FIELD CROPS OF CEYLON

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S. T. SENEWIRATNE
B.Sc. Agric. (Cey.), M.Sc., Ph.D. (Calif.)
Professor and Head of the Department of Agriculture
University of Ceylon

R. R. APPADURAI
B.Sc. Agric. (Cey.), M.Sc. (Texas), Ph.D. (Lond.)
Lecturer in Agriculture
University of Ceylon

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PREFACE

This book has been written with the fervent hope that it will satisfy a vital need for a comprehensive treatment of the culture of the field crops of Ceylon, an area in which no book exists at the present time. During the past few years, the authors have been increasingly aware of the need to collect, collate, and interpret the information relating to the culture of field crops that lie fragmented in various papers and publications. This book is an attempt to present such information in an organized manner so that it would serve as a complete and comprehensive reference on the field crops of this country.

The book includes forty-one chapters, of which 40 deal with the culture of the main food and other subsidiary crops, including the unirrigated field crops. Every attempt has been made to incorporate as much as possible, the available, locally published data relating to each crop. Wherever such information was available, costs of cultivation and returns per acre have been included. In most cases these values represent costs of production on Government farms, where Government rates of wages obtain, and these have to be examined with this factor in mind. The book is intended for all persons interested in agriculture in Ceylon, be they persons engaged in production, extension, research, or education.

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THE AUTHORS

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1. FIELD CROP PRODUCTION IN CEYLON

Agricultural activity dominates and will continue to dominate the economic life of this country for a long time to come. No industrial development of any substantial proportion will at all be possible without the surplus earnings of a prosperous agriculture. Outside the successful plantation sector, the contribution from other sections of the agricultural sector to the national income has been negligible. Consequently, food imports have steadily risen over the years and now accounts for nearly Rs. 1000 million. Increasing attention has therefore to be paid to increasing the productivity of our lands, as well as to cultivating the lands yet to be developed, with suitable crops. In this programme, field crop production must necessarily play a prominent part.

It would be well to consider some of the reasons why field crop production has lagged behind, resulting in an increased outflow of foreign exchange for the purchases of vital items of food and clothing. Even in the production of rice on which the Government pays handsome subsidies, progress has been slow. The chief factors that have limited the production of field crops in Ceylon are the low incomes derived from certain crops, the lack of organized processing and marketing for some others, and the unsuitability of a good number of these crops for peasant agriculture.

Field crops generally grown in Ceylon can be divided into two categories: those that are of low income which have to be grown extensively, and those that are of high income and need to be grown under intensive conditions. The main features of the 'extensive' crops include low capital investment, low returns per acre, and relative non-perishability of the finished product. 'Intensive' crops on the other hand are characterized by high capital and labour requirements per acre, high returns, and relative perishability of the harvested produce. The extensively grown crops are more suited to mechanized large scale farming enterprises, whereas the intensively farmed types are well suited for peasant farming. A proper appreciation of these factors in their true perspective and a recognition of the technical considerations that determine the culture of these crops, will have to guide the national programmes designed to promote field crop production in Ceylon.

The imports of cereals and pulses cost this country around Rs. 400 million in foreign exchange annually. A close examination of the costs of production and returns from these crops will indicate that the cereals generate an income of less than Rs. 100.00 per acre, with irrigated paddy giving an income of about Rs. 250.00. Pulses yield an income of about Rs. 150.00-200.00 per acre. All these could be considered to be low income producers, except rice, which enjoys an attractive guaranteed price, equal to twice the world market value.

On account of this low profitability it would be unreasonable to expect increased production of these crops from peasant agriculture. Even an increased guaranteed price will not help expand production as the very nature of labour requirements for their cultivation cannot be met by family labour alone, because labour needs at sowing, weeding and harvest are high. This invariably leads to the neglect of the crop.

Such low-income-producing crops with seasonal peak labour requirements should be grown in large extents of land with mechanized cultivation, to make them a paying proposition. It will be desirable if national programmes for agricultural development take these considerations into account, particularly when alienating land for the production of these crops.

On the other hand, the cultivation of root crops presents a more satisfactory situation, and the prospects and potential for expanded production show considerable promise. Root crops generate high incomes per acre, most of the locally grown root crops producing around Rs. 1000/- per acre. The great diversity of types that are available for cultivation makes it possible to find a root crop for every ecological situation. As a small holdings crop, therefore, particularly in the low country wet zone, root crops have few rivals. The wide range of varieties available, make it possible also to grow these root crops all the year round.

Unfortunately much of the national effort in this field has been directed towards the cultivation of only one of these, namely potatoes, a project which has already cost the country a considerable sum of money. The culture of potatoes is beset with numerous problems, chief amongst which is the problem of disease. It would be some time before these problems are satisfactorily resolved. In any case, the efforts in this direction, should not stand in the way of a sustained effort at the increased production of the locally grown root crops that can be raised with great facility in the low country wet zone. Most of these crops are singularly free of any serious pests or diseases, and that is another desirable feature recommending their widespread cultivation. Most root crops also lend themselves to staggered harvests, cultivation at various times of the year and good post-harvest storage. The only crop with poor keeping quality is manioc. Even so, this crop can be utilized for numerous processed products and could also substitute for cereals like maize, in animal feeds.

In spite of these advantages cultivators are reluctant to undertake the cultivation of root crops, since it is not possible for them to market their own produce effectively. An organized marketing service through Co-operative societies or other means that guarantee the collection and marketing of such produce could step up the cultivation of these potato and cereal substitutes within a short period of time.

Chillies and onions are intensively grown crops of the dry zone, while ginger and turmeric are intensively grown crops of the low and mid-country wet zone. All these are high income producing crops, supported by attractive guaranteed prices, and capable of giving handsome returns per acre. They are most suited for peasant cultivation as they are all labour intensive crops. In the case of chillies the picture is complicated, however, by low yields resulting from disease hazards, and self-sufficiency still remains a distant prospect. Self-sufficiency has been reached in the case of ginger. Substantial progress has also been made in the cultivation of turmeric and onions, and self-sufficiency can be realized if facilities for the processing of turmeric and storage of onions can be provided.

The cultivation of commercial crops like sugar-cane and cotton have received considerable attention in recent times. They have been undertaken or proposed as state ventures, but the returns from both crops have been disappointing. On the other hand rain-fed cotton in Africa and some sugar-cane in India are undertaken successfully as peasant crops. If it is proposed to alienate land for the cultivation of these crops to peasants it should be done only after the proper evaluation of the size of an economic unit, and after determining whether a peasant family can handle such an extent.

One of the most successful field crops in Ceylon is Tobacco. In spite of the fact that it is largely a small holdings crop, production has substantially increased and now saturated the country's requirements, particularly for cigarette tobacco. Part of this success must be attributed to the fact that the crop has enjoyed the patronage of the private companies that sponsor its cultivation by providing the necessary services, supplies and credit facilities, and also by purchasing the leaf. The crop provides a good example of the impact that these auxiliary services in agriculture can have on production. The extension of similar facilities to some other crops are bound to produce beneficial results. Tobacco cultivation and production has reached a stage when any further incentives to production are being stifled by the restrictions placed on the acreage cultivated as well as the yields produced per acre. A careful study of these trends is required to see whether tobacco could not be made an effective foreign exchange earner and to gear production to meet this end.

