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EMPIRE MARKETING BOARD

MAY 1932 to MAY 1933



JUNE 1933

LONDON

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PREFACE

THE EMPIRE MARKETING BOARD IN 1932-33

FOR the last four years the Empire Marketing Board has been able to announce in its Annual Report new records of shipments of a variety of Empire products to the United Kingdom. It is satisfactory again to be able to report, notwithstanding the difficult times through which we have recently passed, that this progress has continued during the year under review.

The following table gives the volume of imports of twenty-four products into the United Kingdom from Empire sources which established new records during 1932:—

Commodity.	Country of Origin.	Quantity in 1932.	Previous Record.
		Total.	
Wheat	Australia ..	24,159,000 cwts.	23,300,000 cwts. in 1931
	Canada ..	46,874,000 "	41,005,000 " " 1928
Wheat flour	Australia ..	2,830,000 "	2,558,000 " " 1931
Frozen lamb	New Zealand ..	8,454,000 carcasses	8,168,000 carcasses " 1931
	New Zealand ..	2,190,000 cwts.	1,925,000 cwts. " 1931
Butter	Australia ..	1,829,000 "	1,558,000 " " 1931
	Australia ..	15,147,000 dozen	9,182,000 dozen " 1931
Eggs ..	Australia ..	15,147,000 dozen	9,182,000 dozen " 1931
Tea ..	Ceylon ..	172,000,000 lbs.	159,000,000 lbs. " 1931
Canned pine-apple.	B. Malaya ..	911,000 cwts.	676,000 cwts. " 1931
Tobacco	Canada ..	10,844,000 lbs.	6,273,000 lbs. " 1931
	Nyasaland ..	15,064,000 "	13,781,000 " " 1927
	S. Rhodesia ..	10,452,000 "	10,280,000 " " 1928
Bananas ..	B.W. Indies ..	10,609,000 bunches	6,971,000 bunches " 1931
Apples	Australia ..	1,684,000 cwts.	1,442,000 cwts. " 1928
	New Zealand ..	573,000 "	380,000 " " 1930
Oranges ..	Palestine ..	1,639,000 "	1,359,000 " " 1927
	South Africa ..	75,000 "	65,500 " " 1931
Grapefruit	Palestine ..	81,000 "	35,500 " " 1931
	B.W. Indies ..	72,000 "	41,000 " " 1929
	South Africa ..	32,000 "	29,000 " " 1931
Plums	Canada ..	20,000 "	18,000 " " 1928
	South Africa ..	68,000 "	59,000 " " 1931
Peaches ..	South Africa ..	30,000 "	25,700 " " 1930
Pears ..	New Zealand ..	40,000 "	19,500 " " 1931

Some of these records are sufficiently striking to deserve comment. Not only did imports of wheat from Canada constitute a record for supplies coming to the United Kingdom from that country, but the 1932 total has never been exceeded by any country except during the two war years, 1916 and 1917, when imports from the United States of America reached a higher figure. Imports of eggs from Australia, bananas from the British West Indies, tobacco from Canada, apples and pears from New Zealand, and grapefruit from Palestine and the British West Indies all exceeded by 50 per cent. or more their previous best. Besides the record importation of Canadian tobacco, it is noticeable that imports from both Southern Rhodesia and Nyasaland established new records, exceeding the quantities imported in 1928 and 1927 respectively; in those years the heavy imports led to large accumulations of stocks in the United Kingdom, but no similar accumulation has resulted from the record imports of 1932.

In addition to the products mentioned in the table, attention should also be drawn to apples from South Africa, oranges from Cyprus and grapefruit from British Honduras. These as yet constitute only a small fraction of the United Kingdom annual supplies, but in each case the 1932 imports were on a higher level than in any earlier year.

South African butter and eggs and Australian frozen lamb failed to reach the 1931 level, but imports were larger than in any other year. Imports of South African oranges fell short by only 20,000 cwts. of the record imports in 1930. Imports of tea from India, at 312 million lbs., were greater than in any year since 1918, and imports of Australian rabbits, totalling 574,000 cwts., were the largest since 1916. A welcome improvement in imports of rice from India brought the total to over 1,000,000 cwts. for the first time since 1925.

Neither Australian nor South African wine quite reached the highest figures previously recorded—in 1927 for the former and in 1931 for South Africa; but clearances for home consumption established new high records and it is evident that Empire wines are continuing to strengthen their position in the United Kingdom market.

No new individual records in sugar imports were established in 1932, but the total of over 14 million cwts. from all Empire countries combined was the largest ever recorded. Imports from Australia

and South Africa failed to reach their 1931 record levels, but there was an increase in supplies coming from Mauritius, while imports from the British West Indies (including British Guiana and British Honduras) totalled nearly 4,000,000 cwts. and were the highest for over 50 years.

THE OTTAWA CONFERENCE AND THE EMPIRE MARKETING BOARD

The future of the Board's work was discussed at the Ottawa Conference* in 1932, when it was recommended that a Committee should be appointed forthwith, consisting of not more than two representatives of each of the participating Governments, to consider the means of facilitating economic consultation and co-operation between the several Governments of the Commonwealth, including a survey of the functions, organisation and financial bases of certain specified agencies, and an examination of what alterations or modifications, if any, in the existing machinery for such co-operation within the Commonwealth were desirable.

The Conference further recommended that it should be an instruction to the Committee to elect their own Chairman from among their members, and to report to the several Governments represented thereon not later than the 31st May, 1933, with a view to the consideration of their report by the several Governments not later than the following September.

The United Kingdom delegates to the Conference stated that, in order that the necessary time might be available for the preparation and consideration of the report of the Committee, the Government of the United Kingdom would continue to furnish any funds which might be required to finance essential work of the Empire Marketing Board down to the end of September, 1933. The Conference recorded its deep appreciation of the action of the United Kingdom in this respect.

The Committee which was appointed, upon the invitation of the Government of Canada, as a result of the recommendation of the Ottawa Conference, met in London during the early months of 1933 and signed its report just before Easter. Its recommendations had not been published at the time of printing this Annual Report.

* See "Imperial Economic Conference at Ottawa, 1932. Summary of Proceedings." H.M. Stationery Office. Cmd. 4174 (1s. 6d. net).

FINANCE

Following the issue of the report of the Committee on National Expenditure in 1931, the Government decided that it would be necessary to limit the Board's net Vote for the year 1932-33, to £300,000. In consequence, the work of the Board during the year under review has had to be restricted almost entirely to the maintenance and consolidation of pre-existing activities.

RESEARCH

Last year's report gave an account of the action taken by the Board to give effect to the recommendation of the Imperial Conference of 1930 in regard to the planning of joint programmes of research on a broad Empire basis. Further replies have been received during the year to the Board's letter of March, 1931. A significant feature of these and previous replies is the striking measure of agreement among the Empire's scientific authorities as to the problems most urgently requiring further research in the general economic interests of the Empire.

The most promising development in the research activities of the Board during the past year has been its part in the initiation of a programme of parasitological research at the newly established Institute of Helminthology at Macdonald College in Montreal. The Institute has started its work under a special Associate Committee on Parasitology of the National Research Council of Canada and a Director appointed from Scotland.

As will be seen from the research section which follows, good progress continues to be maintained in the many fields of research covered by the Board's grants.

STATISTICAL SURVEYS AND MARKET INTELLIGENCE

Financial considerations during the past year have prevented that extension of the Board's work in the direction of market intelligence and statistical surveys which was envisaged by the Imperial Conference of 1930, but there has been at any rate no curtailment of these activities. Throughout the year the weekly market intelligence services have been maintained for fresh fruit, canned and dried fruits, dairy produce and pig products. Enquiries have been prosecuted among retailers into regional preferences and changing

demand for Empire foodstuffs. Further experimental consignments have been handled of fruits and vegetables for which Empire growers hope to develop a market in the United Kingdom. The series of brief statistical pamphlets on the production and trade of the countries of the Empire has been completed, and the series dealing on somewhat similar lines with groups of commodities has been continued. Progress has been made with statistical world surveys of individual agricultural products; and three reports, on oil palm products, coconut palm products and wool, have been issued during the year.

At the suggestion of the Board's Wool Statistics Advisory Committee, the Board has made concrete proposals to the Governments of the Empire, to the International Institute of Agriculture and to the International Wool Textile Organisation for the improvement and better co-ordination of international wool statistics.

MARKET PROMOTION

The work of the Marketing Branch of the Board, with its team of four Marketing Officers, has continued to develop, particularly in its approach to large consumers, such as Local Authorities, hotels, shipping companies, etc., with a view to guiding their purchases into Empire channels. It has been possible to enlist the sympathetic co-operation of the organisations approached, and supplies from Empire sources not only of foodstuffs and tobacco, but also of such articles as glassware, hospital equipment and school furniture are now being specified in an ever increasing number of tender forms as the result of this branch of the Board's work.

Similarly the Food Products Committee, whose members include men well versed in problems associated with the various branches of the food trades, have extended the scope of their work during the year under review. The results of their investigations into the market conditions in this country of a large number of Empire commodities have been made available to the producers or packers concerned.

PUBLICITY

No marked development or extension of the Board's publicity activities has been possible during the past year. Following the rigorous curtailment of the Board's finances, provision was made for the continuance during the year 1932-33 of existing publicity work on a care and maintenance basis only.

Encouraged by the experience gained at the Empire Shops opened previously in a number of provincial towns, the Board made special provision for the leasing of two further Shops during the year. From May to September, 1932, a Shop was opened in Sheffield; and from September, 1932, to February, 1933, another was opened in Cardiff. In both instances it was again demonstrated that this particular form of publicity was singularly suited to the Board's purposes. It is also interesting to note that the sales of samples of Empire products at the six Shops which the Board has opened have now exceeded one million.

In continuation of its work in connection with the marketing of Empire Timbers, the Board, in the Summer of 1932, published a "Handbook of Empire Timbers". This work, which was compiled with the assistance of the Forest Products Research Laboratory, the Royal Botanical Gardens, Kew, and the Imperial Institute deals with a wide range of the timbers which are produced in different parts of the Empire and which are commercially obtainable in the United Kingdom. In conjunction with the "Buy British" Committee of the Forum Club, and with the Building Centre in New Bond Street, exhibitions of Empire Timber, and articles made therefrom, have been staged. Both of these efforts, which have been made possible by the generosity and whole-hearted co-operation of the bodies concerned, have helped considerably to bring Empire timbers to the notice of potential users.

The Board's Film Unit has continued the production of films for both theatrical and non-theatrical display, and in addition has undertaken the production of a number of films for other Government Departments.

A group of the Board's films in silent form has been sold for a substantial sum to a commercial company, for subsequent synchronisation and distribution in public cinemas. For school use and other non-theatrical displays 43 films have been prepared and added to the Board's Film Library. In addition the Library has been appreciably strengthened by the addition of films generously placed at the Board's disposal by Dominion Governments, the Canadian National Railways and other organisations. The number of schools and other bodies making use of the Library has nearly doubled since the previous year. So rapid, indeed, has been the development of this type of distribution that, although the number of prints of films

available has been more than trebled, considerable difficulty has been experienced in meeting the demand. During the course of the year displays of the Board's films have been given to audiences totalling over 1,000,000 people.

CHANGES IN MEMBERSHIP

Few changes in the membership of the Board have occurred during the past years. Major Elliot, on his appointment as Minister of Agriculture, was succeeded by Mr. Hore-Belisha. Sir Robert Hamilton, on his retirement from office, was succeeded by Lord Plymouth. More recently, Mr. W. A. Wilson, who had been a member of the Board from its first establishment, retired from the Board, in view of the pressure of his other duties, and was succeeded by Mr. Harrison Watson, the Chief Canadian Trade Commissioner in the United Kingdom.

The Board suffered a heavy loss in May, 1933, by the death of Mr. J. C. Stobart, Director of Education of the British Broadcasting Corporation, who had been a member of the Publicity Committee since its formation.

Mr. Gervas Huxley, who had been Secretary of the Publicity Committee since 1926, left the Board's service in December, 1932, upon his appointment as Commissioner of the Ceylon Tea Propaganda Board.

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PREFACE

Nearly four million acres of land in the Empire are devoted to coconut cultivation. From the agricultural point of view the cultivation of the coconut has received a great deal of attention, but the depression from which the industry at present suffers suggests the need, as in the case of sisal, for a programme of research designed to embrace not only the agricultural problems, but the exploration of industrial possibilities by the development of new uses for the fibrous products of the coconut palm. A most important product is the fibre or coir extracted from the husk.

The present report by Dr. S. G. Barker represents an attempt to study the qualities and uses of coconut fibre on a scale commensurate with the importance of the product. Dr. Barker, besides reviewing the attributes of the fibre and the existing methods of retting and extraction, directs attention to some of the many uses to which it could be put if properly treated and rendered suitable for modern requirements. The fact that coir, properly treated, resists decay, is not disintegrated by bacteria nor harmed by water, and can be easily impregnated with bituminous and resinous materials provides a unique opportunity for exploiting its uses in directions hitherto untried in commerce or industry; but, as Dr. Barker points out, modern industry must have a scientific foundation and the fundamental characteristics of coir must be explored by scientific research if, as with coconut oil, knowledge is to be yielded for its development in new directions.

I am confident that this report will not only prove of considerable interest and value, but will stimulate research into the possibilities of the greater utilisation of coir.

It should be mentioned that this report is the result of Dr. Barker's private study of coir and embodies the findings of a number of Research Workers who have associated themselves freely and voluntarily with him.

PLYMOUTH.

*Chairman of the Research Grants
Committee.*

Empire Marketing Board,
26th August, 1933.

COIR
OR
COCONUT FIBRE

To the traveller who has approached tropical portions of our Empire by sea, memories of coconut palms, beneath which nestle the houses and huts of the native populations, flit across his mental vision. To the tropical dweller himself, the coconut palm supplies his food, clothing, habitation, domestic utensils, as well as being his source of livelihood from the sale of its products as a raw material for industry.

Every part of the tree is utilised and there is small wonder therefore that the coconut palm has been given the pseudonym of "The Consols of the East". Tradition, legend and customs are associated with the coconut, varying locally in subject and association. In certain districts the birth of a child is celebrated by the planting of a coconut palm, and it is believed that a mysterious relationship exists between the development of the human life and the growth of the palm, a belief enhanced by the fact that the usual span of the former corresponds to the period of life of the latter. What of the products and uses of the coconut palm? Let us outline them carefully.

- (1) *The tree trunk* may be used,
 - (a) The hollowed trunk for water pipes.
 - (b) The wood for fuel or door and window posts.
- (2) *The leaves* may be used for—
 - (a) Manufacture of roofing materials when interwoven, e.g. the "Cadgan" of S. India and Ceylon.
 - (b) The central rib of the fronds as the bristles of brooms.
 - (c) The dried leaves furnish fuel.
- (3) *The blossom*.—The flower stalk when bruised and incisions made, yields a saccharine juice which when fermented becomes "toddy" or alternatively can be utilised for the production of sugar.
- (4) *The nut* may be considered under the following headings.
 - A. *The Husk*.
 - i. Retting the husk and extraction of fibre.
 - ii. Utilisation of the residue.
 - iii. Subsequent manufacturing processes, manufacture of yarn, matting, etc., dyeing, bleaching, etc.

B. *The Shell.*

i. Utilisation of the shell by destructive distillation, yielding :—

(a) Vegetable charcoal.

(b) Acetic acid.

(c) Tarry residue.

ii. Utilisation as cups for rubber latex collection and domestic utensils, buttons, etc.

iii. Utilisation of the waste products yielding gas to work the manufacturing plant, or for copra drying.

iv. In polished form for ornamental purposes.

C. *The Kernel.* Production of copra.

(a) Copra drying.

(b) Oil expression.

(c) Desiccation.

(d) Cattle cake. (Poonac of S. India and Ceylon.)

5. *The Roots* are often used medicinally as an astringent.

In the present discussion an attempt will be made to show that the above items are really closely related into one continuous series of manufacturing processes, interdependent on each other, and how unity of treatment and continuity of processes of manufacture will lead to a great economic saving. In the past, the industry being largely in the hands of the individual ryots as a cottage industry has largely militated against continuity, but in the case of large estates, and composite areas devoted to coconut cultivation this need no longer be a deterrent. Co-operative organisation might do much for the former and in the case of the latter, it would seem to be only essential that better methods should be indicated. One fact is paramount in dealing with the husk, namely, that almost one-half of the husks available to-day are left unused owing to lack of retting facilities.

From the agricultural point of view, the cultivation of the coconut palm has received a great deal of attention from the Departments of Agriculture in the tropical districts where it is found; but the development of the subsequent industrial processes for the utilisation of its products has been largely left to the initiative of those dealing in these commodities who, in the past, have found that under the economic conditions prevailing, manual methods of extraction and recovery of the fibre, etc., have proved profitable.

It is the old story of an industry which sails along on an even keel in the comparatively placid waters of commercial security, drawing for its development and propulsion upon the motive and directive power of its own experience. Suddenly, an "economic blizzard" strikes the craft. No longer can the ship of industry be guided by the usual rules under storm conditions. There must be keen perception and quick alteration of tactics to meet the new conditions which have arisen, if wreckage is to be avoided.

It will be generally admitted that the world's industry has, since the War, developed largely on a chemical and scientific basis. The advent, for war purposes and subsequent development in times of peace, of cellulose products, has undoubtedly revolutionised the position of old-established commodities on the modern market, and coconut fibre, or coir, in common with many other commercial materials, has felt the repercussion of such competition. In an article in the "Engineer" of June 12th, 1931, the following statement appears :—"At present the whole year's production of coir fibre for spinning is about three and a half million tons. Actually only a hundred thousand tons are used, the remainder being wasted owing to the fact that no commercial use can be found for it." There is, therefore, an abundance of the raw material, and the future of the industry would seem to lie in finding new uses for the fibre and carrying out research work to discover if it can be rendered comparatively cheaply into forms more favourable for utilisation in other directions than those at present. As far as the Empire is concerned, the principal exporting countries are Ceylon and India, but small quantities are exported from the Federated Malay States and there is a very small export of coir manufactures from Tanganyika and Zanzibar. Malaya as a whole is an importer of coir fibre and manufactures. As regards foreign countries, the trade returns of the Dutch East Indies do not differentiate between the coconut and other fibres, but the German import returns show a small import of coir from this source. There is also a moderate export of coir fibre from the Philippines.

Broadly speaking, Ceylon is the largest exporter of the raw fibre while India (besides being an importer of raw fibre) exports very large quantities of manufactured coir products. The Indian trade returns do not differentiate between coir yarn and other types of manufacture, and exclude coir rope and cordage but both in the case of Ceylon and of India, coir yarn comprises the bulk of the coir

manufactures exported. The following tables show the principal exporting countries during the period 1928-30 and distinguish between unmanufactured and manufactured fibre.

I. *Domestic Exports of Coir Fibre.*

	<i>Thousand cwts.</i>		
	1928.	1929.	1930.
Ceylon*	569·2	595·4	481·1
Philippine Islands ..	(a)	59·7	1·1
India	5·8	5·0	5·3

II. *Domestic Exports of Coir Manufactures (excluding rope and cordage).*

	<i>Thousand cwts.</i>		
	1928.	1929.	1930.
Ceylon(b)	93·7	101·4	105·5
India(c)	654·8	609·3	650·7

III. *Exports of Coir Rope and Cordage from Ceylon.* (Indian figures not available.)

<i>Quantity.</i>	1928.	1929.	1930.
Thousand cwt.	19·1	15·0	11·9

Grove Palmer (American Dyestuff Reporter, December 9th, 1929) gives the following figures for the year 1928 regarding the coir industry of the Malay States :—

“ In the coconut growing parts of the Malay States, where there are something like one-half million acres of ground given up to the cultivation, producing approximately a million tons of fibre, we are

(a) Not separately distinguished.

* Includes exports of coir bristles :—

1928.	1929.	1930.
<i>Thousand cwts.</i>		
182·2	200·0	171·2

(b) Includes exports of coir yarn :—

1928.	1929.	1930.
<i>Thousand cwts.</i>		
92·2	100·6	104·4

(c) Imports of coir and manufactures :—

<i>Unmanufactured.</i>			<i>Manufactured.</i>		
1928.	1929.	1930.	1928.	1929.	1930.
<i>Thousand Cwt.</i>			<i>Thousand Cwt.</i>		
16·2	17·2	14·8	1·6	1·3	0·9

officially informed that the quantity of coir used is negligible ; a small amount is converted into yarn and other goods in the gaols, and this is sold locally. Of that which is made in factories, the following quantities are exported, mainly to neighbouring countries :—

For the year 1928—

	<i>Pounds</i>
Fibre	41,400
Ropes, twine, etc.	3,900,800
Mats, matting, etc.	4,068,704

Oddly enough, the same States import from the countries to which the above commodities are sent the following quantities of the same :—

	<i>Pounds</i>
Fibre	699,600
Ropes, etc.	10,578,800
Mats, matting, etc.	8,791,216

In their "Survey of Oilseeds and Vegetable Oils", Volume II, "Coconut Palm Products", the Empire Marketing Board have quoted figures in Table 137 giving the estimated area under coconut cultivation in the Empire. It is of interest to reproduce that table here.

