crossed with trees in the second group. Trees belonging to the second group would only set fruit when crossed with trees of the first group, and self-pollination and mutual cross-pollination would give no results.

POSNETTE (1945) showed that this simple theory was untenable if wild cocoa was also included, as he found that self-incompatible, wild cocoa from the Amazon region could be separated in different groups; trees belonging to the same group are mutually incompatible, but those from different groups are cross-compatible¹. Continuing on the same lines COPE (1959) also studied the genetic aspects of the compatibility problem. After an exhaustive investigation he came to the conclusion that the self-incompatible ICS clones from Trinidad (Trinitario and Criollo types) were also mutually incompatible, but could nevertheless be crossed with self-incompatible clones from the Amazon region. Like the parents, all the progenies he obtained from these crosses were self-incompatible, but each seedling family could be divided in a few groups mutually compatible, despite the fact of cross-incompatibility within the groups.

TAMMES and VAN DER KNAAP (1953) regarded the wild Amazon cocoa as an exception. They held the view that all Trinitarios and Criollos could be classified in two groups,

1. In this connection it should be noted that OSTENDORF (1948) rightly assumes it to be possible that POSNETTE's experimental trees were not actually self-incompatible because the investigation only extended over a short period and there is no evidence that self- and cross-pollination occurred simultaneously.

viz. one group of self-compatible and one of self-incompatible trees, the latter also being mutually cross-incompatible whatever their geographical origin. COPE (1959) did not make any statement to this effect, but the results of his work do not disagree with this view.

For several years in succession large numbers of self-pollinations were made at Manokwari on four trees (designated Wa 10, 48, 55 and 57) of the Wageningen population. They are progeny of the cross (Getas 8 × Djati Roenggo 38) × (Djati Roenggo 1 × Djati Roenggo 38); all three grandparents are well-known Java Trinitarios. In most cases none of the pollinated flowers set fruit, and in a few cases only 1 to 2 % of the pollinations were successful. According to the accepted standards, this warrants the conclusion that the four trees were self-incompatible, but in order to settle the question beyond all doubt further control pollinations were carried out at the end of 1960, on which occasion cross-pollinations were also included. They led to results which to some extent were wholly unexpected (TABLE 1). It was confirmed that ICS 1 is self-compatible and that the four Wa-trees, as well as ICS 89, are self-incompatible.

TABLE 1. Results of self- and cross-pollinations

Pollinations	Number of	
	flowers pollinated	fruits after one month
ICS 1 selfed	12	6
ICS 89 selfed	66	—
ICS 89 × ICS 1	28	26
Wa 10 selfed	14	—
Wa 10 × Wa 48	9	7
Wa 10 × Wa 55	9	—
Wa 10 × Wa 57	42	—
Wa 10 × ICS 1	16	16
Wa 10 × ICS 89	11	11
Wa 48 selfed	130	1
Wa 48 × Wa 10	9	9
Wa 48 × Wa 55	67	43
Wa 48 × Wa 57	14	12
Wa 48 × ICS 1	15	10
Wa 48 × ICS 89	16	12
Wa 55 selfed	118	2
Wa 55 × Wa 10	15	—
Wa 55 × Wa 48	55	44
Wa 55 × Wa 57	14	—
Wa 55 × ICS 1	15	12
Wa 55 × ICS 89	10	5
Wa 57 selfed	160	—
Wa 57 × Wa 10	50	—
Wa 57 × Wa 48	17	13
Wa 57 × Wa 55	12	—
Wa 57 × ICS 1	15	11
Wa 57 × ICS 89	12	12

As was to be expected, the crosses between the five self-incompatible trees and ICS 1 were successful. But mutual crossing the Wa-trees and ICS 89 showed that Wa 48 and ICS 89, although both self-incompatible, were both mutually cross-compatible and

also compatible with the three other Wa-trees. On the other hand the latter were mutually cross-incompatible.

It would therefore appear that the theory according to which all self-incompatible Trinitarios and Criollos belong to one group in which there is cross-incompatibility is incorrect, since in the present investigation two incompatibility groups were already found in a part of the progeny of a cross between Java clones and it is quite possible that more than two groups would have been found if the investigation had also been extended to the other 56 trees of the population of 60. In addition it was found that a Trinidad clone belonged to one of these groups, or to a third group which was cross-compatible with regard to the other two groups.

3.5. Material, methods and results

3.5.1. *Manokwari selections and their progeny*

During the first few years subsequent to 1950 four trees were selected from the remnants of the old cocoa plantations in the neighbourhood of Manokwari, viz. M 4, M 6, M 7 and M 9, as they had previously been considered to show much promise. During the period from 1954 to 1956 two field trials were laid down on the terrains of the Manokwari Agricultural Extension Service in which the clones themselves were tested (in the form of scions) as well as their illegitimate seedlings. But these trials were not well designed and moreover the experimental fields were often subject to water-logging. As a result both trials could not be continued after the end of 1959. M 6 and M 7 proved to be clones which were closely related to Criollo, having an abnormally great sensitivity to *Phytophthora palmivora* BUTL.; M 4 and M 9 were free from this drawback but were nonetheless disappointing, nor did the illegitimate progeny of the four clones afford any better prospects (MOLL; RUINARD, 1959a and 1960a).

3.5.2. *Wageningen seedlings*

COOLHAAS crossed two descendants of the crosses Getas 8 × Djati Roenggo 38 and Djati Roenggo 1 × Djati Roenggo 38 in the greenhouses of the Wageningen Agricultural University, Netherlands, and obtained a few pods which he sent to West Irian. They produced 60 plants which were planted out at Manokwari in October 1955 and termed "Wageningen seedlings". The parents of these plants were not selected seedlings, but the grandparents were excellent Java Trinitarios, viz. Getas 8 and Djati Roenggo 1 with a marked Forastero character, and Djati Roenggo 38 with a marked Criollo character.

The plantation grew rapidly despite the poor permeability of the loamy soil. Drainage was improved by the provision of a trench system. The plant spacing is 5 × 5 m square. *Leucaena glauca* BENTH. is used as the shade tree. The trees were not fertilized in the planting hole but were given an occasional light NPK-dressing. The first ripe pods were harvested in April 1957, eighteen months after planting. Twelve months later all 60 trees were in bearing.

According to the data summarised in TABLE 2, which are partly taken from previous publications (RUINARD, 1961b and 1962), the pod yield in the past years was considerable. However, the pod weight is on the low side and in general the seeds are also correspondingly small. The average weight of the wet beans in 1959 and 1960 was only 2.5 g, or 0.5 g less than would be required for the dry product to reach the minimum weight of 1 g per bean specified by the trade.