Finally, in order to minimize the outflow of foreign exchange, and to achieve self sufficiency, the whole question of field crop production in Ceylon has to be re-examined from a national point of view. Clear decisions will have to be taken as to whether a particular crop is more suited for peasant farming than for large scale production. A further consideration would be the selection of particular areas for the production of specific crops. This specialization on a regional basis is fundamental to the provision of an effective extension service and marketing organization. The alienation of land for agricultural production whether as a peasant enterprise or as a large scale venture would accordingly hinge on these considerations.

Hitherto irrigated agriculture in Ceylon has been synonymous with rice culture. In terms of foreign exchange savings, the value of the produce of one acre of paddy land would amount to Rs. 350.00 (50 bushels yield at world market price of Rs. 7/- per bushel). It is quite evident that a number of other field crops could effect a greater foreign exchange saving per acre than Rs. 350.00, when grown under irrigated conditions. In view of this fact, the more important field crops should be pro-rated on the basis of the foreign exchange savings that could result from their cultivation under irrigated conditions. Alienation of land for irrigated culture could then be made on this rating. Meanwhile increased efforts should be directed towards minimizing the water used in rice cultivation, so that some of this irrigation water could be diverted for the production of other more remunerative crops.

GROUP I—CEREALS

2. RICE

World Production

The origin of rice culture dates back over 5000 years and is lost in antiquity. Rice is the staple food of about half the people of the world. It is estimated that nearly 255 million acres of paddy are grown and that 93 % of this acreage is confined to Asia. (Table 1).

TABLE 1

Acreage and Production of Rice

	AREA		RICE PRODUCTION	
	Million Acres	%	Million Tons	%
Asia	238·01	93·04	108·43	92·85
America	9·75	3·81	4·89	4·19
Africa	7·07	2·76	2·36	2·02
Europe	0·89	0·35	1·02	0·87
Oceania	0·11	0·04	0·08	0·07
Total	255·83	100·00	116·78	100·00

(Rice production reported as 2/3 paddy or rough rice)

The highest rice yields are reported from Japan, Egypt, Italy Spain and Argentina. Ceylon yields however, compare favourably with those of other South East Asian rice growing countries, and small yield increases have been consistently obtained over the last few years. (Table 2)

TABLE 2

Average Paddy Yields—(Bushels/acre)

Year	Ceylon	India	Burma	Thailand	Japan
1952	30·9	22·8	29·0	25·6	81·9
1953	27·1	26·8	27·8	27·6	68·4
1954	30·4	24·2	29·3	25·0	74·4
1955	32·7	26·0	29·3	27·2	95·4
1956	30·0	26·6	31·7	28·6	77·1
1957	32·3	23·4	26·8	25·4	87·8
1958	34·7	27·8	32·7	27·4	91·6
1959	34·8	27·0	33·7	27·6	94·2
1960	36·3	—	—	—	—
1961	36·1	—	—	—	—
1962	37·9	—	—	—	—
1963	37·9	—	—	—	—

Source—Figures for Ceylon from Statistical Abstract.
Other data from F.A.O. Production Year-book.

ECONOMIC IMPORTANCE

Paddy cultivation in Ceylon covers an area of about 1.3 million acres and provides employment for a large section of the peasantry of the country. In spite of this, local production meets only a little more than half our requirements of rice. It is encouraging to note, however, that local rice production has showed a steady increase in recent years. (Table 3)

TABLE 3

Local Rice Production and Imports (In tons)

Year	Local Rice Production	Rice Imports
1957-58	522,800	489,193
1958-59	520,500	577,826
1959-60	615,250	548,510
1960-61	617,120	453,205
1961-62	686,700	426,906
1962-63	685,000	548,960
1963-64	705,200	549,300

The urgency for stepping up rice production arises from the need to conserve the foreign exchange that is now spent on rice imports. The average expenditure varies around Rs. 250 million per year and is largely dependent on the prevailing world market price of rice. Table 4 indicates the annual outflow of foreign exchange on rice purchases and the average price paid for rice in the world market.

TABLE 4

Value of Rice Imports

	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
Annual Expenditure (in Rs. millions)	221	264	255	238	283	242	217	195	192	326
Price paid per ton (in Rs.)	584	545	496	501	492	466	470	482	515	550

Self sufficiency in rice has been the declared objective of Agricultural policy in this country for many decades and numerous measures have been adopted in an attempt to realize this goal with varying degrees of success. Rice has been the chief crop on which the Government has spent most of its energies in the past and this same trend justifiably continues. This being the general pattern it is desirable to consider the various measures that have been taken to stimulate and increase production.

TABLE 5

Paddy acreage cultivated and harvested

	1956/57	1957/58	1958/59	1959/60	1960/61	1961/62	1962/63
Asweddumized acreage	—	—	1,107,000	1,141,000	1,160,000	1,197,000	—
Acreage sown Maha	779,512	840,651	848,028	920,747	934,473	958,358	1,000,412
Acreage harvested (gross) Maha	729,774	716,688	758,914	856,990	887,337	936,264	981,772
Acreage harvested (net) Maha	618,608	608,658	645,079	728,442	754,486	795,824	834,506
Acreage sown Yala	426,472	541,533	482,191	547,659	537,510	577,594	561,508
Acreage harvested (gross) Yala	411,075	523,114	469,138	535,871	519,285	555,999	543,571
Acreage harvested (net) Yala	349,414	444,647	398,587	455,490	441,392	472,599	462,035

Area under paddy

The programmes for increased production have included the expansion in the acreage cultivated and attempts to raise the yields obtained per acre. The question of increasing the acreage harvested each season is more complex than it appears at first sight and needs careful consideration. Table 5 gives the total asweddumized acreage of paddy lands, the acreage sown and the extents harvested (2).

The net harvested area is derived by using a correction factor (less 15%) on the gross harvested area reported.

These figures indicate that the entire asweddumized area of paddy land is never cultivated. It would appear that 200,000 to 250,000 acres remain uncultivated in the Maha season and about 800,000 acres remain idle in the Yala season, making a total of 1 million idle acres during a single year. The reasons for this non-cultivation vary, but lack of water, lack of drainage and salvinia infestation are some of the main reasons. Table 6 shows the discrepancy between the areas sown and gross harvested acreage which represents the acreage lost through crop failure. On an average, about 50,000 acres of crop appear to be lost each year, in both the Yala and Maha seasons.

TABLE 6

Acreage lost through crop failure

Season	1956/57	1957/58	1958/59	1959/60	1960/61	1961/62	1962/63
Maha	49,738	124,583	89,114	63,757	47,136	22,094	18,640
Yala	15,397	18,419	13,053	11,788	18,225	21,595	17,937
Total	65,135	143,002	102,167	75,545	65,361	43,689	36,577

Causes of this crop failure have been investigated and it is quite clear that lack of water and flooding have accounted for most of the losses encountered. Losses from seed failure, pest and disease attack, which accounts for less than 10%, may decline with better standards of cultivation. (Table 7)

TABLE 7

Causes of Paddy Crop Failure (in acres)

Season	Seed Failure	Drought	Flooding	Pests etc.	other Factors	Total
1959/60 Maha	2,904	16,205	42,520	894	4,556	67,079
1960 Yala	962	5,923	2,915	467	2,784	13,051
Total	3,866	22,128	45,435	1,361	7,340	80,130
1960/61 Maha	3,280	33,981	4,177	2,965	4,252	48,655
1961 Yala	452	2,480	3,371	158	10,702	17,163
Total	3,732	36,461	7,548	3,123	14,954	65,818

Source—Statistical abstract 1962.

