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The Soils and Agriculture of Western Samoa.

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THE SOILS AND AGRICULTURE OF WESTERN SAMOA.

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Summary.

Samoa, in common with other communities relying solely or principally on agricultural products as a source of national income, has had its revenue severely depleted by the low level of prices on the world's markets during the past few years. From a record value of £422,175 in 1928, exports steadily decreased in value to a low level of £128,117 in 1934, the fall being augmented by a marked decrease in production of native copra due to the low prices being realized. Apart from seasonal influences, the production of cocoa and bananas has remained relatively stationary during the period under review. When, however, individual plantations are examined over a period, it is found that in the case of both coconuts and cocoa, production per unit of area tends to show a small but quite perceptible downward movement, which if not checked may in time make production unprofitable.

In order to study soil influences as a possible cause of this decline the present survey was undertaken. The soils of the area studied were divided into a number of series according to the age of the lava flow from which they were derived and the extent to which they had been leached by rain, and these series are described.

In the case of coconuts this decline in productivity is not due to the operation of any single factor, but to the interaction of three major factors: (i) Increasing age and height of the palms in many of the plantations; (ii) the high rate of palm mortality on some areas with consequent reduction in the number of producing units per acre; and (iii) the gradual depletion of reserves of "plant food" in the soil, more particularly on the older soil types such as the "Malatula" and the "Vaitele" series. Various measures have been discussed with the object of suggesting methods of maintaining production, and a replicated plot trial was laid down to test the efficacy of various fertilizers for this purpose. The world trade position in copra is briefly reviewed and is not held to be sufficiently favourable to warrant further extension of plantations by Europeans.

The area under cocoa has been increasing in recent years, but production on many blocks is at a low level. Here again no single factor is responsible in all cases. Severe root competition with windbreaks of *Ficus elastica* or overshading by interplanted rubber (*Hevea braziliensis*) have been contributory causes in some instances, but the gradual depletion of the reserves of "plant food" in a soil initially rather lacking in certain elements appears to have been a major cause. Suggestions are made in regard to manuring, pending results from a manurial trial laid down.

Samoan cocoa is highly sought after on the world markets as a blending cocoa, and it appears that some economic justification exists for promoting further plantings. If extension of plantings should be contemplated, it is urged that careful selection of types for planting be undertaken in order that the present high reputation of Samoan cocoa on the market may be maintained.

Finally, suggestions are made in regard to possible diversification of Samoan production so that the territory might supply in greater or smaller measure a proportion of New Zealand's imports of tropical products, at the same time rendering the revenue of the Islands less subject to violent fluctuations in sympathy with prices on the world markets.

INTRODUCTION.

THE Samoan Group lies between latitudes 13° and 15° S. and longitudes 169° and 173° W., occupying a position among the South Sea Islands near the centre of the Pacific Ocean. By regular steamship routes the port of Apia is 1,583 miles from Auckland (or 1,775 miles via Fiji); 2,355 miles from Sydney; 2,275 miles from Hawaii; and 4,150 miles from San Francisco.

The group consists of four main islands—Savaii, Upolu, Tutuila, and Ta'u—together with a number of smaller islands. From Savaii to Tutuila the islands have a linear disposition in a direction from west-north-west to east-south-east. Savaii has a length of 47 miles, a greatest breadth of 27 miles, and an area of 700 square miles. Upolu is the same length as Savaii, but is only 16 miles in breadth and 400 square miles in area. These two islands, together with the small Islands of Apolima and Manono, constitute

Western Samoa now administered by New Zealand under mandate from the League of Nations. Eastern or American Samoa consists of the much smaller Island of Tutuila, 44 miles to the east-south-east of Upolu, and the islands of the Manua Group, lying 60 miles further eastward. The total area of American Samoa is 73 square miles, or approximately one-fifteenth of the area of Western Samoa.

The population of the Mandated Territory as shown by the census of 1936 is 55,946.

CLIMATE.

The climate is characterized by a "wet season" extending from November to April, and a "dry season" from May to October. Even during the "dry season," however, precipitation is usually sufficient to avoid any serious lack of moisture by crops, and cocoa is grown without shade trees. The average annual rainfall at Mulinu'u is 110·87 in. (202 days with rain), but precipitation increases at higher elevations inland, being 116 in. at Tuanaimato; 128 in. at Aleisa; 140 in. at Tanumapua; 180 in. at Solaua; and 200 in. in Tiavi Saddle.

The average humidity is 83·3 per cent., the mean temperature 78·5° F., and the mean wind velocity 6·9 miles per hour. Notwithstanding the high proportion of days with rain, Apia enjoys 2,258 hours of bright sunshine per annum.*

THE SOILS OF SAMOA.

The soils on the Crown Estates and most of the European plantations on the northern side of Upolu were examined in some detail. A rapid survey was made on Savaii, making a traverse from Tuasivi to the Crown Estate behind the Mormon Mission Station, and a day was spent crossing Upolu from Vailima through Tiavi Saddle to several miles southward towards the coast.

A broad classification of the soils, all of which may be termed laterites, was obtained and has shown the problems on which research is needed. The soils are most uncommon in that they contain from 7·8 per cent. to 12·6 per cent. of titanium oxide, and as yet little work has been done on such soils. Related types occur to a small extent in Hawaii, where they are regarded as infertile. The apparently varying fertility within a soil type, the form of phosphate to be applied (if this nutrient is necessary), and the relation of minor elements to growth and yield of trees are some of the other problems which need investigation.

TOPOGRAPHY.

The Island of Upolu is roughly elliptical in outline, with a range of volcanic peaks extending as a ridge along the greater axis. The range varies from 2,500 ft. to 3,600 ft. in elevation. For several hundred feet below the peaks the land falls away fairly steeply, but farther down flattens out to gentle slopes, which continue to the coast (Fig. 2). On the northern side of the island, west of Vailele, the slopes are little dissected by streams, and it is on this area that the majority of the Reparation Estates plantations have been established. East of Vailele the country is more dissected, and

* Full climatic records may be obtained from the annual reports of the Apia Observatory or from "Researches in Polynesia and Melanesia," Parts I–IV, by Buxton and Hopkins (London School of Hygiene and Tropical Medicine, 1927).

*

ridges with steep slopes extend to or near the coast, where they end in cliffs or steep slopes (Fig. 1 shows the spur behind Apia). In this sector there are occasional low-lying coastal flats, and inland an old crater floor, Solaua, at an elevation of 300 ft. to 500 ft. above sea-level and surrounded by cliffs.

The Crown Estates that are being actively developed and the European plantations lie on the easy slopes west from Vailele to Falepuna, the slopes utilized rising from sea-level to about 1,000 ft., though most of the plantations do not extend above 700 ft. At Vailele and Vailima, and in the Central Group, streams are well entrenched, but their fairly steep valley-sides occupy a relatively small area. The moderately steep slopes to the streams on Vailele are planted in coconuts. In the Goebel Block on Tafaigata moderately steep slopes of relatively small area are planted in cocoa. West from Central Group to Falepuna there are very few streams, and the easy country continues practically uninterrupted.

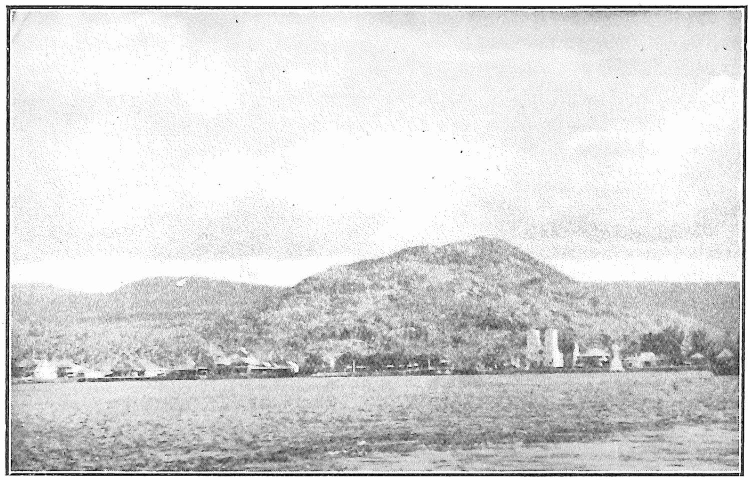

FIG. 1.—Steep spur behind Apia, and Vailima gentle slopes on left.

On that portion of Savaii visited (Tuasivi to the Crown Estate block beyond the Mormon Mission), apart from small volcanic domes, the land rises gradually from sea-level to 675 ft. ; there is practically no dissection by streams.

FACTORS IN SOIL DEVELOPMENT.*

Basalt lava poured out of the craters extending the length of Upolu, most of the flows reaching the coast. Of the flows outcropping at the surface, the oldest, judged by the amount of dissection by streams, are those that form the steep spurs that end abruptly at the sea-coast. The numerous surface flows of the easy slopes on the north side of the island are not all of the same age ; some have a remarkably fresh appearance, the blocks and fragments of lava being jagged and but little weathered, whereas on others the blocks are rounded, and weathered material extends to a depth of several

* For an account of the geology of Western Samoa the reader is referred to an article by Thomson(1). Thomson summarizes the observations of earlier geologists, chiefly German, and includes a few observations of his own.

feet. The numerous boulders on the surface and in the subsoil point to the flows having a blocky surface. The younger lavas are of a blocky nature, resembling closely those on Rangitoto Island in New Zealand. The basalt is coarsely scoriaceous, and on that account weathers readily. Here and there are dense-grained basalts. Basalt is the parent material of the soil in all parts except on the coast, where there is a discontinuous narrow strip of blown or water-sorted sands and clay containing some coral sand.