Some details of minor importance are presented in TABLES 3, 4 and 5. As TABLE 3 shows, the 30 trees which were the thickest at the end of 1962 had by then produced

TABLE 2. Wageningen seedlings; mean growth and yield data

	1957	1958	1959	1960	1961	1962	Total
Stem diam. 40 cm off the ground at end of year (cm)	—	10,0	11,6	12,9	14,1	15,6	—
No. of pods p. ha	6.400	29.200	46.400	57.200	65.600	56.000	260.800
Mean weight p. pod (g)	—	—	396	370	416	427	—
Wet cocoa p. tree (kg)	1,3	6,3	10,2	11,7	15,2	13,4	58,1
Dry cocoa p. ha; ratio dry/wet 1 : 3 (kg)	170	840	1.360	1.560	2.020	1.790	7.740

TABLE 3. Wageningen seedlings; mean growth and pod-yield data, after distribution of the 60 trees over two groups according to their stem diameter at the end of 1962

		Thickest 30 trees	Thinnest 30 trees
Stem diam. 40 cm off the ground at end of year (cm)	1960	14,1	11,8
	1961	15,6	12,6
	1962	17,5	13,6
Total pod yield p. tree up to end of year	1960	366	331
	1961	545	480
	1962	715	590

TABLE 4. Wageningen seedlings; mean growth and pod-yield data of the 27 border and the 33 inside trees

		Border trees	Inside trees
Stem diam. 40 cm off the ground at end of year (cm)	1958	9,9	10,0
	1959	11,8	11,5
	1960	13,3	12,6
	1961	14,7	13,6
	1962	16,3	15,0
Total pod yield p. tree up to end of year	1958	71	104
	1959	183	224
	1960	331	363
	1961	514	512
	1962	676	634

far more pods than the 30 thinner specimens; their surplus yield increased from year to year, as, in fact, did also the difference in stem diameter between the two groups. According to TABLE 4 the border trees (the plantation is enclosed on all sides by roads and open land) did not originally have a thicker stem than the inner trees. But as the seedlings grew older and the plantation closed up the border trees were in a more favourable situation as they were able to spread unhindered in one direction. This resulted in more rapid growth and higher pod production. TABLE 5 shows the production trend from month to month over four successive years. In these figures

TABLE 5. Wageningen seedlings; total pod yield of all trees per month in a four-year period

Month	1959	1960	1961	1962
January	670	269	261	496
February	352	340	345	166
March	784	362	291	433
April	545	192	695	464
May	1.899	2.084	2.025	539
June	1.224	2.979	2.275	1.694
July	93	1.207	620	1.557
August	255	161	602	1.464
September	435	202	450	412
October	325	230	944	351
November	199	285	749	477
December	206	260	589	354
Total	6.987	8.571	9.846	8.407

the marked production peaks are noticeable, viz. in May and June of both 1959 and 1961, from May to July in 1960 and from June to August in 1962. It was found that during 1961 and 1962 the pods obtained at the time of these production peaks were much lighter than the pods harvested before and after (RUIARD, 1964).

The favourable production figures were sufficient inducement to make a provisional selection from the Wageningen seedlings, despite the fact that the trees were rather young for selection work. As TABLE 6 shows, the order of the trees according to the height of the total wet-cocoa yield changed from year to year from the commencement of bearing. The table also reveals that the pulp production differed extensively from tree to tree.

TABLE 6. Wageningen seedlings; mean weight per wet bean and cumulative pulp yields from year to year of the 15 trees with the highest total pulp yields up to and including 1962

Tree number	Total pulp yield per tree (kg) up to and including					Mean wt. p. wet bean, 1959 and 1960 (g)
	1958	1959	1960	1961	1962	
57	9,1	29,8	48,2	66,8	91,5	2,8
55	5,3	17,7	32,6	47,4	87,4	2,4
39	11,9	22,7	40,5	61,7	87,2	2,7
58	5,3	17,3	35,0	62,2	84,8	2,6
1	7,9	19,7	35,7	65,3	79,3	2,6
19	4,6	19,1	33,3	59,5	79,2	2,4
40	10,1	25,9	47,1	66,9	77,7	2,6
3	6,6	18,2	35,8	58,5	77,7	3,0
2	9,7	16,5	36,5	53,7	75,5	2,5
48	10,4	24,9	42,2	52,9	75,0	2,7
31	10,8	23,1	41,7	59,2	74,6	2,4
41	8,7	20,5	34,1	55,2	71,8	2,5
56	4,7	17,0	28,2	53,6	71,2	2,6
37	11,5	26,3	33,2	49,8	71,2	2,3
60	6,7	15,8	29,6	55,9	70,6	3,2
Mean of all 60 trees	7,6	17,8	29,5	44,7	58,1	2,5

The best tree, No. 57, had produced the equivalent of 12.200 kg of dry cocoa per ha up to the end of 1962, which is practically three times the yield of the poorest tree (No. 20, with 4.430 kg).

3.5.3. *Keravat selections and their progeny*

The first cocoa plantations were established in Australian New Guinea about 1900, the planting material used coming from Trinidad, Java, Ceylon, Samoa and probably Venezuela. Afterwards imports were limited to a certain amount of Java cocoa seed. During the second world war a considerable proportion of the existing plantations was lost. The remainder were found to be in an extremely neglected state and in most cases severely damaged; the former sites of well-kept plantations were occupied by dense cocoa woods in which the old trees had often been forced to make way for younger specimens derived from illegitimate natural seedlings. In order to restart cocoa growing a number of plantations at Keravat and Asalingi were cleaned up and, so far as possible, laid out in a regular plant spacing. It was on these plantations that post-war cocoa cultivation and research in Australian New Guinea were based. They represent the Keravat Trinitario, a complex type that includes both numerous intermediate forms as well as substantially pure Criollos and Forasteros. On the basis of vigour, pod yield, pod characteristics and resistance to pests and diseases a number of trees were selected, the K and KA selections, after which illegitimate seedling families of these trees were planted out in variety trials. Selection in these trials produced large numbers of clones. The testing of these clones and their progeny is still in full swing (BRIDGLAND, 1960; MOLL).

In 1955 MOLL brought cuttings of six of these clones to West Irian, *viz.* KA 2—106, KA 5—104, KA 10—103, K 24—103, K 1—103 and KA 6—101. The first four were said to be self-incompatible and the other two self-compatible; this was confirmed by an investigation made by HEKSTRA at Manokwari in 1962.