The major portion of the losses from non-cultivation and crop failure could perhaps be remedied with a relatively small capital investment, by the provision of drainage and improved irrigation facilities to these asweddumized lands wherever possible. With a view to expediting this work, improvements to minor irrigation works were undertaken by the Department of Agrarian Services and a total number of 2517 projects were undertaken in 1962-63, costing over Rs. 4 million, out of which a total of 1514 were fully completed. The total extent of land benefited by all the schemes is estimated to be approximately 70,688 acres of which 8,151 acres were double cropped for the first time and 1,438 acres were newly sown. (2). Any improvements that make double cropping possible will be desirable, as this will in addition help to reduce the enforced under-employment that now confronts the peasant cultivator.

The energies of the Irrigation and Land Development Departments are largely directed towards asweddumizing new land and alienating it to peasants. Top priority has been given to this programme in the expansion of the non-export agricultural sector of this country. Table 8 shows the extent of investment in irrigation and land development. (3).

TABLE 8

Expenditure on Irrigation and Land Development
(In Rs. million)

	1958/59	1959/60	1960/61	1961/62	1962/63	1963/64
Agricultural component only	57·64	52·60	66·56	72·89	66·31	67·35
Including colonists houses etc.	102·73	96·40	111·15	115·60	104·90	104·92

This programme has resulted in an increase in the asweddumized acreage and in the improvement of irrigation facilities for existing paddy areas. On an average 10,000 acres have been brought under irrigation every year and improved facilities provided for a further extent of land. (Table 9).

Although the cost relationships of this programme may not be considered very favourable the non-economic benefits conferred in the way of providing employment and relief of congestion in the densely populated areas must be taken into consideration. The built-in social service component is estimated to be 30 per cent of the expenditure on a colonist's allotment, and this is regarded as being high. Development of new areas in agriculture as peasant holdings, cannot proceed without a fair expenditure on social services.

TABLE 9

Investment in Irrigation and Acreage made Irrigable

Year	Investment (Rs. millions)	Acreage made irrigable for the first time	Acreage for which irrigation facilities were improved
1955	10·057	7,589	6,167
1956	22·814	11,293	6,148
1957	28·428	10,410	10,929
1958	24·180	5,041	3,248
1959	23·604	11,545	4,264
1960	21·969	12,644	7,111
1961	34·418	6,115	3,239

Efforts at increasing rice yields, by expanding the asweddumized area under cultivation, by increasing the area of asweddumized land cultivated every season and minimizing the extents abandoned due to crop failure are an integral part of any programme designed at making Ceylon self-sufficient in rice production. The rate of such increase will however be slow on account of the restricted capital resources available for land development.

TABLE 10

Average Maha Yield of Paddy (Bushels per acre)

District	Maha 57/58	Maha 58/59	Maha 59/60	Maha 60/61	Maha 61/62	Maha 62/63
Colombo	31·09	34·56	34·76	35·05	35·95	32·42
Kalutara	23·70	26·95	28·22	22·85	28·22	31·25
Kandy	44·13	51·30	51·80	46·00	55·58	52·90
Matale	43·48	32·61	47·62	48·50	43·12	43·92
Nuwara Eliya	65·11	34·89	55·23	50·58	43·10	58·48
Galle	24·67	25·22	26·85	26·20	23·88	26·62
Matara	28·80	34·48	32·22	29·30	33·80	37·45
Hambantota	37·83	40·65	43·80	42·10	41·80	37·42
Jaffna	24·89	22·72	25·65	34·02	28·78	28·50
Mannar	45·87	33·27	40·82	38·18	41·15	45·95
Vavuniya	30·43	21·74	31·42	32·10	39·32	37·25
Batticaloa	30·98	25·54	31·80	27·42	36·78	33·12
Trincomalee	29·89	37·50	40·95	37·40	41·80	33·88
Kurunegala	31·85	29·24	31·40	31·70	34·50	34·68
Puttalam-Chilaw	23·48	38·37	25·70	33·08	33·00	34·05
Anuradhapura	27·17	39·67	42·25	47·50	39·72	37·65
Polonnaruwa	58·04	61·41	53·85	54·48	54·52	56·45
Badulla	59·89	37·69	—	48·28	48·12	50·80
Moneragala	—	—	—	—	51·32	55·25
Ratnapura	24·42	25·73	31·28	31·75	28·25	27·48
Kegalle	47·06	44·45	42·82	44·78	50·92	51·70
Amparai	—	—	—	—	—	35·82
Island	34·06	34·04	36·10	35·93	38·02	37·84

Increasing acre yields

A quicker and less expensive method will be to increase acre yields of paddy on the asweddumized and cultivated acres. This responsibility has been vested largely with the Government Department of Agriculture and numerous avenues for improvement of yields have been amply demonstrated. The release of high yielding pure line varieties, the use of chemical fertilizers, better agricultural practices like row seeding, weeding, pest and disease control have all been suggested. The use of these combined practices should show phenomenal yield increases but in actual fact the average yield still remains around 40 bushels per acre. (4). (Table 10)

Average Yala Yield of Paddy (Bushels per acre)

District	Yala 1958	Yala 1959	Yala 1960	Yala 1961	Yala 1962	Yala 1963
Colombo	29·02	30·00	29·95	34·15	29·12	33·80
Kalutara	28·04	31·63	22·80	26·02	24·10	33·05
Kandy	39·02	35·33	50·80	44·10	45·78	44·22
Matale	33·26	43·59	44·15	37·15	43·28	37·22
Nuwara Eliya	29·78	78·91	41·45	51·45	42·12	44·60
Galle	26·30	—	28·72	29·40	25·95	27·05
Matara	29·24	28·37	30·78	28·32	28·90	34·97
Hambantota	40·11	43·70	43·18	39·10	44·60	43·00
Jaffna	—	37·06	33·00	27·82	34·98	36·92
Mannar	—	30·54	33·88	37·48	45·42	44·37
Vavuniya	—	22·82	33·22	37·48	45·42	43·92
Batticaloa	39·56	33·04	30·65	37·75	40·37	35·75
Trincomalee	54·67	47·61	47·48	43·55	42·45	42·35
Kurunegala	29·46	33·91	34·12	34·12	33·00	35·97
Puttalam-Chilaw	26·41	34·67	29·62	38·58	24·55	30·45
Anuradhapura	28·37	37·06	43·22	43·22	41·68	39·92
Polonnaruwa	60·87	54·78	49·82	40·05	46·22	47·75
Badulla	—	—	—	52·88	—	51·47
Moneragala	—	—	—	—	51·28	49·45
Ratnapura	26·41	33·37	27·88	27·85	32·78	31·47
Kegalle	28·91	34·67	42·02	49·70	49·40	44·05
Amparai	—	—	—	—	38·82	38·67
Island	34·87	37·17	36·82	36·06	37·69	38·04

This depressed average yield could be due partly to the conservatism of the peasant, as a result of which he does not use improved techniques of culture. Table 11 shows the extent to which these improved techniques of culture have been utilized. (4)

TABLE II

Spread of Improved Techniques of Culture (In acres)

Cultural Practice (In Acres)	Maha Season				Yala Season			
	1959/60	1960/61	1961/62	1962/63	1960	1961	1962	1963
Transplanted in rows	26,551	24,637	33,702	37,235	6,622	12,295	13,744	12,686
Transplanted not in rows	99,007	85,814	106,057	120,570	23,313	22,927	42,545	39,767
Row seeded	32,325	25,406	28,291	28,323	22,673	13,215	23,812	20,273
Total transplanted or row seeded	157,883	135,857	168,050	186,128	52,608	48,437	80,101	72,726
Extent Weeded, Weedicides used and crop Harrowed	231,931	227,922	297,894	383,358	146,234	150,565	205,500	226,982
Quantity of pure line seed issued (Bushels)	65,785	61,679	—	78,732	21,677	17,203	—	19,330

The improved methods of planting recommended are transplanting or row sowing. Of a total extent of 900,000 acres sown for the Maha season only about 160,000 acres are either transplanted or row sown, which amounts to only 17% of the planted acreage. This is a disappointing result as extension workers have stressed the advantages of transplanting for over 20 years. In the case of weeding the position is somewhat better. An extent of 25%-40% appears to be weeded in the Maha and Yala seasons respectively. However it is most disturbing to think that 2/3 of the paddy acreage in Ceylon is never weeded, particularly when unemployment and underemployment are problems in most villages.