On Savaii the geological conditions, as far as the soil is concerned, are the same as on Upolu. The lava at Tuasivi is of the same age or a little older than the oldest lavas on the easy slopes of Upolu.

The basalt of the older flows on the easy slopes grades up into rotten rock, on which lies the surface soil and subsoil, generally from 5 ft. to 6 ft. thick.

FIG. 2.—Looking towards coast from Vaipoto young coconut area.

Rain forest is the natural vegetation, and when this is cleared a thick mat of weeds soon develops unless weeding is practised. On the forest-floor the leaf litter is less than an inch thick; in temperate climates it is much thicker.

Summarizing, it may be said the soils are derived from basalts of different ages that have been leached in a high rainfall climate with rain forest as the vegetation.

DESCRIPTIONS OF SOIL SERIES.

The classification of the soils on which the plantations are situated—*i.e.*, on the easy slopes—presents some difficulty. The relative age of the lava-flow in areas where rainfall is similar is the first division that was made in the field. On this basis three divisions may be made: (1) Soils at Saleimoa derived from the youngest basalt flow; (2) soils at Falepuna derived from somewhat older flows; and (3) soils covering a large area weathered from much older flows. The third division contains the great bulk of the soils on which coconuts and cocoa are planted, and is subdivided on field characteristics.

Soil Series.

The series into which the soils are divided are—

(1) Saleimoa stony loam.
(2) Falepuna stony silt loam.
(3) Vaitele stony clay loam.
(4) Magia stony clay loam.
(5) Tuasivi clay loam.
(6) Malatula stony clay loam.
(7) Tiavi clay loam.
(8) Fusi clay loam and Solosolo gravelly sand.

(1) *Saleimoa Stony Loam.*—The soils of this series, located at Saleimoa and extending from a quarter of a mile or so back from the beach through the plantation of Messrs. Klinkmüller and Meyer to Saleimoa bush-land near Aleisa rubber-factory, are derived from the youngest lava-flow on Upolu, and there are many stones in the soil. Probably the flow came from Sigaele Volcano. Messrs. Klinkmüller and Meyer's cocoa trees on the stony loams are planted up to a height of 670 ft. above sea-level. Possibly the stony loams at Saleimoa bush-land are a little older than those on the Saleimoa plantation.

A profile is—

6 in.–9 in. dark yellow-black-brown stony loam with good crumb structure;
On dark red-brown-yellow, very free stony sandy loam.

The stony loams contain more organic matter and are much darker in colour than the soils of the other series, and should, strictly speaking, be classed as peaty loams. Their nitrogen content averages 1·98 per cent., which is about four times the amount in the other soils. The soils are neutral in reaction and, according to chemical analyses, are moderately well supplied with phosphate and potash, even in the subsoil.

The Saleimoa stony loam is the most fertile soil amongst those of volcanic origin, and this is borne out by the fact that cocoa-trees two and a half to four years old are making excellent growth. Only a few years ago Saleimoa plantation was covered with forest, and the other block is still so covered. No doubt part of the fertility is due to this fact. The soil is light in texture—lighter than any of the other types—but if plenty of shade and leaf mould is provided it should not dry out unduly, since there is a very high humus content.

It is desirable that the boundary of this fertile soil type should be mapped.

(2) *Falepuna Stony Silt Loam.*—The Falepuna soils occur at Falepuna on the western end of Upolu, where the lava-flows are somewhat older than at Saleimoa. Many stones lie on the ground and in the subsoil, but the ground is not as stony as at Saleimoa.

A profile is—

6 in.–9 in. dark yellow-black-brown stony silt loam with crumb structure;
On brown-yellow free stony silt loam.

The soils contain more organic matter than the Vaitele stony silt loams; nitrogen is apparently in good supply. Analyses show that their phosphate content is somewhat low. Judging by the profiles, one would say that the fertility is not as good as that of Saleimoa stony loam but better than Vaitele stony silt loam. The soils at Falepuna are considered more fertile than those at Mulifanua.

(3) *Vaitele Stony Clay Loam.*—The Vaitele stony clay loam occurs at Vaitele, Central Group, Nuu, Solaua, Vailele (excluding Malatula), and Casala. A typical profile is—

6 in. dark brown-yellow stony clay loam with good crumb structure
4 ft. + moderately compact brown-yellow stony clay loam.

Rotten basalt containing cores of fresh rock lies in general from 5 ft. to 7 ft. from the surface.

In several localities—*e.g.*, Vaitele and Casala—there is a dark yellow-brown compact layer about 1 ft. thick at 2 ft. below the surface, indicating a more leached soil; in others, free brown-yellow clay loam extends for 3 ft. below the topsoil. In places—*e.g.*, Telematua—the soil to a depth of 12 in. is dark red-brown-yellow. The shade of red is thought to indicate a younger soil than those in which it is absent, and in a detailed survey would be mapped as a separate type.

All these soils, except Solaua, are only weakly acid—pH 6·2 to 7·0. Solaua, an acid soil, is in a high rainfall area and, strictly speaking, should be separated from the Vaitele type. In general, the soils are poorly supplied with readily available phosphate as shown by the citric solubility test. Available potash as measured by citric-acid extraction is, in general, present in greater quantities than the phosphate; in several of the samples it is low. The nitrogen content is high and the carbon-nitrogen ratio lies between 12·0 and 14·0—figures comparable with those for the fertile Saleimoa stony loam.

(4) *Magia Stony Clay Loam.*—Magia stony clay loam has been recognized at Magia and on a portion of Vaipapa, east of Mulifanua block. The profile is—

6 in. dark brown-drab stony clay loam with crumb structure;
12 in. free dark brown-drab clay loam;
18 in. + fairly compact dark brown-drab clay loam.

This type differs from all the others in having a dark brown-drab colour. The plant food status and pH are similar to those of the Vaitele stony clay loam.

(5) *Tuasivi Clay Loam.*—The Tuasivi clay loam is located on the Crown Estate block behind the Mormon Mission, Savaii. A profile is—

3 in. dark brown-yellow clay loam with weak crumb structure;
On moist sticky brown-yellow clay loam.

In places there is a darker horizon at 18 in.

This soil—still with a forest cover—lies in a high rainfall belt and, like Tiavi clay, is fairly acid—pH 5·4. Readily available phosphate is decidedly low, but the nitrogen is high (0·83 per cent.).

(6) *Malatula Stony Clay Loam.*—Malatula stony clay loam is located at Malatula and at No. 6, Fagalie, on Vailele plantation, a typical profile being—

6 in. dark brown-yellow clay loam with crumb structure;
10 in. loose dark brown-yellow clay loam;
32 in. compact dark brown-yellow clay loam;
On 1 ft. mottled dark black-yellow clay loam.

The compact layer is fairly general and is closer to the surface than in Vaitele soils. The pH of the topsoil is 5·6 and that of the subsoil between 6·5 and 6·9. Available phosphate is decidedly low and potash is somewhat low. The quantity of nitrogen is about equal to that in Vaitele stony clay loam.

(7) *Tiavi Clay Loam.*—Tiavi clay loam is found to the south of Apia on a saddle (2,250 ft.) of the main range extending the length of Upolu. The profile is—

3 in. black-brown-yellow sticky clay loam ;
19 in. dark brown-orange sticky clay loam ;
6 in. compact dark yellow clay loam ;
On reddish-brown compact clay loam.

The subsoil is lighter in colour than any of the other soils already described, this being no doubt due to the high rainfall, 200 in. The topsoil is not darkened by humus and is difficult to distinguish from the subsoil. The pH of the topsoil is 4·9 and that of the 6 in. dark brown layer 5·8. Available phosphate is particularly low, potash is in short supply, and nitrogen is about equal to that in Vaitele soil.

(8) *Fusi Clay Loam and Solosolo Gravelly Sand.*—Samples of soils were obtained from raised beaches 4 chains or 5 chains wide lying about 6 ft. above sea-level at Fusi and Solosolo east of Vailele. On these areas closely spaced coconut-trees have a healthy appearance and are bearing well. Samples were taken for comparison with the widespread soil types derived directly from the basalt.

At Fusi the profile is—

3 ft. + dark brown sticky clay loam. Coral sand occurs mainly at 5–8 in. below the surface.

At Solosolo, near the sea, the soil is a stony sand and at the foot of the steep slopes is—

6 in. black to dark brown gravelly sand ;
On dark grey moist gravelly sand.

The soils are neutral in reaction and are lower in nitrogen than any of the other soils described. In both potash is in fair supply ; phosphate is high in the Solosolo soil and very low in the Fusi soil.

CLASSIFICATION IN RELATION TO CHEMICAL ANALYSIS.

The volcanic soil types described above are arranged in order according to the amount of leaching they have undergone, No. 1 being the least leached. This order is based on field evidence, and if moisture status is neglected it also gives the fertility rating. Saleimoa soil is obviously derived from a very young flow of basalt, its subsoil containing only 5·9 per cent. of clay. The other soils are difficult to classify, as the textures are similar and the profiles do not show other striking differences. Magia soils are separated because of their dark brown-drab colour and the Malatula soils on account of the presence of a darker-coloured compact layer fairly close to the surface. Tuasivi and Tiavi clay loams, in very high rainfall areas, are sticky and are evidently well weathered, as stones are scarce in the subsoil.