It was decided that in a new cocoa plantation to be laid out at Manokwari all six clones would be tested (as scions), as well as all legitimate seedling families to be produced by self- or mutual cross-pollination, insofar as these could be reproduced by natural pollination in mono- or polyclonal seed-production areas. The artificial pollinations needed for this purpose were carried out mid-1959 (RUINARD, 1960b). Since a note was taken of the dates and other information it was found, among other things, that the time required for the pods to develop was not the same for all clones. There were some clones of which the pods could be harvested only 5 months after pollination, whereas pods from other clones took nearly 6 months to develop fully. We also ascertained the colour of the cotyledons of seeds produced by these legitimate pollinations. From this data it was concluded that K 1—103 is uniform violet and KA 6—101 and KA 2—106 white to very light violet; KA 5—104 and K 24—103 are light violet to violet; the cotyledon colour of KA 10—103 could not be determined.

It was planned to include all clones and seedlings in three latin squares with six treatments each, *viz.* the six clones in the first latin square, five seedling families and one clone in the second, and the five other seedling families and the same clone in the third. Via the common clone it would thus be possible to compare the treatments situated in different experimental sites. But since two of the crosses did not produce sufficient seed this plan had to be somewhat modified.

The trial fields were laid down on a level and fairly uniform site near Manokwari which had just been cleared. The soil is a moderately fertile, poorly permeable loam,

FIGURE 1

FIG. 1. Cocoa growing under the shade of *Leucaena* hybrids (trial 1, par. 3.5.3)



In the foreground the border row of ICS clones two years after budding; *Leucaena* hybrids likewise two years after budding; there are only a few remnants of the *Indigofera* ground cover.

situated just above sea level, which at first was very marshy after heavy rainfall (VAN SOELEN and SCHLETTE, 1958). But waterlogging was averted by excavating and maintaining a dense system of drains. After the drain system was completed a ground cover of *Indigofera endecaphylla* JACQ. or *Mimosa invisa* MART. var. *inermis* was laid down. At the same time hedges of *Leucaena glauca* BENTH. were sown at intervals of 4 m and hedges of *Crotalaria anagyroides* H.B.K. in between. The cocoa was planted out from March to June 1960 in the form of 4—6 month-old pot plants in a square pattern of 4 × 4 m. A dressing in the plant hole equivalent to 6½ kg N, 6½ kg P₂O₅ and 6½ kg K₂O per ha was given. Subsequently no further fertiliser was applied. All relevant treatments were budded with the required clones in January 1961. The stocks used were illegitimate Amelonado seedlings, a very homogeneous population which may be regarded as very suitable for this purpose. As the canopies closed the ground cover died, as was expected. Meanwhile the *Crotalaria* temporary shade had been removed. The *Leucaena* was severely thinned at regular intervals, and after some time it was budded with *Leucaena* hybrids. It should also be mentioned that a border row was planted round each trial field so as to give the outermost plots some protection against boundary effects. Other details are as follows:

- trial 1: latin square containing 6 treatments and 16 trees per plot (4 rows of 4 trees); stocks planted in May 1960; treatments K 1—103, K 24—103, KA 2—106, KA 5—104, KA 6—101 and ICS 1 (see FIG. 1);
- trial 2: latin square containing 6 treatments and 25 trees per plot (5 rows of 5 trees); seedlings and stocks planted in March 1960; treatments KA 5—104 × K 1—103, KA 5—104 × KA 6—101, K 24—103 × K 1—103, K 24—103 × KA 6—101, KA 6—101 self-pollinated and ICS 1;
- trial 3: latin square containing 6 treatments and 25 trees per plot (5 rows of 5 trees); seedlings and stocks planted in April 1960; treatments KA 2—106 × K 1—103, KA 2—106 × KA 6—101, K 1—103 self-pollinated, Amelonado illegitimate, KA 10—103 and ICS 1;
- trial 4: two plots planted in June 1960 with the seedling families KA 10—103 × K 1—103 (43 trees) and KA 10—103 × KA 6—101 (46 trees).

The diameter of the stem of each tree was measured 40 cm off the ground at the end of 1960 and 1962. As far as possible the results of these measurements were statistically treated (TABLES 7 and 8). The trees were harvested fortnightly from the time at which the first ripe pods were obtained (November 1961) to the end of 1962. At each harvesting the number of pods taken from each tree was noted, as well as the total weight of pods obtained from each plot and the total weight of the wet-cocoa content. The results of the counts and weighings were listed (cf. TABLES 7 and 8), but not statistically treated because the crop was still too young. The dry-cocoa/pulp-weight ratio was taken as 1 : 3. A small number of pods were also analysed during the first months of 1963; for the results the reader is referred to TABLE 9.

It was found that the clones differed extensively both with respect to vigour and early maturity. There were also considerable differences with regard to pod characteristics. It is noticeable that the same differences are usually also reflected in the progeny. Finally it should be noted that in most cases the pods of a seedling family were smaller and contained less wet cocoa than the pods of the parent clone, or less than half the sum of the two parent clones. Despite this the average bean size in all seedling families was just or amply sufficient.

TABLE 7. Keravat selections and their progeny; mean growth and yield data up to end of 1962

No. of trial	Cocoa	Stem diam. 40 cm off the ground (cm)		Difference	Bearing trees (% of total)		Total yield up to end of 1962			
		End			1962		pods p. ha	dry cocoa p. pod (kg)	pod wt. (g)	wet cocoa p. ha (g)
		1960	1962	mid	end					
1	K 1—103	2,7	8,5	—	1	22	1.340	54	381	120
	K 24—103	2,6	8,6	—	0	42	870	50	785	173
	KA 2—106	2,7	8,2	—	0	47	1.370	66	514	145
	KA 5—104	2,7	7,1	—	5	77	3.920	172	477	132
	KA 6—101	2,6	7,5	—	0	23	930	56	650	182
	ICS 1	2,7	8,2	—	5	77	5.920	318	570	161
		stem diameter: sign. diff. for P = 0,05				} end 1960 — 0,2 cm				
						} end 1962 — 0,5 cm				
2	KA 5—104 × K 1—103	3,5	11,0	7,5	65	89	17.880	757	437	127
	KA 5—104 × KA 6—101	3,2	10,2	7,0	69	95	19.140	931	519	146
	K 24—103 × K 1—103	3,6	11,1	7,5	29	71	7.720	368	515	143
	K 24—103 × KA 6—101	3,2	10,3	7,1	31	77	7.910	422	592	160
	KA 6—101 selfed	2,5	9,4	6,9	12	57	4.240	205	564	145
	ICS 1	3,2	8,8	—	0	71	2.600	150	632	173
		stem diameter: sign. diff. for P = 0,05				} end 1960 — 0,2 cm				
						} end 1962 — 0,3 cm				
						} diff. — 0,3 cm				
3	KA 2—106 × K 1—103	3,2	11,3	8,1	19	76	8.430	323	382	115
	KA 2—106 × KA 6—101	2,8	10,4	7,6	42	92	11.430	530	496	139
	K 1—103 selfed	2,7	10,4	7,7	2	28	1.070	35	336	98
	Amelonado ill.	2,7	9,6	6,9	97	99	35.430	1.264	385	107
	KA 10—103	2,7	8,2	—	3	34	650	28	528	127
	ICS 1	2,6	8,0	—	1	67	3.700	190	568	154
		stem diameter: sign. diff. for P = 0,05				} end 1960 — 0,2 cm				
						} end 1962 — 0,3 cm				
						} diff. — 0,3 cm				
4	KA 10—103 × K 1—103	2,3	10,7	8,4	14	66	6.890	262	435	114
	KA 10—103 × KA 6—101	2,0	9,5	7,5	33	75	5.100	262	583	154

3.5.4. ICS selections

As TABLES 7 and 9 show, ICS 1 did rather well as compared with the Keravat selections as regards vigour, pod production and pod characteristics.