In comparison to the poor response with regard to transplanting and weeding, fertilizer use shows a phenomenal rate of increase. Consumption stood at 26,000 tons in 1958/59 and has more than doubled by 1963/64 (2). (Table 12). Fertilizer is made available through Co-operative Societies and the Department of Agrarian Services, with a 50% subsidy when fertilizers are purchased for cash and a 33 1/3% subsidy when obtained from Co-operatives on credit. Even at the present levels of fertilizer consumption of about 60,000 tons per year, it only amounts to an average application of 90 lbs. per sown acre, which is far short of the desired level of 250-350 lbs. per acre.

TABLE 12

Fertilizer use by components (Tons) (2)

Fertilizer	1958/59	1959/60	1960/61	1961/62	1962/63	1963/64
Ammonium sulphate (20·6% N)	12,832	11,473	18,512	24,747	31,023	39,780
Urea (46·0% N)	503	167	258	675	872	3,131
Saphos Phosphate (27·5% P_2O_5)	8,195	5,521	6,723	8,020	9,946	11,389
Super Phosphate (42·0% P_2O_5)	505	—	—	—	—	—
Muriate of Potash (50% K_2O)	4,306	3,012	3,548	4,633	5,217	5,796
	26,341	20,173	29,041	38,075	47,058	60,096

The whole concept of fertilizer use and acre yields in Ceylon has been raised as a fundamental issue by Treasury officials and others who control the allocation of foreign exchange for the purchase of fertilizers from abroad. It has been pointed out that fertilizers applied to rice have more than doubled in 5 years from 1959-1964, whereas yields have shown only modest increases. (Table 13).

TABLE 13

Rice Yields and Fertilizer consumption (2)

	Local Rice Production (in Bush.)	Fertilizer Consumption (Tons)	Annual Change In Rice Production (Bushels)	Annual Change In Fertilizer Consumption (Tons)
1956/57	31,322,000	14,100	—	—
1957/58	36,600,000	16,900	+ 5,278,000	+ 2,800
1958/59	36,440,000	26,341	— 160,000	+ 9,441
1959/60	43,068,000	20,173	+ 6,628,000	— 6,168
1960/61	43,199,000	29,041	+ 131,000	+ 8,868
1961/62	48,069,000	38,075	+ 4,870,000	+ 9,034
1962/63	49,153,507	47,058	+ 1,084,507	+ 8,983
1963/64	50,500,000	60,096	+ 1,346,493	+ 13,038

A closer examination of the figures would reveal a very inconsistent pattern. Increases in fertilizer use have not been accompanied by corresponding increases in yields and the actual increases in yield may have come partly from other factors like the more extensive use of pure line seed and small increases in the extents cultivated.

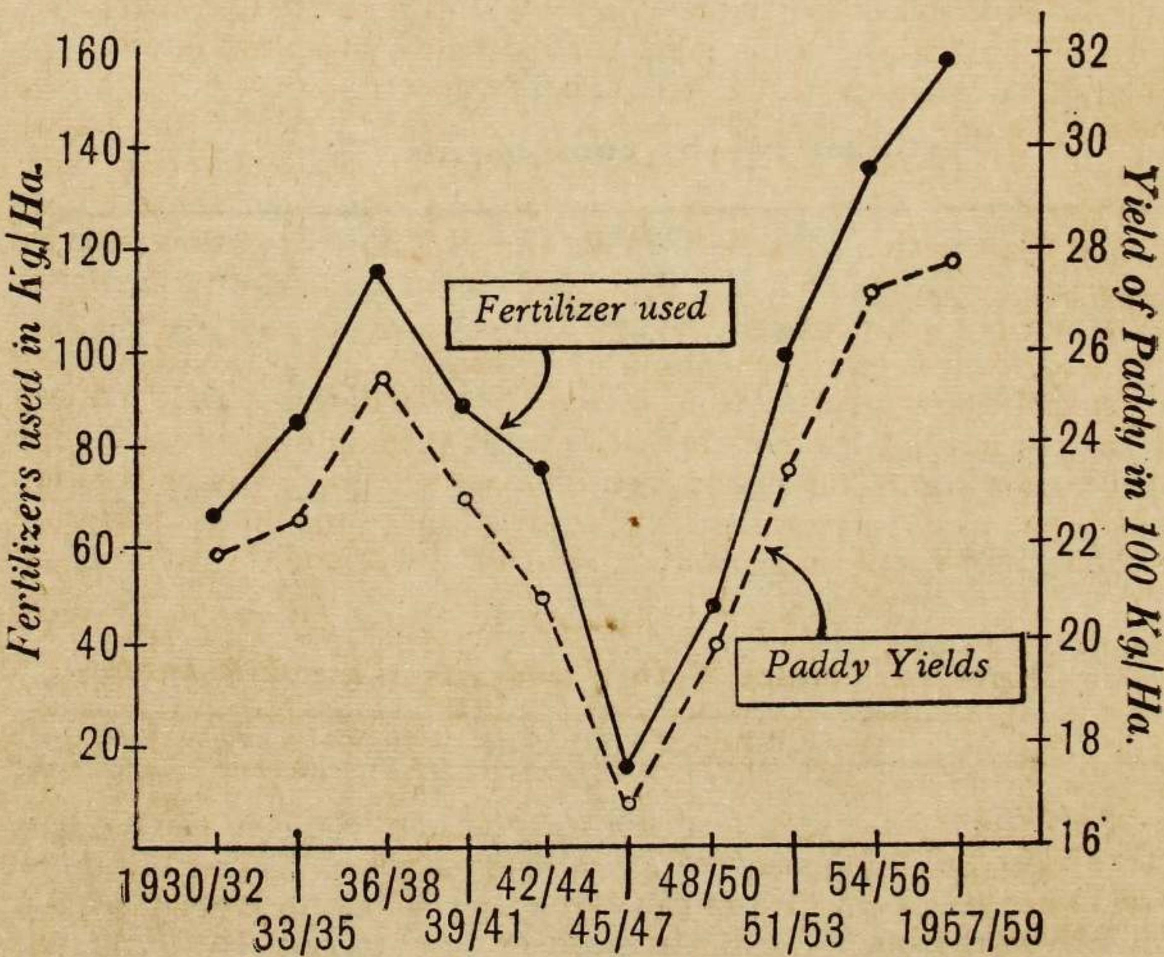


Figure 1. Relationship between Yields of Paddy and Fertilizer use in Taiwan (Von Uexhuell, 1964)

If this distressing trend continues the entire programme of fertilizer use will need to be reviewed, in view of the large sum of foreign exchange and subsidy involved.