Chemical evidence supports these conclusions and has been helpful in placing in the classification the soils from some of the smaller plantations. Tables I and II below contain a selection of the analyses which show the difference in the types.

TABLE I.—FUSION ANALYSES.

	(1)	(2)	(3)	(4)	(5)	(6)
SiO_2	38·41	23·64	15·65	6·73	3·73	2·50
Al_2O_3	15·15	23·28	33·73	35·02	35·76	34·98
Fe_2O_3 ..	6·02	24·66	37·80	42·04	43·67	48·83
FeO	11·26	..	..	..	..	..
TiO_2	5·63	7·34	9·12	10·65	13·36	11·53
P_2O_5	0·82	0·52	0·98	1·09	1·13	0·70
Cr_2O_3 ..	..	0·14	0·21	0·37	0·18	0·49
CaO	9·77	9·22	0·58	0·76	0·18	Trace
MgO	10·98	10·40	1·03	2·59	1·24	0·62
Na_2O	0·48	0·25	0·11	0·09	0·07	0·06
K_2O	1·08	0·14	0·06	0·13	0·09	0·06
MnO	0·25	0·45	0·79	0·74	0·65	0·14
Total ..	99·85	100·04	100·06	100·21	100·06	99·91

(1) Basalt rock from Vailele, Western Samoa.
(2) 0–3 in. Saleimoa.
(3) 0–3 in. Mauga, Vaitele.
(4) 0–3 in. Crown Estate, Tuasivi, Savaii.
(5) 0–3 in. Malatula.
(6) 0–3 in. Tiavi Saddle.

TABLE II.—TOTAL SILICA IN TOPSOIL.

Locality.	Total Silica (SiO_2). Per Cent.	Locality.	Total Silica (SiO_2). Per Cent.
Saleimoa	23·64	Casala	10·2
Telematua..	19·2	Vailele	10·0
Nuu	17·3	Magia	7·74
Solaua	17·3	Vaipapa	7·5
Vaitele	15·65	Tuasivi	6·73
Mulifanua	15·6	Malatula	3·73
Fagalie	13·95	Tiavi	2·50

The fusion analyses show that during the process of leaching, silica, alkalies, and alkaline earths are the constituents that are being lost ; in consequence the percentages of iron oxide, alumina, titania, &c., increase. Obviously, then, the percentage of the major constituent that is lost (silica) or of those that are saved (iron oxide and alumina) gives an indication of the extent to which leaching has proceeded. From these data it is seen that the field classification is correct. The determination of silica alone (Table II) was selected as a means of further testing the classification and of placing soils in regard to which there was some doubt. These figures lend support to the statement already made that some of the Vaitele soils are better than, and some not as good as, the typical Vaitele soil. When further work is done on these soils silica analyses should be a valuable aid in mapping.

SOIL NUTRIENTS.

The chemical analyses indicate that all types of soil are well supplied with nitrogen. Available plant foods as measured by citric-acid extracts do not seem a reliable guide as to the elements that are deficient. Saleimoa sandy loam—judged by crops the most fertile soil—contains a moderate amount of available potash and phosphate, but in the other soils the figures show a great deal of variation within the types. In some Vaitele soils where crops are showing poor growth the available potash and phosphate percentages are above those of Saleimoa soils, and the very low amounts in the Malatula soils are equal to those in some of the Vaitele type. It seems that a knowledge of soil processes together with the evidence from leaf analyses (p. 618) will have to be utilized in assessing the soil requirements. Saleimoa stony loam, an immature soil, would be expected to grow good crops without manuring for some time, whereas the other soils are well leached and should be deficient in available potash and phosphate. The natural supply of these elements will determine the economic life of the commercial crops—the longest period being obtained in the Vaitele soils, and the least on the Malatula type. Areas of very high rainfall—Solaua and Tuasivi—have in addition the physical disadvantage that the soils are sticky. Tiavi soil type, with 200 in. of rain and located at a high altitude, need not at present be considered from the point of view of economic crops. The evidence suggests a need for potash and phosphate—the need being greater the more leached is the soil.

The form in which phosphate is applied should be considered, for the fixation of this compound is high. The permanently fixed phosphate by the method of Beater(9) amounts to between 85 per cent. and 98 per cent. This is not unexpected, for similar soils—*e.g.*, those of Hawaii—with low silica-sesquioxide ratios are well known on account of this property. Soluble phosphates applied to the soil will be fixed by iron and aluminium compounds and no response will be obtained from the dressing. If dressings of phosphate are necessary, the best form is ground rock phosphate, basic slag, or some form of reverted phosphate.

PHYSICAL CONDITION OF THE SOILS.

All the soils, except those in the very high rainfall areas, have a good crumb structure in the topsoil, and a loose subsoil to at least 16 in. This condition ensures free root development, ample aeration, and good drainage, and is not uncommon in volcanic soils in New Zealand—*e.g.*, the ironstone soils of North Auckland and the Te Awamutu soils. Using the term "fertility" in a wide sense, the factor most likely to limit the fertility of Samoan soils is deficiency of available potash and/or phosphate.

In general, methods of management are favourable for the preservation of the crumb structure of the soil, but on one European plantation visited the crumbs are very small, and this breakdown is attributed to lack of shade on a bare soil.

SOIL EROSION.

Despite the high rainfall, soil erosion is practically absent, as all conditions favour very little run-off. Steep slopes are covered with forest; easy and moderately steep slopes, when cleared of forest and not cultivated quickly, grow a thick covering of weeds, and where commercial trees are grown the open porous nature of the topsoil and subsoil and the thick mat of dead leaves or grass allow of good downward percolation. The fact that the topsoil has a good crumb structure points to soil erosion having been unimportant. There are, however, certain conditions under which erosion may operate—*i.e.*, on moderately steep slopes in young cocoa plantations, or in banana plantations where there are no dead leaves on the ground. On Block 5, Tanumapua, it was thought that there had been soil erosion. Even very gentle slopes bare of vegetation, especially those with a compact subsoil, need watching.

THE MAJOR CROPS GROWN.

GENERAL.

The main products constituting the export trade of Samoa are copra, cocoa, and bananas. The following returns show the principal exports of the territory during recent years :—

TABLE III.—PRINCIPAL EXPORTS FROM THE MANDATED TERRITORY OF WESTERN SAMOA OVER THE PERIOD 1927 TO 1935.

Year.	Copra.		Cocoa.		Bananas.		Value of Total Exports.
	Tons.	Value.	Tons.	Value.	Tons.	Value.	
		£		£		£	£
1927 ..	11,665	242,672	792	48,216	..	..	335,978
1928 ..	15,989	319,259	959	69,507	815	11,219	422,175
1929 ..	12,941	205,330	677	46,286	1,916	24,640	293,938
1930 ..	12,285	166,221	1,007	61,294	3,424	44,259	284,515
1931 ..	11,062	109,220	620	35,284	3,044	39,022	194,447
1932 ..	10,879	108,698	825	49,712	2,383	20,016	183,028
1933 ..	11,526	101,347	899	41,813	2,928	26,999	173,837
1934 ..	8,948	60,654	1,027	29,498	3,437	35,796	128,117
1935 ..	12,501	108,695	576	19,639	3,893	38,146	189,298

Copra and cocoa are products sold on the world market, and since these are responsible for over two-thirds of Samoan export receipts, revenue is particularly susceptible to changes in world demand and prices. Bananas are sold exclusively on the New Zealand market, which is protected by a system of quotas from excessive imports, and hence enjoys greater stability than the copra and cocoa markets. Even in this case, however, market realizations are likely to be low in a period of low purchasing-power of the New Zealand consumer.

COCONUTS.

Of the total copra production approximately 15 per cent. is from European plantations. The plantations owned by New Zealand Reparation Estates produce the majority of the copra so classed, their area being :—

Mulifanua	4,679 acres.
Vaitele	1,515 acres.
Vailele	1,504 acres.
	7,698 acres.

If all the Native plantations were of similar bearing capacity to those operated by the Reparation Estates, this would indicate that the total area in coconuts, the produce of which is harvested for copra-production, is in the vicinity of 46,000 acres. The estimate of area given by the Empire Marketing Board is 52,949 acres, but the area planted is probably in excess of this when allowance is made for the quantity used locally for food or from various causes not collected.

Production Trends.

Most of the plantations of New Zealand Reparation Estates were planted prior to 1890, and the plantations are from forty-five to seventy-five years of age, the only extensive planting in recent times being the Vaipapa Block at Mulifanua, which was planted about 1928. Many of the trees are therefore approaching the limit of their useful bearing life.

The general downward trend of production is shown by the following table of production figures for the past twenty-one years (Table IV), but it should be pointed out that other factors besides the gradual decline of the palms have been operating. From time to time since the plantations were taken over, areas of varying size have been leased to Europeans or returned to Native ownership. No accurate figures could be secured in order to estimate the extent to which an actual contraction of area had occurred, but this would be greatest in the case of Vailele and Vaitele.

TABLE IV.—COPRA-PRODUCTION ON THE NEW ZEALAND REPARATION ESTATES (IN TONS) SHOWN AS AVERAGES FOR FIVE-YEARLY PERIODS, 1914–1933.

(Note the marked downward trend of production on Vaitele and Vailele plantations.)