Table 91 of the same publication by the Empire Marketing Board quotes interesting figures regarding the foreign trade of the United Kingdom in miscellaneous coconut palm products. It is again of interest to reproduce their table in so far as it affects Coir fibre, yarn, mats and matting.

The industry is therefore one of considerable Imperial importance, a fact which is emphasised when it is considered that the total area of land in the Empire devoted to coconut cultivation in 1930 was given as being nearly four million acres, being about 53 per cent. of the total coconut area of the world. In India and Ceylon, the production of coir from the husks is to a considerable extent a cottage industry with the natural consequence that in dealing with a small unit, each ryot has recourse to methods which, in the light of modern science, may seem inefficient and uneconomic, yet which even now are profitable. The question arises as to whether these methods could be rendered more remunerative by scientific development.

TABLE 1.—*Estimated Area under Coconuts*

Countries.	1921.		1930.	
	Acreage (in millions of acres).	Percentage of total of acreage.	Acreage (in millions of acres).	Percentage of total acreage.
<i>British Empire countries—</i>				
India (a)	1.2	21	1.4	20
Ceylon	0.8	14	1.1	15
British Malaya	0.4 (b)	7	0.6	8
British South Sea Islands (c)	0.4	7	0.6	8
British West Indies	0.1	2	0.1	1
British Borneo, Kenya and other British countries ..	0.1	2	0.1	1
Total	3.0	53	3.9	53
<i>Foreign countries—</i>				
Dutch East Indies (d)	1.1	20	1.5	21
Philippine Islands	1.1 (e)	20	1.4	20
Foreign South Sea Islands(f)	0.2	3	0.3	4
Siam	0.1	2	0.1	1
Mozambique, French Indo- China and other foreign countries	0.1	2	0.1	1
Total	2.6	47	3.4	47
Grand Total	5.6	100	7.3	100

(a) Excludes a number of Indian States, data for which are not available.

(b) Based on the acreage for 1924 shown in Table 20.

(c) Excludes Cook Islands for both years and native reserves in New Guinea for 1930, the data not being available.

(d) Estimated on the basis of the official figure for 1917 (949,000 acres).

(e) 1923.

(f) Estimated on the exports from the whole group, and the exports from, and acreage in the Japanese Mandates.

Note.—The aggregate estimates compare fairly well with an estimate given in "Copra and Coconut Oil," by K. Snodgrass. Writing in April, 1928, and therefore referring presumably to 1926, the author states, "On the basis of data obtained from official documents and by direct application to government representatives in the tropics, it appears that the area devoted to the cultivation of the coconut palm is probably not much more than 6 or 6½ million acres."

TABLE 2 (E.M.B. Table 91).—*Foreign Trade of the United Kingdom in miscellaneous Coconut Palm Products*

Product.	1909-13 (aver- age).	1924.	1925.	1926.	1927.	1928.	1929.	1930.	1931.
Coir fibre and yarn :—	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Imports—									
India	12,496	20,494	23,794	18,187	18,308	21,675	22,352	22,927	20,571
Ceylon	3,777	8,382	8,439	6,883	7,032	5,854	5,580	5,857	8,274
Other countries ..	236	486	487	636	1,543	714	1,772	726	394
Total	16,509	29,362	32,720	25,706	26,883	28,243	29,704	29,510	29,239
Exports and Re-exports..	3,866	14,840	16,602	13,023	13,658	15,224	15,832	16,535	15,647
Net imports.. ..	12,643	14,522	16,118	12,683	13,225	13,019	13,872	12,975	13,592
Coir mats and matting :—	000's	000's	000's	000's	000's	000's	000's	000's	000's
	sq. yds.	sq. yds.	sq. yds.	sq. yds.	sq. yds.	sq. yds.	sq. yds.	sq. yds.	sq. yds.
Imports—									
India	} (a)	3,069	3,064	3,739	4,046	3,801	4,572	4,766	5,332
Other countries ..		734	836	699	1,245	1,531	1,564	1,341	1,231
Total	(a)	3,803	3,900	4,438	5,291	5,332	6,136	6,107	6,563
Exports and Re-exports..	(a)	229	209	285	256	312	352	331	243
Net imports.. ..	(a)	3,574	3,691	4,153	5,035	5,020	5,784	5,776	6,320

(a) Not available.

(b) Included in " Other countries."

The Palm

Many species of cocos are known in the group of monocotyledons which includes the coconut palm. *Cocos nucifera* is at present found growing naturally in the eastern as well as the western hemisphere. The members of genus cocos growing in cooler climes remain small in stature, but the coconut palm grows with true tropical luxuriance to a height of 50-100 feet with a stem diameter of 18 or more inches. It is curious that in the last fifty years this palm became so important to the rest of the world. In Europe and America the present generation was the first to learn the uses of the cocos palm products, such as margarine and other vegetable fats, palm oil soap, and of mats, brushes and other things made of the fibre. This was accompanied by a revival and extension of the palm culture in the tropics, and in a short time copra, the dried endosperm of the coconut, became the chief export product of native agriculture in the Dutch East Indies, and afterwards from the Philippines, Ceylon, British India, some islands of the West Indies, and from some parts of Africa.

Cocos nucifera has become almost entirely a cultivated palm. As a monocotyledonous plant the palm has no taproot and no side branches ; it has no massive trunk which can be sawn into planks, it does not grow in thickness, but only in length, it has only 20 or 30 leaves at a time and they are all in a tuft at the top. The roots, growing in a circle round the foot, become strong and fairly thick, but do not go very deep into the ground. The trunk or stem of this palm is a hard casing with a spongy substance, through which the sap is drawn upwards. The hollow centre of old palms, when the filling has been removed, is so large, that such stems are often used as water-pipes. The scars left on the stem, where the old leaves have fallen off, give it a rough appearance.

Old palms grow thicker at the base in consequence of the pressure exerted by the weight of the continually lengthening stem. The leaves at the top are from fifteen to twenty feet in length ; they have a thick mid-rib with from 60 to 80 pairs of long and narrow leaflets all along it, each of these may be 20 inches or so long and also have strong mid-ribs. The cocos palm therefore has a feather-like leaf. The enormous inflorescence takes place in the axis of the leaves and is at first enclosed in a sheath, but this dries up and falls off. The inflorescence may be six feet long and male and female flowers appear in the same inflorescence ; fertilisation takes place by means of insects and the wind. Each flower is in itself not large, but there are many of them. After fertilisation the male flowers fade and drop off and a year later the heavy fruit may be seen in the tops of the palms.

In describing the inflorescence and the subsequent fruit the Bulletin of the Imperial Institute may be quoted :—“ The flowers are produced on a branched spadix, which in its young state is enclosed in a tough tubular spathe situated in the axil of a leaf ; they are unisexual and both pistillate and staminate flowers are borne on the same inflorescence, the former being situated towards the base of the branches. The perianth consists of three outer and three inner segments of a yellow or greenish-yellow colour ; the stamens number six ; the ovary is three-celled, but at an early stage of development two of the cells become abortive, and only one finally matures.

“ The fruit is a drupe, usually three-sided with rounded angles, more or less ovoid in outline, but varying considerably in shape according to variety. It takes nearly a year to arrive at maturity and then measures 10 to 12 inches or more in length by about 10 inches in breadth. The outer husk is usually bright green in colour, but some

varieties produce yellow, red, bluish-brown or black fruits. In cross section the fruit is seen to consist of four distinct layers—the thick fibrous mesocarp, which is situated just below the outer skin or epicarp, the endocarp or shell of the nut ; and the white endosperm which is usually spoken of as the kernel or 'meat'. The hard shell of the nut is marked with three 'eyes' that correspond to the three carpels of which the fruit is composed. The embryo, which under favourable circumstances develops into a young palm, is situated just beneath the largest of the three 'eyes'. In the early stages of development the cavity of the nut is filled with water, and the kernel is of a creamy consistence. As the fruit ripens some of the water is absorbed and the kernel becomes firm in texture. When mature the watery contents of the nut only partly fill the cavity and may be detected by shaking. At this stage the fruit is considered fit for gathering for use as food or for the preparation of copra. A green fruit, the total weight of which is about 3 kilos. (6½ lb. approximately) has the following percentages of component parts :—Husk 30·6, shell 10·0, fresh kernel 29·4, water 30·0."

Lekkerkerker gives the following figures for the weight of the nut :—" A fully ripe fresh coconut weighs from 4 to 5 lb., this weight being accounted for as follows :—Husk 35 per cent., shell 13 per cent., kernel 30 per cent., and the milk 22 per cent."

Habitat of the Coconut Palm

The coconut palm grows well on coasts consisting of mostly coral sand with a large proportion of common salt in the soil. It is not readily liable to disease, but needs much sun, water and warmth.

The best soil is that found in the alluvial flats along large streams which are not liable to excessive or prolonged floods, but excellent results are obtained in deep sandy or gravelly loams. At the end of the fifth year after planting the plant possesses a definite trunk and when nine or ten years old begins to bear fruit abundantly. Pests such as boring beetles, rats, flying foxes and squirrels do considerable damage by feeding upon the young nuts and also upon the terminal bud or "cabbage" (Vide Bulletin of Imperial Institute, Vol. III. No. 3, 1905).

According to Lekkerkerker it does not live where the annual rainfall is less than 50 inches, and to prosper exceedingly well it should have at least 75 to 100 inches of rain per annum, unless either by artificial irrigation or some other natural supply, such as rivers or

backwater lagoons, an ample supply of water is assured. In places where the average annual temperature is less than 75° F., the tree does not thrive and at altitudes above 2,650 feet or so the fruit does not ripen. The Bulletin of the Imperial Institute states that being essentially a tropical palm, whilst it can grow up to the 25th degree, north or south latitude, it rarely ripens fruits in the extreme limits of this region. It definitely thrives with an average mean temperature of 80° F. and a rainfall between 60 and 80 inches.

It is not intended in the present work to deal with the subject of copra, except in passing, but to confine one's attention to the fibre obtained from the husk of the nut, and suggest methods for its more rapid recovery, better treatment and in consequence indicate some new uses thus rendered possible.

Maturity of the Nut

The question of the maturity of the nut best suited for the extraction of coir fibre is one about which there has been considerable controversy. It has to be remembered that copra in most cases is the main quest and possibly the degree of ripeness of the nut for obtaining good coir may not coincide with that for obtaining the best yield of copra.

There has not been any real proper investigation on this point but on the other hand it is stated that the greatest quantity and the best quality of coconut oil is most easily and cheaply produced from copra obtained from nuts gathered when fully ripe.

The Bulletin of the Imperial Institute, which apparently gathered its information from Ceylon, states "For the preparation of Coir the coconuts should be gathered before they are quite ripe. The fibre becomes coarser as the nuts ripen and then requires to be soaked for a longer period in order to free it from the corky tissues with the result that the coir acquires a dark colour."

According to information communicated by Sampson on the West Coast of India it is generally accepted that "good quality Coir is made from the husks of ripe nuts which have been harvested before the husk has ripened and dried."

Copeland states that "as the ripening of the nuts goes on, the coir becomes exceedingly lignified and so dark, harsh and brittle that its value decreases very materially."

Fowler and Marsden in dealing with this question state that their "experiments indicate that the riper the nut the less dense is the mesocarp and the more easily it is resolved and the fibres separated.

Comparative experiments showed that the extraction of the colour-producing principles was more rapid, and discoloration of the fibre correspondingly less, with a ripe husk than with an unripe one.

The change in weight and chemical composition of the coconut is summed up in the following table of the results of analysis of San Ramon Nuts by Walker, as quoted by Copeland in his book :—

“ The table gives the weight of each part of a nut and the percentage of the whole nut. The figures are averages, based on the number of nuts indicated at the head of each column :—

TABLE I.—*Analysis of San Ramon Nuts, by Walker*

	Sea-shore 1000.		Inland 1000.		From one tree					
					Hardly ripe, 10.		Fairly ripe, 9.		Dead ripe, 10.	
	gms.	%	gms.	%	gms.	%	gms.	%	gms.	%
Husk ..	897	38.0	703	30.8	2,779	70.0	1,268	51.1	520	33.4
Shell ..	282	11.9	291	12.7	227	5.8	214	9.4	201	12.9
Meat ..	647	27.4	688	30.1	405	10.3	465	20.6	453	29.1
Water ..	537	22.7	603	26.4	547	13.9	437	18.9	384	24.6
Total ..	2,363	100.0	2,285	100.0	2,958	100.0	2,384	100.0	1,558	100.0

Choudary effects an interesting comparison of Walker's analyses of San Ramon “ dead ripe nuts ” and of Malabar nuts by Norris. These are shown in Tables II and III below, and also the chemical composition :—

TABLE II

	San Ramon nuts (Walker)			Malabar nuts (Norris)		
	Gms.	% on total.	% on total (disregarding water).	Gms.	% on total.	% on total (disregarding water).
Husk	520	33.3	44.2	329	37.7	42.6
Shell	201	12.9	17.1	145	16.6	18.8
Meat	453	29.1	38.7	298	34.1	38.6
Water	384	24.6	—	101	11.6	—

TABLE III

	San Ramon nuts (Copeland).			Malabar nuts (Norris).		
	N. %	K ₂ O %	P ₂ O ₅ %	N. %	K ₂ O %	P ₂ O ₅ %
Husk	23.2	53.4	0.8	18.3	66.7	18.6
Shell	9.5	12.9	20.7	6.6	3.7	1.5
Meat	63.3	33.7	78.5	75.1	29.6	79.9

Choudary remarks then " the experiments of Fowler and Marsden indicated that the husk from unripe nuts gave a dull coloured fibre and took longer to ret. It seems to be clear that the best way to harvest the nuts for the production of good coir is to permit them to ripen on the tree until they fall."

At the same time this statement must be accepted with caution for as yet no really definite confirmation of the degree of maturity necessary for the extraction of good coir is available.

On the other hand it is claimed that by methods of chemical retting the ripeness of the nut and the time in which it has been in storage is immaterial. Here again this remains to be proved, but it is certain that excellent results have been obtained with nuts gathered in Ceylon and India and stored for as long as six months after being transported to this country.

Harvesting the Crop

Closely allied with the question of maturity there is the question of the methods of harvesting the nuts on their removal from the tree. In South India and also in other places where the nuts are plucked in the unripe state, they are cut down by climbers who ascend the trees with the aid of notches cut in the trunk or by means of a short girdle which they wrap round the ankles so as to give them a grip round the tree trunk. In districts of South India where such methods of harvesting prevail, fully dried fruit are seldom seen, and in general the coir industry flourishes in such localities. The climber gauges the ripeness of the bunch of nuts by tapping one of the fruits with his nail, the sound thus emitted affording a gauge of the amount of moisture in the husk, i.e. the degree of maturity of the fruit. If

ready, the whole bunch is cut. If methods are found for the production of good coir from dried nuts, then a great labour problem will be solved, for owing to the laborious nature of the work of climbing and the small remuneration attached to it, of economic necessity, the supply of climbers is becoming smaller and smaller as time goes on. On the other hand, if unripe nuts are required for the best grade coir, and cutting from the tree is necessary, then in many places a complete revision of existing practice would be essential.

In Malaya, for example, no fruits are harvested until they are dead ripe and in many other places where labour is scarce and expensive, nuts are only collected from the ground when they are fully ripe and have fallen from the tree. Labour which can climb trees is, in many places, not available, and in any case the method of cutting is more expensive than letting the nuts ripen and fall naturally. It is essential therefore, in face of these facts, that the question of retting should be examined to see if the ripe nut could be made to yield coir as good as the green variety.

It must be borne in mind, however, that two methods of approach to this problem are open :—

- (1) the improvement of cottage retting methods,
- (2) the introduction of retting upon a factory basis for large quantities, and by chemical methods.

In any case it will be best at this stage to process from the harvested nut and to examine the products therefrom as recovered. Obviously, the removal of the husk is the first step.

Removal of the Husk or opening the Nut

The manner at present adopted by the natives is to have an iron or wooden spike or sharpened stake stuck rigidly in the ground. The point of the stake is struck by each nut in such a manner that the force of the blow causes the point to penetrate the husk. This penetration splits the husk away from the nut into two or three parts, which are readily separated. One worker treats about 1,000 to 1,500 nuts per diem in such a manner. In other places the splitting is done by means of a peculiarly shaped iron tool almost like a chopper, the worker remaining seated on the ground and chopping each husk open individually.

Machines are available for this purpose (*vide* Larmuth and Bulmer, Ltd., Manchester, and Fairbairn Lawson Combe Barbour, Ltd., Leeds). The complete nut is placed in a hopper over the centre of

the machine and as it passes through it is divided into three portions by the circular cutters or millers. The blades of the cutters cut right through the husk, shell and nut, all of which fall beneath the machine and are then separated each away from the other. The husk is now ready for retting, and the kernel for separating the shell to be made into copra.

Copeland records that in Samoa, it is customary to split the entire nut, husk and all, at one and the same time.

Choudary states that the splitting of the nuts on the West Coast of India occurs not later than four days after they are plucked from the tree, during which time they are kept in the shade. On the other hand, on the East Coast the nuts may be stored for months before splitting.

The husk, split by striking against a sharp flat edged wooden spike, is usually separated into four pieces. It is said that iron spikes tend to discolour the fibre, but nevertheless they are frequently used. The split husks must be kept in the shade and not exposed to the weather, but soaked with as little delay as possible. If dried before soaking, or wetted by rain, discoloration of the fibre results.

The whole of the fibre is thus usually removed except the short and little fibres at the upper end of the nut covering the three eyelets.

Where coconuts are a plantation crop the nuts are usually husked in the field, except perhaps when water transport is readily available. Husking has not been an expensive job by manual labour and possibly a husking machine would not be more economical, considering the present distribution and conditions of the industry. Although in India 1,000 to 1,500 nuts are usually a day's work, Sampson records that in the West Indies the husking of 2,000 nuts per diem has been regarded as a daily task. He further states that the unhusked fruit occupy in bulk about $4\frac{1}{2}$ times the space of husked nuts and from the point of view of weight the unhusked fruit may be from 60 per cent. to 112 per cent. more than the husked.

On the West Coast of India the yield of fibre from 600 nuts is roughly one hundredweight. This number will vary somewhat in other countries as the thickness of the husk is a very variable quantity. Some of the West Indian strains of coconuts have, for example, a thin husk while those of East Africa have a very thick husk. The size of the fruit also varies greatly according to the fertility of the soil and variety grown. Working on Indian figures, however, it can be taken that the annual crop from an acre would give 5 cwt. of coir

fibre, i.e. the crop from 3,000 nuts. The capacity, prior to chemical retting, of a machine for the preliminary crushing of the husks is given as 8,000 a day, i.e. the total crop for the year from about $2\frac{1}{2}$ acres. Six harvests a year would be necessary if the husk has to be green for fibre extraction ; thus for one harvest this machine would have to deal with the crop from about 15 acres each working day. It is obvious therefore that in many places the cost of transport is of vital importance to a scheme of chemical retting on any large scale, except perhaps where water transport is available.

Before proceeding further let us recapitulate the several parts of the opened nut as now exhibited.

Outside is the husk, then the shell and inside this the kernel. The outer skin is a thin, leathery, waterproof "epicarp" (epidermis or outer skin), by means of which flotation on water is possible, whilst the nut retains its living properties or potentialities for germination unaffected. Immediately beneath the skin comes a thick "mesocarp", consisting of a mass of fibres called "coir", between which is a mass of cork-like substance which ultimately becomes the coir dust. Fowler and Marsden state that the word "coir" is the translation of "kayira", meaning rope.

The very hard shell, about one-eighth of an inch thick, forms the "endocarp" and encloses the seed. The seed is composed of a thin brown skin, enclosing the white endosperm or oleaginous white "meat" (when dried known as copra), around the embryo, which is very small. The hollow of the nut contains the coconut milk, which, in the case of absolutely ripe fruit has become "water", the fats having been largely absorbed.

The hard shell of the nut is marked with three eyes that correspond to the three carpels of which the fruit is composed. The embryo, which develops into the young palm, is situated beneath the largest of the three "eyes".

We now come to the crux of the whole fibre question, namely, how is the separation of the fibre from the husk to be effected?

Separation of the Fibre from the Husk

It has become an axiom amongst those workers engaged in scientific investigation of industrial processes and practice that there is always a good scientific basis for established industrial practice even though this may be unknown to those actually performing the several functions of the process itself. Thus, when one considers the question of soaking and retting of the coconut husk in the tropics, although at

first sight there may seem to be somewhat haphazard methods employed, yet closer observation will probably reveal that there is reason for each and every part of the performance. Let us therefore first of all review the various methods utilised at present for soaking the husks and then later study the question from the point of view of more recent discoveries in modern science and industry.

Soaking

Choudary, in his excellent and critical review of the various factors regarding the retting of coconut husks outlines very lucidly the methods used for soaking of coir on the West Coast of India.

(1) The husks are usually soaked in pits by the side of the backwaters, which are provided with a channel to allow the water to flow in and out according to the state of the tide. To accommodate 1,000 nuts, a volume of 250 cubic feet is allowed, with a water depth of approximately four feet. The soil and water conditions for the sites of the retting pits are carefully selected since the owners realise that certain conditions produce the right colour and quality of fibre.