The trial 1 border row of 111 Amelonado seedlings (cf. par. 3.5.3) was alternately budded with ICS 1, ICS 89 and ICS 95 in January 1961. Since the same observations were made in this border row as in the actual trial some data are available on ICS 89 and ICS 95 (TABLE 10) in addition to ICS 1. The dry-cocoa/pulp-weight ratio was again taken as 1 : 3.

3.5.5. Amelonado cocoa

The Amelonado seedlings, of which numerous plots were planted in the experimental trials discussed in par. 3.5.3, are illegitimate progeny of the earlier-mentioned small Amelonado plantation at Hollandia-Binnen. The six parent trees were strikingly uniform. Their pods usually contained 30 to 50 beans having an average weight of 2 to 3 g. As TABLES 7 and 9 show, the progenies of these trees were very early in

TABLE 9. Keravat selections and their progeny; mean results of pod analyses (February and March, 1963)

Cocoa	Wet cocoa p. pod (g)	Number of beans p. pod	Mean wt. p. wet bean (g)
Amelonado ill.	103	43	2,4
ICS 1	170	40	4,3
K 1—103	124	35	3,5
K 1—103 selfed	88	30	2,9
KA 6—101	165	34	4,9
KA 6—101 selfed	139	30	4,7
KA 2—106	149	30	5,0
KA 2—106 × K 1—103	92	26	3,5
KA 2—106 × KA 6—101	116	30	3,9
KA 5—104	147	35	4,2
KA 5—104 × K 1—103	121	38	3,2
KA 5—104 × KA 6—101	153	35	4,4
KA 10—103	123	35	3,5
KA 10—103 × K 1—103	113	35	3,2
KA 10—103 × KA 6—101	139	33	4,2
K 24—103	167	34	4,9
K 24—103 × K 1—103	156	38	4,1
K 24—103 × KA 6—101	178	34	5,2

TABLE 10. ICS selections; mean growth and yield data up to and including 1962

	ICS 1	ICS 89	ICS 95
Stem diam. 40 cm off the ground, end 1962 (cm)	8,2	7,4	8,5
Bearing trees, end 1962 (% of total)	38	8	68
Total yield up to end 1962 :			
pods p. ha	1.940	170	3.850
dry cocoa p. ha (kg)	109	7	136
pod weight (g)	602	635	541
wet cocoa p. pod (g)	168	122	106
Pod analyses (Feb./March 1963) :			
pod weight (g)	629	688	486
wet cocoa p. pod (g)	158	136	106
No. of beans p. pod	37	36	37
mean wt. p. wet bean (g)	4,3	3,8	2,9

to have inherited their parents' good characters. They grew rapidly, came into bearing very early, produced a large number of pods, and also supplied a product of which the average weight per bean was very satisfactory. For the calculation of the yield of market produce the dry-cocoa/pulp-weight ratio is here taken as 1 : 3 (TABLE 11).

3.5.7. Cross KA 2—106 × Wa 12

21 plants were produced by a cross made in February 1959 of the Keravat selection KA 2—106 with Wageningen seedling Wa 12; in January 1960 they were planted out in a 4 × 4 m square design in the shade of *Leucaena glauca* BENTH. The soil here consists of a layer of only 10 to 30 cm of brown weather-worn limestone overlying porous limestone. The plants were placed in 60 × 60 × 60 cm planting holes

TABLE 11. Cross KA 5—104 × Amelonado, partly budded with ICS 95; mean growth and yield data up to and including 1962

	KA 5—104 × Amelonado	ICS 95
Stem diam. 40 cm off the ground, end 1962 (cm)	9,9	8,9
Bearing trees, end 1962 (% of total)	99	79
Total yield up to end 1962:		
pods p. ha	26.490	6.290
dry cocoa p. ha (kg)	1.180	231
pod weight (g)	472	528
wet cocoa p. pod (g)	134	110
Pod analyses (Feb./March 1963):		
pod weight (g)	499	548
wet cocoa p. pod (g)	139	115
No. of beans p. pod	40	37
mean wt. p. wet bean (g)	3,5	3,1

filled with topsoil. The only dressing given was that applied to the holes and was equivalent to 6½ kg N, 6½ kg P₂O₅ and 6½ kg K₂O p. ha. Notwithstanding the limited volume of soil available for the roots the trees showed excellent growth. By the end of 1962 the average stem diameter 40 cm off the ground was 9,2 cm, 90 % of the trees were in bearing and 375 pods had been harvested, which is equivalent to a yield of 1.440 kg of wet cocoa per ha. These pods had an average weight of 455 g and contained an average of 32 seeds having an average weight of 4,0 g.

3.5.8. Cross SCA 6 × ICS 1

During the past few years excellent results have been obtained in Trinidad with crosses between ICS clones and SCA clones imported from the Amazon valley. These seedling families attained exceptionally high yields and combine a satisfying aroma and a good bean-size (of the ICS clones) with a high degree of Witches' broom resistance (of the SCA clones). As a result a start has already been made in issuing these hybrids to the farmers (RUINARD, 1961c).

Adopting this method, COOLHAAS made an SCA 6 × ICS 1 cross in the greenhouses of the Wageningen Agricultural University. Owing to the damage caused by cold when the pods were flown to West Irian, only 12 seedlings were obtained. They were planted out at Manokwari in July 1960 in the same manner and under the same conditions as the seedlings referred to in par. 3.5.7. The population developed favourably. By the end of 1962 the average stem diameter at 40 cm off the ground was 8,2 cm and 10 out of the 12 trees were in bearing. The average weight of pods harvested up to that time was 504 g and they contained an average of 42 seeds having an average weight of 3,2 g. Up to the end of 1962 the total pulp production was 390 kg per ha.