Period.	Mulifanua.	Vaitele.	Vailele.	Total.
1914–18	1,103	641	575	2,319
1919–23	1,314	613	539	2,466
1924–28	1,409	500	511	2,420
1929–33	1,296	474	397	2,167
1934–35	1,241	453	393	2,087

General Condition of the Plantations.

The plantations operated by Reparation Estates were planted on a variety of systems, some being 10 metres by 10 metres on the square (approximately 45 trees per acre), others being 10 metres by 10 metres on the triangle, giving approximately 54 trees per acre, while some of the oldest areas are only roughly lined and spaced. The newest planting at Vaipapa is spaced 35 ft. on the square, but such wide spacing is probably not conducive to maximum production per acre. In many of the Native plantations the trees are not regularly lined, while the spacing is closer and would probably run 80 to 100 trees per acre.

The influence of planting distance on tree yield is shown by the following table from Cooke(2) :—

TABLE V.—INFLUENCE OF PLANTING DISTANCE ON YIELD OF COCONUTS IN THE PHILIPPINE ISLANDS.

Data from Cooke(2).

District.	Planting Distance (Feet).	Approximate Yield per Mature Palm (Nuts).
Romblon	12 to 13, irregular	10.
Laguna	13, 16, 20, and 23	40.
Tayabas	15, 23, 26	55 to 60.
Mindanao	30 to 32	70 or more.

The optimum distance of spacing is also influenced by the fertility of the soil. It would appear, however, that under Samoan conditions the present spacing of 30 ft. by 30 ft. probably approximates to an optimum for the conditions obtaining.

The plantations are managed under a grass sward which is kept under control by the use of cattle which provide most of the fresh meat available in the Islands. The sward consists of Vailima grass (*Paspalum conjugatum*) and " sensitive plant " (*Mimosa pudica*), together with a number of other species of minor importance. Machine cultivation, except for limited areas on Vailele Plantation, is not possible owing to the stony nature of the soil, and the growing of leguminous cover crops is therefore out of the question, unless hand-planting—as for Japanese clover—is resorted to. The Manager of Reparation Estates raised the question of whether the continual trampling of cattle on the soil might not have a deleterious effect in causing undue consolidation of the ground, so contributing to the decline of the trees. This point has been discussed with Mr. H. C. Sampson, of the Royal Botanic Gardens at Kew, and he has suggested that hand hoeing might be valuable in improving soil aeration and stimulating the formation of new feeding roots. It is therefore suggested that shallow surface cultivation might be tried out on a small area.

FIG. 3.—Coconut-roots exposed in pit near Manager's house, Vailele.

Rooting of Coconut-palms.

Pits were dug on the Vaitele and Malatula soils and in two the root profile was plotted. A pit dug 10 ft. from the trunk of a coconut-tree near the Manager's house, Vailele (Fig. 3), shows that most of the roots are located in the top 2 ft. In a hole nearby, dug 5 ft. from the tree, the roots were fairly abundant to 34 in., and only six roots—less than $\frac{1}{8}$ in. in diameter—extend below that depth. In another pit 5 ft. from a coconut-tree on Malatula stony silt loam at Malatula the roots are abundant to a depth of 2 ft. and a few extend to 4 ft.

On Vaitele, at the foot of Mauga, one pit shows most of the coconut-roots at the surface, but there is a good distribution of roots to 4 ft. On Block 6, Vaitele, planted in coconuts and cocoa, the coconut-roots are abundant to 3 ft. and some are found below that depth. In another pit they are abundant to a depth of 3 ft.

Rhinoceros Beetle (Oryctes rhinoceros).

Simmonds in his report (unpublished) states: " At first, when landing in Samoa, one is not greatly struck by evidence of attacks by the beetle, as on the large estates surrounding Apia all breeding-places are destroyed, and the insect not normally flying far it is only on the outskirts that its ravages show up."

The most seriously affected area observed was Block No. 6, Fagalie, on Vailele Plantation. This block has an area of bush on either side, and has been so severely attacked that the area is being replanted. At the same time a " beetle break " of teak-trees is being planted round the area in the hope that these may possibly prevent the spread of beetles from the adjoining bush. Possibly evergreen trees might be more efficient for this purpose. The damage on Native areas was surprisingly small, probably

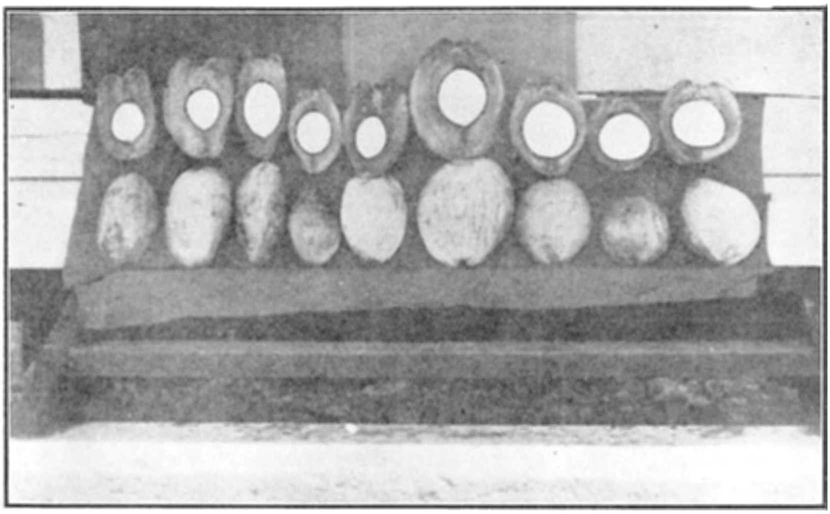

FIG. 4.—Showing the various types of coconuts grown on Vailele Plantation, Samoa. Details of nuts shown are given in Table VI.

owing, as Simmonds suggests, to the destruction of beetle larvæ by pigs. Beetle damage, on the whole, was not so extensive as we had anticipated from reports, but might at any time become a serious menace if vigilance were relaxed.

Methods of Harvesting, &c.

Nuts are permitted to ripen on the trees and fall when mature. On Reparation Estates the fallen nuts are collected into bullock wagons and taken to the copra-drying sheds. Where the ground is too stony to allow passage up the plantation rows, the nuts are collected into donkey panniers, and transferred to bullock carts for the final haul.

At the drying-shed the husks are removed, the nut itself is halved transversely, and the halved shells with their contained " meat " are then placed in the drier. In drying, the meat shrinks away from the shell and is subsequently removed by hand, the empty shells with the husks being used as firing for the driers. The final dried copra contains 3·6 per cent. to

4·1 per cent. of moisture, and 65·6 per cent. to 67·5 per cent. of oil. The yield of dry copra per nut from Vailele Plantation averages 167 gm. (compare Table VI)—*i.e.*, 6,143 nuts per ton of dry copra.

Types planted.

Examination of the nuts collected at the copra-drying sheds shows that the nuts are of widely varying types, while visual observations of trees in the plantations suggest that trees vary tremendously both in productivity and habit of growth. A number of different types of nuts were collected at the Vailele Plantation and are shown in Fig. 4, while details of the nuts are given in Table VI.

TABLE VI.—DETAILS OF DIFFERENT TYPES OF COCONUTS COLLECTED AT VAILELE PLANTATION, SHOWING THE VARIETY OF TYPES PLANTED.

——	A.	B.	C.	D.	E.	F.	G.	H.	I.
Diameter of nut—									
Transverse (in.) ..	2·75	2·80	3·25	3·00	2·70	4·20	4·45	4·35	4·50
Longitudinal (in.)..	3·65	3·85	5·15	3·70	3·95	5·00	5·00	4·15	4·35
Thickness of meat (in.)	0·45	0·35	0·50	0·45	0·45	0·50	0·45	0·45	0·50
Dry weight of copra produced (grams)	71	79	150	92	80	197	207	209	198

Since the best of the nine nuts recorded above return three times the amount of dry copra per nut that is obtained from the poorest, it would appear that there is considerable room for improvement in the type of nut which should be selected for future plantings. The opinion was fairly freely expressed, however, that any selection for the larger-sized nuts would lead to a decrease in the number of nuts produced per tree ; but work conducted in Malaya seems to lend no support to this contention, provided selection for size is kept within reasonable limits. Smith(3) gives details of the results of selection in that colony. An area of 80 acres which had an average bearing record of 82 nuts per palm, or 19½ cwt. of copra per acre per annum, was selected and the individual trees graded according to production with the following results :—

Total number of palms examined ..	3,975
Total producing 100 nuts and over ..	690 = 17·8 per cent.
Total producing 50 nuts and under ..	1,109 = 28·6 per cent.
Average of " 100 nuts " palms	117·23 nuts.

Nuts from those palms producing 100 nuts and over were then taken and the yield of wet copra per nut determined, with the following results :—

Wet Weight of Copra per Nut, in Grams.	Number of Nuts in Class.	Percentage of Nuts in Class.
Over 700 grams	3	0·4
600 to 700 grams	47	6·8
500 to 600 grams	191	27·7
400 to 500 grams	307	44·5
300 to 400 grams	128	18·6
Under 300 grams	14	2·0

FIG. 5.—Looking across to Malatula from Fagalie. On slope Malatula stony silt loam soil type. Many trees have died.

FIG. 6.—"Sensitive plant" and Vailima grass on Malatula grazed by cattle.