The knowledge thus utilised, perhaps empirical, but born of experience, is sound and as will be seen later, is based upon the presence of a suitable admixture of sand and clay in the mud and the amount of water movement in the mud of the river or backwater. The pits are basin-shaped, but in contour may be square or round. The husks are laid in the basin of the pit upon a carpet of coconut or palmyra leaves and the whole mass is covered with further leaves after pressing the husks hard and levelling the top surface. The whole mass is then weighted down to prevent flotation when the water is admitted. The latter is admitted through a small deep channel, and the tidal action should leave the husks, if effectively set in the pit, undisturbed in position. Choudary states that the narrow channel is opened just before high tide, in order to let out the dirty water which has accumulated and is closed once more as soon as the flood of the tide has effected a complete change, so that the pit is filled again with clear water.

(2) In other cases the husks are enclosed in a coir net, which is securely weighted and affixed to four stakes driven into the bed of the backwater, at the corners of a square. This method is frequently used in ponds and rivulets of fresh water not subjected to tidal action.

(3) Soaking is commonly done on the West Coast of India in enclosures, divided off from the lagoons or backwaters. Places where a constant water depth of 4 to 5 feet is maintained are selected,

and stakes of bamboo or poles are driven in as the primary foundation of the boundary of the enclosure. The interspaces are then filled in with coconut leaves or cadgans, whereafter the husks are put into the enclosure so made, covered with leaves, pressed down by the feet, and weighted in position. The poles project 18 inches above water level and are firmly fixed in the mud. This method finds more popular favour than the others mentioned above.

(4) The Bulletin of the Imperial Institute (Vol. X, No. 2, July, 1912) makes the following statement:—"In the preparation of the best commercial coir by modern methods, the husks are retted by being steeped in tanks of water warmed by steam, thus shortening the treatment considerably."

(5) Copeland, in his book gives an insight into modern practice in the Philippines wherein he states that in the best equipped factories the husks are soaked in concrete tanks in fresh water and for only two or three days. They are then removed and subjected to a mechanical decorticating or combing device, which holds them against a revolving cylinder furnished with long sharp teeth in the periphery. The combing is repeated four times or so. After this the fibre is washed by brushing in fresh water until practically clean, then it is sun dried in open yarns or upon concrete courts. The fibre thus obtained is combed again when dry, before sorting.

Investigation of Factors concerned in Retting

Before passing to a discussion of newer chemical methods of retting, etc., let us examine the processes involved in the natural methods outlined above. Two outstanding pieces of research work on these points are available, namely that of Fowler and Marsden, and that of Choudary. The former workers devoted their attention to the microbiological and bacteriological aspects of the process, whilst the latter closely investigated the relative importance and functions of the several factors involved in retting as ordinarily practised. Fowler and Marsden concluded that the process of retting was due to organisms which were derived from the coconut husk direct, irrespective of water conditions, and they elucidated the activity of such organisms fully. Their argument may be quoted as follows:—"If the coconut husk itself carries the bacteria which assist the sproutlet of the seed to force its way through the husk, and these bacteria in the presence of water are able to disintegrate and destroy the matter binding the fibres together, then soaking in water under suitable conditions should permit them to develop their activity

and whether the water is salt or fresh should be immaterial so long as the necessary conditions for maintaining full bacterial activity are assured. The main condition for this would seem to be a controlled temperature and a sufficiently frequent change of water to prevent the killing of the bacteria by any accumulation of toxic life-products". After an exhaustive and logical sequence of experiments, they stated the following opinions :—

(1) That the effective retting of the coconut husk requires only suitable water-conditions. The effective organisms reside in the husk itself, and can exert their full influence in water changing sufficiently frequently to prevent the organisms being poisoned by the products of their action, provided the change is not so violent as to remove too rapidly the accumulating bacteria, etc. That temperature plays a part, and that the influx of cold water retards the retting process by diminishing the activity of the organisms.

(2) That the blue-black colour of the water and the dulling of the fibre are due to its coming into contact with ferruginous water brought down by fresh-water floods from inland, forming tannate of iron with the tannin-matter in process of extraction from the husk.

(3) That the brown colour of the water on first setting to soak is due to the tannin-matter extracted with the juices and that the reddening of the fibre is caused by exposure of the husk to the action of the air, the tannin-matter being highly oxidisable and readily convertible into coloured, insoluble phlobaphenes, similar to the oak-red obtained from the tannin of oak-bark. The growing organisms remove oxygen from the water, and if their activity is checked by fall of temperature, or they are washed away by too rapid a flow of water, the dissolved oxygen in presence of oxidising enzymes suffices to oxidise some of the residual tannin and cause discoloration.

(4) That the cork or pith of the husk is not itself the binding material, but that it is associated with a gum, mucilage or hemicellulose, which is disseminated throughout its cells, is insoluble in water and can be resolved by the action of bacteria or by treatment with water under pressure or by chemical agents. The nature of the tannin-matter however will preclude the possibility of obtaining a coir equal in quality to that obtainable by natural retting unless it can be removed by working under anaerobic conditions.

For producing good coir the conditions near Anjengo appeared to be the best suited, as there the husks are soaked in submerged fields of a fair area, the water being sufficiently shallow for the warming effect of the sun to have full value in accelerating the rate of retting and the narrow openings in the bunds regulating the flow of water and preventing the change being too rapid. No appreciable oxidation of the tannin-matter in the husk can take place therefore and if the openings into the "fields" could be closed at flood time and clean water alone admitted, at high tide say, and any entry of ferruginous water thus prevented, there would be a diminished risk of "blue" fibre being obtained.

As regards shortening of the period required for retting, experiments have shown that it might be feasible to set the husk to soak until the bacterial growth is well established and softening has commenced; then to lift, pass between heavy squeezing rollers and return without delay the squeezed husk to another pit, already prepared. The bacteria could then more rapidly remove the binding matter and since a period of (five weeks sufficed for the complete disintegration of a husk in the laboratory the present requirement of ten or twelve months might be reduced to a period of at least three months.

Now let us turn to the work of Choudary and examine his conclusions.

With regard to the freshness of the husks for soaking his experiments showed that it was far easier to beat soaked fresh green husks than soaked stored husks, i.e. whether soaked in salt or fresh water. In point of time, the stored husks took 1.8 times as long to beat as the fresh husks, showing that the economic factor of labour costs comes into the matter. The colour of the fibre, an important item in assessing its value, from the stored husks is invariably deeper and darker than that from the fresh husks showing that when once the husks are dried, mere water retting alone even under the best conditions, the fibre will be discoloured. It is thus obvious why the current practice postulates that the husks from the freshly harvested green nuts, should not be exposed to storage, etc. for more than 48 hours after removal by splitting. Exposure to sun and weather, results in the husks not soaking properly, the fibre being distinctly more difficult to separate, discoloured and more pithy. The conclusions of Fowler and Marsden would indicate that the nature of the water had little to do with the efficiency of retting, provided that proper conditions of flow and temperature were maintained, etc.

Choudary's work confirms this view largely. He found that there is no difference observed in the ease with which fibres can be separated from husks soaked in fresh, as compared with salt water. The colour of the fibre is very nearly the same. He made one vital observation, however, regarding the relative merits of the two methods, namely, that if the husks are kept in fresh water in ponds for as long a time as they are in salt water they are ruined. The salt in salt water or brackish water prevents over-fermentation without discolouring the fibre, whereas the same is not the case with fresh water. Even with salt water one year seems to be the maximum time of soaking, if loss of colour, strength, and brilliancy are to be avoided. If, however, the husks are removed from fresh water after six months' soaking, the trouble does not arise, neither does it do so if frequent movement of the water, i.e. removal and renewal is maintained. Further experiments upon the addition of salt to fresh water retting tanks, led to the conclusion that "salt does not in any way add to the essential quality of the water for retting." The two main advantages of the salt water method are (a) the constant changing of water due to tidal action and in consequence the continuous removal of deleterious matter which has been created; (b) the time of soaking may be extended to 10 months, thus rendering the process more complete and further, giving greater purity of product with ease of extraction. Where fresh water has to be used it is found that running water is a great advantage, and a shortening of the time of retting by as much as one third is recorded.

Whatever may be the method of soaking, the husks have to be soaked until complete separation is possible and incidentally not for a longer time in fresh water than in salt water. On the West Coast of India the husks are soaked for from six to ten months, and somewhere about the mean of these two figures, i.e. eight months may be taken as about the minimum necessary, under ordinary conditions, to obtain the best coloured fibre. In fresh water soaking, after about seven months, the outer skin gets rotten and cannot easily be removed, therefore the husks should in these cases be removed when they are well soaked after about six months. It has been found that the period of soaking can be shortened by crushing the husks before soaking. A simple crushing machine consists of two heavy rollers, similar to sugar cane crushers, and immediately after splitting the green husks are passed through such an arrangement. If, after soaking husks so crushed for one month, they are removed from the

retting pit and again crushed, upon subsequent restoration to the retting pit the action proceeds more rapidly, the period of soaking being appreciably shortened even reducing the time to as little as three months. To sum up, therefore, it would seem that the time of retting could be reduced, if the economic factors involved made it worth while, and secondly, thanks to the workers mentioned above, a much more complete understanding of current practice is now extant.

Extraction of the Coir from the Retted Husk

Before treating the subject of chemical retting, it would be well to note the methods used for extraction of the fibre after the retted husk is recovered from the pit. When the husk is sufficiently soft it is removed from the pit and any adhering mud or slime is removed by washing in fresh water, the outer skin being peeled off with the hand by squeezing. The husks are then placed upon wooden blocks and beaten with wooden mallets to separate the soft inner fibre from the cork and pith, the latter being eliminated by the beating and shaking. The fibres, still wet, are next spread out in the shade to dry, and when this is attained they are threshed with smooth bamboos about 6 or 8 feet long, thus accomplishing a two-fold purpose of freeing the fibre from entanglement and from residual pith or dust. Smooth and soft fibres should result from the treatment. The fibre, after extraction should not remain wet for more than 24 hours and should be dried in the shade. Drying in the full sun is reputed to render the fibre more difficult to spin, even after re-wetting. As thus obtained the material is now ready for willowing. A hand driven willowing machine is used, which consists of a cylindrical drum in the axis of which revolves a wooden shaft carrying a number of teathed blades set spirally and radially on its axis, which pass through similar teeth fixed to the inner part of the machine at the top and bottom. The pith and cork are thus removed leaving the clean and soft fibre ready for sorting and subsequent processing. Two persons can thus willow some 300 lb. of fibre in eight hours. There are variations of the willowing process but in all cases the object is to secure clean fibre free from pith, dust or cork, and ready for subsequent use.

It will be convenient at this stage to leave the description of these uses until a consideration of other methods of retting has been accomplished.

Chemical and Mechanical Methods for quick Retting of the Husks

It is generally recognised, that provided the raw material from which the start of a process is made, is of the same type and quality, great uniformity of final product can be obtained by carefully controlled and manipulated chemical treatment. It would seem a *sine qua non* that previous to chemical treatment the husk should be split or crushed as much as possible, a factor which may not be economic except upon a fairly big scale. In the study of such processes one may perhaps concentrate upon a discussion of some three or four methods of more recent origin, and different in principle. As to crushing there are already machines on the market for this purpose, but special apparatus is provided to render the husk in the most suitable form for specific treatment in two of the methods described below.

Apart from this, one machine exists wherein the husks, fresh from the opening, are passed through heavy rollers into which they are fed mechanically and continuously through a hopper from above. One of the rollers is so arranged that it is capable of movement sliding backwards and forwards to meet the requisite variability in husk size. Although only occupying a floor space of 5 sq. ft., it is claimed that such a machine could deal with 8,000 husks per day, i.e. the total yearly crop from 2½ acres of plantation, approximately, thus requiring a large area and further, good transport facilities. The husks, crushed in one way or another, are then ready for one of the retting processes, the details of which may now be described.

(1) *The Nanji Process*.—An Indian scientist, Dr. D. R. Nanji, working in the University of Birmingham, studied the question of retting and separation of various vegetable fibres, one of which was coir. Owing to the low economic price level prevailing in the coir industry, his process has not yet found commercial application, and even so, still needs careful investigation before adoption. The process briefly consists in the treatment of partially crushed green or dry husks with a mixture of lime or sodium sulphate or sodium carbonate containing a trace of aluminium sulphate at steam pressures of 80–100 lb. per square inch, for a period of 1–2 hours. On such treatment the inter-cellular pithy substance gets completely loosened from the fibre proper. It is then removable by washing off the digestion liquor and the remnant drops off completely in willowing or opening after subsequent drying. It is claimed that the strength of the fibre is not affected by the treatment although the colour is

darker than that of commercial coir. The fibre so obtained is, in general, finer than that obtained by ordinary retting, and the best results are obtained with green husks freshly opened, although dried husks are quickly responsive to the treatment.

(2) *Elod and Thomas Process*.—A similar method is apparently covered by Elod and Thomas in a U.S.A. patent taken out in November, 1931. They state that the material is immersed for a short time in hot water, pressed, immersed again for a short time in hot water, after which the embedded fibres are separated from the cork and pith by mechanical treatment. During the second hot water treatment, substances of "the slaked lime type" are added to the water and discoloration is thus avoided.

(3) *Rowell Process*.—A further method on similar lines is described by C. V. Rowell in E.P. 338,561, in 1932. The mesocarp and shell of coconuts may be decorticated by being subjected in a compacted condition, in a closed chamber, to steam gradually raised to 550–900 lb. per square inch, the temperature being substantially equalised throughout the mass from 8–50 seconds, and the material extruded under steam pressure through one or more constructed orifices.

This process is claimed to be more economical and effective than retting in warm water or steeping in alkali solutions, followed by cutting or crushing. The fibres come out loose from the steaming chambers, the waste as mud and liquid. The whole fibre mass is then washed, after which the fibre is ready for drying into a condition for manufacture.

The pressure is varied for different fibres ; for instance, for coconut husk and hard dry stock it is from 800–900 lb. per square inch. This process is claimed to be applicable to mature nuts.

(4) *The Van der Jagt Process*.—It is claimed that by this method it is possible to extract the fibre in marketable form from fully matured nuts in less than two hours by chemical and mechanical means. The method also covers the subsequent spinning and weaving, and since matured nuts can be used it is stated that copra can be produced in the same factory, utilising the waste, the shell and coir dust in suction gas generators, to provide heat and power to drive the machines and dry the products. There is no doubt that such co-ordination of all branches of the industry would be most economical but it remains to be seen whether the methods now proposed could accomplish this. A full description of the Van der Jagt process has appeared in the "Engineer" for June, 1912, and can be consulted for details.

The raw husks are fed on to a conveyer and opened in a husk preparing machine. A second conveyer takes the opened husks to the boiler in which revolves an endless chain, equipped with paddles, carrying the husks round with it in a weak solution of caustic soda, raised to the boiling point. After boiling for the requisite time, adjustable by the speed of the endless chain, the soft weak husks are conveyed to a machine which not only opens but squeezes them thoroughly. The opening is performed by pinned bars fitted on chains moving at different speeds and finally the excess caustic soda solution is expressed from the fibre by means of fluted rollers. It is stated that the liquor thus recovered can be used again for boiling fresh charges, in fact the caustic soda seems to be only utilised to start the operations. Thus the process is really more mechanical than chemical. A picker card, specially constructed to work fibre more than 100 per cent. wet, re-opens the compressed fibre, and discharges it on to a conveyer which delivers it to a softener and cleaning machines which equipped with six pairs of fluted rollers, removes the last remnant of coir dust from the fibre. The material passes from the fluted rollers immediately on to a series of six pinned rollers, which after opening it out once more, cause separation of the coir dust ; the action of cleansing and dust elimination being continued in the machine, where the fibre passes through four sections each of four rollers.

The fibre is now dried mechanically and softened for the spinning process which is to follow. The latter process is accomplished in an ordinary jute softener. The coir fibre so obtained is adapted for carding and thence forward, the process is carried out on machinery similar to jute machinery, with modifications to meet the special characteristics of the fibre. At the delivery end of the breaker card, there is an arrangement for subjecting the sliver to heavy pressure in order to keep it together. The sliver is collected in four reels, side by side on the same shaft and is then fed into a finisher card.

From this stage a set of drawing frames of the ordinary jute type are employed and at the conclusion of this process the material is spun on a self-regulating gill spinner of the ordinary type, suitably modified. It is claimed that coir fibre can be thus spun into one lea yarn or 48 lb. yarn.

The cost of a complete unit, inclusive of buildings and bungalows for employees, for working five million coconuts per annum is given as £40,000. Coir so produced has been woven into sacking for transport of manures, etc., and is certainly softer than the ordinary type

of coir produced normally. It is, however, considerably darker in colour than the best fibre produced ordinarily. This process is one for which full patent rights have been acquired. It would seem, however, that such a softening process would render the fibre unsuitable for many of its ordinary uses, and yet for cordage purposes and textile uses in new spheres of utility, it would undoubtedly have to meet the competition of other fibres of similar character. The economic consequences are therefore undetermined.

(5) *The "H.G." Process, with ionised oil.*—This process, developed by E. V. Hayes-Gratze of London, is the subject of a series of patents, and is distinct from any other in regard to the method and the material used. It is adaptable to either factory or co-operative village conditions.

Taking full cognisance of the existing methods for extraction of coir, it is proposed in the following short resume, to divide the description of the Hayes-Gratze process into three sections so that its alternative applications to existing methods and conditions may be understood, namely:—

- (1) General outline of the process with mechanical and fluid treatment.
- (2) The treatment and softening of coir fibre already extracted and available.
- (3) Adaptability to the widespread extraction by native labour and methods.

For bulk production at a central factory the process would embody:—

- (a) The handling and treatment of the whole nut and husk.
- (b) The handling and processing of the husks alone.

In the former case (a) the nut can be extracted and husk removed in one operation, effected by a single machine, the useless "core" or top where the stem had been connected being cut away and the husk (fleshy pith and fibre) sliced into sectional layers running lengthwise with the grain of the fibre therein.

The husk is therefore ready for retting treatment and the nuts for cracking and extracting of the kernel for copra, etc.

The husk contains a considerable percentage of moisture and coloured matters, etc., and as these are apt to stain the fibre during treatment, the sections are compressed or rolled to exclude excess of these substances, after which they are passed continuously through one or more washes of water (preferably hot) and then rolled again.

The next operation subjects the husk sections to immersion in a solution of water and ionised water-soluble H.G. oil, having a pH value of not less than 7, the solution being maintained for preference at boiling point, or not less than 200° F. The period of immersion depends on the freshness of the husk and will vary from 1-4 hours during which time the mass of saturated pith and fibre is kept in constant movement and subjected to intermittent mechanical pressing and rubbing action by a special machine combining the tank and pressure jets, etc.

This machine ensures removal of the bulk of the fleshy and other extraneous matter through suitable grids and frames by allowing it to sink to the bottom where its removal is facilitated. The extracted fibre piles up at one end and may be removed at periods or continuously.

The ionised oil not only facilitates the splitting up and separation of the fibre and adhering matter, but has the effect of being absorbed by the former. The fibre is thus softened to an extent which enables it to be spun and woven on machinery of the jute type, eliminating the necessity of "flattening" the filaments, thus leaving them with their natural sectional structure. It is claimed moreover that the colour is lighter and elasticity improved without impairing their natural strength.

After removal from the ionised oil machine the fibre is pressed or rolled to exclude the excess of liquor; the fleshy matter or pith being treated in the same manner and the liquor returned and used again. By this means very little oil is wasted and that remaining on the fibre facilitates the subsequent operations of brushing, combing, carding and spinning, etc. It may easily be made into a sliver, impregnated or dyed, moreover it is absolutely immune from bacterial attack and enables the worked yarn or fabric to be self-scoured.

An even greater flexibility and softness may be imparted to the fibres by washing them after they have been pressed or rolled (following the oil treatment) if they are then dried and again immersed in a second solution of ionised oil and water, squeezed again and finally dried.

No appreciable loss of oil or liquor (beyond the small percentage absorbed by the fibre) should occur during these operations and the excluded fluid is returned to the tanks.

The ionised oils undoubtedly have a bleaching effect as well as being easily emulsified.

It may be noted that the splitting of the husk into sections enables the division or separation of the coarse and finer fibres to be attained more easily.

The fibre may be carded and spun immediately after the squeezing following the oil process, providing machinery for this purpose is available.

(b) Alternatively, if the split husks, i.e. those husked on the field, are received at the factory for treatment, these are sliced into sections by a special cutting machine, immersed in water, and then compressed or rolled, thus enabling the bulk of extraneous juices to be removed, after which the procedure is exactly the same as already detailed.

Quite apart from the large amount of coir fibre already extracted and in existence, the supply is bound to continue to come from existing methods of extraction and sources. This fibre is unsuitable for fine spinning or making into thinner fabrics, and the fact that it may be softened by the ionised oils at low cost might be useful.

The procedure is described as follows :—

The fibre is first immersed in hot (or preferably boiling) water for 30 minutes to 1 hour, then pressed or rolled to exclude as much moisture as possible. After drying it is placed in a tank containing the H.G. ionised oil and water solution and boiled for about 1 hour, the immersion period depending on the quality and fineness of the fibre. The solution is then excluded, the fibre dried and is ready for the following processing as previously detailed.