The results obtained in Taiwan are interesting in this regard, where a close relationship between yield of paddy and fertilizer use has been convincingly demonstrated over a period of 30 years. (5). Figure 1.

In general, attempts to increase acre yields have made some impact, but these advances have not approached the high yields that could be obtained if the recommended improved techniques of culture were freely adopted. It is possible that these low yields result from socio-economic considerations rather than from a lack of knowledge of improved techniques of cultivation.

Paddy Lands Act

These considerations have also received considerable Government attention. The Paddy Lands Act which assured tenant cultivators security of tenure and a greater share of the crop was one attempt to promote production. The results of these measures are still to be realized and the work of the Agrarian Services Department through the cultivation committees should boost yields considerably in the near future. The Act was brought into operation in all 22 districts in 1963 and a total of 936,923 acres or approximately 80%of the total acreage of paddy are now covered by the full provisions of the Act. The balance 20% are either crown lands or are excluded by definition from the Act. All the paddy lands covered have been constituted into 3445 cultivation committee areas. Useful spheres in which cultivation committees have been most active have been in the provision of irrigation facilities and to a lesser extent in the enforcement of rules on the better management of fields.

A similar programme of land reform was started in Japan in 1946. Actually those reforms went further in that they not only assured tenancy but also gave ownership on the principle of "land for the cultivator" and these changes along with good prices resulted in rapid yield increases. (6). Table 14 shows the changes in land tenure that occurred between 1938-1955 in Japan.

TABLE 14

Types of Tenure Before and After Land Reform

Types of Tenure	1938	1955
Owners	29·2%	69·2%
Owner-tenants (owners hiring additional land)	45·5	27
Tenants	25·3	3·6
Others	—	0·2
Total	100·00	100·00

Guaranteed Price Scheme

From an economic point of view, paddy was never a paying crop as prices were low and returns small. This was remedied by the introduction of a guaranteed price for paddy. Table 15 shows the changes in the guaranteed prices along with the actual market value of a bushel of paddy based on the price of imported rice into Ceylon.

TABLE 15

Guaranteed Prices for paddy and actual market value of paddy based on the imported price of rice.

(In Rs. per bushel)

Year	Guaranteed Price of Paddy	Value of Paddy
1948	8·00	—
1950	8·00	7·74
1951	9·00	8·15
1952	12·00	11·25
1953	12·00	10·95
1954	12·00	9·43
1955	12·00	7·99
1956	12·00	7·45
1957	12·00	6·78
1958	12·00	6·85
1959	12·00	6·75
1960	12·00	6·37
1961	12·00	6·43
1962	12·00	6·59

These figures would indicate that the present price paid for paddy is roughly twice the world market price. Although it is difficult to isolate the actual impact of guaranteed prices it has proved to be an incentive and many marginal and other lands have been brought under paddy cultivation. Even chena lands that grow a wide variety of crops are now grown largely with paddy.

Agricultural Credit

The problems of the peasant's capital needs for cultivation have also been satisfied by Government initiative. This has been achieved by granting production and marketing loans to cultivators through Multi-purpose Co-operative Societies. (Table 16)

A complete review of the existing policy regarding the issue of loans for agricultural purposes took place in June 1963 and a liberalized credit scheme was initiated, designed to make available all the credit required, to adopt improved cultivation practices. This scheme also approved the payment of marketing advances to farmers about one month before the harvest is due in order to insulate them against the operations of traders and middlemen who are particularly active at this time. Loans were made available at the rate of Rs. 175.00 per acre for cultivation purposes. (Table 17)

TABLE 16

Statements of Loans Granted (2)

Year	Amount (Rs.)
1957/58	13,918,707
1958/59	18,466,824
1959/60	13,612,481
1960/61	11,406,210
1961/62	12,618,837
1962/63	10,310,027
1963/64	34,488,683
1964/65 (Oct April)	19,000,000

TABLE 17

Details of Loans obtainable per acre of cultivated extent

Item	Rs. cts.
Preparatory tillage	40·00
Seed Paddy	24·00
Fertilizer	36·00
Transplanting or Row Seeding	25·00
Weed Control	25·00
Harvesting	25·00
Total	175·00

The liberalized credit scheme led to a spectacular increase in the extent of credit given to cultivators. It increased from Rs. 12 million to over Rs. 30 million. A proper evaluation of its actual impact on production has still to be carried out.

Crop Insurance

As a further incentive, Government has introduced crop insurance for paddy growers. The programme was initiated in 1958/59 and has been gradually expanded to cover about 300,000 acres.

Under the Act, compensation will be paid where the loss exceeds 30% of the average yield from that insurance unit. The following causes of loss are specified: (*a*) Lack of water. (*b*) Drought. (*c*) Excessive water. (*d*) Floods. (*e*) Plant diseases. (*f*) Insect infestations. (*g*) Wild boar. (*h*) Wild elephant. (*i*) Adherence to methods of farming approved by the Commissioner. The maximum coverages offered per acre vary from Rs. 100 to Rs. 180. Certain changes in the scheme are contemplated so as to make it more attractive to the farmer as well as a more effective instrument for increasing production. (2)

Size of holdings

Paddy production in Ceylon is undertaken by a large number of small producers. A study of the size of holdings indicates that 36 % of the holdings are below ½ acre, 45 % from ½ acre to 1½ acres and that only 3.2 % of the holdings are over 5 acres each. This information on the number of holdings below 1½ acres, has been related to district yields by Bansil (7). He has shown that the highest yields are obtained in the Moneragala and Polonnaruwa districts where there are ideal conditions for paddy growing with extensive irrigation facilities. The same trend does not hold for other similar areas and he attributes this to the reluctance on the part of cultivators to use improved methods of culture. Districts with over 9 per cent of the holdings below 1½ acres are mainly located in the wet zone and some of these are among the highest yielding districts in Ceylon: *e.g.* Badulla, Kandy, Kegalle and Matale. The small size of holding in itself does not appear to be a detriment to obtaining high yields. However the organization of production on about one million individual holdings presents a formidable task.

Rice occupies a pre-eminent place in the economy of this country. The total producer paddy subsidies have grown into enormous proportions and expenditure on expanding acreages and raising per acre yields have also substantially increased. This enormous expenditure, still appears to be justifiable as it is designed to make Ceylon self-sufficient in rice.

ORIGIN OF THE CROP

The paddy plant belongs to the genus *Oryza*, sub-tribe *Oryzeae* and family Gramineae. The genus was considered to include 24 accepted species, of which 22 are wild and two, *Oryza sativa* and *Oryza glaberrima* are cultivated (8). All varieties grown in Asia, Europe and America belong to the species *Oryza sativa*, the West African varieties belong to the species *Oryza glaberrima*.

Recent work by Chandraratna (9) summarizes the information on the origin and interrelations of *Oryza* species and states: "There appears to be general acceptance today of the view expressed by Roscheviez (1931) that the centre of origin of this species was South East Asia, particularly India and Indo China, where the richest diversity of cultivated forms has been recorded."

Oryza sativa var. *fatua*, the common wild rice of India is polymorphic and is considered the immediate progenitor of cultivated rices. It has since spread to various parts of the world and thousands of varieties are recognized. (8). On the other hand some workers consider *Oryza sativa*, monophylectic in origin.