From the data given by Smith it would appear abundantly evident that it is possible to find trees which combine both large size of nuts and heavy yielding capacity, and there appears considerable scope for selection if further areas are to be planted in Samoa. In a crop of this nature planting is done once and for all, and expense incurred in securing selected seed may be repaid many-fold during the normal life of the crop. Initial lack of selection cannot be rectified as in the case of annual crops.

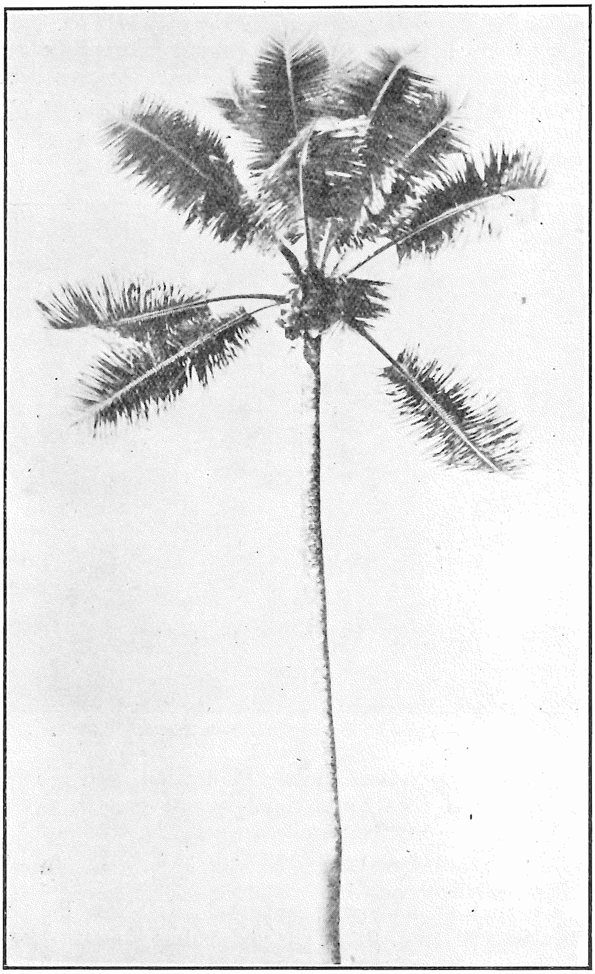

FIG. 7.—A poor bearing tree on Malatula.

Some selection has been practised in the past on the basis of nut shape and size, but while this is of undoubted importance it should be carried a stage further and the yielding-capacity of the trees producing such nuts determined, or results are likely to be disappointing. Even with careful selection phenomenal results should not be expected, as it is well known that the coconut, being generally cross-fertilized, does not breed true ; if, however, production could be increased by 10 per cent. the cost of selection would be amply repaid, while the elimination of low-producing, or " boarder," trees should materially assist in raising the average level of production.

Decadent Areas.

The main problem in the coconut plantations is the reduction in productivity due partly to the increasing age of the plantings and partly also perhaps to depletion of the reserves of soil nutrients. The view is taken that while the latter may be a contributory factor in the decline in production, the main issue is the increasing age and height of the trees.

The extent to which the trees are declining may be judged from the accompanying photographs, which illustrate decadent trees bearing practically no nuts at all or areas where the number of trees per acre has been seriously reduced by the premature dying of trees (Figs. 5, 6, and 7). When searching for a uniform area on which to establish a manurial experiment,

FIG. 8.—Young coconuts in " New Place," Vailele.

various areas were surveyed on Vailele Plantation, and the most uniform block available showed that approximately one tree in every eight had died. Such a reduction in tree-numbers where the trees are widely spaced must represent a serious loss in production and considerably reduce the efficiency of production.

As an experiment an area was replanted on " New Place " on Vailele Plantation in 1931–32 (Fig. 8). The old palms were sixty-five years of age, in a declining condition, some having died out completely. The replants were interspaced between the old palms, which are still standing. The area was ploughed* and sown in Mauritius beans for two years. Recently it has been periodically grazed to control growth, and cattle have done some damage to the young palms. In this area a mixture of Nauru rock phosphate and superphosphate at the rate of 10 cwt. per acre has been applied in an attempt to stimulate growth.

* Not usually possible owing to the stony nature of most of the soil types in Samoa.

Feasible methods of renewal appear to be—

(1) Planting renewals as older palms die, or become unfruitful. This necessitates fencing or the building of stone walls to protect the young palms from stock.

(2) Total clearing of an area after the yield drops to an unprofitable level, and replanting. This necessitates logging and burning of all dead material to prevent beetle spread. It also presents difficulties in controlling grass-growth while the young palms are establishing for a period of four to five years. Where, as on parts of Vailele, mechanical cultivation is possible and a leguminous cover crop can be planted the method appears to be practicable, but nevertheless expensive.

(3) Complete replanting under the shade of the remaining mature trees as has been done at "New Place." This appears to be practicable, at least on arable areas, but would prove expensive on the large proportion of stony areas where hand cultivation or slashing was necessary. Yields of the newly established palms are also likely to be low, owing to excessive shade until the older trees are fallen and logged.

(4) Abandonment of present areas to Native ownership as production falls, and the opening-up of fresh areas, production being maintained as long as may be economic, possibly by the use of fertilizers.

(5) No replacements made and reliance placed on fertilizers to maintain the remaining trees in healthy bearing condition for an extended period.

Any of the above methods is open to objection at various points, and the choice of method will depend partly on the sale value of copra and hence the cost that may be reasonably incurred in re-establishment; partly on local factors such as absence or presence of stone in the soil, ease of fencing, contour of the land, cost of labour, manures, &c.; and also on the long-term policy of Reparation Estates and the Administration in regard to the further expansion of plantings. Each area must be considered on its merits, and possibly various methods used according to the differing conditions of each block. The question of manuring is treated in a separate section.

Manuring.

Manurial Experiment on Coconuts.—Since soil analyses alone have repeatedly proved their unreliability as a guide to successful manuring, and the only satisfactory basis yet secured is that of carefully controlled field experiments, it was felt desirable that experiments should be initiated before leaving Samoa. The problem also appeared the more urgent since consideration was being given to the feasibility of manuring the more decadent of the large coconut and cocoa plantations in an endeavour to restore them to some of their former vigour. Such a programme means the expenditure of considerable sums in the purchase of fertilizer, and the comparatively small cost of running controlled yield trials over a period of several years seemed amply justified.

A randomized Latin square including six differential treatments was therefore laid down on Vaitele Plantation, using various combinations of phosphate, nitrogen, and potash, and records of yields are being kept by the plantation manager.

Interim Recommendations for Manuring.—While it is felt that final recommendations in regard to the manuring of coconut plantations cannot be made until our present knowledge is augmented by the results of the manurial experiment laid down, it is appreciated that it may be desired to take some immediate action in an effort to prevent any further decline in production. The following briefly summarizes our observations and the points which we think should be considered in regard to manurial treatment :—

(i) Many of the older plantings of coconuts are definitely declining in productivity and there is a considerable mortality of palms on some areas.

(ii) The greatest decline is occurring on the older soil types which analyses show to be lowest in "available plant foods."

(iii) The somewhat meagre reports available of overseas manurial experiments suggest that under the conditions of the experiments reviewed, coconuts may be expected to give a considerable response to manurial treatment, though there is an initial lag before any significant increase is observed.

It therefore appears that a mixed fertilizer containing phosphate and potash might be expected to give most satisfactory results. We suggest that a suitable dressing might be made by applying 3 cwt. of basic slag and 1 cwt. of muriate of potash. Basic slag is selected as the form of phosphate for application, since laboratory tests show that the phosphate absorption is fairly high. This means that if superphosphate is applied a good deal of it will combine with soil compounds and consequently become available only with difficulty to plants. It is therefore deemed advisable to use basic slag, ground rock phosphate, or some form of reverted phosphate. The ashes from the copra driers should also be carefully conserved and returned to the plantations, since these ashes contain relatively large amounts of potash.

These considerations can be regarded as no more than guides pending the result of the manurial experiment already laid down. Even when this experiment is completed many questions will remain unanswered, such as the influence of liming or cultivation on yields, the relative efficacy of various forms or rates of application of phosphate, &c., thus emphasizing the need for some continuous policy of experimental work on plantation problems in the territory.

Further, manuring is only one aspect of the larger problem of tree decline already discussed on p. 610. On no account should manuring be regarded as a panacea which will overcome inherent defects of situation, poor strains of crop plants, or other factors likely to lead to low production. The greatest success from a manurial programme is likely to be achieved on those areas which are receiving the most careful attention in other directions.

General.

Since the heavy fall in world prices for copra experienced during the recent depression, more economic methods of working the plantations have resulted in a 50 per cent. reduction in the cost of production of copra, the cost for the 1935–36 season being £6 8s. 5d. per ton.

World market conditions, however, do not appear to be sufficiently favourable to warrant extensive planting unless costs can be maintained at a low level so that production may be profitable even with low prices for copra on the world's markets.

COCOA.

Production and Types planted.

No accurate estimate of the area under cocoa is available, but it is probably approaching 5,000 acres, some of which is not yet in full bearing. The average production over the last nine years has been 820 tons per annum, with a slight upward trend made somewhat irregular by climatic influences. Average production approximates to 3 cwt., or slightly over, of dry cocoa-beans per acre. Practically the whole of the production is from plantations run by Europeans, Native production being negligible in amount.