With regard to the uses of the oil for local extraction by native labour, the method should reduce the time for retting from months to hours. Assuming financial and other problems preclude installation of large plant, it may be advisable to form small co-operative "centres" where the husks can be treated. This would enable the operations for cutting or sectioning the husks, mechanical action during immersion in the ionised oil solution and rolling or pressing, to be carried out in semi-bulk fashion. On the other hand, individual or small growers can instal a tank to contain the oil solution, heat this from a fire made with shell or waste and immerse the broken husks for several hours, agitating occasionally. The loosened fibre and fleshy matter or pith must then be pressed or drained after which the fibre is cleaned and washed by the usual methods as performed after water retting. The consumption of oil will naturally be higher but further saving could possibly be effected by allowing the husks to dry partly (failing facilities for squeezing) and then steeping them first in a tank containing "used" oil solution.

The provision of suitable tanks should not present any great difficulty as these may be, if necessary, made of concrete, etc. at low cost. It is claimed that any extra cost, if such ensued, would be more than compensated by the saving of time, higher yield and better fibre, quite apart from doing away with the pollution of water and other unpleasant effects of existing procedure.

Claims regarding the process are to a large extent being vindicated. It must be remembered, however, that full scale experiments on a manufacturing basis have not yet been completed ; on the other hand, samples submitted in sufficient quantity to be treated on ordinary jute machinery have been successfully carded into a sliver and spun with little modification of the ordinary jute process. The colour of the fibre so produced left little to be desired and it was demonstrated that by further treatment the fibre could be almost bleached to a pale straw colour, although in so doing, there was a slight loss of strength. In any case, the process is now being developed and large scale plant is already designed and installed in London, and in view of the new uses for the fibre resulting therefrom, it is worthy of careful consideration and investigation.

Before passing on to the discussion of subsequent treatment of the coir, there are two aspects that seem to call for investigation. Although the question of salinity of the retting liquor has been closely observed, yet the question of alkalinity, or in general, the pH value of such liquors has been apparently largely disregarded.

That such is of importance is indicated by the bacterial action which is stimulated upon ordinary pit retted coir fibre in contrast to the chemically and mechanically separated material. Retting with a view to subsequent dyeing or even with a view to subsequent utilisation, may become a possibility when conditions, etc. are more definitely controllable.

Sorting the Fibre

Before utilisation, the coir has to be sorted into the various market gradings. The fibre has to be subjected to a process of combing or hackling with a view to ready separation into sorts of different lengths and qualities. Roughly, a threefold commercial classification is made.

(1) "*Mat Fibre.*"—This is of the finest quality and is spun into yarns for the manufacture of ropes, twines and matting.

(2) "*Bristle Fibre.*"—A coarser and thicker quality employed in the manufacture of brushes and brooms.

(3) "*Curled Fibre.*"—A short variety, used for mattresses or for stuffing upholstery as a substitute for horse hair, etc.

Any dust or refuse resulting from such separation may be used locally as a manure or as fuel.

It has been suggested that the opening of the husk and sorting of the fibre could be mechanised. A method has been put forward by a British firm of machine makers and briefly may be described as follows :—

After the retting is complete, by any method, the husk is quickly passed through a crusher, and the crushed and retted husks are conveyed directly into an opening machine. Here they are seized by a pair of fluted rollers which carry the husks through to a cylinder and hold them whilst a serrated or toothed drum extracts the fibre and so shreds the whole husk up completely. In the extraction of the fibre, facilities can be provided for the separation of fibres of various degrees of fineness. The first treatment would subject the husk to the action of a steel drum, round the periphery of which are fixed steel teeth. The teeth attack the husk and tear away the fibres. If the process is only partially completed on this machine and the husk then subjected to a similar treatment on a drum clothed with finer teeth, the second product naturally completed the extraction of all the fibre except that next the skin or outer layer. The outer layer consists of long, harsh, strong fibres known as "bristles" or "brush" fibre. This needs special treatment. The bristle fibre is passed into steel combs several times, and finally, after being freed from all extraneous matter, is dried, sorted in sizes, and made up in bundles ready for the brush makers.

The above processes separate the classes of the fibre mechanically and keep distinct the separate qualities of the fibre. Of course, if this separation is not required the whole extraction can be done in one treatment. The fibre and the separated dirt and former adhering matter now fall together and are transferred to a willowing machine. This consists essentially of a gauze cage capable of rotation, attached to the axis of which are rapidly rotating steel beaters, carried spirally. The cage rotates slowly and the beaters rapidly, thus ensuring thorough willowing and cleansing. The waste matter, dust, dirt, short bits of fibre, etc., are thrown out through the interstices of the mesh of the cage and the fibre remains to be gradually withdrawn as the process is completed. By tilting the cage, the length of time of operation of the treatment can be controlled at will. The fibre is now ready for drying, either normally or by artificial heating methods.

There seems to be a point here for investigation. Can quick artificial drying yield the same fibre characteristics as ordinary methods? A partial bleaching action would seem to go on simultaneously with drying and one is tempted to wonder whether some form of irradiation during the process would ensure a better product.

The speed of such a process as outlined above is obvious. On the other hand, Choudary and others have shown that removal of the husk from the pit and mechanical crushing during the time of ordinary retting greatly reduces the period necessary. This is the principle of the Van der Jagt and in part of the H.G. systems.

Mechanical action is maintained during the whole time of treatment continuously, so that the question of mechanical opening does not arise directly in their processes.

Sorting, however, is important, and no doubt both manual and machine methods could be profitably employed. The whole point would seem to become economic and if insufficient quantities are available for machine treatment without undue transport charges, then probably hand methods would prevail for sorting. Local conditions of production and marketing have to be considered in this regard. Nevertheless, just as in India the jute industry has progressed towards industrialisation in factories, and the cotton spinning and weaving industry has moved similarly, it may be that the future of the coir industry, in conjunction with the copra and coconut oil industry, will traverse a similar path. In any case, the latter has already done so to a large extent, the power-driven driers and oil presses quickly replacing the older methods.

It may be argued that such developments would have a profound effect upon the economic life of the country in the coir producing districts. History shows that wherever progress is made from manual to power production, from the cottage industry to the factory, economic life is altered for a large number of people. On the other hand, history shows, as exemplified in the jute industries, that such transition inevitably results in larger production and a great increase in the number of the personnel employed. Such economic dislocations are therefore to a large extent only temporary. In the ionised oil process, use can be made of coconut oil, ionised and suitably treated, and on this account it is worthy of close investigation.

Utilisation of the Residues from Fibre Extraction

It has been estimated that in point of weight the yield per nut of the pithy and cork-like matter constitutes as much as 70 per cent.

of the husk. At present this is a waste product, which is largely irrecoverable. The mechanical and chemical retting methods suggested above make this portion of the nut definitely recoverable. Van der Jagt suggests its use as a source of gas or for combustion to supply heat and power, along with the shell, etc. Hayes-Gratze suggests that it is recoverable as a fine dust for which a variety of uses could be found—amongst others he mentions its possibility as a substitute for cork dust.

On the other hand, as Sampson has pointed out, in most countries coconuts are generally husked in the field and these are often spread on the ground to form a mulch as well as to assist in the maintenance of the fertility of the soil. Thus the idea of rendering the waste residues, which are highly carboniferous and contain a fair proportion of nitrogen, into manure may be examined. The scarcity of manure for purposes of tropical agriculture is often a serious matter in the production and development of various forms of cultivation. The creation of manure from waste products on the spot, with only minor transport costs, is worthy of consideration.

Sampson quotes comparative figures regarding the amounts of nitrogen, potash and phosphoric acid present in coir dust and cattle manure. His figures are appended below:—

				<i>Cattle Manure. lb. per ton.</i>	<i>Coir Dust. lb. per ton.</i>
Nitrogen	..	..	..	21·73	9·75
Phosphoric acid	..	..	..	10·66	1·54
Potash	..	..	..	4·00	2·24

The analyses of the fresh and the retted husk suggest that there is not an excessive loss of fertiliser ingredients in the process of retting, except in the case of potash.

<i>Calculated on Dry Weight.</i>				<i>Fresh Husk. Per cent.</i>	<i>Retted Husk. Per cent.</i>
Nitrogen	..	..	..	0·53	0·74
Ash	..	..	..	6·71	8·07
containing					
Phosphoric acid	..	..	..	0·111	0·076
Potash	..	..	..	2·65	0·15

These figures for comparison of coir dust and cattle manure are taken allowing the same amount of moisture in each (50 per cent.), and the latter refers to stall-fed bullocks in the tropics. It is evident that in this form, as taken from pit retted husk, the value is considerably less than cattle manure, but on the other hand, there may be, as a result of research, a method—bacterial or otherwise—as is known for other carbonaceous materials, of rendering the final product more valuable in this direction. Alternatively, it is probable that the dust will prove to be most economically used as fuel in the process, especially where copra drying is done continuously and would supplement the supply of shell for this purpose.

Experiments are also being conducted to explore the possibilities of utilisation of coir in the form of short fibres, say less than one-eighth of an inch in length, as a reinforcing medium and consolidation basis when admixed with plastics, such as rubber, cement, plaster, etc.

In the former case attempts are being made to produce material to withstand abrasion such as might be experienced by leather, etc., and in the latter to evolve a medium suitable for casts, moulds, etc. which may be subjected to the rigours of weathering on the outside of buildings or for decorative ceilings, etc.

The highly polished surface of the coir, however, militates against good adhesion in ordinary plasters, but combined with ionised oil and rubber latex, a compound is obtained which has distinctly promising characteristics as an imitation leather.

The coir dust which has proved most efficacious for admixture with pitch or bitumen consists of 6–7 parts by weight of coir waste or short ground fibre up to $\frac{1}{8}$ in. in length together with 3–4 parts of granular coir pith or waste fleshy matter, recovered after the retting process by beating or in the waste liquors of the ionised oil method, of the right size of grain to mix correctly in the plastic mass. Such plastic mixtures have been applied successfully to pipe and cable coverings with excellent results as a protective medium.

Properties of the Fibre

Before turning to a discussion of subsequent manufacturing processes and uses, it may be well to review the existing scientific data relative to the fibre. It is extraordinary how little is known and how little has been done to investigate the fibre as a chemical or physical material and to study its possibilities of exploitation in

new directions, having regard to its peculiar characteristics, or the possibility of modification of the same, thus rendering it suitable for utilisation in new spheres of industry.

Kirk (Textile Manufacturer, March 15th 1931) states that Claviez working in Saxony, gives the fibre as being tubular in section and by freezing he was able to reduce the material to its ultimate fibres, finding that such were one two-hundredth of a millimetre (0.005 mm.) in diameter. Copeland quotes a table taken from Lecomte's "Textile Vegetaux" which gives the data for the size of ultimate cells of the various textile fibres of commerce and shows that the ultimate individual coir cells are the shortest of all commercial fibres extracted from plants having an approximate length of 0.7 cm, and an average diameter of 20 microns.

The long strands, which are more commonly referred to as the coconut fibres, have a length of 30 cms. or so, depending on the nut from which they are extracted whilst the diameter is somewhere about 0.3 cm. Copeland states that the cross-section of the fibre is roundish and somewhat heart-shaped, "the concavity or groove along one side being the place where the vessels were located. The fibre is strongly lignified and to this is due its colour and harshness and its relative brittleness as compared with pure cellulose fibres."

Heerman and Herzog give the average length of the ultimate coir fibril as 1 mm. and its mean breadth as 16-18 μ . Of the total area of cross-section (given as an average of 168 sq. μ) 76.8 per cent. is cell wall and 23.2 per cent. lumen. They give the metric number of the fibre as 4717. The fibre is described as being of reddish brown colour, the cross-section being fasciculate and polygonal. The fibre is highly lignified. The lumen is round and somewhat narrow. The end of the fibre is blunt and stumpy, whilst a microscopic investigation shows that the pores in the fibre are small and oval. In the ash the chief constituent is composed of siliceous particles of yeast-like appearance, grouped together. Matthews in his book on "Textile Fibres" gives the average fibre length as about 10 inches and consists of a smooth, stiff, elastic filament which possesses remarkable tenacity and curls easily. He gives the fibre elements as being from 0.4-1 mm. in length and 12-24 microns in diameter, the average ratio of length to thickness being 35. The cell wall is thick, although irregularly so, and the lumen consequently has an irregularly indented outline. Pore canals penetrate the cell wall. The surface of the fibre bundles is occasionally covered with small lens-shaped silicified stigmata, about 15 microns in breadth. Matthews states that "These stigmata fuse together on ignition, giving a blister on the ash".

Microchemical Reactions

Matthews quotes a table showing that coir gives the following microchemical reactions :—

<i>Reagent</i>	<i>Result of Action</i>
Iodine and sulphuric acid	Golden yellow coloration.
Aniline sulphate	Intense yellow coloration.
Schweitzer's reagent	No action.
Neocarmine W.	Olive brown coloration.

Matthews gives the shape of the fibre as oval and quotes its superiority to all other fibres in its resistance to water, mechanical wear, combined with its lightness and elasticity.

Elasticity

Mark has recently suggested that the bundles of long molecular chains of which the ultimate fibrils of coir are built, known as "micelles", are originally orientated almost at random in the fibre and on stretching gradually turn to assume a direction parallel to that of the stretching force. He proposed a formula connecting tensile strength with the dimensions of the various attributes of the fibre, namely

$$F = F_0 \frac{v^3}{1 - \rho + \rho v^3}$$

where v is the extension of the fibre as given by the equation $v = l/l_0$, l_0 being the initial length and l the actual stretched length of the sample, ρ represents the axis ratio of breadth to the length (i.e. $b/l = \rho$) of the geometrical dimensions of the micelles, and F represents the strength of the fibre.

Van Iterson has shown that if fibres are classified by the method due to Sonntag, into ductile and non-ductile varieties, the extension curve of the non-ductile fibres (flax, ramie, hemp, etc.) has the form corresponding to $l = 10b$ in Mark's equation, whilst for ductile fibres, such as coconut extension curves corresponding to $l = 3b$ in Mark's equation are obtained. He concludes that in the unstretched fibres of the non-ductile variety the micelles are orientated almost parallel to the direction of stretching whilst in the ductile class under the same conditions they are orientated obliquely in regard to the fibre axis. The first kind of fibres only allow a small extension and the latter a large one, thus producing a larger range of the extension curve.

The important characteristic of ductility of coir or its ability to stretch beyond its elastic limit without rupture, as well as its power to take up a permanent stretch when so loaded, is of the greatest commercial consequence. Sonntag has shown that ductile fibres are generally highly lignified, but the degree of lignification and the ductility are apparently not directly related, many highly lignified fibres being non-ductile. Sonntag connects the ductility with the physical structure of the cell wall. It has often been noted that striations appear on the lamellae of cell walls. These markings usually form a right-hand spiral on the outer or primary membrane and a left-hand spiral on the inner or secondary membrane, and are generally regarded as indicative of the molecular structure of the cell walls. Sonntag looked for the explanation of ductibility in the arrangement of these spirals. By maceration he isolated the cells and measured the angles made by the striations with the longitudinal axis of the cell. The angle of the micellar planes is often indicated in the pores which follow the line of cleavage. By microchemical methods Sonntag measured the angles between the striations or pores in each membrane and the axis of the cell. His results for a ductile fibre (coir) and a non-ductile fibre (*Cannabis sativa*) are shown below:—

Fibre.	Condition.	Inclination of striations in the		Extensibility of Fibre.
		Primary Membrane.	Secondary Membrane.	
Coir	Air dry	53°—54°	30°—53°	Up to 16·0%
<i>Cannabis sativa</i>	Air dry	90°	4°—8°	Up to 1·27%

These figures clearly show that the striations of the non-ductile fibre in the outer lamella are nearly perpendicular to the cell axis, whilst those of the inner lamella run more nearly parallel to it. In the ductile fibres the striations are obliquely orientated to the cell axis.

Polarised Light

The examination of ductile fibres by means of polarised light shows that variations in the polarisation colours follows very closely the variations in the figures for the angles of inclination of the striations, ductile fibres forming a distinct group. The early discovery of the

significance of double refraction of light by fibrous cellulose structures and its subsequent verification by X-ray analysis is well known. There results from such measurements, therefore, two values of the refractive index for light corresponding to the deviation of the ordinary and extraordinary rays in their passage through the fibre. The difference between these two values of the refractive indices is indicative of the internal structure of the fibre material. Thus with the assistance of what are known as addition or subtraction methods of analyses by polarised light, the position of the optical index ellipse of a fibre may be determined. Heerman and Herzog have shown that most technically employed fibres are optically positive in relation to the axis of their length, i.e. the long or major axis of the index ellipse runs parallel to the longitudinal axis of the fibre. In this regard, however, coconut fibre presents an interesting exception to the rule, in that different from other technical fibres of commerce, it is optically negative. This affords a means of identification and differentiation from other fibres. Thus, from arguments derived from its molecular structure, we should expect to find coir highly extensible and elastic.

With regard to elasticity, Choudary states that a coir fibre will extend by fully 25 per cent. of its original length before rupture, whilst Copeland confirms this figure. He remarks that ropes made of coir will stretch more than ropes made of any other commercial fibres of a similar nature. This property makes coir ropes singularly efficacious where intermittent or jerky strains are concerned.

Coir has another great advantage in that it is more durable than most other fibres, particularly where water exposure is concerned, that is, it is less subject to decay. Its tensile strength and its resistance to decay are illustrated by Copeland in the following table :—

Name of Fibre.	Breaking strength when fresh.	Breaking strength after 116 days in water.
	kg.	kg.
Arenga saccharifera	43	42
Coir	39	24
Jute	30—31	18—21
Sansevieria zeylanica	54	13
Crotalaria juncea	31	decayed
English Hemp	47	"
Calcutta Hemp	34	"
Agava americana	50	"

Copeland concludes :—" Of the fibres represented in this table, then the most resistant to decay is Arenga (the sugar palm, Cabo, Negro), and after it, coir. Arenga is the best of them where it can be obtained, and is accordingly first choice in all such places, but it is not an article of general commerce."

Besides its resistance to decay as indicated above, it has unique powers of resistance to microbiological attack. Eight samples of coir were examined in this regard, three of which, Nos. 1, 2 and 3, were ordinary Cochin fibre retted and separated by ordinary methods, whilst the others were selected as follows :—Nos. 4, 5 and 6 were produced by chemical retting from nuts sent over by the Director of Agriculture, Madras, whilst No. 7 was a further product from Madras nuts, treated slightly differently. No. 8 was a sample of fibre, retted in India which had been subjected to a special softening process in England as an experiment to see if such was possible, without seriously detracting from the resistant properties of the fibre. Two sets of experiments were performed, the modus operandi being described below.

One gramme portions of the material were placed together with 100 cc. of a filtered suspension of soil in tap water (pH 7·05) in flasks and incubated at 23°C. The contents of the flasks were examined after periods of seven and nineteen days with the following results :—

Description of sample.	Observations.	
	After 7 days.	After 19 days (Microscopical examination).
No. 1. Dull yellow	Abundant growth of mould fungi.	Much fungal growth and a slight degree of fraying of the fibre edges. Bacteria were absent. Liquid acid.
No. 2. White to pale yellow.	Abundant growth of mould fungi.	The material was distinctly weak, the fibres disintegrating into their component elements. Fungus mycelium prominent but bacteria absent. Liquid acid.
No. 3. Brownish yellow.	Abundant mould growth.	Fibres showing slight fraying along their margins. Mould mycelium abundant. No bacteria present. Liquid distinctly acid.
No. 4. Light reddish brown.	No obvious change or evidence of growth.	Coir appeared to be in good condition. Bacteria active but mould fungi less conspicuous. No disintegration of fibres. Liquid neutral to bromo thymol blue.

Description of sample.	Observations.	
	After 7 days.	After 19 days (Microscopical examination).
No. 5. Brown ..	No evidence of microbial growth.	Bacterial growth taking place but no evidence of fibre disintegration. Liquid alkaline.
No. 6. Pale brown	No apparent change except for a brown discolouration of the liquid.	Bacteria abundant. Moulds present but less common. No evidence of fibre damage. Liquid slightly alkaline.
No. 7. Reddish brown.	No apparent change except that liquid is slightly coloured.	Bacteria present but no positive signs of fibre disintegration. Liquid slightly alkaline.
No. 8. Light brown	No apparent change except for discoloration of liquid.	Bacteria active but no fibre disintegration. Liquid slightly alkaline.

As far as the experiment progressed it appeared that all the samples of coir exhibited a very considerable resistance to attack by micro-organisms. The first three samples weakened slightly, No. 2 being in the worst condition after nineteen days. It is of interest that these materials had most probably been attacked by mould fungi only and not by bacteria, which are unable to thrive under acid conditions.

The five other samples remain unaffected after 19 days' incubation in spite of the presence of large numbers of bacteria. The neutral or slightly alkaline condition of the liquids appears to favour these organisms rather than the mould fungi.