Oryza sativa varieties are grouped into two sub-species, the *japonicas* and the *indicas.* Hybrids between these show varying degress of sterility and they are identified by the following characteristics. (Table 18)

TABLE 18

Characters of the Japonica and Indica sub-species

Characters	Sub-species Japonica	Sub-species Indica
1. Leaf type	Narrow, dark green	Broad, pale green
2. Angle of boot leaf with stem	Wide	Narrow
3. Grain type	Broad, thick circular in transverse section	Narrow, flattened in transverse section
4. Cooking quality	Moist, sticky cooked rice	Non-cohesive cooked rice

A third sub-species, the *javanicas* are also recognized by some workers. These *javanicas* or *bulu* sub-species are found mainly in Indonesia. They are characterized by stiff-straw, long panicle with awned grains, sparse tillering habit, long duration and low sensitivity to differences in natural day length. (8).

The varieties cultivated in Ceylon fall into the *indica* group. This group also includes most varieties grown all over tropical Asia.

BOTANICAL DESCRIPTION

Paddy is an annual grass with erect culms, a few feet tall. The height of the plant depends on the number of internodes which may vary from 10-20. At the early stages of growth the stem remains short, it later elongates after flower primordia initiation, to give a cylindrical hollow culm except at the nodes. Only the buds at the axils of the lower leaves grow out to give a tillered plant. The extent of tillering is a varietal character.

The first leaf is a sheathing leaf, the second has practically no blade, other leaves are normal and have leaf sheath, blade, ligules and auricles. Some varieties are devoid of auricles and ligules. The inflorescence is a loose terminal panicle of perfect flowers. The flower has six stamens and two plumose sessile styles, surrounded by a five nerved lemma and a three nerved palea at the base of which are two small glumes. The lemma may be awned. The fruit is a caryopsis. The endosperm contains mainly starch grains; the germ and the pericarp contain varying quantities of protein, fats and vitamins.

The root system has at the commencement a primary seminal root and two secondary seminal roots. The bulk of the roots develop from the lowest nodes, both from the mother plant and the tillers. The plant produces both short thick white unbranched roots and long, brown much branched roots. The nature of the root system changes with age. The number of roots increases and reaches a maximum at heading, and thereafter decreases gradually until harvest time.

ECOLOGICAL ADAPTATION

The area of culture extends 40°N and 40°S of the Equator. The ability of the crop to grow under such a wide variety of conditions arises from the tremendous number of varieties that are grown all over the world.

The crop is regarded as one suitable for the wet tropics although it grows in other parts as well. It is generally grown under flooded culture and is subject to the restraints that a monsoon imposes on productivity. The crop is generally sown with the early rains and harvested at the end of the monsoon when dry weather sets in. Heavy rain and cloudy weather are unfavourable at flowering as it interferes with pollination and rain causes lodging at maturity. Paddy grown under upland conditions is dependent on a well distributed rainfall. In experimental plots established in the Colombo District it was observed that the crop could survive for only 14 consecutive rainfree days. A longer period of drought caused partial or complete loss of the crop. (10)

Numerous inconclusive studies have been carried out on the light requirements of the paddy crop. Short day length and low light intensity, on account of cloudiness, are characteristic of the tropics whereas long days and high light intensity favour rice production in the temperate regions. Although light is known to influence growth, net assimilation and yield, no quantitative relationships have been established, with reference to the effect of light intensity or spectral composition on those factors. It has also not been established that light is a limiting factor in the tropics. On the other hand some varieties of paddy are known to be grown successfully in Malabar under the shade of trees. (11). In Ceylon upland crops giving over 40 bushels per acre have been obtained from crops grown under shade of mature coconut. (10).

Lodging caused by wind, results in considerable loss of crop. Wind damage is most serious at maturity. Transplanted crops and varieties with good straw strength resist such damage.

The influence of temperature on growth, respiration, uptake of nutrients, translocation and yields is also not clear. It is accepted that paddy needs a warm growing season, and that temperatures as high as 40°C do not harm the crop if moisture is available.

The bulk of the work on temperature has been done in relation to cold tolerance. These studies indicate that cold causes (*a*) delay in plant growth and tillering (*b*) damage at the time of reductive division of pollen mother cells, formation of floral structures and at fertilization, and (*c*) damage by making the plant more susceptible to disease. (12), (13). Some screening of varieties and hybrids has been done at Rahangala to select suitable types for cultivation at altitudes of over 5000′ such as the Nuwara Eliya district. (4). In general temperature is not a serious problem affecting the rice crop in Ceylon.

Paddy is grown on a wide range of soil conditions quite successfully. The crop appears to prefer a heavy soil. The loss of irrigation water from light soils imposes a restriction on their suitability, particularly in areas where water is scarce. Mechanical analyses carried out on paddy soils have shown wide differences, the clay content varying from 7-27% and coarse sand from 8-63%. (14). Grist goes on to state, "The chemical analysis of a soil does not appear to provide a very sure guide as to its suitability for paddy cultivation."

Very acid, alkaline and saline soils are known to produce poor results. The low-country wet zone soils of Ceylon, strongly acid in reaction and deficient in bases have shown striking increases in yield when limed. The depressed yields obtained on saline tracts in the coastal areas have been overcome to a point with the use of tolerant varieties. Apart from these problem soils the majority of the soils are capable of giving good yields with adequate management.

The recent symposium on the Mineral Nutrition of the Rice Plant, conducted by the International Rice Research Institute, summed up their discussions on ecology by recording that "There is no clear cut evidence that climate or soil is a serious limiting factor to high rice yields in the tropics.(15)

Areas for cultivation

Paddy is grown in all of the 22 Districts in Ceylon. (Table 19). The smallest acreage is grown in the Nuwara Eliya and Moneragala districts and the highest in the Kurunegala District. Further extension of rice growing areas will have to be located in the undeveloped dry zone with suitable provision for irrigation.

The wide discrepancy between the areas cultivated for the two seasons is a direct result of the non-availability of water for the Yala season. Nearly 100,000 acres remain uncultivated in the Kurunegala District alone. In tank irrigated areas, the more economic use of water may help to bring a larger acreage under cultivation in the Yala season.

TABLE 19

Areas of Paddy Cultivation (In acres)

District	Maha 1961/62	Yala 1961
Colombo	53,388	23,359
Kalutara	35,709	37,285
Kandy	43,525	35,395
Matale	21,372	13,652
Nuwara Eliya	16,256	8,575
Galle	38,468	41,011
Matara	40,090	36,056
Hambantota	37,939	35,450
Jaffna	67,449	8,954
Mannar	29,733	3,467
Vavuniya	46,615	5,350
Batticaloa	57,017	33,986
Amparai	64,807	38,132
Trincomalee	35,688	19,162
Kurunegala	138,425	42,312
Puttalam-Chilaw	23,228	6,375
Anuradhapura	84,349	37,000
Polonnaruwa	46,006	39,982
Badulla	11,640	21,276
Moneragala	12,069	2,630
Ratnapura	27,046	28,550
Kegalle	27,519	19,551
All Island	958,338	537,510

(*Source*: Statistical Abstract of Ceylon, 1962)

CROP IMPROVEMENT

It is believed that plant type is the biggest obstacle to high rice yields in the tropics and not environment. Recent work has emphasized the importance of this concept. In the past, a large number of village varieties have been grown in Ceylon and these are gradually giving way to selections with high yield potential. Most tropical varieties exhibit vigorous vegetative growth, are tall and well adapted to a hazardous environment and poor management. They are less suited to intensive cultivation. Because of vigorous early growth and profuse tillering, they respond to applied nitrogen with a burst of vegetative growth which causes mutual shading, over-elongation of internodes, severe lodging and low grain yield. (15).