The cocoa plantings are at present restricted to a fairly limited area lying to the west and south-west of Apia on the northern slopes of Upolu at elevations of 200 ft. to 800 ft. The climate seems well adapted to the cultivation of cocoa, and the product of Western Samoa enjoys a high reputation on the world markets, the Empire Marketing Board referring to it as " a very choice variety of cocoa." While this may be legitimate cause for self-congratulation on the part of the planters, it is no excuse for lack of care in seed-selection. Neglect of necessary precautions may turn legitimate congratulations into mutual recriminations.

The first plantings of cocoa were made in Western Samoa about 1902–3, plantings being of the superior *Criollo* variety on the square system with 5 metre centres. This spacing has, with slight variations, persisted to the present time, though the Tanumapua Blocks are planted 10 ft. by 20 ft. The *Criollo* variety first planted, however, proved very susceptible to attacks of canker (*Phytophthora palmivora*) and much loss was caused. The more resistant *Forastero* variety was then introduced to replace trees which had died from canker. This intermixture of varieties led to hybridization, and subsequent plantings have been hybrid forms combining much of the hardiness of the *Forastero* variety with many of the superior qualities of the *Criollo* type.

Some selection has been practised in planting fresh areas at Tanumapua, but owing to the difficulties inherent in the problem the methods adopted appear to have failed to secure any appreciable improvement. A comparison of random samples of pods from " selected " and " unselected " stock showed no appreciable improvement. The average number of pods required to give 1 lb. of dry cocoa was found to be twelve, but the largest pods included in the sample yielded approximately one-sixth of a pound of dry cocoa each.

These results are interesting when viewed in relation to selection work being undertaken by the Imperial College of Tropical Agriculture, Trinidad. Cheesman(4), in an address to Trinidad planters, remarks: " Whilst on the average about twelve pods make 1 lb. of dry cocoa, there are trees from which six or seven are sufficient, and others from which more than twenty are required." It would appear, therefore, that, on the average, a Samoan cocoa-pod yields approximately the same dry weight of cocoa as an average Trinidad pod. As in Trinidad, there is ample scope for improvement in the general type of cocoa grown. Nor are we concerned solely with yield per pod. The returns per acre depend on—

(*a*) Yield of dry cocoa per pod.
(*b*) Number of pods per tree.
(*c*) Number of trees per acre.
(*d*) The quality of the product.
(*e*) Susceptibility to disease.

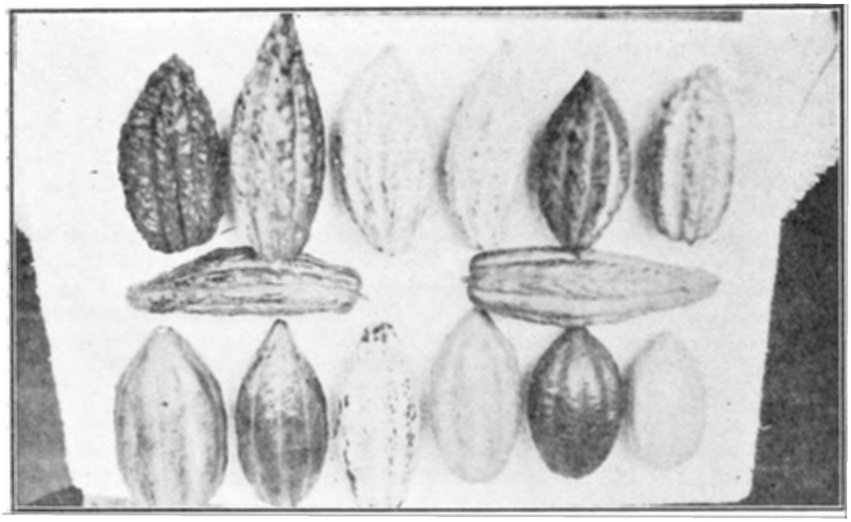

FIG. 9.

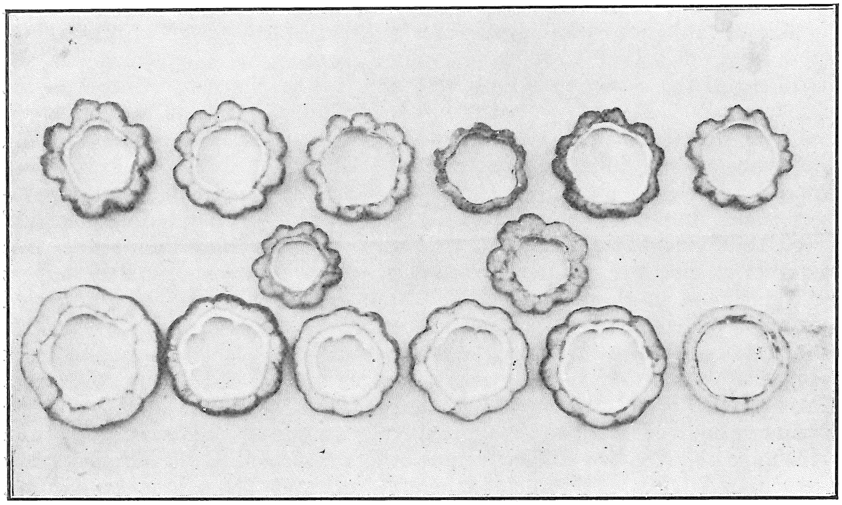

FIG. 10.

FIGS. 9 and 10.—The two figures illustrate the variability of pod type found in Samoan cocoa. The types on the top left-hand corner approach pure *Forastero* type, while the third from the left in the lower row approximates to pure *Criollo* type. The other pods illustrate various intermediate forms.

The yield of dry cocoa per pod has been discussed above, and since the largest pod is yielding nearly four times that of the smallest pod there is ample scope for selection.

During the period of our visit it was difficult to arrive at any conclusions in respect of number of pods yielded per tree, but observations suggest that there are major differences between trees. These differences may be partly due to differing environmental factors, but they are probably in large part genetic. Observations extending over at least two seasons are required before selection for yield per tree can be of much value, but such selection should be worth while.

The question of planting distance and its influence on yield per tree has been stressed by Cheesman(4). He points out that " a tree occupying 17 ft. by 17 ft. to the detriment of its neighbours planted at 12 ft. by 12 ft. has to give twice the yield of an average picket before it is even up to average performance. A tree spreading over 24 ft. by 24 ft. has to yield four times the average. This correction removes from the class of true high yielders a great many of the heavy bearers of smallish pods, which make a good show only by smothering their neighbours."

Planting distance must be governed in part by soil fertility and hence size of tree-growth, while, if average humidity is sufficiently high, somewhat wide spacing in order to allow free access by air and sunlight probably tends to reduce loss of yield by disease. The Samoan climate, fortunately, is humid and warm with a well distributed rainfall, so that relatively wide spacing has been possible without the use of shade trees.

Although quality is more difficult to assess than yield it is not the less important on this account. Precise chemical or physical standards of quality are lacking, and it cannot be reduced to the same statistical basis as yield. The only method available by which it was possible to estimate quality in the pod was by a count of bean colours. Some trees yield pods the beans of which are entirely " white " (*Criollo* type), while others yield dark-purple beans of *Forastero* type (Figs. 9 and 10). If Samoan cocoa is to maintain its present high reputation on the market the latter type must be kept at a minimum consistent with disease-resistance. The " white," or *Criollo*, type is favoured as giving a lighter " break " and as containing less of the bitter principle found in *Forastero* types. The selection of a type breeding true for " white " beans should be a comparatively simple process, as S. J. Wellenseik(5) has shown " white " to be a single factor character recessive to " coloured."

Black pod or canker (*Phytophthora palmivora*) under conditions of prolonged rainfall usually causes heavy losses and at all times claims a certain proportion of the crop. Simmonds in his report (unpublished) makes various suggestions for control of this disease. These need not be repeated here, but the resistance of individual trees to attack appears to show considerable variation, and by selection it is possible that a highly resistant type combining other desirable characters might be found.

To sum up, Samoan cocoa, while recognized on the market for its high quality, is a hybrid form, and, being sexually propagated, exhibits the variation characteristic of hybrid forms under such conditions. There are apparent large variations in yield per pod, yield per tree, quality and size of bean, and disease-resistance. In view of the difficulty of selecting trees which combine such a variety of desirable factors, the services of a qualified man would be needed to undertake selection, in addition to other work, if any further extension of cocoa areas were contemplated, or even for the purpose of providing the propagating material required for refurnishing existing areas as replacements become necessary.

Black-pod Disease (Phytophthora palmivora).

While probably the most hopeful line of attack on black-pod disease would be the selection of resistant strains also possessed of other desirable characteristics, such selection is likely to be a process extending over a number of years. As a short-term measure, in view of the high value of Samoan cocoa, it appears that spraying might be economic as a control measure. References in overseas literature to attempts to control this disease by spraying are scanty, owing to the fact that most of the world's cocoa is grown under plantation methods. Graham(6), however, states that Bordeaux mixture has proved efficacious in Jamaica, and it is suggested that spraying could be tried out on an experimental scale in Samoa.

Cultural Methods.