The second experiment was carried out in a medium designed to facilitate the growth of micro-organisms. The composition of this medium was as follows :—Dipotassium hydrogen phosphates, 0·1 per cent. ; magnesium sulphate, 0·1 per cent. ; sodium chloride, 0·1 per cent. ; peptone, 0·2 per cent. ; calcium carbonate, 2·0 per cent. ; the ingredients being added to tap water. The presence of excess calcium carbonate ensured a slightly alkaline reaction which in the case of the acidified samples Nos. 1, 2 and 3 was of importance since it enabled bacteria to develop. The liquids in the second test were inoculated with soil water and incubated at 23° C. The observations made were as follows :—

Description of Sample	Expt. 1. Contd. from Previous Table.	Expt. 2 (Special Medium).	
	After 87 days.	After 30 days.	After 61 days.
No. 1. Dull yellow.	Slight increase in tendering. Material not appreciably weakened. Abundant fungus growth.	Slight evidence of tendering. Fibres fraying at the edges and easily split by treatment with dissecting needles.	No appreciable increase in tendering. Material soft and fairly easily torn apart. Mould fungus action slight.
No. 2. White to pale yellow.	Tendering slightly advanced. Bulk of fibres still intact but material definitely weakened. Mould fungi abundant.	Material badly tendered, fibres being split up into their constituent elements (fibrillae). This sample was more damaged than any other of the series on this date.	Material reduced to a mush. Abundant disintegration into individual fibrillae. Mould fungus negligible.
No. 3. Brownish yellow.	Material definitely weakened, more so than sample No. 1, much less than sample No. 2. Fibres easily dissected into their component elements. Mould abundant.	Definite tendering of the fibres, many having disintegrated. The remainder break up easily on teasing out with dissecting needles.	Tendering slightly advanced. Material definitely weak. Abundant detached fibrillae but fibres not reduced to the mush condition. Fungi not conspicuous.
No. 4. Light reddish.	No definite evidence of tendering. Fibres still coarse and strong.	No definite evidence of disintegration. Fibres very slightly frayed locally at the edges.	No change in condition. Mould fungi not observed.
No. 5. Brown	Tendering definite but slight. Less than sample No. 1 and 3 (in envelope) Material soft. Fibres dissected into component elements fairly easily. Mould fungi conspicuous.	Fibres slightly softer but do not appear to have undergone much disintegration.	Tendering at most only very slight. No mould growth observed.

Description of Sample	Expt. 1. Contd. from Previous Table.	Expt. 2 (Special Medium).	
	After 87 days.	After 30 days.	After 61 days.
No. 6. Pale brown.	Material not perceptibly weak. Slight superficial tendering. Fungus growth abundant.	Material softer than original but amount of tendering slight.	No appreciable change. Material may have been slightly tendered.
No. 7. Reddish brown.	As for No. 1 (loose)	Fibres have undergone at most only very slight tendering. No splitting up observed.	No change in condition. Mould present but scanty.
No. 8. Light brown.	Fibres show evidence of slight superficial tendering but they are neither split nor perceptibly weak. Mould growth very abundant.	Material slightly softer perhaps but shows no definite evidence of disintegration. Fungus growth at surface liquid very pronounced.	Fibres in bottom half of liquid show no perceptible change. Those near surface are definitely tender although not begun to disintegrate. In all probability specific fungus growth at surface was responsible for this condition.

It will be observed that the prolonged exposure of the first series of coir samples to microbiological action failed to bring about their complete disintegration. One sample only, viz. No. 2, was seriously damaged.

With regard to the second experiment, bacteria grew abundantly in all the liquids due to the stimulating influence of the peptone and the alkaline reaction. In spite of this, four of the samples, viz., Nos. 4, 5, 6 and 7, suffered little damage. Of the remaining four samples No. 2 was almost disintegrated, No. 3 fairly badly damaged, and No. 1 slightly damaged as the result of bacterial action. Sample No. 8 suffered severe local damage due to the action of a specific mould fungus in the presence of air. It is probable that in the

absence of this fungus, little tendering would have taken place. A control in which sample No. 2 was exposed to the action of tap water in which microbiological action was suppressed by the addition of thymol, failed to show signs of deterioration after 31 days' incubation.

In conclusion, therefore, it would appear that, with the exception of sample No. 2, which was susceptible particularly when subjected to alkaline conditions, all the samples of coir are very resistant to micro-biological action. Samples Nos. 3 and 1 appeared to be next in order of susceptibility.

A further and more rigorous test was made independently to determine the bacteriological susceptibility of coir, by according it a test equivalent to attack by bacteria if the material was buried in damp earth for a protracted period. With ordinary retted Cochin or India coir, after 194 days' immersion the cellulose content had dropped from 65·2 per cent. to 45·7 per cent. When chemically retted coir was used on the same test the figures before and after 134 days' immersion were 57 per cent. and 56·6 per cent. respectively. This deterioration is much less than that of any other previously tested, showing the superiority of coir in this regard, and especially of the chemically treated samples.

It would seem, therefore, that coir from chemical and mechanical retting processes as outlined above, is more resistant to bacterial attack than that produced under ordinary conditions. This may be due to the more complete separation of the pith and dust, thus leaving no matter on the fibre likely to decay further under the action of bacteria, as also, as shown by Marsden and Fowler, leaving little chance of the presence of a remnant of the bacteria inherent in the husk, which ordinarily assists in its disintegration during backwater retting. This characteristic will be referred to at length, later, as it is the basis of a new use for the fibre.

Chemical Properties

Very little is known as to the chemical nature of the coir fibre, and analysis shows considerable variation according to the retting, the type of nut and the origin. Sampson's figures for fresh and retted husks are already quoted. In the "Analyst," 1924, pp. 430-431, Mitchell stated that his analysis showed that coir fibre prepared at Mitcham contained 0·013 per cent. of soluble chlorine, whilst Ceylon fibre, according to the same observer, was returned as having 0·019

per cent. Dawson in the same report gave his figures for another sample as being 0·07 per cent. of soluble chlorine, whilst yet another analysis gave the figure as 0·017 per cent. The salt content apparently is influenced by the nature of the retting liquor, a factor which does not come in where chemical retting is employed. Copeland gives figures for the actual mineral content of the ash of the husk showing them to be—

Nitrogen	..	..	..	..	1·609	gms.
K ₂ O	..	..	..	..	3·915	„
P ₂ O ₅	..	..	..	..	0·017	„

He further quotes the following figures for the mineral content of the ash of the husk as due to Bachoffen and Lepine, the former apparently based on an unripe nut.

	Total Ash % of total wt. of nut.	By Lepine. % of total ash.		Total Ash.	By Bachoffen. % of total ash.	
		Salts of K.	Calcium Phosphate.		Potash (K ₂ O).	Phosphoric acid.
Husk ..	6·08	73·69	0·98	1·63	30·71	1·92

Copeland remarks that the coconut uses both in its products and in its body a conspicuously large amount of potash, and further “ to a less conspicuous degree as compared with crops in general, the coconut ties up in its own substance and in its products an appreciable amount of nitrogen. To a still less extent, as compared again with crops in general, it removes the phosphorus of the soil.” Copeland’s book may be referred to for further details on these points which are outside the scope of the present work. There is one other factor which should be considered in regard to the husk, namely the tannin which is obtainable therefrom. Grove Palmer remarks that the tannin present in the fibre serves the purpose of a mordant for basic dyes, and there is, in consequence, no necessity for this part of the dyeing process. Choudary quotes some interesting figures with regard to tannin. He shows that the ratio of tannins to non-tannins in the husk is very low, being 0·2 to 0·4 and the percentage of extractable tannin on the weight of the husk is about 1·3 per cent., a very low value. Bulletin No. 32, Department of Industries, Bengal, found

the ratio of tannins to non-tannins to be 0·2671 and the percentage of tannin extracted on the weight of the coir as 0·74 per cent. They concluded that "the substance is of no use for the tanning of leather." This is correct, but as shown above, the tannin may have its own function in the dyeing of the fibre.

One cannot help remarking once again on the paucity of the chemical information regarding the fibre. Although it is dyed and made into fabric for carpets, etc., the chemistry of the fibre is practically unknown, as also its physical structure. It seems to afford another instance of a raw material which has fallen into an obvious method of utilisation without any attempt at exploitation. Knowledge is wanted for the latter, and until it is available, the industrial development in new direction is seriously retarded.

Uses of Coir

A review of the qualities of Coir as set out above reveals its obvious uses. For ropes it is to be recommended where elasticity or resistance to decay is especially desired, in fact, on account of its ability to withstand the prolonged action of sea water, it has been extensively used in the Orient for making rope and cordage from time immemorial, dating from long before the discovery of Ceylon by Europeans. It served not only for rope and cables but also for fishing net cord, for tying the rafters and cadgan roofs of houses, to caulk boats, for mats and matting and in numerous other ways. The native fisher folk found its property of swelling when saturated with water, and hence giving a tighter joint, combined with its durability, a great asset in boat building and caulking.

On the other hand, its brittleness and its low tensile strength as ordinarily produced placed distinct limitations upon its use. Copeland remarks that "as a textile fibre it is of very little general value because of its coarseness, harshness, brittleness and colour". The qualities of harshness and stiffness and dark colour, all make it an especially good material for door mats, hall mats, matting and "for various kinds of brushes."

Thus its limitations have been prescribed and left largely at that. A glance at chemically and mechanically retted fibre quickly reveals a new vista in the outlook for the future of coir. Research is needed to find if these qualities cannot be modified in some degree, whilst its

good characteristics are maintained. The foregoing facts and figures indicate the start of such work and yet the fringe is as yet unruffled. Hayes-Gratze claims, with some justification, to obtain a lighter product as regards colour. His coir has been so softened as to spin and weave on jute machinery to produce yarn of fineness not before attained with coir. Van der Jagt has spun and woven coir to make gunny bags similar to jute sacks for sugar bags, etc., although the colour was as dark as usual. Such processes, enabling the coir to be spun and woven into softer and more flexible fabrics obviously opens out new uses for it. One of these has now passed the experimental stage successfully, namely, the use and preparation of protective lagging materials for underground pipes, such as gas, oil or water pipes and cables, subjected ordinarily to the corroding influences of bacteria, electrolytic action for tramways, etc., and chemical corrosion from the clay and soil itself in which it is buried.

When one considers the expense involved in repairs to corroded pipes, the pulling up and restoration of a road surface, the traffic delays, etc., it is obvious that modern science must assist in relieving such economic waste. Coir, retted chemically and cleaned mechanically so as to be perfectly free from bacteria or adhesive matter likely to decay, probably affords the solution. It resists decay, bacteria do not disintegrate it, water has no derogatory effect, it is easily impregnated with tar, bitumen, etc., or other insulating materials and now that it can be obtained in carded sliver form with a greater degree of softness and pliability than ordinarily or previously possible, it can be used for such purposes without weaving. If woven, coir presents a fabric of considerable strength, able to withstand the tension of winding and capable of use in band or ribbon form. Softened coir can be used for production of fabric for bags for sugar, etc., produced on machinery similar to jute and there also opens out possibilities for it in carpet manufacture. It must not be thought that retting problems are solved and nothing more is to be done.

The Journal of the Textile Institute, June, 1933, records an interesting experiment recently undertaken by the Indian Jute Mills Association involving the use of jute cloth in road surfacing:—
“ The process briefly is that the road surface, after being scraped and cleaned, is coated with bitumen ; it is then laid with jute fabric—in this case 40”/8 oz. hessian—which is thoroughly rolled to make it adhere to the road surface. The fabric is then again coated with

bitumen, covered with a layer of fine stone metal, and rolled so that the upper coating of bitumen penetrates the cloth and forms a solid mass with the bitumen underneath, and at the same time the stone chips adhere to the bitumen and fabric, producing the wearing surface.

“ Experiments on similar lines have, it is understood, been carried out in Germany and elsewhere, with the object of finding an additional outlet for jute goods. ‘ An experimental stretch of road which was built with jute last summer near Neckars, Ulm ’—states a report on one of these experiments—‘ is behaving exceptionally well, and in fact retains a better appearance than another stretch of road which was built at the same time without jute cloth. This latter, a tar road, has sweated considerably during the hot weather, so that split and sand have had to be strewn on it from time to time. The jute stretch, on the other hand, has so far remained perfectly dry and has needed no repairing. A few weeks ago the whole of the road, with the exception of the jute stretch, had, indeed, to be treated with tar and gravel, and the cost of this work amounted to as much as the additional cost for building it with jute cloth would have been. It is therefore an established fact that the employment of jute cloth in road building renders the road more durable.’ ”

When one considers the superior durability and resistance to decay of coir, as well as its wonderful absorbent properties for pitch, etc., it is obvious that there is a use for coir as a road surface reinforcing medium which should be tried. Experiments in this regard are now being organised.

It is certain, however, that along the path of scientific research in the light of modern chemical and mechanical industries, progress and the future of coir must travel, and undoubtedly the application of ionised oils is one of the directions for coir investigations to be promoted.

On a small scale, i.e. the laboratory and semi-manufacturing scale, the products have vindicated many of the claims put forward by their sponsors, but there is often a long way to industrial success on a factory basis which has to be traversed from these points. Snags, economic and geographical, bestrew the path, yet it is well that such efforts be recorded even if only as an indication and sign-post to point out the way for future workers.

Subsequent Manufacturing Processes

A brief review of one or two factors concerning the processes to which coir is ordinarily subjected, are of interest. Choudary has recorded fully the method of hand spinning in vogue in South India. He records that "The spinning wheel consists of two frames, one of which contains two spindles and is stationary in one end of the spinning yard; the other contains one spindle and is mounted on three wheels and can be moved forwards and backwards.

Two (grown up) persons (spinners) and a girl or a boy to turn the stationary wheel, are required to work on a pair of wheels. The spinners who are generally women take a bagful of fibre each in their left armpit, stand in front of the stationary wheel and hook a little fibre to the two spindles. Then the person who sits at the back of the wheel rotates the wheel towards the left. The two spinners deliver the fibre which is being formed into yarn with the required thickness and walk backwards until the yarns in their hands reach the other wheel which is kept 60 feet distant at the other end of the spinning yard. The two yarns are joined together at their ends and the middle bend hooked to the spindle of the movable wheel. The stationary wheel is stopped rotating for a minute when the two yarns are united and hooked by one of the spinners. The same spinner introduces a triangular piece of wood grooved on two sides (called atchu) between the two yarns at the bend near the spindle. The other spinner stands at the back of the movable wheel to rotate it. The two wheels are now rotated simultaneously and quickly while one walks towards the stationary wheel keeping the two yarns passing through the grooves or channels of the atchu, when the yarns twist or double into coir yarn behind it. The movable wheel has to be moved forward as the length of the coir is shortened. When the person holding the atchu comes to the stationary wheel, he takes off the yarn from one spindle and joins it with the other and one mudi of coir is thus made. The coir yarn is now tied to two trees or posts erected on the ground for the purpose when the coir gets dried and stiff before the evening when it is folded and stored and bundled."

About 75 mudies or 25 lb. of coir is bundled into one bundle and is sent as such to the market. One hundred and twenty mudies of coir each 60 feet in length and weighing about 40 lb. are spun on a pair of wheels by two experienced women and a girl per day of eight hours. On the West Coast of India on the shores of the back

waters almost every house has at least one pair of spinning wheels and carries on the industry on cottage basis. There, with the high price of husks, they earn and live on it.

Choudary also describes the hand spinning of the superior type of coir without wheels, yielding about 3 to 4 lb. per diem of good uniform twist, colour and strength.

This, however, is not general practice and under modern conditions, especially for use in mats and matting, the spinning is done by the wheel in general. More modern plant is also available for spinning by machinery. Machines, power driven are available for spinning by hand in similar fashion to the wheel spinning described above. The spinner, standing or sitting in front of the machine, has the fibre round his waist, and he regulates the quantity of fibre passing to the machine by hand, as so to form a thread of yarn of the thickness he requires. This yarn is twisted by the machine, drawn in, and wound on to the spinning bobbin. These machines are generally made in two sizes, the small one for spinning weaving yarns and the larger one for spinning rope yarns.

A multiple head machine of similar type is also available. Rope machines, balling machines, etc. are familiar to all larger concerns.

With regard to weaving, it has already been recorded that for the chemically and mechanically produced coir the power looms, ordinarily associated with jute can be used. There are, however, recent developments even in this direction which are as yet on trial for coir retted by the ionised oil or other processes. With regard to mat making, Grove Palmer records that a useful loom frame for mat making can be fitted with a warp roller instead of a creel for fine work, thus preventing the chafing of the yarn. It is claimed that such a machine is self-supporting, requires little fixing and is easier to work than the ordinary loom. He also describes a form of cropping machine fitted with dust proof ball bearings. A treadle lifter allows the operator to lift the cutting unit very slightly with his foot, while his hands are free to manipulate the mats. A dust extraction plant is also incorporated, thus rendering the waste available for other uses, fuel, etc.

It is not intended to dwell upon this side of the industry further since, in other branches of textiles, weaving and weaving mechanism is well advanced, and if the fibre can be obtained in more suitable form to be worked profitably on a higher production basis of weaving, then such improvements and advances will inevitably follow. This, therefore, once more turns our attention to matters of production and

treatment of the raw fibre, i.e. the retting involving the chemical, mechanical and bacteriological factors concerned therewith. Truly work of investigation for all branches of scientific thought and effort.

Bleaching

Copeland remarks that chemical bleaching is often practised to render the fibre a better colour. In the use of ionised oils, the paleness of the fibre is a matter of degree and time of treatment.

In his article in the American Dyestuff Reporter (Vol. XVIII, No. 21, 1929) Grove Palmer gives two methods for the bleaching of coir fibre. He also indicates certain improvements which have been made for rendering the fibre suitable for dyeing. He states that the method of bleaching varies slightly according as the fibre is coarse or fine; the difference lying in the greater strength of the solutions required in some cases for the coarser kinds and in others in the longer time of exposure to their action.

For coarse fibres he recommends that after soaking for 24 hours in boiling water the fibres should be macerated with 3 changes of liquor consisting of boiling caustic soda solution for six hours in each case. He then soaks the fibre with hydrochloric acid solution and after such preparation he bleaches the fibre, by immersion for 18 hours in water, with chloride of lime and afterwards plunging it again into a hydrochloric acid bath before washing off and drying.

For finer fibres he recommends a similar procedure but with more dilute liquor and less time of contact therewith.

Grove Palmer further states that "Owing to the colour of coir, the fabrics that are made from it cannot, of course, be dyed in delicate pastel shades; full bright tints are obtainable, however, as well as those of a duller nature, and for these dyes belonging to the basic, substantive, acid and sulphur classes are all available. In order to overcome the impenetrability of the fibre, a process has been brought out (German Patent No. 428,038) for the purpose of assisting the dyer. This consists of steeping the batch in a bath containing 2 per cent. or 3 per cent. calculated on the dry weight of the goods, of sulphite cellulose lye obtained from the paper mills."

He states, however, that on coir, none of the basic colours are very fast to light, whilst there are very few of the large range of substantive dyestuffs unsuitable for the fibre. They penetrate the fibre easily, and give good results as regards fastness to water, light and abrasion. With acid colours, shades are obtained which are faster to light,

washing and rubbing and also which are brighter, giving more brilliant tints, in some cases, than the basic colours. When, however, coir fibre is to be dyed with colours very fast to light and brilliance is of secondary importance, sulphur dyes, within a limited range are used.

Grove Palmer's original paper should be consulted for lists of suitable dyestuffs of the different types as well as useful hints in dyeing technique. Here is afforded a tremendous scope for fundamental research, for without knowledge of fibre composition and structure, its dyeing properties cannot properly be assessed.

The Shell

The present uses of the shell of the coconut are as diverse as the ingenuity of man can possibly make them. Mostly they are used for fuel. During the war large quantities were used for the production of charcoal. Let us consider the products of destructive distillation of the coconut shell.

A still designed for the destructive distillation of the shell is not an expensive item and the experiments described below were carried out in such an apparatus capable of yielding 5 gallons of pyroligneous acid per day. Facilities were provided for the removal of tar and the charcoal obtained. The distillate yielded pyroligneous acid containing small quantities of methyl alcohol, acetone, tar, higher organic acids, and a good proportion of acetic acid. The product was fractionally distilled, with the following results.

1st fraction.—87° to 98°. Methyl alcohol and acetone chiefly. 10 per cent. of the liquid was distilled over this range.

2nd fraction.—98° to 115°. Contained acetic acid. 85 per cent. of the liquid was distilled over this range.

3rd fraction.—Tarry residue for the remaining 5 per cent.

The second fraction was filtered over charcoal several times, the resulting liquid containing 7.75 per cent. of acetic acid. The sample was now redistilled with $\frac{3}{4}$ per cent. of its weight of potassium bichromate (or potassium permanganate), and the first 2 per cent. by volume rejected as being slightly coloured. The next fraction was collected up to a temperature of 115°C., at which temperature all the acid portion volatilised, leaving a small charred residue. The loss in this portion of the process was negligible. This pure sample of liquor

was practically free from all aromatic substances and contained 10 per cent. of acetic acid; 44 lb. of shell yielded $7\frac{1}{2}$ lb. of 10 per cent. acetic acid, and 13 lb. of charcoal.

The value of the pure vegetable charcoal needs no comment. For medicinal filters, and a variety of other uses, it commands a high price. During the war large quantities were used, and apart from medicinal purposes it has a wide field in other directions. It is too valuable a product to be lost.

Bunbury has pointed out that valuable products may be obtained by destructive distillation at a temperature of about 550°C. The nature and yield of these may be seen in the following tabulation:—

	<i>Per Cent.</i>
Moisture	7.60
Total distillate	46.40
Charcoal	35.20
Gas	18.40
Acetic acid	5.79
Methanol	1.12
Tar	5.80

The acetic acid yield is notable.