Desirable characteristics of a paddy variety

A desirable variety should have the following characteristics amongst others :

I. Moderate tillering. Tillering is a variable character dependent on variety and environmental conditions. Profuse tillering causes mutual shading and over-elongation of internodes.

Late tillers in most cases remain sterile and do not contribute to grain yields. The desirable type should complete the grand period of tillering in a short period of time, give a high percentage of fertile tillers and mature uniformly.

II. Resistance to lodging. Losses caused by lodging vary. Yield decreases up to 60 % have occurred when lodging occurs at pre-flowering stage and 18 % at the dough and ripening stages. (8). In addition lodged plants are difficult to harvest and it also leads to a deterioration in quality. Four types of lodging are recognized. (12). (*a*). By breakage of the culm at the base. (*b*) By bending of culms. (*c*) Lodging due to short roots. (*d*) Plant tillers of a spreading habit. Lodging resistance is determined by stem strength, stem height and panicle weight. High yields are dependent on panicle weight and lodging resistance must then be developed by breeding varieties with short strong culms. Culm strength should be accompanied by some degree of elasticity to resist wind damage.

III. Non-shattering. Shattering is a common characteristic of the wild species. It causes considerable loss which in some cultivated varieties can amount to 20 to 30 % of the crop. This characteristic is particularly important when it is desirable to harvest the crop over an extended period of time or where harvesting is mechanized. The shedding character appears to depend on the nature of the abscission layer in the pedicel.

IV. Fertilizer response. The two recognized sub-species, the *indicas* and the *japonicas* show different responses to fertilizer application. The *indicas*,do not respond markedly to fertilizer application. Varieties which respond to high levels of fertilizer by producing high grain yields have small, thick, erect dark green leaves, and short stiff stems. They rapidly attain the optimum leaf area and reproductive phase is initiated as soon as this optimum is reached. High fertilizer response is also closely associated with early maturity, slow senescence and active nitrogen uptake till the end of growth. In contrast the low fertilizer response *indicas* show unrestricted vegetative growth following nitrogen uptake. The mutual shading that results associated with low light intensity during monsoon periods, creates a serious imbalance between photosynthetic and respiratory activity during the critical period from flowering to maturity. This also leads to increased sterility and decreased grain straw ratios. (15).

Japonicas do not perform well in the tropics and extensive *japonica indica* hybridization programmes are underway to develop high fertilizer response rice varieties for these areas.

V. Pest and disease resistance. The use of resistant varieties is the cheapest and simplest way of eliminating losses from pest and disease attack. For example some varieties show varying degrees of resistance to blast (*Piricularia oryzae* Cav.).

VI. Ease of threshing. The importance of the non-shedding character is evident, at the same time the grain attachment to the panicle should not be so firm as to hinder threshing. This is particularly critical in areas where the crop is threshed by trampling.

VII. Early Maturity. The age of cultivated rice varieties vary from 90 days to over 200 days from sowing to harvest. Long duration varieties impose an unnecessary restraint on planting time, lead to inefficient use of land and longer exposure to natural hazards without compensating increases in yields. (15) Early maturing varieties are useful in areas which are double-cropped, where irrigation water is scarce, or where the growing season is short. Earliness is a desirable character provided it is not associated with a severe loss of yield. Work conducted at the Ibaraki Prefectural Agricultural Experiment Station, Japan, established the relationship between the straw and grain yields of early and late maturing varieties grown under the same conditions. (16). The results indicated clearly that long aged varieties produced more straw but that grain yields were similar to those of the short aged varieties. (These results were obtained with *japonica* types). (Figure 2).

VIII. Seed dormancy. The germination of seed in the field during periods of wet weather, is due to the lack of seed dormancy. This is usually associated with early varieties and can lead to heavy losses of yield and quality. However dormancy is a common characteristic of the *indicas* and is supposedly related to its photo-period sensitivity.

IX. Plant type and yields. The final object of selecting a suitable variety is to obtain the highest possible yield under the prevailing conditions. Yield in itself is made up of a number of components and may be represented thus :

Grain Yield per unit area	=	number of fertile panicles	×	number of grains per panicle	×	weight of 100 kernels (size of grain)

Varieties which have a number of fertile panicles per plant are lighter in panicle weight and are known as "panicle-number types". Varieties that have fewer fertile panicles per plant are heavier in panicle weight and are known as "panicle-weight type". The intermediates are grouped as "medium type". Panicle weight types are associated with tall vigorous growing varieties, suited to poor lands or cultivation with low fertilizer applications. Panicle number types are short, plant growth is light and are suited to fertile lands or cultivation with heavy applications of fertilizer. (16).