3.5.9. Conclusions

As appears from the above details on the most important of the many clones and seedling populations available for breeding and selection work in West Irian, cocoa starts to produce at a very early age in the vicinity of Manokwari, giving an excellent yield even during the first few years. The same is true of the other cocoa centres in West Irian. If we also include Australian New Guinea, this may possibly be con-

sidered as unique. No doubt the favourable annual rainfall distribution (there is no marked period of drought) is a contributory factor.

The data also show that continuation of cocoa breeding will probably produce some interesting results. There is a great diversity of starting material, so that many different combinations can be tried without the need for fresh imported material (there is always a risk that such imported planting material will introduce undesirable pests and diseases). Although it is still too early to make a definite assertion, it would appear a reasonable suggestion that crosses between the local Trinitarios and the local Forastero (the Amelonado of West African origin) will eventually afford the best prospects.

4. Diseases and pests

We have stated above that there are many parts of West Irian which are exceptionally favourable for growing cocoa, and it can also be said that an optimistic view may be taken of the situation with regard to the pests and diseases to which cocoa growing is subject.

Hitherto no trace has been found of Witches' broom disease (*Marasmius perniciosus* STAHEL), monilia pod rot (*Monilia roreri* CUF. & PAR.), ceratostomella disease (*Ceratostomella fimbriata* E. & H., ELLIOT), cushion gall and swollen shoot disease, which elsewhere often cause immeasurable damage to crops. But the equally important *Phytophthora palmivora* BUTL. is found, a fungus that causes a stem and branch canker as well as pod rot. A number of M clones closely related to Criollo, together with their progeny, were so badly affected with canker that both diseased and still healthy trees had to be removed. Subsequently there was no further serious outbreak of this disease. Where it still occurred incidentally it was found that effective control was obtained by scraping off the canker patches and then smearing them with copper preparations. Pod rot occurs here and there, especially in dark plantations and in damp conditions, but no extremely severe attacks have ever been found. JOHNSTON (1961) observed both *Phytophthora* and other less well-known diseases, but they only occurred sporadically and were never of any importance.

Nor, as yet, have insect pests of cocoa assumed alarming proportions. According to SCHREURS and SIMON THOMAS (1961) 63 different kinds of insects have been found on cocoa plantations, but there are only a few which cause, or might cause an epidemic and moreover they do not occur in all cocoa centres. Since 1960 SCHREURS has been making a detailed investigation of these insect pests. He considers *Glenea lefebueri* GUEN. to be the most serious; this is a bark and wood borer which is only found in the stem and thicker branches of trees at least a few years old. Widespread damage was found on neglected plantations in particular. But this pest can be effectively controlled by regularly inspecting all trees and cutting out the larvae, or by treating with dieldrin the parts of the stem and branches infected with larvae. A less important although frequently encountered borer is *Panseptia teleturga* MEYR.; the larvae gnaw the bark of the stem and branches under a webbing of frass. They can be successfully controlled by smearing the infected areas with carbolineum. Two *Pseudodoniella* capsids, viz. *Pseudodoniella laensis* MILL. and an undetermined P. species are capable of causing much damage to the pods, but it was found that both pests could be readily suppressed by treating the plantation with lindane. The same applies to *Helopeltis antonii* SIGN., which is a major pest in Indonesia. This capsid was first observed on cocoa in West Irian in 1959 (RUINARD, 1959d). During succeeding years *Helopeltis* was particularly numerous in cocoa plantations at Ransiki,

but thanks to the timely use of chemicals it never assumed the proportions of an epidemic. The cocoa moth, *Acrocercops cramerella* SN., which is such a serious menace to cocoa cultivation in Indonesia, has not hitherto been found in West Irian. It will be readily appreciated that the aim was to perpetuate this favourable situation as regards pests and diseases. Consequently strict quarantine regulations were enforced when importing cocoa planting material from abroad (material imported from areas other than Australian New Guinea was always kept in quarantine for at least a year in the greenhouses of the Wageningen Agricultural University), and the necessary steps were taken to prevent pests and diseases limited to certain districts from spreading throughout the country.

5. Cultivation

5.1. Provision of ground cover and shade

5.1.1. *Ground-cover crops*

The great value of a well-closed ground cover in young cocoa plantations has also been proved in West Irian. The planting of such a cover is warranted merely by the saving on weeding costs, not to mention its soil-protecting and improving capacity. The crops which gave the best results at Manokwari were *Indigofera endecaphylla* JACQ. and the thornless *Mimosa invisa* MART. var. *inermis*. Unlike such better-known leguminous plants as *Centrosema pubescens* BENTH. and *Calopogonium mucunoides* DESV. they are not climbers, so that there is no risk of the young cultivated crop being stifled. On native plantations in particular, which are often poorly looked after, this may be a decisive factor. Both *Mimosa* and *Indigofera* provide a rapid cover. The latter was found to require more labour to plant (it has to be planted in the form of cuttings and it grows more slowly during the initial stage, so that more weeding is required) but eventually it provided a finer cover than the former. When after some years the cocoa plantation had a closed canopy all covers gradually died, but by this time there was no further weed nuisance. The soil was then covered instead with a generous deposition of cocoa litter.

5.1.2. *Temporary shade crops*

In cases where owing to the absence of shade trees an auxiliary crop was required as temporary shading, *Crotalaria anagyroides* H.B.K. was found to be the most satisfactory of the many shrubby leguminous plants. Only a few months after sowing, *Crotalaria* hedges (in a n.-s. direction, at 2 m intervals) provided enough shade to enable cocoa to be planted. The *Crotalaria* canopy was forced to spread out and any subsequent tendency to lodge was prevented by pruning the hedges once or twice at a very early stage.

5.1.3. *Permanent shade trees*

In Indonesia and elsewhere in Asia it is nearly always considered necessary to grow cocoa under a more or less dense shade of leguminous trees. It was therefore obvious that the same provisions would be taken in West Irian.

Of the various shade trees in the collection, *Leucaena glauca* BENTH. was found to give the best performance on the plantations of the Manokwari Agricultural Research Station. The rule was to sow hedges, preferably in a n.-s. direction, immediately after the land had been cleared and to gradually thin these hedges out during succeeding years. In some cases this method proved adequate, but the slow growth of this species

and the abundant seed production were considerable drawbacks. In such cases it was found that a considerable improvement could be effected by budding a seedling at predetermined intervals with *Leucaena* hybrids which had already been bred in Indonesia before the second world war (produced from crosses of *L. glauca*, *L. pulverulenta*, *L. glabrata* and probably *L. esculenta*). These hybrids combine vigorous growth, a complete or almost complete absence of seed and a good canopy shape with a rapid increase in girth, so that the rootstocks also increase in girth-size far more rapidly than non-budded *L. glauca*. Even where the latter showed remarkably poor development, the shade crop made a quick recovery after being budded with the hybrids.