Other methods of Utilisation.—The ingenuity of the native craftsman has resulted in the use of the coconut shell in a large variety of ways. With a handle attached it acts as a ladle, it is used as a cup, and it is also used as a receptacle for the catching of rubber latex, etc. The wood of the shell is hard and capable of taking a high polish. The property renders it suitable for the manufacture of buttons, an industry that has met with a small amount of success in certain places.

According to Sampson, the amount of shell available can be estimated at about 1,000 lb. per acre per annum on a plantation. Where genuine sun drying of copra is carried out, as in South India, this may be regarded as a waste product but in other places especially where the crop is grown on a plantation scale, copra is prepared in hot dryers, heated by artificial heat and coconut shells are the usual fuel employed. They are ready to hand and cheap and it is probable that such a use in these instances is the most economic. Van der Jagt stresses the point in his process and utilises all forms of waste for thermal purposes, both for coir and copra drying. If the retting of the fibre became a factory industry, then co-ordinated with copra drying, this scheme might eventuate, appropriate for any form of chemical and mechanical fibre separation on a large scale.

Before leaving the subject of the shell an analysis of the ash due to Copeland is of interest from the manurial point of view.

Ash Analyses

Grams, average, in one nut at San Ramon

	N.	K ₂ O.	P ₂ O ₅ .
Shell	0.660	0.947	0.459

Conclusion

The object of this memorandum has been to show how little real scientific knowledge we possess of the coconut fibre.

Scientific investigation of coconut products is a correlated study. There is probably no industry in the world with greater wealth of raw material untapped, no industry so ripe for the application of scientific method and research, no industry where economic production of the manufactured articles could be so accelerated by more careful treatment of raw material. The *via media* is clearly scientific research, hand in hand with close application of the findings therefrom under practical conditions.

A quotation from Bulletin No. 30 of the Department of Industries, Madras, issued in 1931, records a truth which merits careful consideration in relation to coir. It reads :—" There has never been as careful a study of the source of coir and of the natural qualities of the husks of the coconuts under the different conditions as the importance of the product would justify."

At the beginning of their note on the retting of the coconut husk, Fowler and Marsden complain " There is practically no literature on the subject of coir-preparation." This is still the case.

This report is an attempt to begin the application of the remedy for this lack of knowledge and is a modest attempt to sow the seed of scientific research to accomplish this end.

When one contemplates the hidden wealth of our Empire with regard to vegetable fibres, as yet undeveloped in forests and plantations, and untried in commerce or industry ; and if the potentialities of those fibres in new directions could be visualised, fibres which have, in the past, found favour on the market but which, in the light of modern competition and the orientation of fashion or usage in other channels, have become victims of depression, then it would be realised that such attacks on the prestige of a raw material for a

world's industry can only be met by intensive study and elucidation of fundamentals leading to the fullest possible exploitation, perhaps along paths not even dreamt of at present.

The essentials for the development of modern industry, scientific origin, scientific method and scientific uniformity of production and product, must be applied to coir. In the past, coconut fibre, in company with many other fibres has withstood competition from synthetic filaments largely because it was comparatively cheap. The day is over for haphazard agricultural or industrial methods, and if coir is to remain an asset to the East, then along with other coconut products, its fundamental characteristics must be explored by scientific research, thus yielding, as already in the case of coconut oil, knowledge for the development of new products for the amenity of mankind. It must be remembered that the coconut oil industries are of comparatively recent growth and their success directly resulted from scientific research and exploitation. What new future uses may be in store for Coir if properly treated and rendered into a form suitable for the dictates of modern requirements?

In conclusion, therefore, let us all seek to stimulate the desire for scientific research into, not only Coir, but all other vegetable fibres of commerce used similarly. Successful issues from such research will only be attained if such investigation and exploitation is begun immediately for as in other things in life, delays are dangerous.

Acknowledgements

The author wishes to acknowledge with grateful thanks the assistance he has received from many collaborators. In particular he would recall the work of Mr. E. V. Hayes-Gratze of London, of Mr. Van de Jagt of the Hague, Holland, and Dr. D. R. Nanji, who have co-operated in practical experimental work with successful issues as regards products. Also his thanks are due to Mr. C. A. Masterman, Chief Chemist to the Gas Light and Coke Co., Ltd., London, for helpful advice and work on the durability of Coir, as also to Mr. J. K. Anderson, of Messrs. Fairbairn Lawson Combe Barbour, Ltd., of Leeds, for carrying out much practical experimental work in spinning and weaving the products obtained by various systems of retting. To Dr. H. C. Sampson, of Kew, London, to Dr. E. Goulding, of the Imperial Institute, London, and to Mr. F. A. Stockdale, of the Colonial Office, London, the author is grateful for

candid criticisms and helpful facts. He also wishes to thank the Research Control Committee of the Wool Industries Research Association for according him permission to write the Report.

He would also include in such thanks his colleague, Mr. Arnold Frobisher, Secretary of the Research Association, for his help and encouragement during the work. He owes a deep debt of gratitude to Mr. E. M. H. Lloyd, of the Empire Marketing Board, of London, through whose initiative and encouragement the work has largely proceeded. The author's thanks are accorded to Mr. I. G. Evans, of the Department of Scientific and Industrial Research, for facilitating useful contacts for the promotion of experimental work. Finally, the author would acknowledge the patient and careful services of Mrs. G. M. Glead for her assistance in preparing the manuscript.

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BANANA STORAGE

An Account of recent investigations into the
Storage Behaviour of several varieties

By

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PREFACE

THIS Report is the fourth which Drs. Wardlaw and McGuire have written on the progress of their investigations into the effect of storage and transport conditions on certain varieties of West Indian bananas. The previous Reports were published in this series of E.M.B. "Grey Books" in 1931, 1932 and 1933 (E.M.B. 36, 45 and 60) and, together with the following account of further experiments, record the first stages of a piece of long-range research which forms part of a threefold attack on the main difficulties of the West Indian banana industry. This was among the earliest of the problems with which the Board has been concerned; and, although the present Report on the progress made in one branch of the tripartite research will be the last on this subject to appear under the auspices of the Empire Marketing Board, it is rather an interim note of work still in progress than a final estimation of complete results.

The importance of the banana as an economic crop in the West Indies (and in other parts of the Empire as well) needs no emphasis. It is grown both for local consumption as well as for export. In order to make export crops of bananas profitable the growers must be able to keep their production costs at a reasonable figure and at the same time to deliver to the consuming market fruit exactly fit in appearance, flavour and storage qualities for easy handling and ready sale. These two requirements are hard to combine; and, until the present comprehensive research was put in hand, there were such large gaps in the scientific knowledge of the subject that the prospect of more than a rule of thumb solution of the difficulty was remote.

The West Indies grow an excellent variety of banana—the Gros Michel—which behaves admirably in storage and transport, arriving in the British fruiterers' shops in an attractive state of ripeness. It is, however, susceptible to Panama disease, a virulent fungal rot which devastates even the best situated and the best tended plantations. Other difficulties arise with this as with all crops, but Panama disease is by far the most formidable. The attempts which have been made by the Imperial College of Tropical Agriculture, with the aid of grants from the Empire Marketing Board, to discover a banana at once resistant to Panama disease and as suitable as the Gros Michel for the export trade, have followed three main lines. The fungus which causes Panama disease—*Fusarium Cubense*—and the conditions which favour it have been studied by Drs. Wardlaw and McGuire, who made a tour of banana growing countries in the

Caribbean area reported in E.M.B. 20. Secondly, an endeavour is being made to utilise the knowledge obtained from this research by breeding strains of bananas immune to Panama disease. A Report on this work, by Professor Cheesman, has been published as E.M.B. 47. The third of the convergent lines of research, a stage of which is described in this Report, is the study of the behaviour of the immune varieties in storage and transport, with a view to discovering a variety which, like the Gros Michel, will be able to travel uncrated in naked bunches, and which will succeed—where the Gros Michel fails—in escaping the ravages of Panama disease.

While it is too early to say that the desired new variety has yet been discovered or produced, or that the effect of changes in the technique of harvesting and storage have yet been adequately studied, valuable data have been obtained. The Giant Governor, which the investigators believe to be a tall mutant of the Cavendish, often called the Canary banana, has been found to display many of the qualities which fit the Gros Michel for trans-oceanic shipment—shape, symmetry, and toughness of skin—while the experiments here recorded have shown how the ultimate condition of this variety—as regards flavour, colour, etc.—can be improved so as to approach the standard of Gros Michel. Promising results have also been obtained with a rather more delicate hybrid variety, bred at the Imperial College and known as I.C.2; and further trials with this variety, which possesses many of the more attractive qualities of the Gros Michel, are recommended. One valuable contribution to the subject of banana research, which the authors have been enabled to make in the course of their work, is the simplification of the nomenclature by the discovery that many of the names in current use refer to what are, in effect, only a few varieties.

While much has been done by the research so far done to clarify the subject and particularly to indicate the most promising lines for future study, this series of experiments is by no means ended. The E.M.B. takes leave of the authors, in publishing this Report, with the hope that the work will be continued to the benefit of the West Indies and of the Empire as a whole.

PLYMOUTH,

Chairman of the Research Grants Committee.

Empire Marketing Board,

7th September, 1933.

IMPERIAL COLLEGE OF TROPICAL AGRICULTURE,
Low Temperature Station,
Trinidad, B.W.I.

July 8, 1933.

The Empire Marketing Board.

Gentlemen,

I have much pleasure in submitting, on behalf of Dr. McGuire and myself, a report on further investigations into the storage behaviour of bananas.

We consider that the research embodied in this Report constitutes an important advance in our practical knowledge of banana problems. Not only have we examined in some detail the storage behaviour of a new and potentially useful variety, the Giant Governor, but also, for the first time, we have been able to make comparative observations on the new College hybrid known as I.C.2. Further, by a careful study under controlled conditions of temperature and humidity, it has been possible materially to advance our knowledge of the botanical affinities of such difficult and widely spread groups as those represented by the Dwarf Cavendish and Lacatan varieties.

In submitting a report under present circumstances of difficulty and uncertainty, the writer would like to express his sense of the helpful co-operation, encouragement and unqualified support he has received from Members and Staff of the Board during the past five years—a sentiment in which he is sure Dr. McGuire is in full agreement.

I have the honour to be,

Gentlemen,

Yours respectfully,

CLAUDE W. WARDLAW,

Pathologist.

BANANA STORAGE

I. INTRODUCTION

In recent investigations at the College Low Temperature Station, further storage trials have been undertaken with a number of banana varieties to determine their behaviour under commercial conditions, and to assess their value and suitability for export. In these experiments the following varieties, in large or small quantities as material became available, were kept under observation : the Giant Governor ; the Trinidad Governor or Cavendish variety ; various Cavendish types ; Fillbasket ; Gros Michel ; the College Hybrids I.C.1 and I.C.2 ; an assemblage of tall types including the Giant Fig, Lacatan, Bumulan, Martaban and Masak Hijau.

II. THE GIANT GOVERNOR

This interesting variety, locally known as the Giant Governor, is apparently a tall sport or mutant derived from the ordinary Dwarf, Cavendish or Governor variety.* In the field, under average conditions, it is a plant of intermediate stature, much taller than the Dwarf, but definitely not so tall as the Gros Michel or Giant Fig. The stout trunk or pseudo-stem is strongly reminiscent of the Dwarf variety from which it is thought to have originated (Fig. 1).

The fruiting characters show some points of interest. Immediately below the female flowers there is a region of the fruit stem from which the male flowers and bracts drop off ; lower down, near the compact bud, adherent bracts are again encountered. In general, though not in all cases, the bunch habit shows some departure from the normal dwarf type ; as a whole it tends to be more cylindrical, the vertically upturned hands being less spreading. The fruit skin is also more resistant to mechanical injury. In short, other things being equal, the bunch habit is much more suitable for naked bulk transport than the ordinary Dwarf type (Figs. 2 and 3).

The fruit used in these investigations was obtained from a Maqueripe estate. The plantation, situated on a light sandy loam, was established from suckers and bits gathered from the Moruga

* For an account of mutant types of the Dwarf banana, readers should consult Professor E. E. Cheesman's paper (1).

district. Side by side in the same area the Trinidad Governor or Dwarf variety has also been planted. Although both received the same manurial treatment, namely, a basket of pen-manure at the time of planting, the response of the two varieties was very different indeed. In the case of the Governor variety, bunches of moderate size only were obtained, whereas the Giant Governor responded vigorously, and has consistently produced remarkably fine, well-developed bunches. Experience will show whether this holds good for other soil types also.

So far, four bulk storage trials have been carried out with the Giant Governor, the Dwarf or Trinidad Governor from the same and other areas being included for comparison.

First Trial.—On arrival at the Station, the bunches, 50 in all, after having their stems re-trimmed and vaselined, were labelled and given a serial number to facilitate inspection during ripening. At the commencement of loading, the storage-chamber air temperature was 53.4° F. ; 3½ hours later, on completion of loading, the air temperature was 66° F. This was cooled to 53° F. in 28 hours. The chamber was blown out for ten minutes at 6 a.m. and 6 p.m. daily.

In this trial, bunches of the Giant Governor were selected which approximated closely in size and "fullness" to the standard "¾-full" fruit exported from the Caribbean region to English markets, but bunches decidedly more and less than "¾-full" were included for the purpose of accumulating data on the question of maturity in relation to storage behaviour and the rate of ripening.

As the storage trial proceeded it became evident that a good many of the bunches—plant bunches—which appeared to be approximately "¾-full," were obviously more immature, as indicated by their slowness in ripening. In this connection two possibilities have to be considered: (i) this variety may be better suited by higher storage temperatures or (ii) grown rapidly as the result of manurial treatment, the plant may have acquired unusual vigour, and, in consequence, judgment of maturity by the usual criteria was inaccurate. Unfortunately, ratoon bunches were not available.

After 18 days at 53° F. the fruit was transferred to the ripening room maintained at 70° F. The following points were noted (Table 1), parallel observations on the Governor being made as a standard of comparison:—



FIG. 1.—Giant Governor plant with half-full bunch. Note stature of plant.



FIG. 2.—Young bunch of Giant Governor. Note its cylindrical shape.

(Figs. 1 and 2 by courtesy of Messrs. F. W. and P. Urich.)

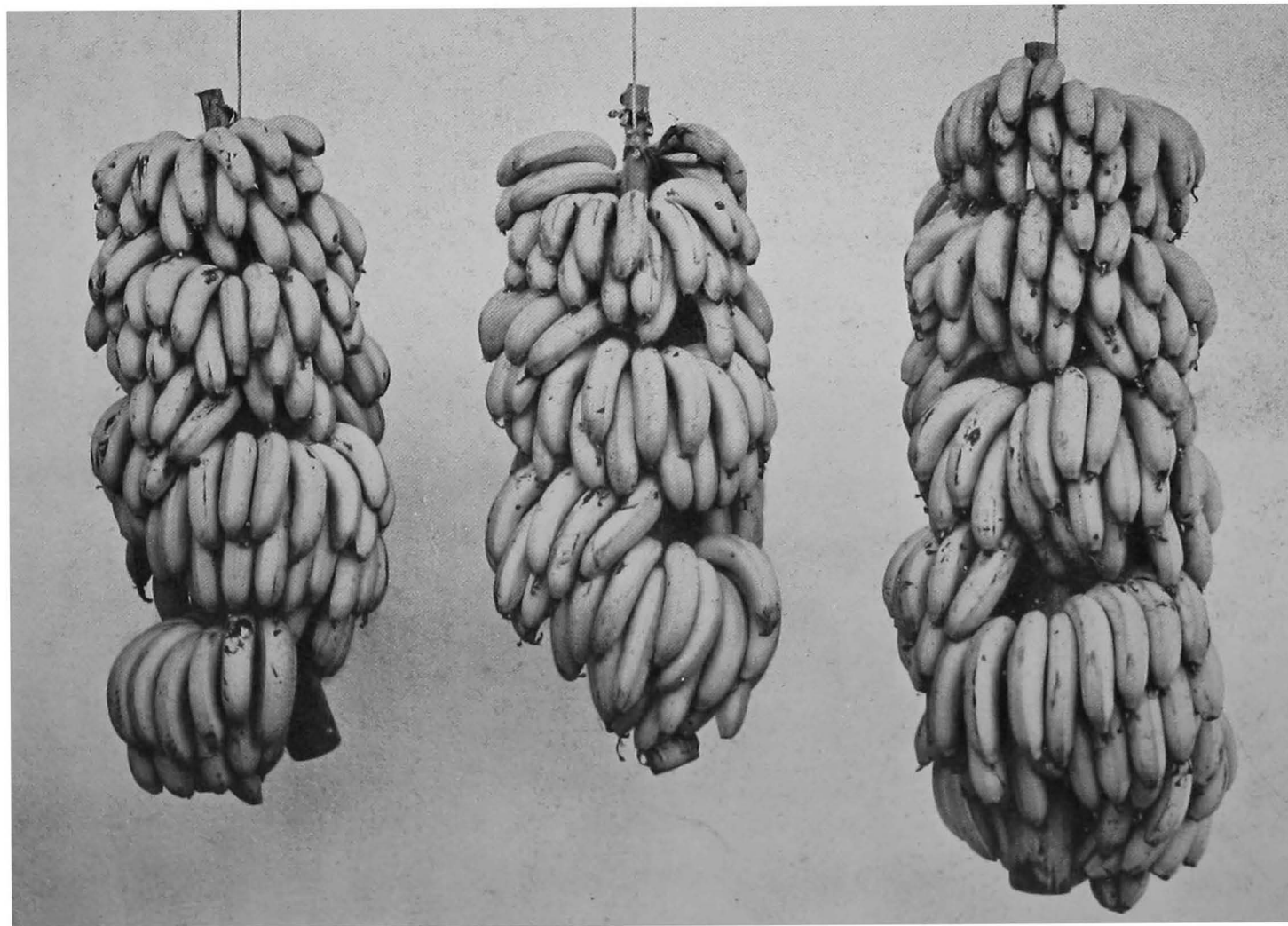


FIG. 3.—Good commercial bunches of Giant Governor, reaped at the correct stage of maturity for transport to British and European markets. (2 nine-hand bunches and one eleven-hand bunch.) This photograph was taken when bunches were being removed to the ripening room.

TABLE 1

	Giant Governors.	Ordinary Governors.
<i>Main-stalk rot</i> ..	15 per cent. showed slight rotting.	13 per cent. showed slight rotting
<i>Pitting disease</i> (4) ..	24 per cent. of the bunches showed some pitting : 13 per cent. very slight, 5 per cent. slight, and 6 per cent. severe.	50 per cent. of the bunches showed some pitting : 6 per cent. very slight, 31 per cent. slight, 6 per cent. severe, and 7 per cent. more severe.
<i>Mechanical injury to top and 2nd hands.</i>	5 per cent.	61 per cent.
<i>Ship-ripes</i>	None.	None.

Two bunch habits appeared to be represented in this collection of Giant Governors. One had a typical truncated-conical habit with curved fingers like the ordinary Governor, whereas the other approached the cylindrical habit of the Gros Michel with fingers folding back towards the central axis (Fig. 3). In later consignments from the same area all the bunches were of the cylindrical type, suggesting that the conical bunch habit is related to cultural conditions or to the physiological status of the plant during the period when the bunch is being formed or developed. Some of the Giant Governor bunches in this consignment had very flexible stems, perhaps due to rapid growth, but in spite of this they showed less transport injury than the ordinary Governor.

Ripening at 70° F. was very slow compared with the ordinary Governors (Table 2).

TABLE 2

	Giant Governor.	Governor.
Bunches ripened by 8th day	27 per cent.	75 per cent.
Bunches ripened by 15th and 12th days respectively.	31 ..	100 ..

After 15 days, 69 per cent. of the Giant Governor bunches had failed to ripen, and were developing a dull russet colour. It was concluded, therefore, that what had appeared to be a standard grade

of fruit was definitely too immature for such storage conditions. On the other hand, of the ordinary Governors, 75 per cent. were ripe on the eighth day and the remainder four days later.

The outstanding feature of this first trial was the fact that the cylindrical bunch habit of the Giant Governor enables it to stand up well to local transport and storage while the fruit skin seems definitely more resistant to bruising than that of the Governor.

The ripe fruit was of good quality and pleasing in flavour and texture ; those bunches which ripened during the first 10 days at 70° F. were of quite attractive external appearance.

Second Trial.—Fifty bunches of Giant Governors and sixty of ordinary Governors from Macqueripe were carefully packed in trash, transported to the Station, and, after the customary re-trimming of the stem, were loaded into a chamber maintained at 53° F.

The Giant Governors were placed on the lowermost tier and the ordinary Governors superimposed by way of again testing the resistance to bruising shown by the former in the preceding trial. This consignment was more uniform than the first, practically all the bunches being approximately “ $\frac{3}{4}$ -full.” The Giant Governors were of excellent bunch habit, and for the most part did not have the hands spaced so far apart, bearing out the assumption that wide spacing is cultural and attributable to rapid growth.