In most of the cocoa plantations dadap (*Erythrina*) is planted at regular intervals as a leguminous cover crop, the plants being slashed and the trash allowed to lie on the surface of the soil.* The ground is kept clean-weeded by Native or coolie labour through the year. Owing to the porous nature of the soil, very little surface erosion appears to occur, except on one or two hillsides. One would expect the continual clean cultivation to lead to fairly rapid breakdown of the humus content of the soil and a partial breakdown of the crumb structure ; but, taking total nitrogen as the index of the humus content, this does not appear to be marked.

Some difficulty is experienced with a small sedge known locally as nut-grass. Efforts are being made in Fiji to control this troublesome weed biologically. Small colonies of the weevil, *Athesapeuta cyperi*, and a moth, *Bactra truculenta*, both enemies of this weed, were obtained from Hawaii. The numbers, however, were small, and no success resulted. It is hoped to renew the attempt to introduce these insects to Fiji during the present year. The progress of these efforts should be closely watched, and, if successful in attaining their objective, introduced into Samoa.

Little or no manuring has been practised in the past, but a start has been made this year with the application of phosphates at Tuanaimato Plantation. Yields on the better quality blocks are averaging from 6 cwt. to 9 cwt. of dry cocoa per acre, which is below the average which was achieved when the plantings were first made on virgin soil. The Manager of the Central Group Estates informed us that when first planted the Talimatau Block produced an average yield of 14 cwt. to 16 cwt. of dry cocoa per acre for a number of years. This same block produced 6 cwt. 2 qr. 11 lb. dry cocoa per acre 1934–35 season, and 7 cwt. 2 qr. 5 lb. for the 1935-36 season, it being now thirty-two years since the original planting. Many of the original trees have, of course, died, their place being taken by replants. Many of the areas which are giving lower yields, as at Falelauniu, were originally planted in rubber, which has only recently been removed, and

* There appear to be no grounds for the belief that the *Erythrina* plants must be killed before the associated crop plants can secure the benefits of the nitrogen fixed by the *Erythrina*.

the cocoa replanted. Average production over the whole group is therefore considerably below what may be expected in the future when these refurnished areas come into full bearing.

In the early plantings *Ficus elastica* was planted as a shelter-tree around cocoa blocks. These trees have now grown to an enormous size, and are spreading by sending down aerial roots over a wide area. Lateral roots sent out from these *Ficus* belts penetrate to great distances out into the cocoa blocks, and probably partly account for the early decadence of blocks, such as those at Magia. Every effort is being made to fell and clear away these *Ficus* belts as rapidly as conditions permit. In our opinion this is the first move that should be made in improving the condition of such blocks, and manuring or other improvements should be deferred until the *Ficus* belts have been cleared.

Some pruning of cocoa is regularly undertaken in order to maintain the shape of the tree and to admit access to light and air to the main framework.

Rooting of Cocoa-trees.

A number of pits were dug in order to observe the rooting systems of cocoa. The roots form a thick mat in the top 3 in., stout surface roots frequently extending out from the tree for several feet. Roots are fairly common to 18 in.; below that, only occasional ones are seen. In a few pits they were observed to be confined to the top 9 in. On an alluvial flat at Alafua the roots of cocoa-trees twenty years old extended down into a 13 in. layer of clay loam, 24 in. to 37 in. below the surface; in a face about 6 ft. long there were seven big and thirteen small roots. No difference was noticed in the rooting system of healthy and declining trees.

It is difficult to interpret the profiles of cocoa-roots in the absence of comparative profiles from other countries, but on general consideration it may be said that the rooting for trees of such size is shallow, and it is significant that the cocoa-tree roots deepest in the fertile alluvial flat.

Manuring.

Analyses of Cocoa-leaves.—The deficiency of a soil nutrient is sometimes made evident by leaf symptoms. Potash and phosphate deficiencies are described by Hardy(7) as follows: "Potash deficiency is indicated by crenulated (or scolloped) browning or scorching of the apical and lateral margins of the cocoa-leaves; this is a very characteristic symptom, and can easily be recognized in the field. Phosphate deficiency is suggested by long, 'whippy,' pendulous, thin side-branches which carry tufts of leaves at their extremities, but few or no leaves along the stem; this symptom is not always easy to recognize in the field; it is especially difficult to distinguish during periods of natural leaf-fall."

The trees in Samoa showed no sign of phosphate being in short supply, but there appeared to be a widespread evidence of potash deficiency, the apical portions of the leaves and margins of the leaves back from the apical end frequently being brown. The browning, however, had not advanced so far as to make a scolloped boundary with the green portion of the leaf.

As analyses of leaves have been found by workers on cocoa in the West Indies to be a reliable guide to the soil nutrients required, and since it is believed that the leaves indicate a potash deficiency, the composition of samples from Vaitele and Saleimoa soil types were determined (Table VII).

TABLE VII.—ANALYSIS OF COCOA-LEAVES COLLECTED FROM THRIFTY AND UNTHRIFTY TREES ON VAITELE STONY SILT LOAM AND SALEIMOA STONY LOAM.

An analysis of cocoa-leaves from trees in good condition in the British West Indies given by Hardy, MacDonald, and Rodriguez(8) is shown for purposes of comparison.

—	Casala Trees, Twenty-five Years old, surrounded by *Ficus*.	Falelauniu Block I: Vaitele Stony Silt Loam.	Tuanaimato: Unthrifty Trees. Vaitele Stony Silt Loam.	Unthrifty Trees. Vaitele Stony Silt Loam.	Tuanaimato; Thrifty Trees. Vaitele Stony Silt Loam.	Tuanaimato; Thrifty Trees. Vaitele Stony Silt Loam.	Thrifty Trees on Saleimoa Stony Loam.	"Ideal," British West Indies.
CaO	2·73	2·24	3·37	3·62	2·38	2·82	2·68	..
MgO	1·43	1·24	1·24	1·35	0·88	1·02	0·94	..
K_2O	1·64	1·93	1·87	1·79	2·70	2·70	2·68	2·64
P_2O_5	0·52	0·38	0·30	0·31	0·46	0·36	0·50	0·50
N	1·83	2·10	1·91	1·97	2·05	2·00	2·12	2·35
Total ash ..	11·06	9·69	11·12	11·57	10·27	10·86	10·38	9·90
Soluble ash ..	8·78	8·32	9·36	9·65	9·09	9·23	8·74	..
Insoluble ash ..	2·28	1·37	1·76	1·92	1·18	1·63	1·64	..
Ratios—								
N/K_2O ..	1·12	1·09	1·02	1·1	0·76	0·74	0·79	0·9
K_2O/P_2O_5 ..	3·16	5·08	6·23	5·8	6·0	7·5	5·36	5·3
N/P_2O_5 ..	3·52	5·53	6·36	6·36	4·46	5·56	4·24	4·7

The third or fourth leaves back from the tips of the branches of six or more trees were in all cases selected. The leaves were almost the size of the mature ones. This is in conformity with the practice in Trinidad.

The composition of the leaves on Saleimoa stony loam is practically identical with that quoted for healthy Trinidad leaves, but on the Vaitele stony silt loam some of the trees show a definite deficiency of potash. The nitrogen/potash ratio is high, indicating unhealthy growth and, according to work in progress in Trinidad, may mean a greater liability to attack of thrips and black-pod disease. Phosphate tends to be low in three of the samples. Thus the evidence from the analyses suggests that potash is in short supply and there is a probability that phosphate is also required.

Supplies of zinc sulphate and copper sulphate were despatched to Apia, and experiments were laid down under Mr. Eden's direction to ascertain whether zinc or copper was deficient in the cocoa-leaves and played a part in the poor growth; but so far no response has been obtained. If the analyses of leaves are a guide to zinc-deficiency, then the possibilities of this element being in short supply are small, since leaves collected from unhealthy trees at Tuanaimato contained 75 and 64 parts per million of zinc and healthy leaves 54 and 51 parts per million.

Cocoa Manurial Experiment.—As in the case of the coconut plantations, it was felt that before any definite recommendations in respect of manuring cocoa could be made, more definite experimental information was required. An experiment was therefore laid down on Block IV, Tanumapua (Fig. 11), seven treatments giving different combinations of phosphate, potash, and nitrogen being included in a Latin square.

These manurial experiments cannot be expected to yield any conclusive results for at least three years. The recording of results is slow and laborious, but, in view of the heavy expenditure contemplated for manuring an area such as the New Zealand Reparation Estate, the time and trouble involved is considered to be warranted.

Interim Recommendations for Manuring of Cocoa.—It is suggested tentatively that, pending any results being available from the experiment already laid down, a dressing of 3 cwt. basic slag and 1½ cwt. muriate of potash per acre should be applied to cocoa showing poor growth.

GENERAL.

During the period 1931–36 the cost of production of dry cocoa has been reduced from £87 to £36 per ton, and if this lower figure can be maintained there seems no reason why the production of high-grade cocoa in Samoa should not be considerably extended.

FIG. 11.—Looking east over the manurial experimental block, Tanumapua, Block IV. Photograph taken August, 1936.

BANANAS.

Production and Cultural Conditions.

The export of bananas from Samoa commenced in 1928 with a modest total of 815 tons, and a value of £11,219 shipped. The trade has steadily increased to a peak in 1935, when 3,893 tons (109,000 cases), valued at £38,146, were exported from the territory. The price to growers through 1935 was 4s. 6d. per case, which must be considered very satisfactory.

There is no official record of the total area planted in bananas in the territory, but we were informed that approximately six hundred planters (Native and European) were shipping through four hundred depots. All fruit from these depots is assembled on the wharf at Apia and inspected prior to shipment. The grading, packing, and inspection are of a very high standard, and are a credit to the officers concerned.