Other shade trees were also tried out, e.g. the well-known *Albizia falcata* BACKER, but the latter was found to be entirely unsatisfactory. Although the trees grew exceptionally rapidly they were so brittle at a very early age and so heavy less than a year after being planted out that it was decided to cut them down in order to prevent damage to the cocoa.

Better results may be anticipated from *Albizia chinensis* MERR. and *Erythrina subumbrans* MERR., but at the end of 1962 plantations planted with these trees were still too young to enable a considered opinion to be given.

5.2. The problem of shade

There is no absolute proof that in general cocoa can be grown better with than without shade. In some countries it is even the rule not to plant any shade trees, or to fell them as soon as the canopies of the cocoa trees close. But such practices are usually based on tradition and are not warranted by research. In recent years, however, the opinion has been gaining ground that proper research is also essential with regard to the problem of shade. Both in Africa and Central America large and often complex field trials have been planted which it is hoped will contribute to the solution of this problem. It will be obvious that the work has not yet made enough progress to enable definite conclusions to be drawn, but there are indications that under certain conditions the production of cocoa plantations can be increased by providing a far lighter shade than had ever been considered possible, or by felling all shade trees and giving the cocoa a regular, generous dressing of fertiliser (CUNNINGHAM, 1959; RUINARD, 1961c).

One effect of shade trees is to create, within certain limits, a cool and humid micro climate in young cocoa plantations with not yet closed canopies and to prevent the moisture reserve from becoming exhausted. But as there is no marked period of drought in the cocoa centres of West Irian it seems likely that no great significance is to be attached to this effect of the shade trees in that country. When we also consider that serious doubt has been cast on the use of shade trees in far drier regions, it was an obvious conclusion that the Manokwari Agricultural Research Station would have to pay a great deal of attention to the problem of shade. Several field trials were actually being prepared, but since such trials need wide areas they could not be planted until the land had been cleared and this would have been executed during 1963.

But a small preliminary trial had already been laid down some years previously. Six seedlings of each of the legitimate Keravat seedling families included in trials 2 and 3 (cf. par. 3.5.3) were planted out in March/April 1960, likewise in a 4 × 4 m square design on an unused plot beside those trials. The soil conditions were also identical, the same ground cover was provided and the same planting hole manuring was applied. The

FIGURE 2

FIG. 2. A divergent plant-spacing trial under the shade of *Leucaena glauca* BENTH. (par. 5.4); cocoa 16 months after planting



The upper photo shows a part of the border row at the apex of one of the trapezoidal plots (spacing 2,07 m, next row's spacing 2,21 m), and the lower photo a part of the border row at the base (spacing 6,00 m, next row's spacing 5,61 m); notice the *Mimosa* ground cover (practically all dead under the most densely planted cocoa) and the abundant fruit produced by *Leucaena*.

only difference from trials 2 and 3 was that these plants were fully exposed to the sun right from the beginning and never given any shade. Despite this the cocoa showed excellent development. By the end of 1960 the average stem diameter 40 cm off the ground was 2,4 cm, and by the end of 1962 it had increased to 10,9 cm (the averages of the same seedling families in trials 2 and 3 were 3,1 and 10,5 cm respectively). Nor was the yield disappointing; by the end of 1962 76 % of the trees were in bearing (73 % in trials 2 and 3). Up to that time the yield per ha was 9.290 pods or 415 kg of dry cocoa (the averages of the corresponding treatments in trials 2 and 3 were 9.730 pods or 446 kg of dry cocoa).

5.3. The manuring of cocoa

Generally speaking cocoa grew and bore so well in West Irian that no manuring was called for (the dressing in the plant hole applied on the plantations of the Manokwari Agricultural Research Station was an exception, and moreover it was only rarely followed by the application of fertiliser in succeeding years). It should be realised that the use of fertilisers places a considerable additional burden on the smallholder and causes complications in his farm economy, so that such measures were definitely undesirable. This does not mean, of course, that manuring would not be of some use, but the time was not considered ripe to give priority to research on this subject and to reduce the results of such research to practice.

Some preliminary studies in this sphere have been undertaken by SCHROO (1959, 1960). He found a zinc deficiency in experimental cocoa plantations on two widely different types of soil; this deficiency phenomenon disappeared after the trees were periodically sprayed with zinc sulphate for long continuous periods. But since both soil types were found to be unsuitable for cocoa cultivation for other reasons this treatment was never applied on a large scale. From a second trial laid down on a type of soil which frequently occurs in the Manokwari area and on which cocoa grows well, SCHROO concluded from the results of leaf analyses that phosphorus fertilisers had a good effect but that there was practically no response to nitrogenous and potassic fertilisers. Growth and production figures confirming these tendencies were not available at the time.

5.4. Spacing

Following the usual practice in other countries under similar conditions, a 4×4 m square design was usually employed in the cocoa plantations of the Manokwari Agricultural Research Station and in some cases 5×5 m square; these planting densities respectively correspond to 625 and 400 trees per ha. As a rule the same number of trees per ha were also planted on the native holdings in West Irian. It is not known whether these spacings are to be considered as the economic optimum, *i.e.* whether they will in fact give the greatest nett return under the given conditions.

In one of the experimental plantations at Manokwari two plant-spacing trials were laid down in 1961 according to completely different principles. The first follows the conventional design, *viz.* a randomised plot trial with three treatments (plant spacings of 2×2 m, 3×3 m and 4×4 m square) in six replications; there was not enough land available to include a 5×5 m square treatment. The second is a divergent trial according to the modified Marchal system (BOCQUET, 1953) and consists of eight identical plots in the shape of an equilateral trapezoid. The plant spacing is approximately square and in each plot gradually increases via 13 intermediate stages from $2,21 \times 2,21$ m to $5,61 \times 5,61$ m (FIG. 2). As a result the num-

ber of trees decreases from 2,048 to 318 per ha. In each plot each of the 15 plant spacings is represented by five trees in a row. The plots are surrounded on all sides by a border row, the spacing in that row being adjusted to the spacings in the plot itself. Legitimate Trinitario seedlings were used as the planting material for both trials. At the end of 1962 it was obviously too early for any conclusions to be drawn.

5.5. Seedlings, cuttings and budded cocoa

It was stated in par. 3.1 that it has always been the policy in West Irian to let smallholders plant seedlings on their plantations, unlike the situation in Trinidad (and many other regions in which the same pattern has been followed) where until recently only cuttings of high-grade clones were issued with a view to expanding and rehabilitating cocoa cultivation. But even here the availability of good, legitimate seedlings has created a preference for the latter to cuttings (RUINARD, 1961c).