Temperature at commencement of loading was 54° F., and on completion 59° F. ; after 12 hours, 53° F. was attained. After 17 days the fruit was transferred to the ripening room. After five days at 70° F. the Giant Governor bunches were subjected to a critical analysis. The details may be conveniently summarised thus :—

TABLE 3

<i>Main-stalk Rot</i> ..	No bunches showed any marked progression.
<i>Pitting Disease</i> ..	52 per cent. of the bunches showed some pitting : slight pitting, 20 per cent. ; moderate pitting, 22 per cent. ; severe pitting, 10 per cent.
<i>Mechanical Injury</i> to top and 2nd hands.	34 per cent. ; the main stalk, despite its flexibility, behaved as in the first trial, none being broken by the weight of superimposed bunches.

There was a marked tendency in the top and second hands to lesions at the junction of the cushion and the main stalk, the lesions being possibly mechanical in origin. Again, in many bunches, presumably partly as a result of rapid growth and partly as a normal

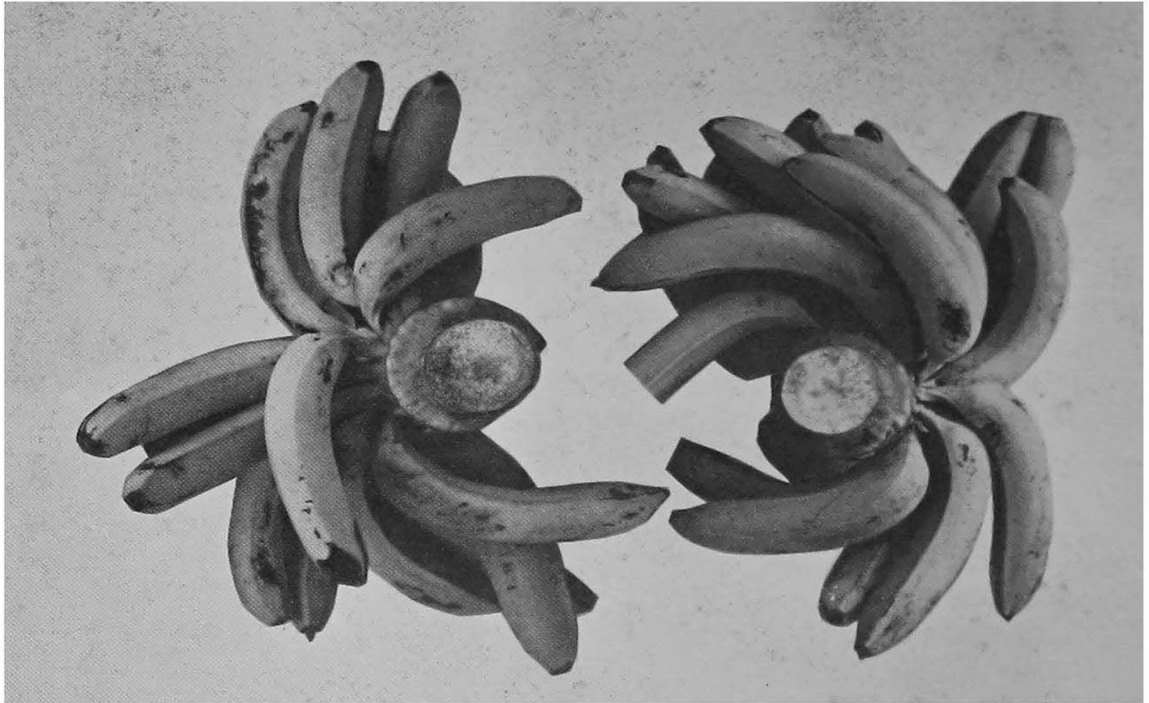


FIG. 4.—Top and second hands of the Giant Governor, illustrating the tendency of fingers to fall apart when bunches are held with the proximal hand uppermost.

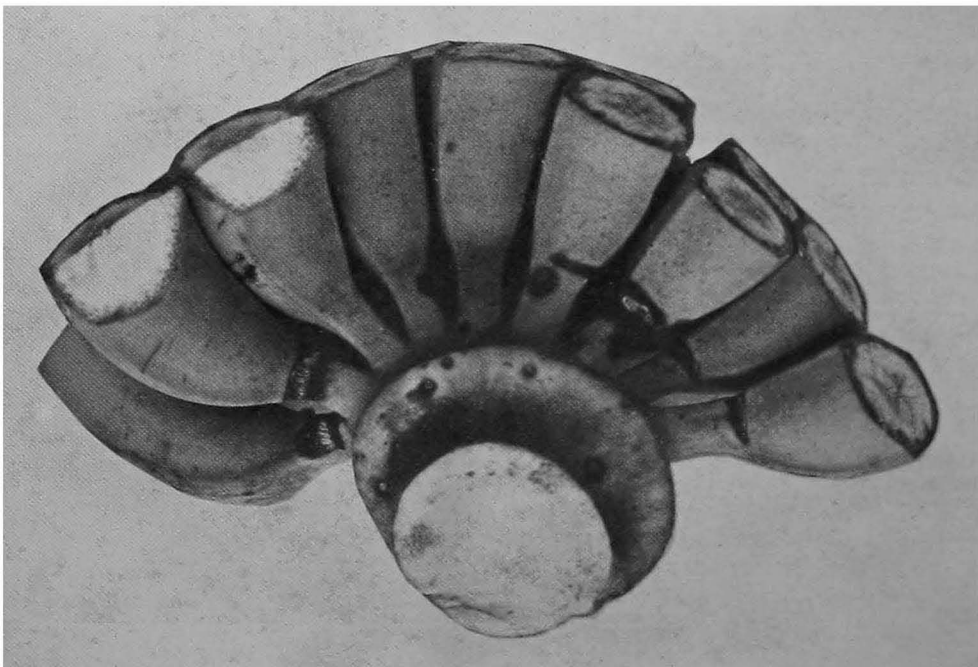


FIG. 5.—Mechanical notching of finger-stalks and pitting disease in the Giant Governor.

varietal characteristic, the individual finger stalks were very long ; where this was the case, many fingers showed slight transverse notching due to the shape and length of the fingers and to the upward and inward pressure during stowage (Fig. 5).

In bunches suspended with the large, topmost or proximal hands uppermost to facilitate inspection, both the cushion lesions and the mechanical notching of the finger stalks were responsible for some loss of marketable fruit through the rotting-off of hands and finger-dropping. In bunches suspended upside-down, i.e. with the heavy top-most hands downwards as is customary in the trade, such mechanical injuries were less extensively developed, and losses through finger-dropping were accordingly greatly diminished. In bunches liable to finger-dropping, the rate of ripening is, of course, the decisive factor in deciding whether or not such bunches can be disposed of profitably.

In bunches suspended with the large hands uppermost, a considerable number showed a marked departure from symmetry during ripening, particularly in the two top hands. The individual fingers which were rigid and upright at the time of reaping and during cold storage showed a marked tendency to sag down irregularly with the onset of maturity. This characteristic, illustrated in Fig. 4, is very similar to what was observed in other varieties such as Bumulan in earlier studies (2). While this departure from symmetry is interesting as a characteristic feature, it should not necessarily tell against the value of this variety, since, in the usual trade practice, the bunches are suspended upside-down and the original symmetry is easily maintained.

In this consignment, which was regarded as a good standard "¾-full" grade, the rate of ripening was again much slower in the Giant Governors than in the ordinary Governors (Table 4.)

TABLE 4.—Rate of Ripening (stated as percentages)

	Giant Governor.	Governor.
Bunches ripened by 5th day	0	22
" " 10th " 	24	75
" " 12th " 	60	92
" " 15th " 	84	100
" " 18th " 	92	—
" still green on 18th day	8	—

In short, on the tenth day 75 per cent. of the Governors, but only 24 per cent. of the Giant Governors were ripe. Such slow ripening would, of course, considerably increase warehouse and ripening costs.

On the whole the results of this storage trial were disappointing. Not only was slow ripening the rule, but at least 48 per cent. of the bunches developed abnormal colouration, including sooty or pasty colour in yellow fruit, and russetting of green fruit, characteristics which suggested chill effects or immaturity at the time of reaping. A further possibility that had to be considered was the question of humidity since, during the prevailing dry weather, low relative humidities (e.g. approximately 70-75 per cent.) had been the rule in our storage rooms. In the third storage trial, therefore, it was decided to raise humidities, to work with a more mature grade of fruit, and to divide the consignment into two comparable parts and store them at 53° F. and 58° F. respectively.

Third Trial.—As indicated above, the fruit used consisted of heavy mature bunches, which, by reference to the Gros Michel, would be described as “heavy $\frac{3}{4}$ -full” or even “full,”* being comparable to fruit shipped from the Caribbean region to American ports. The consignment was divided into two uniform lots which were held at 53° F. and 58° F. respectively. After 16 days the fruit was transferred to the ripening room at 70° F. Care was taken to maintain the relative humidity at approximately 85 per cent. The rates of ripening are shown in Table 5.

TABLE 5.—*Rates of Ripening (Giant Governor)*

Classification.	Fruit originally stored at 53° F.				Fruit originally stored at 58° F.			
	1st day	5th day	7th day	9th day	1st day	5th day	7th day	9th day
Green	84	46	20	12†	87	48	17	4†
Turning	16	33	29	} 80	9	48	43	} 83
Ripe	0	21	51		88	4	4		40	96

* If this grade of fruit, i.e. “full” Gros Michel, was stowed for shipment to English ports, many of the bunches would become “ship-ripes” before the conclusion of the voyage period.

† This represents bunches which were definitely more immature than the general consignment.

From Table 5 it will be seen that the rates of ripening of these lots of fruit were quite compatible with the general Trade practice ; by the fifth to the seventh days approximately 50 per cent. of the fruit was ripe or available for distribution, while, with the exception of a small percentage of immature fruit, all the bunches were ripe by the ninth day at 70° F.

From this experiment it is evident that the successful ripening of this variety depends on reaping at the correct stage of maturity. In fact, only well developed bunches should be selected if expeditious ripening is desired. The figures in Table 6 which refer to the weights of fingers from bunches showing different rates of maturation bear out this point. As a standard, five fingers were taken from the second top hand of the several bunches which were to be compared. These were then weighed and the average weight of one finger obtained.*

TABLE 6

Number of Sample.	Variety and Description of Fruit.	Average weight (gms.) of 1 finger of the second hand.
	<i>Giant Governor.</i>	
I.	From bunches quite ripe on 6th day	253.4
II.	" " " " 9th "	227.6
III.	" " " " 11th "	210.2
IV.	" " still green on 11th day	158.1
	<i>Trinidad Governor.</i>	
	(At 53° F. for 11 days then transferred to 70° F.)	
V.	From full bunches quite ripe on 3rd day ..	210.0
VI.	" heavy $\frac{3}{4}$ -full bunches quite ripe on 5th day	165.0
VII.	" $\frac{2}{3}$ -full bunches quite ripe on 5th day ..	151.0
VIII.	" thin $\frac{1}{4}$ -full bunches quite ripe on 5th day	128.0
	<i>Gros Michel.</i>	
	(At 53° F. for 16 days then transferred to 70° F.)	
IX.	Heavy $\frac{3}{4}$ -full fruit turning on transference and yellow on 2nd-3rd day at 70° F.	225.3
X.	" " " " " " " "	211.2
XI.	" " " " " " " "	199.5
XII.	Heavy $\frac{3}{4}$ -full fruit, ripe on 5th day at 70° F. ..	234.4
XIII.	" " " " " " " "	198.9
XIV.	$\frac{3}{4}$ -full fruit, ripe on 7th day at 70° F.	187.5

* It is not intended that these figures, based on a limited number of weighings should be accepted as absolute standards for the several grades of fruit. In so far as they refer to average bunches whose precise ripening record is known, however, they may be regarded as useful for general comparisons.

From these data it will be seen that the fullest grade of Trinidad Governor (i.e. ripening on the third day at 70° F., after only 11 days at 53° F.) is comparable with Giant Governor which did not ripen till the eleventh day. Normal "¾-full" bunches of the Governor, on the other hand, weighed only 151 gms. per finger against 253 gms. per finger in the Giant Governor ripening at approximately the same time.

Relation to Temperature.—As both lots of fruit were maintained at favourable humidities throughout the trial it was possible to assess critically the influence of the temperature factor. During ripening it was soon apparent that the fruit stored at 58° F. was considerably superior in colour and quality to that which had been kept at 53° F. In the former, the bright pale golden-yellow colour which developed was in marked contrast to the rather pale yellow and sometimes sooty or pasty colour of the latter. In short, most of the bunches held at 53° F. had definitely suffered from chilling. The quality of the yellow colour in ripe fruit and the development of a pasty or sooty appearance, particularly towards the distal ends of the fingers, were very similar to the chill effects induced in the Cavendish variety (Trinidad Governor) by exposure to low temperatures (3).

The fruit which had been stored at 58° F. not only coloured well, but its maturation, as shown by Table 5, was not unduly hastened by this temperature. Here it should be stated that ripening of the bunches from top to bottom proceeded uniformly and evenly.

In the light of this storage trial it was thought that a transport temperature of 56° F. would probably be well suited to this variety, and accordingly a fourth trial was undertaken.

Mechanical Injury.—On transference to the ripening room after 16 days at 53° F. and 58° F. respectively, the following observations were recorded (Table 7).

In commenting on these figures it is to be noted that only injuries or scarring described as "severe" would be such as to cause fruit to be graded as second or perhaps third class, while those described as "moderate" are normal to first-class fruit handled naked in bulk. The resistance of the Giant Governor to mechanical injury is again borne out by these figures.

Pitting disease, though present, only caused slight wastage in these consignments.

TABLE 7.—*Nature of Wastage*

Cold Storage Temperature.	Nature of Wastage.	Percentage.
53° F.	A. <i>Injury to top and second hands.</i>	
	(i) None	40
	(ii) Very slight	32
	(iii) Moderate	24
	(iv) Severe	4
	B. <i>General Scarring.</i>	
	(i) None	33
	(ii) Very slight	33
	(iii) Moderate	25
	(iv) Severe	9
C. <i>Pitting Disease.</i>	0	
58° F.	A. <i>Injury to top and second hands.</i>	
	(i) None	55
	(ii) Very slight	14
	(iii) Moderate	26
	(iv) Severe	5
	B. <i>General Scarring.</i>	
	(i) None	13
	(ii) Very slight	52
	(iii) Moderate	26
	(iv) Severe	9
C. <i>Pitting Diseases.</i>		
(i) Slight	26	

Fourth Trial.—In this trial heavy bunches were held at 56° F. for 18 days with subsequent ripening at 70° F., a relative humidity of approximately 85 per cent. being maintained throughout.

The following observations on the condition of fruit at the end of the cold storage period were recorded (Table 8) :—

TABLE 8.—(Results stated as percentages)

<i>Condition of Fruit.</i>					
Green	..	..	..	..	80
Turning	..	..	..	..	15
Ripe	..	..	..	..	5
<i>Injury to Top and Second Hands.</i>					
None ..	..	..	..	..	55
Very slight	..	..	..	..	35
Moderate	..	..	..	..	10
Severe	..	..	..	..	0
<i>General Scarring.</i>					
None ..	..	..	..	..	45
Very slight	..	..	..	..	25
Moderate	..	..	..	..	10
Severe	..	..	..	..	10

Rate of ripening is shown in Table 9.

TABLE 9.—Rate of Ripening in the Giant Governor Variety
(Results stated as percentages)

Classification.	Number of days at 70° F.				
	1st day (on transference)	6th day.	7th day.	8th day.	10th day.
Green	80	10	10	10	5
Turning	15	60	40	20	5
Ripe	5	30	50	70	90

The presence of "ship-ripes" on removal from cold storage and of bunches quite green after 10 days at 70° F. show the need for careful selection at reaping. In the event of this variety acquiring commercial status, it may be anticipated that some difficulty will be experienced at first in selecting suitable grades for shipment, particularly on certain soil types and during the dry season.

In Table 10 representative weighings of fingers from the second hand of bunches showing different rates of ripening are recorded.

TABLE 10

Bunch.	Description of Fruit.	Weight in grammes of one finger from second hand.
1	Fruit quite yellow after 18 days at 56° F., i.e. on transference to ripening room at 70° F.	248·5
2	Fruit mostly yellow on transference to ripening room	220·5
3	Fruit turning on transference to ripening room ..	219·5
4	Fruit " " " "	215·5
5	Fruit quite " yellow on " 7th day at 70° F.	238·0
6	" " " " (short fingered fruit).	182·0
7	Fruit turning on 7th day at 70° F.	199·0
8	" " " "	173·2
9	Fruit turning on " 10th day " at 70° F.	152·4
10	Fruit still green on 10th day at 70° F.	150·0

In general these weighings are comparable with those set out in Table 6, but they again call attention to the fact that considerable experience will be required before export grades of this variety can be reaped with the precision and uniformity characteristic of Gros Michel consignments.

In general, although flavour and texture were good, this fruit was not quite so attractive in external appearance as that which, in the previous trial, had been held in cold storage at 58° F. At maturity a rather poorer pale yellow colour was the rule, and some bunches showed a slight suggestion of sootiness, particularly towards the finger tips, which might be interpreted as a chill effect. In slowly ripening less mature bunches some russetting also developed. It may be concluded, therefore, that 56° F. is a critical temperature for this variety, particularly if the transport period is prolonged.

As the chill effects were very slight, it is probable that cold air at 56° F. could be supplied during the early stages of the voyage without fear of adverse effects, and no doubt in future investigations it may be possible to define these important relationships with greater precision.

Discussion.—From the four storage trials described above it appears that the Giant Governor may be regarded with a certain amount of optimism. On soil which could not be regarded as being suitable for the Gros Michel, the Giant Governor produces large well developed bunches. These are cylindrical in shape, and the disposition of the fingers is such as to permit of naked stowage in bulk without undue loss through mechanical injury. Further, such fruit as has been available for experimental purposes possesses a much tougher skin than the ordinary Cavendish or Governor variety, and accordingly bunches suffer less from superficial bruising and scarring. In this respect, however, it cannot be claimed that the Giant Governor is the equal of the Gros Michel. This is partly due to the constitution of the skin in relation to wounding or bruising, and partly to the fact that fruits of the Cavendish group are inherently more subject to fungal attack than the Gros Michel.

Disadvantageous characters in the Giant Governor are concerned with questions of maturity and the temperature factor.

Even where a long period in cold storage is anticipated, fruit must not be reaped until it is heavy and almost fully developed. Instead of reaping at “ $\frac{3}{4}$ -full” as in the Gros Michel, Giant Governor bunches for transport to English or European markets should be “heavy $\frac{3}{4}$ -full” or almost “full,” otherwise delay and irregularities in ripening will certainly be experienced later. Such heavy bunches are not only liable to receive rather rougher handling, but as the individual fruits are of very large size they may prove less acceptable to certain markets.

With regard to the second factor, this variety requires a higher storage temperature than is at present customary in the Trade, and this may prove a difficulty, particularly in the inaugural stages when mixed consignments would have to be carried. Given careful handling and stowage and suitable protection against main-stalk rot, fungal wastage need not become excessive, even though fruit is being carried at a higher transport temperature.

From the strictly scientific point of view the foregoing studies should only be regarded as being of a preliminary nature. As supplies of fruit become available, further investigations should take into consideration the influence of different soil conditions and of different seasons on storage behaviour, the relative merits of ratoon versus plant bunches, the influence of manurial treatment, criteria of maturity to achieve greater uniformity in consignments, the effect of ripening at different temperatures and so on.

Before the final assessment of commercial suitability can be made, shipping trials must be carried out, and the fruit, subsequently handled and distributed by the usual brokers and agents, must meet with the approval of the public palate. It is to be hoped that such trials will be carried out under suitable supervision as larger consignments of fruit become available.

III. THE DWARF, CAVENDISH OR GOVERNOR VARIETY

By way of amplifying the observation on this variety already submitted (2), several consignments were taken into storage and held at 53° F.,

- (1) for comparison with the Giant Governor (see above) ;
- (2) to determine the influence of manurial treatment on the subsequent storage behaviour ;
- (3) to observe the behaviour (a) of " $\frac{3}{4}$ -full " bunches from parent plants affected with " Moko " or Bacterial Wilt disease, and (b) of the so-called " May " bunches.

Influence of Manurial Treatment.—Fruit for these experiments was obtained from the College Farm from a series of plots with different manurial treatments.

In the fruit from two plots, viz., synthetic pen-manure and those to which in addition there was added 2 lb. potash per stool, there appeared to be no difference, either in rapidity of ripening and senescence or in bruise resistance. In general it may be said that considering the initial unsuitability of this soil for banana growing, the parent plants have shown an amazing response to manurial treatment, as shown by vegetative vigour and size of bunch and fingers (5).

Almost without exception these bunches of rather turgid fruit have been very subject to bruising. This may be attributed to the rushed growth and perhaps to the long rainy season. Top hands have consistently shown mechanical damage despite the short journey to the Low Temperature Station, some 60–80 per cent. of the bunches being affected. From the several trials conducted it can only be concluded that fruit of this variety, grown with the help of fertilisers on relatively poor soils, is so subject to mechanical injury during transport that it is quite unsuitable for exporting as naked bulk consignments.

In general, bunches of the Governor variety from the College Farm ripened attractively within the usual time (Tables 2 and 4). The Governors from the Agricultural Experiment Station and from Woodford Lodge behaved much as fruit from these localities in former trials. They were not such large bunches, but ripened well, and were less bruised.

Bunches obtained from the College Farm and from Maqueripe Estate consistently developed pitting disease (4) in storage, while those from the Agricultural Experiment Station and Woodford Lodge did not.