Plantations vary in size from ½ acre to 12 or 15 acres, and the total area planted is estimated at approximately 1,000 acres, but in view of the large quantity consumed locally as food it is probably considerably in excess of this. Plantings are usually made at a spacing of 15 ft. to 16 ft. on the square, but some are more closely spaced. The areas are kept clean-weeded, or under less careful management the growth between plants is merely kept slashed. Recently considerable areas have been grown as shade plants with cocoa underplanted, the intention being to remove the bananas after the cocoa has become well established—*i.e.*, in about three years from planting. There is definite danger, however, that the bananas will be allowed to remain for too long a period, to the detriment of the successful establishment of the cocoa.

The whole of the bananas exported have in the past been shipped to the southern New Zealand markets by the N.Z.G.M.V. "Maui Pomare." With the advent of the M.V. "Matua" it will now be possible also to ship to the Auckland markets, and at more frequent intervals than previously.

Varieties.

A considerable number of banana varieties are grown in Samoa, but the principal commercial variety appears to be a strain closely resembling that described by Cheesman and Wardlaw in the West Indies as the Lacatan, and almost identical in appearance with the variety known as Veimama in Fiji. No Gros Michel were observed, although we were informed that this variety was present on the Island. Recently a selection from the Trinidad College of Tropical Agriculture has been imported and established at Vailima. Two of these stools have established satisfactorily and are now sending up a number of suckers. It is recommended that these be propagated as speedily as possible, and a small area planted out where they could be kept under observation and their growth and general characteristics compared with the typical Samoan variety. Also, if any Gros Michel exists on the Island, specimens should be obtained and planted in an adjacent area so that the behaviour of the two species could be compared.

Importations, if made, should be attended by every precaution owing to the risk of disease, and are not recommended as a general procedure. Samoa is fortunately free of many of the more serious diseases of bananas, and every effort should be made to ensure that this remains so. Definite restrictions, if such do not exist, should be placed on the importation of any plant material from Fiji, Tonga, or any of the other neighbouring island groups, where a number of diseases are established which have not yet reached Samoa.

Simmonds in his report suggested that the Gros Michel variety would probably prove superior to the prevailing Samoan variety. While the Gros Michel has undoubtedly a better colour and is less subject to bruising than the Lacatan type it is not usually considered to be of such a fine flavour. The New Zealand public has become used to the somewhat inferior appearance of the Samoan bananas usually shipped to the Dominion, and it is doubtful whether the demand would be increased by substitution of a fruit of superior appearance but poorer flavour.

Harvesting and Shipping.

Bananas in Samoa are grown for commercial purposes chiefly along the northern slopes of Upolu and as far afield as Samatau on the south coast. Most of the plantations are some distance removed from the coast, but are usually accessible by rough roads negotiable by motor-lorry. Prior to a shipment, which in the past has been once a month, fruit, at a suitable stage of maturity, is cut and carried to a small shelter usually in or near the plantation. The fruit is cut from the hands and placed on slatted trays to permit the sap which exudes to flow away without danger of staining the fruit or cases. After a short period, when no further exudation of the sap is occurring, the fruit is packed into double cases, the cut ends being placed outermost. The fruit is then conveyed by lorry or in some cases by boat to the Apia wharf, where the cases are opened and inspected for freedom from scab-moth injury, or for overripe fruit. Since the boat lies in the roadstead, it is necessary to lighter the fruit out in barges.

General.

Bananas in Samoa are usually considered to have a commercial life of only five to six years when planted on virgin soil. At the end of that period the general practice in the past has been to allow the area to revert and shift

FIG. 12.—A view along the southern edge of the banana manurial trial at Tanumapua.

to another area. Recently an effort has been made to induce the Native growers to plant up the abandoned area in dadap (*Erythrina*) so that they may more quickly be again available for replanting. Bananas are considered to draw very heavily on the soil for supplies of potash, and it is possible that manuring might considerably extend the commercial life of a plantation. With this in view a small observational manurial trial has been laid down at Tanumapua and should give some indication of the result by which manuring is likely to be attended (Fig. 12).

In order to avoid the continued clearing of fresh areas for banana culture it is suggested that experiments should be conducted on a small scale on the possibilities of devising a suitable rotation to restore soil fertility. An experimental rotation being tried in Fiji is bananas, taro, green manure (Mauritius bean), maize, rice or cassava, green manure, bananas. While some of the crops, such as upland rice mentioned above, are not usually grown in Samoa, other crops might be substituted.

PAPAIN.

Papain is a vegetable pepsin derived from the sap or latex exuded when the green fruit of the pawpaw is scratched. This juice is collected in enamel basins, coagulated, and finally dried on trays at approximately 140° F. The dried papain is immediately bottled and tightly corked, as it is hygroscopic.

The total production is approximately 2 tons per annum of dried papain. It appears to meet with a fairly ready demand at payable prices.

RUBBER.

Considerable areas were planted in rubber by the German firm of G.P. and D.H. subsequent to 1900 at Solaua, Aleisa, and also on the south coast of Upolu at Lotofaga. Tapping was commenced some years ago, but discontinued in 1932 owing to the low price being received on the market. Tapping commenced again in 1935, and is being continued at the present time. Tapping was attempted at Solaua for a period, but owing to the high rainfall (180 in. per annum), which seriously interfered with the collection of the latex, the area was abandoned. Similarly, the area at Lotofaga has not been recently worked. The only area where tapping is now proceeding is at Aleisa. An area of 500 acres is here under rubber (*Hevea braziliensis*) and was originally planted 150 trees to the acre, but this number has been considerably reduced by the inroads of root fungi destroying the trees. This disease, known locally as Limoma'a (*Fomes lamoensis*), has caused considerable trouble in Malaya, and is likely eventually to destroy trees at present established in Samoa. The number of trees per acre is now rapidly dwindling to the point where collection of the latex will become uneconomic. There appears to be no reason why the measures which have been adopted in Malaya for the control of this disease should not also be effective in Samoa, but the cost would probably be prohibitive.

There are probably considerable areas in the drier parts of Upolu and Savaii which would be suitable for the growth of rubber, but with probable overproduction in other parts of the world, where labour-costs are much lower than Samoa, the extension of the industry does not appear to be warranted.

COFFEE.

Coffee grows well in the climate of Samoa, but only one planter has established the crop on a commercial basis. Mr. Jahnke, on Fasito'o, has approximately 5 acres planted at an elevation of about 500 ft. One acre of this is planted in the Liberian variety and 4 acres in the smaller-seeded Robusta variety. The crop produced is all sold locally, and its wider production appears to be limited by the difficulty in securing labour for picking. There should, however, be prospects of supplying at least part of the New Zealand market demand, since the coffee produced is of excellent quality and much superior, in our opinion, to the general quality of the blends available in New Zealand.

OTHER CROPS NOT GROWN ON A COMMERCIAL BASIS.

Numerous other crops are grown for local consumption or as food by the Natives, but are not produced on a commercial basis, chiefly owing to the lack of markets. These include kapok, sago, tapioca, vanilla, ginger, arrowroot, and tropical fruits such as mango, mangosteens, avocados, pawpaws, grapefruit, &c. It appears that the production of such tropical produce in a mandated territory administered by this Dominion might reasonably be encouraged as being complementary to the foodstuffs which can be produced locally. Coffee, desiccated coconut, tapioca, tropical fruits, ginger, grapefruit, and probably kapok could be produced in Samoa, if not in sufficient quantity to supply New Zealand demands, at least to a sufficient degree to be of great assistance to the national income of the mandated territory. The imports of these products into New Zealand over the three years 1933–35 are shown in Table VIII.

TABLE VIII.—IMPORTS INTO NEW ZEALAND DURING THE THREE YEARS 1933–35 OF TROPICAL PRODUCTS WHICH MIGHT POSSIBLY BE PRODUCED IN WESTERN SAMOA.

(Data from "Trade and Shipping" statistics compiled by New Zealand Customs Department.)

Commodity.	1933.		1934.		1935.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Cwt.	£(N.Z.)	Cwt.	£(N.Z.)	Cwt.	£(N.Z.)
Coconut-oil	110,470	14,385	10,983	12,819	16,582	25,559
	lb.		lb.		lb.	
Desiccated coconut ..	1,481,904	18,352	1,467,153	9,652	1,390,311	13,652
Coffee—						
Raw	465,364	18,761	379,841	14,544	512,132	17,138
Roasted	565	75	1,689	194	3,476	411
Cocoa-beans	2,345,506	42,018	2,468,853	33,399	3,640,196	56,556
Cocoa-beans (processed) ..	404,657	27,309	588,209	39,818	604,553	41,031
Sago and tapioca ..	2,652,793	13,176	3,228,803	18,580	3,064,633	18,682
Vanilla beans	5,321	1,093	4,599	1,369	6,650	2,416
Ginger (green in brine) ..	304,650	2,519	377,556	3,981	429,109	7,770
Arrowroot	98,812	2,718	122,921	3,180	147,478	3,486
Grapefruit	*		*		359,093	3,852
	Cwt.		Cwt.		Cwt.	
Kapok	9,485	24,486	15,027	39,018	17,951	44,528

* Prior to 1935 imports of grapefruit into New Zealand were grouped with mandarins, and separate figures are not available.

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