This obviously does not imply that vegetative propagation of cocoa is a thing of the past, since under certain conditions and for numerous purposes it still has no better substitute. In such cases, when large-scale propagation was required the Manokwari Agricultural Research Station always preferred scions to cuttings. This was not done in the last resort because scions have a seedling habit (provided orthotropic material is used for budding). A seedling shape can also be given to cuttings, but this is a time-consuming and laborious process. On the other hand the drawback of scions is that they usually have to be made in the field, which leads to all kinds of difficulties, especially in the plantations of smallholders. Trials were therefore in progress in which an attempt was made to bud cocoa when the stocks were still potted in the nursery. These trials were not completed, but there were indications that they would have been successful.

5.6. Effect of stocks on scions

The main difference between cuttings and scions is that whereas the first group is supported by its own roots the second is not (ignoring whether the root system of cuttings can be described as "normal"). This creates the possibility that the growth, production and other properties of the scions are also determined by the stocks.

The tendency in Indonesia was to regard the effect of stocks on scions as so slight that it could be neglected, although the use of very vigorous stock seedlings was in any case advised (VAN EMDEN, 1953). But recent research in Trinidad (MURRAY and COPE, 1959) showed that the stock may have a very substantial effect on the scion. Thus it was found that an inferior clone grows and produces better on a good stock than on an inferior stock or on its own roots, while the growth and yield of a good clone are impaired by an inferior stock. This investigation was carried out with four ICS clones all of which were used as scion and stock, so that a total of 16 combinations was available.

One possible disadvantage of this otherwise excellent study is that the stocks were cuttings and not seedlings. However much cuttings are to be preferred for this type of investigation, in practice there are many reasons why seedlings will be preferred. The problem was therefore tackled from another angle at Manokwari. This was made possible by POSNETTE's (1942) discovery that twins can be made from young cocoa seedlings. Following his directions, a number of KA 5—104 × Amelonado young seedlings were split in two; 72 of the resultant pairs of plants were planted out in the field and one plant of each pair was budded with ICS 95 a good six months later. Hence each pair of plants now consisted of a seedling and a scion of which the stock

was genetically identical with the seedling. Individual observations of all plants and the processing of such conclusions by means of correlation and regression calculations will show what inferences can be drawn as to the mutual effect of stock and scion. But at the end of 1962 the trees were still too young to enable such calculations to be made, although the growth and harvest figures obtained up to that date have been summed and averaged (par. 3.5.6, TABLE 11).

6. Curing and storage

6.1. Fermentation

When the native plantations came into production the government opened processing plants in the various cocoa centres. They were run by the Agricultural Extension Service which bought up the smallholders' harvest (in the form of pods or pulp), fermented and dried the cocoa and then exported the market produce. It was intended to transfer these processing plants at a later date to smallholder co-operatives to be set up for this purpose.

In 1958 and 1959 the first series of fermentation trials were begun in order to determine the best method of processing cocoa in West Irian (RUINARD, 1959b). The best results were obtained by daily turning the fermenting mass, the layer in the fermenting boxes being not much more or less than 40 cm thick and the pulp being covered down with banana leaves and sacking. It was found that the fermentation process took 6 or 7 days to complete, despite the fact that the trials were made with cocoa closely related to Java Trinitario for which ROELOFSEN and GIESBERGER (1947) specified a fermentation time of 2½ days. Subsequently the new fermentation method of ALLISON and ROHAN (1958) was adopted as it would also appear to afford good prospects for West Irian. But no attempt was made to introduce this method in practice since under the conditions then prevailing at Manokwari there would have been no saving of time or labour nor any improvement in the quality of the product (RUINARD, 1961e).

One consequence of the bulk buying of pulp by the processing units is that the contents of unripe pods can be mixed with the pulp of ripe pods without any check being possible. In co-operation with The Royal Institute for the Tropics, Amsterdam, a study was made of the influence of such blending on the quality of market cocoa. Beans from unripe pods were found to be lighter in weight and to have a higher shell content and a poorer shape. They were also more under-fermented and as a result of the pulp remnants left on the shells they were dirtier (HEESTERMAN; RUINARD, 1961d). For this reason the Agricultural Extension Service was advised to stop buying up pulp and instead only to accept pods.

6.2. Drying

Owing to the humid climate of West Irian it is hardly sufficient to dry the fermented cocoa in the sun. To ensure a reasonably good to good quality market product, artificial drying preceding the sun drying is essential. Consequently all processing units in West Irian were equipped with rotary or platform driers in which the heat was provided by oil burners. Simpler artificial driers of the type in use in Samoa, for example (ANON, 1958), had not been tried out at that time because the native smallholdings were too small to justify the introduction of such equipment. Hitherto the cocoa has been sundried on single-platform driers, but by the end of 1962 a start

was being made on the manufacture of the relatively much cheaper multiple-platform driers which are commonly used in other countries (MONTSERIN, 1957; RUINARD, 1961c).

6.3. Storage

Since cocoa is very susceptible to attack by moulds and stored-product insects in moist climates, it is necessary to protect it from the effect of damp during storage. According to research work carried out in Java, the market product can be substantially safeguarded against such calamities by maintaining a relative atmospheric humidity of from 60 % to 70 % in the storage sheds (ROELOFSEN, 1958; ROELOFSEN and GIESBERGER, 1947). There were similar experiences elsewhere. But in most production areas it is impossible to maintain such a low relative atmospheric humidity without hermetically sealing the storage structures and providing air-driers or air conditioners, and in general such costly precautions will not be so readily adopted.

A simpler and cheaper method would seem to consist in packing the cocoa in moisture-resistant packaging material, viz. polythene liners inside the ordinary cocoa bags, immediately after drying. Experiments with such liners at Manokwari, at first on a very small scale (RUINARD, 1959c), and afterwards on a larger scale, gave very satisfactory results. According to URQUHART (1961) such polythene liners have also proved to be a good expedient in the Cameroons.

ACKNOWLEDGEMENTS

The writer wishes to thank Mr. J. L. K. BLOCK, Mr. L. J. J. BROERS, Ir. G. HEKSTRA, Mr. E. B. VREUGDENBURG and Mr. J. H. N. WIERSMA, all of whom were previously engaged at the Manokwari Agricultural Research Station, as well as the Papuan mantris ELIEZER KIRIHIO, WILHELMUS ISIR and OSCAR TAIMEE, who performed most of the counts, weighings and analyses. He is also indebted to Prof. Dr. Ir. C. COOLHAAS for his comments on the manuscript, and to Dr. Ir. K. EBES who advised on the lay-out of part of the field trials.