Bunches from "Moko" Disease Plants.—Three "heavy $\frac{3}{4}$ -full" bunches from plants which had succumbed to "Moko" or Bacterial Wilt disease were included in a storage trial, and apparently ripened normally. This was perhaps surprising, but is probably accounted for by their being well advanced before disease overtook the parent.

"May" Bunches.—Numerous Governor bunches this season have exhibited in the top and sometimes in the second top hand a feature corresponding to the so-called "May" bunches of the Canaries, i.e. the fingers curve irregularly or lie in the horizontal plane instead of standing upwards evenly and in a plane more or less parallel to the central axis. In naked storage, these bunches are extremely liable to damage and breaking off of fingers. Physiologically they are obviously abnormal, and on ripening might be expected to show irregularities. In point of fact, however, though their colour was pasty they were of good flavour.

The following bunches, reaped at approximately " $\frac{3}{4}$ -full" from the variety plot of the Department of Botany, were held at 53° F. for 16 days with subsequent ripening at 70° F. This lot included 16 dwarf and two tall types of Cavendish of different origin. These are tabulated below (Table 11).

By the eighth day in the ripening room two were green, but commencing to colour, while 13 had ripened to bunches of pleasing appearance. By the twelfth day all had ripened.

Judged by their bunch habit, colouring, texture, etc., these dwarf Cavendish from various sources seem to be very closely related if not one and the same variety. The ripening behaviour of the tall varieties was such as to suggest a near affinity to the dwarf forms. Further detailed comparisons with larger lots of fruit are required.

TABLE 11

Tag No.	Type.	Field Label.	Origin.
A1	Dwarf Cav.	Governor, Trinidad	Trinidad
A2	"	" Barbados	Barbados
A3	"	" " "	" "
A4	"	" Tuffy "	Virgin Islands
A5	"	" "	" "
A6	"	Essequibo	British Guiana
A7	"	" "	" "
A8	Tall Cav.	Giant "Chinese	"Guadeloupe"
A9	"	Aranguez	Trinidad
B1	Dwarf Cav.	Cavendishiana I.	Canary Islands
B2	"	" "	" "
B3	"	Tuffy	Virgin Islands
B4	"	Canary	Canary Islands
B5	"	Sampson 7. 42	" "
B6	"	Governor	" B.W.I. "
B7	"	" "	" "
B8	"	" "	" "
B9	Tall Cav.	Congo	Trinidad

Notes :—Series A were grown together and are comparable.

Series B were grown together and are comparable, except that B6, B7 and B8 came from old stools less well grown than the rest.

All bunches about " $\frac{3}{4}$ -full " except A2 and A3 which were nearly " full."

IV. FILLBASKET

Several bunches of this variety were held at 53° F. for 16 days, then ripened at 70° F. Normally this fruit ripens attractively at ordinary temperatures. After the cold storage treatment, however, the colour intensity deepened, and the flesh had good texture and a pleasant flavour of its own. As this fruit, grown in the College variety plot, had been very carefully treated in its short journey to the Low Temperature Station, bruising was obviated. Judged by external appearance, these were quite the most attractive bunches, Gros Michel included, which we have had in the Low Temperature Station. The bunch habit and the very thin skin would, however, preclude rough treatment. It is thought that this variety might be given more attention during the tourist season, as their small fingers (Lady Finger type of banana) would make them a pleasing oddity. Unless quite mature, however, there is a danger that the pulp may appear too astringent for some palates.

V. GROS MICHEL

First Trial.—By way of confirming previous trials with this variety as grown under Trinidad conditions, a consignment of 30 bunches,* “ $\frac{3}{4}$ -full,” and ranging from 8 to 11 hands per bunch, was held at 53° F. for 17 days with subsequent ripening at 70° F. The ripening record is shown in Table 12.

TABLE 12

Number of days at 70° F.	Ripening of fruit (<i>stated as percentages</i>).			
	Green.	Turning.	Ripe.	Over-ripe.
1	100	0	0	0
5	16	40	40	4
8	13	7	76	—
10	0	7	89	—

Although this fruit had been transported more than 20 miles by lorry and stowed in bulk with bunches of other varieties, the fruit, on ripening, had good appearance, and, in the matter of bruising and scarring, was perfectly normal. As judged by commercial criteria the principal defect consisted in the tendency of some bunches to irregular ripening. Instead of the uniform ripening from the top to the bottom hand which is the rule in Central American and Jamaican fruit, the bunches showed either—

- (i) a group of the lowermost hands quite green while the uppermost hands were yellow and mature; or
- (ii) individual fingers in a hand at a different stage of maturity to their immediate neighbours.

As Gros Michel fruit for the best markets has reached a very high standard of uniformity, irregularities in ripening such as those described above would be regarded as a serious defect by the Trade. To what extent this unusual physiological behaviour is related to climatic or cultural conditions has yet to be determined.

* These were obtained from the Sangre Grande district.

A very mild form of pitting disease, but one which is economically important, was observed on the topmost hands of some bunches, the pits in finger-stalks and cushions being very minute and only in evidence as the fruit reached maturity.

Second Trial.—A second consignment of fruit from the same district was divided into two lots (A and B), stowed in bulk and held at 53° F., A for 16 and B for 21 days, with subsequent ripening at 70° F.

On transferring lot A to 70° F. the following observations were made (Table 13) :—

TABLE 13.—(Results stated as percentages)

<i>Appearance of bunches.</i>				
Green	..	..	..	74
Turning	..	..	..	26
<i>Injury to Top-hand.</i>				
None	..	..	..	46
Slight	..	..	..	47
Moderate	..	..	..	7
Severe	..	..	..	0
<i>Injury to second top-hand.</i>				
Slight	..	..	..	7
<i>Scarring.</i>				
None	..	..	..	26
Slight	..	..	..	33
Moderate	..	..	..	34
Severe	..	..	..	7
<i>Pitting Disease.</i>				
Slight (economically unimportant).				33

The ripening record was as follows (Table 14) :—

TABLE 14

Number of days at 70° F.	Ripening of fruit (stated as percentages).		
	Green.	Turning.	Ripe.
1	74	26	0
4	28	26	46
7	15	13	72

Some of this lot consisted of a rather heavy grade of fruit with concomitant rapid ripening. In the fullest bunches, ripening after two to three days at 70° F., it was found that chill effects were invariably present, the fruits showing the characteristic russetting which develops in this variety when over-refrigerated. In the standard "¾-full" bunches, ripening from the fifth day onwards, on the other hand, such chill effects did not develop. As it has been shown that chilling is a cumulative effect of duration of exposure to a given low temperature (3) it is evident from the foregoing observations that the transport of the more mature grades during long ocean voyages is attended with a considerable risk of wastage through chilling. The fact that "heavy ¾-full" and "full" fruit is consistently shipped, during the shorter voyage period, from Caribbean to American ports without chilling, confirms our previous finding regarding the importance of the time factor in this connection.

On transferring lot B to 70° F after 21 days at 53° F., the following records were made (Tables 15 and 16) :—

TABLE 15.—(Results stated as percentages)

<i>Appearance of Bunches.</i>				
Green	..	..	..	72
Turning	..	..	..	28
<i>Injury to top hand.</i>				
None	..	..	..	79
Slight	..	..	..	21
<i>Scarring.</i>				
None	..	..	..	15
Slight	..	..	..	56
Moderate	..	..	..	14
Severe	..	..	..	15
<i>Pitting Disease.</i>				
Slight (economically unimportant).				42

TABLE 16

Number of days at 70° F.	Ripening of fruit (stated as percentages).		
	Green.	Turning.	Ripe.
1 ..	72	28	0
5 ..	7	0	93

Again the more mature bunches which ripened after two to three days at 70° F. showed unmistakable signs of chilling, the normal yellow colour being partly masked by russetting.

With regard to the wastage in lots A and B, it is to be noted that only bruising or scarring described as "severe" would be such as to remove bunches from the first to the second or third class. In short, given the usual careful handling, there is no reason to suppose that Trinidad-grown Gros Michel is more susceptible to depreciation through mechanical injury than the same variety grown elsewhere.

In both lots, uneven maturation in the bunches was again a characteristic feature during ripening. As this tendency, in fruit otherwise excellent, would undoubtedly make for depreciation in its ultimate value, its occurrence, whether determined by seasonal or cultural factors, commends itself as a subject for further investigation.

VI. THE COLLEGE HYBRIDS I.C.1 AND I.C.2

Nine bunches of the new hybrid known as I.C.2, which is highly resistant or immune to Panama Disease, were reaped at approximately "¾-full" from plots in the College grounds and held at 53° F. for 16 days. Bunches of the Hybrid I.C.1 were also stored for comparison.

All the I.C.2 bunches were quite ripe before the eighth day in the ripening room at 70° F. Like the Gros Michel parent they acquired a good yellow colour and several independent tasters declared them to be good in texture and flavour and superior to the I.C.1. Furthermore this hybrid possesses the Gros Michel toughness of skin and resistance to mechanical injury and fungal wastage. On the other hand, the bunches so far obtained are rather small and the fingers short, thick and closely packed. As a result, fullness in fruit soon leads to distortion of the bunch habit so that additional mechanical injury may result. In general, the shape of the finger is more like the Giant Fig than the Gros Michel.

As these bunches were grown on indifferent soil, the results of this preliminary storage trial should not be regarded as affording a true indication of the commercial possibilities of this variety. Like the Jamaican hybrid this fruit is chiefly defective in the shortness of the fingers and further storage trials should be based on fruit grown on good soil. It will be interesting to note to what extent the characters commercially objectionable can be modified by agricultural treatment.

The I.C.1 bunches, introduced as a standard of comparison, behaved in a manner which confirmed earlier storage trials (2).

VII. THE GIANT FIG, LACATAN, BUMULAN, MARTABAN AND MASAK HIJAU VARIETIES

For some time past tall varieties labelled Lacatan, Bumulan, Martaban, Giant Fig and Masak Hijau have been grown in close proximity in the College variety plot with a view to determining their botanical affinities. Hitherto these varieties, known to other observers from plants grown under different conditions of soil and climate had been regarded as quite distinct and separate, though it was appreciated that they all possessed certain features in common. When grown side by side in the same or adjacent rows in the variety plot and kept under close observation, however, it was found that they were quite indistinguishable, and that no definite criteria could be selected by which one could be separated from another. From such data Professor Cheesman has put forward the suggestion that these so-called varieties are not distinct, but are, in point of fact, one and the same. It was thought that further light might be thrown on this point by testing their behaviour during cold storage and ripening. Accordingly, in a first trial, bunches, as described in Table 17, were held at 58° F. for 16 days with subsequent ripening at 70° F.

TABLE 17.—*Bunches sent to Low Temperature Station*

A.	Lacatan	..	..	..	..	82 days old.
B.	Bumulan	..	..	..	..	77 " "
C.	Masak Hijau	..	..	..	..	99 " "
D.	" "	..	..	..	..	98 " "
E.	Giant Fig	..	..	..	..	98 " "
F.	" "	..	..	..	..	98 " "
G.	Giant Fig	..	..	..	..	83 " "
H.	" "	..	..	..	..	87 " "
J.	Lacatan	..	..	..	..	90 " "

A and B were grown alongside, and are comparable.

C, D, E and F were all from one row. G, H and J were grown alongside, and are likewise comparable.

These bunches all had the appearance of fruit grown under rather unfavourable soil conditions. This was confirmed by the ripening data. The two bunches of Masak Hijau were quite ripe after 13 days at 70° F., and the Giant Fig bunches E and F of comparable age were ripe on the seventeenth day. The Lacatan bunch J was the next to ripen. With the exception of occasional fingers which had matured, all the other bunches were still green after 18 days at 70° F.

Apart from these variations in the rate of ripening which are to be expected when dealing with individual samples, the bunches showed a number of features in common.

(1) All possessed a rather thin and weak main-stalk and showed a marked tendency for individual finger-stalks to suffer from mechanical injury and subsequent *Gloeosporium* infections.

(2) The tendency of the fingers of the top most hands to fall apart in an irregular manner when suspended with the proximal hand uppermost was common to all.

(3) Slow or delayed ripening of the rather thin fruit.

(4) All fruits which ripened developed a clear, pale-yellow colour ; with the onset of late maturity a characteristic freckling, quite similar in the several varieties, was the rule.

(5) The smaller and more immature fruits of the lowermost hands failed to ripen and developed a pasty discolouration and russetting which was quite comparable throughout. This effect is similar to that observed in the storage of immature Cavendish or Governor bunches.

While admittedly these observations should be repeated and confirmed on a larger scale, the general concensus of evidence undoubtedly lends support to Professor Cheesman's hypothesis that the several so-called varieties are identical. The further view that these tall varieties are closely allied to the Cavendish type is also borne out by such features as slow ripening of immature bunches, colour, and freckling on ripening, susceptibility to bruising and to *Gloeosporium* infection, and by the pasty and russet colouring developed by immature fruits in the ripening room.

In a second trial the following bunches, enumerated in Table 18, were held at 56° F. for 18 days and then transferred to the ripening room at 70° F.

TABLE 18

Label.	Variety.	Age of bunch in days.
A1	Masak Hijau	104
A2	"	105
3	"	106
B1	Lacatan	108
2	"	124
C	Martaban	100
D	Giant Fig	122

The Lacatan bunch (B 2) ripened after six days at 70° F., and the Giant Fig (D) after eight days. The Masak Hijau (A 1, 2, 3) bunches were quite yellow after 10 days; at this time the Lacatan (B 1) and Martaban (C) bunches were turning. Some irregularity in ripening was characteristic of the whole of this consignment, and even those bunches which were just "turning" on the tenth day at 70° F. showed occasional mature fruits. In addition to the similarities described in the first trial, which were again amply confirmed, it was noted that although an attractive yellow colour developed at maturity, all the varieties displayed a slight sootiness, particularly towards the finger-tips and on the lower sides which may be regarded as a very mild chill effect. Again a characteristic discolouration and dehydration effect induced in the slender finger-stalks was identical throughout.

In the light of the cumulative field and storage data available, based on bunches of approximately equal age grown under identical conditions, it may be accepted that there is no aspect of the evidence which can be regarded as contrary to Professor Cheesman's hypothesis. On the contrary, the ascertained facts lend strong support to the theory of identity.

VIII. MYCOLOGICAL OBSERVATIONS

General

As in previous storage trials, fungal wastage was of the usual type, being chiefly associated with mechanically injured tissues. Main-stalk rot was satisfactorily controlled by the application of vaseline to freshly cut stem ends and by rapid cooling. Tip-rots, caused by *Gloeosporium musarum* Cke. and Masee and *Botryodiplodia theobromae* Pat. were again in evidence as maturity was being reached. In the characteristic mechanical injuries (Fig. 5) which developed in finger-stalks of the Giant Governor, the subsequent rotting could be referred to *Glomerella cingulata* and *Fusarium sambucinum*.

For the first time during our storage trials in Trinidad, Pitting Disease, which is responsible for considerable wastage in Brazilian cargoes (4), has made its appearance on the Cavendish, Giant Governor and Gros Michel varieties (Figs. 5 and 6). This subject and the question of fruit spotting will be dealt with in greater detail in a later report.

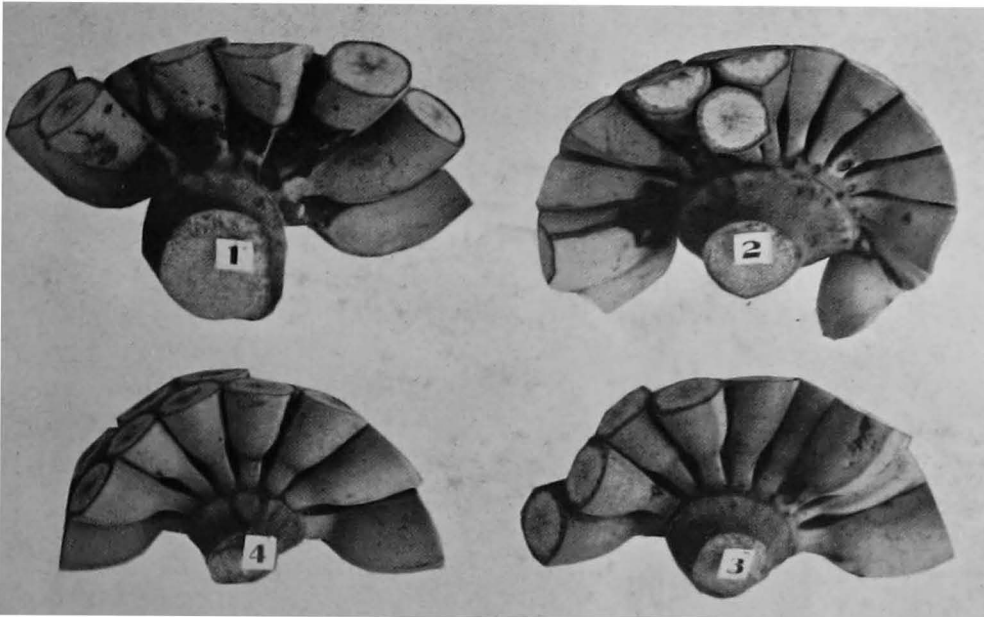


FIG. 6.—The four top hands of a bunch of Governor bananas illustrating the incidence of pitting disease.

IX. CONCLUSIONS AND RECOMMENDATIONS

1. The storage behaviour of the following varieties has been considered during recent investigations at the Low Temperature Station : Giant Governor, the Dwarf, Cavendish or Governor from various sources, Fillbasket, Gros Michel, the Hybrids I.C.1 and I.C.2, Giant Fig, Lacatan, Bumulan, Martaban and Masak Hijau.

2. The Giant Governor, believed to be a tall mutant of the Dwarf or Cavendish variety, in the course of four bulk storage trials has given promising results. When grown under similar conditions, this variety produces considerably larger bunches than the ordinary Dwarf or Governor variety, while the cylindrical shape and symmetry of the bunch and the relatively tough skin of individual fruits render it much more suitable for naked bulk transport. So far, the excessive injury to the top hands and general scarring usually found on the ordinary Governor have not been observed. Chill effects developed in fruit held at 53° F. for 16 or more days, but after cold storage at 58° F. normal ripening to an attractive deep yellow colour was the rule. A transport temperature commencing at 56° F. and rising to 58° F. would probably be suitable for this variety. Bunches must be reaped at a stage corresponding to " heavy $\frac{3}{4}$ -full " in the Gros Michel otherwise ripening at 70° F. is greatly delayed, and abnormal colour effects, such as pastiness or russetting, develop. As a result, fruit for export tends to be heavy and the individual fingers of rather large size. Texture and flavour are good. Shipping trials, conducted under the usual commercial conditions at a temperature of 56° F.-58° F. are necessary before a definitive opinion can be offered.

3. The Cavendish or Governor variety when grown on relatively poor soil with the help of fertilisers showed a very marked response to the manurial treatment. The bunches, however, proved very subject to mechanical injury, damage to finger-stalks, bruising and scarring being excessive even after a very short careful haulage. Such fruit would be quite unsuitable for export.

4. Judged by their bunch habit, colouring, texture, flavour, etc., Dwarf Cavendish from various sources, British Guiana, Trinidad, Barbados, Virgin Islands and Canary Islands, etc., seem to be very closely related if not one and the same variety.

5. Bunches of Fillbasket held at 53° F. for 16 days subsequently ripened very attractively at 70° F. While its bunch habit and thin skin preclude rough treatment, it is thought that it might possess some local commercial value.

6. In two bulk storage trials with the Gros Michel, wastage due to breaking of finger-stalks, scarring and bruising was quite normal and comparable with that experienced in Jamaican or Central American fruit. Uneven ripening in bunches, where single fingers or entire hands were involved, was a characteristic feature of both trials. As this would be regarded as a serious defect by the Trade, further investigations to determine whether it is cultural or seasonal, are required.

7. In a preliminary storage trial with the new College Hybrid I.C.2, it was found that this variety possesses characters common to the Gros Michel, namely resistance to bruising and attractive yellow colour on ripening. The flesh is of good texture, and is regarded as being superior in flavour to the Hybrid I.C.1. The bunches so far obtained—on relatively poor soil—have been small and the fingers short, thick and closely packed. Further storage trials are required with well developed bunches grown on good alluvial soil.

8. Bunches of Giant Fig, Lacatan, Bumulan, Martaban and Masak Hijau, of approximately the same age and obtained from the same or adjacent rows in the College variety plot, were stored and ripened under identical conditions. All showed very great similarity in the characters developed during ripening. This lends support to a view which has been expressed that these several tall forms are not separate and distinct varieties, but are, in fact, identical.

9. Pitting disease, which is responsible for considerable wastage in Brazilian cargoes, was in evidence during these trials on the Giant Governor and Governor varieties. A very mild and economically unimportant form of this disease was also observed on the Gros Michel.

In conclusion the writers desire to acknowledge the assistance they have received in carrying out this work. To the Trinidad Department of Agriculture, Mr. G. F. Huggins, O.B.E., Mr. R. Huggins, Woodford Lodge Estates, Ltd., and the College Departments of Agriculture and Botany they are indebted for supplies of fruit, and they again avail themselves of the opportunity of expressing their thanks to the Principal and Members of the Staff for their helpful co-operation.

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