REFERENCES

- | | | |
|---------------------------------------|------|--|
| ALLISON, H. W. S., and
T. A. ROHAN | 1958 | A new approach to the fermentation of West African Amelonado cocoa. <i>Trop. Agric. Trinidad</i> . 35, 279—288. |
| ANON | 1958 | The Samoan cocoa drier. Published by Cadbury Brothers, Ltd., Bournville. |
| BOCQUET, M. | 1953 | Note sur l'expérience de densité Marchal appliquée à l'hévéaculture. <i>Arch. Rubbercult. Indonesië</i> . Extra Nr. 1, Paper E II, 194—199. |
| BRIDGLAND, L. A. | 1960 | Cacao improvement programme, Keravat. <i>The Papua and New Guinea Agric. J.</i> 12, 149—167. |
| COOLHAAS, C. | | Personal communication. |
| COPE, F. W. | 1959 | Incompatibility in <i>Theobroma cacao</i> . A report on cacao research 1957—1958, Trinidad. 7—17. |
| CUNNINGHAM, R. K. | 1959 | A review of the use of shade and fertilizer in the culture of cocoa. <i>Techn. Bull. West African Cocoa Res. Inst.</i> No. 6. |
| EMDEN, J. H. VAN | 1953 | Vegetatieve vermeerdering. Handleiding voor de cacao-cultuur en cacaobereiding. Chapter 5. Published by Centrale Vereniging tot Beheer van Proefstations voor de Overjarige Cultures in Indonesië. |
| HEESTERMAN, J. E. | | Personal communication. |
| HEKSTRA, G. | | Non-published report. |

COCOA RESEARCH IN WEST IRIAN (WEST NEW GUINEA)

- JOHNSTON, A. 1961 A preliminary plant disease survey in Netherlands New Guinea. *Bull. Dept. Econ. Affairs of Netherl. New Guinea*. Agric. Series 1961, No. 4.
- MOLL, H. W. Non-published reports.
- MONTSERIN, B. G. 1957 Processing of cacao for the market. *Bull. Dept. Agric. of Trinidad and Tobago*, New Series, No. 3.
- MURRAY, D. B., and F. W. COPE 1959 A stock-scion experiment with cacao. III. A report on cacao research 1957—1958, Trinidad. 29—35.
- OSTENDORF, F. W. 1948 Fertility of cacao. *Chronica Naturae*. 104, 101—105.
- POSNETTE, A. F. 1942 Note on twinning cacao seedlings. *Trop. Agric. Trinidad*. 19, 146.
- 1945 Incompatibility in Amazon cacao. *Trop. Agric. Trinidad*. 22, 184—187.
- ROELOFSEN, P. A. 1958 Fermentation, drying and storage of cacao beans. *Advances in Food Research*. 8, 225—296.
- , and G. GIESBERGER 1947 Investigations on the curing of cacao. *Arch. Koffiecult. Nederl.-Indië*. 16, 1—159.
- RUINARD, J. 1959a First results of testing the cacao mother trees Manokwari 4, 6, 7 and 9. *Meded. Landbk. Afd. Agrar. Proefst. Manokwari 1959*. No. 4 (stencil).
- 1959b Results of the first fermentation experiments with Manokwari-cacao. *Meded. Landbk. Afd. Agrar. Proefst. Manokwari 1959*. No. 7 (stencil).
- 1959c Packing and storage of cocoa. *Meded. Landbk. Afd. Agrar. Proefst. Manokwari 1959*. No. 8 (stencil).
- 1959d *Helopeltis antonii* SIGN., a new pest of cacao in Netherlands New Guinea. *Meded. Landbk. Afd. Agrar. Proefst. Manokwari 1959*. No. 9 (stencil).
- 1960a Results of testing the cacao mother trees Manokwari 4, 6, 7 and 9. *Meded. Landbk. Afd. Agrar. Proefst. Manokwari 1960*. No. 1 (stencil).
- 1960b Some data on six Keravat cacao clones and the artificial pollinations performed on these trees. *Meded. Landbk. Afd. Agrar. Proefst. Manokwari 1960*. No. 2 (stencil).
- 1961a Variability of various pod characters as a factor in cacao selection. *Euphytica*. 10, 134—146.
- 1961b First yield data of a young, promising cacao population and preliminary selection in this family. *Bull. Agric. Res. Sta. Manokwari*. Agric. Series No. 2.
- 1961c Indrukken van een reis door de Pacific en Tropisch Amerika. *Circ. Agric. Res. Sta. Manokwari*. General Series No. 1 (stencil).
- 1961d Unripe beans in fermented and dried cocoa. *Circ. Agric. Res. Sta. Manokwari*. Agric. Series No. 1 (stencil).
- 1961e Some remarks on a new fermentation technique of cacao. *Circ. Agric. Res. Sta. Manokwari*. Agric. Series No. 2 (stencil).
- 1962 New yield data of the Wageningen cacao seedlings. *Circ. Agric. Res. Sta. Manokwari*. Agric. Series No. 6 (stencil).
- 1963 A contribution to the technique of hand-pollination in cacao. *Trop. Agric. Trinidad*. (in press).
- 1964 Seasonal influences upon the pod weight of cacao and their consequences for selection. *Euphytica*. (in press).
- SCHREURS, J. Non-published reports.

- SCHREURS, J., and R. T. SIMON THOMAS
SCHROO, H.
———
- SOELEN, W. J. VAN, and B. SCHLETTE
- SPOON, W.
- TAMMES, P. M. L., and W. P. VAN DER KNAAP
- URQUHART, D. H.
- 1961 Cacao pests in Netherlands New Guinea. *Bull. Agric. Res. Sta. Manokwari*. Agric. Series No. 3.
- 1959 Acute zinc deficiency observed in cacao on certain soil types in Netherlands New Guinea. *Neth. J. agric. Sci.* 7, 309—316.
- 1960 A presentation of leaf analytical data of cacao, obtained from a fertilizer trial in Netherlands New Guinea. *Neth. J. agric. Sci.* 8, 93—97.
- 1958 Verslag van een bodemkundige opname van Amban en Andai nabij Manokwari. Published by Agricultural Research Station, Manokwari (stencil).
- 1962 Rapport inzake cacao-onderzoek ten behoeve van Nederlands Nieuw-Guinea. Published by Stichting voor Agrarisch Onderzoek ten behoeve van Nederlands Nieuw-Guinea. (stencil).
- 1953 Algemene botanische gegevens. Handleiding voor de cacao-cultuur en cacaobereiding. Chapter 1. Published by Centrale Vereniging tot Beheer van Proefstations voor de Overjarige Cultures in Indonesië.
- 1961 Cocoa. 2nd ed. Published by Longmans, Green and Co., Ltd., London.