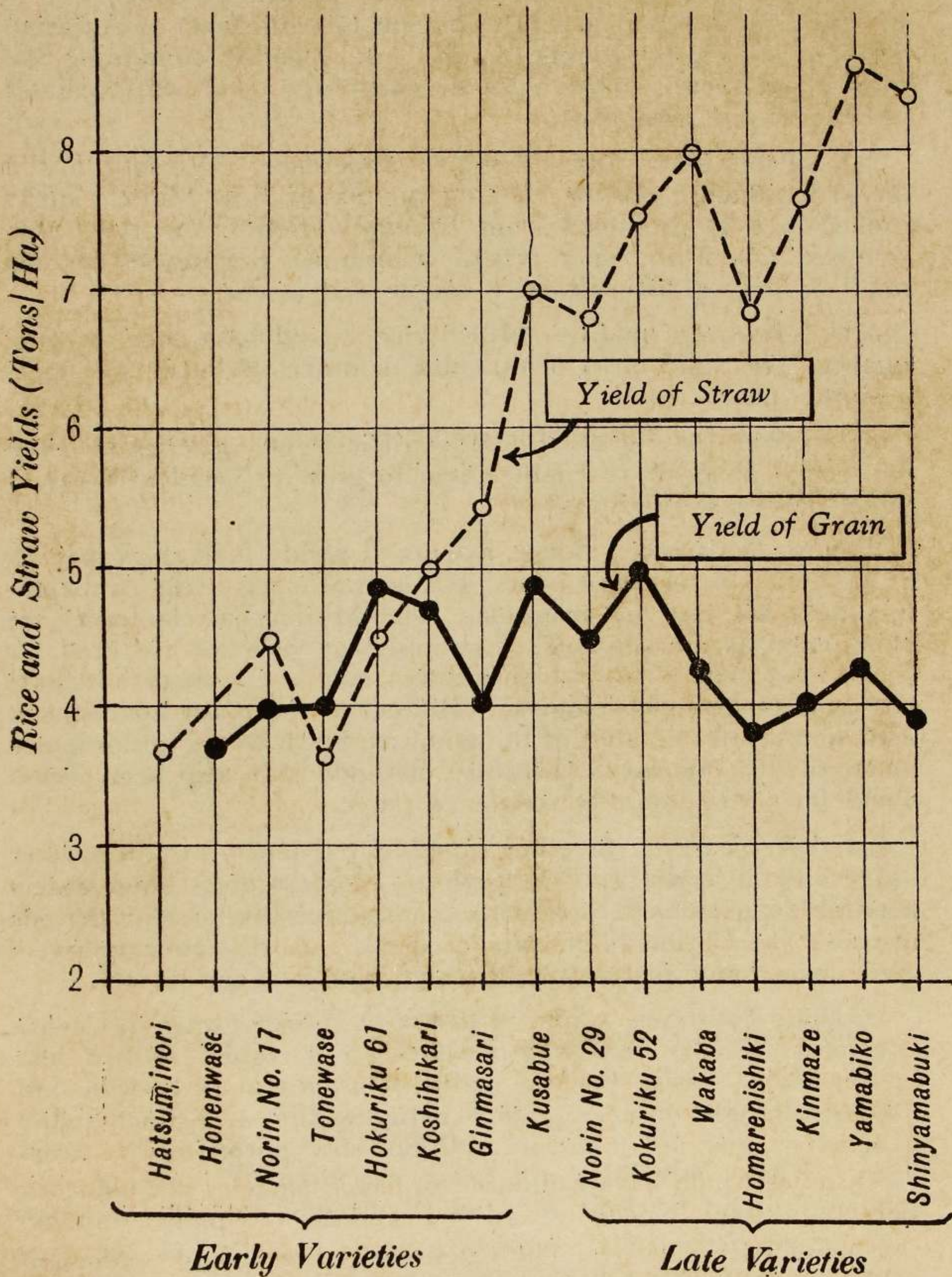


Figure 2. Changes in straw and grain yield with increasing age of variety (Ibaraki Experiment Station)

Courtesy Fuji Publishing
Company Ltd.,
Japan.

X. Milling out-turn. This denotes the ratio of milled rice to paddy. The standard accepted by the Commissioner of Agrarian Services is 51% by volume in the case of paddy containing less than 6% refraction. The volume-weight of the paddy variety has a bearing on milling out-turn.

XI. Palatability and consumer preference. Variety has a marked influence on the cooking quality of rice. Moist, sticky cooked rice is produced from *japonica* varieties, the dry, non-cohesive rice from *indica* types. Consumer preferences include small or long grain, attractive colour and aroma.

XII. Keeping quality. Milled rice should have good keeping quality. The rapid onset of rancidity or other off flavours is not a desirable character.

Apart from these general characteristics some varieties are bred for special purposes to enable them to grow in problem areas or under particular conditions.

Salinity Resistance. Large extents of paddy land show salinity or alkalinity to varying extents. The coastal tracts in the Ambalantota area are just one example. The Muthurajawela tracts are abandoned as uncultivable. Salt resistant varieties are bred for such areas. The term "salt resistance" can be expected to include two aspects, the physiological resistance of the plant against salt and the overall tolerance of the plant as shown by its performance under field conditons. Laboratory methods have also been developed for testing salinity resistance. (17).

Flood Resistance. Breeding for flood resistance is of far greater importance in India than in Ceylon. In these areas flood waters may rise 15-20 feet and the lands remain submerged for long periods of time. In Ceylon flood damage occurs in areas close to rivers and is a common feature in the lower reaches of the Kelani.

Drought Resistance. A large area of the paddy grown in Ceylon is rainfed. Losses from lack of water are a regular feature, and in the Maha season 1964/65 many thousands of acres were lost through drought damage. Some varieties show a distinct ability to survive water stress, and in addition show morphological variations. These characters are being exploited in breeding programmes in an attempt to produce drought tolerant varieties.

Upland Rice varieties. The extension of rice culture under irrigated conditions is limited on account of the capital investment involved. Unirrigated rice has been grown but yields appear to be low compared to those from flooded culture. The physiological factors limiting growth and yields under these conditions have been investigated by Senewiratne and Mikkelsen (18). It may be possible to screen varieties suited to upland conditions on the basis of these physiological findings.

Photoperiodism. Small differences in day length have a marked influence on the flowering duration of rice varieties. The maximum day length difference in Ceylon is less than an hour but this variation has proved to be adequate to alter the flowering of date-fixed varieties. Paddy varieties are grouped into two main categories with reference to their photoperiodic response.

I. The "period fixed" types. The seeding-heading interval is practically constant and unaffected by sowing date. The short aged varieties belong to this category.

II. The "date fixed" or "season fixed" types. The longer aged varieties like the *Mawis* belong to this group. They are sensitive to day length and flower normally when they are grown in the Maha.

Varietal selection must take photoperiodism into consideration. A long aged, "date fixed" variety, like *Mawi* grown in the Yala will fail to flower normally and cause considerable financial loss. The optimum photoperiod of some Ceylon varieties is given below. (19).

Variety	Optimum Photoperiod
Devaredderi	10 hours 30 minutes
Mawi B 11	10 hours
Vellai Illankalayan 28061	10 hours
Heenati	11 hours 30 minutes to 12 hours

The features of an ideal plant type for the tropics were summarized at the International Rice Research Institute Symposium as follows (15).

1. Early maturity (100-125 days from seeding to maturity) to maximize yield per unit of time.
2. Insensitivity to photoperiod to give flexibility of planting date.
3. Moderate tillering to minimize mutual shading and over-elongation of internodes.
4. Short, sturdy culms to minimize lodging.
5. Small, thick, erect, dark green leaves to maximise light utilization.
6. Resistance to the prevailing races of blast.
7. Seed dormancy to avoid germination in the panicle.
8. Moderately firm threshability to reduce shattering losses.
9. Glabrous leaves and husks to facilitate mechanical harvesting and processing.
10. High milling yield.
11. Accepted shape, size and cooking quality of grain.
12. Low respiration rate.

13. Strong oxidizing power of roots.
14. It is not sure whether the quality—"moderately vigorous early growth"—necessary for an early maturing transplanted crop, could be retained without the undesirable vigorous later growth characteristic of present tropical *indica* varieties.

Among the promising sources of the desired characteristics are:

(1) The *japonicas* (ponlais) from Taiwan.
(2) A number of *japonica* × *indica* lines developed in the United States and elsewhere.
(3) The dwarf *indica* varieties from Taiwan.
(4) The SML varieties from Surinam.

Recommended varieties

The recommended varieties for cultivation in Ceylon, and their characteristics are as follows :(20)

Podiwi A 8

Podiwi A8 is a very popular long duration variety commonly known as Muttu Samba on account of its pearly white grain. In all probability, it is an introduction from India.

Podiwi is characterised by its tall and bulky habit, being invariably taller than 125 cms., thick culms, moderately profuse tillering, medium long fairly dense panicles with round, bold, grain. Even though the variety tillers freely, a high percentage of them are ineffective or unproductive. Anthocyanin pigmentation is present in several parts of the plant.

Podiwi is a low yielder which exhibits the entire range of economic defects, such as very low fertilizer response, high susceptibility to blast and stem-borer, in addition to grain shedding, severe preharvest lodging and low grain straw ratio. The exceptionally high stem-borer susceptibility is a conspicuous varietal draw-back, which may result in severe yield reduction. 20-25 lbs. of nitrogen is considered a suitable upper level for manuring. Liberal fertilization may result in the crop running into leaf followed by early lodging. In fertile fields too, the same tendency may occur. The only justification for the persistence of Podiwi as a recommended variety is its unique palatability which commands a 25% premium over the guaranteed price.

This particular variety exhibits a fair degree of drought resistance. Hence, it is also used for dry sowing under rainfed conditions. A 10-12 weeks dormancy period is necessary for successful germination.

This variety is photo-sensitive. It matures in six months. It is strictly a Maha season variety on account of its photo-sensitivity and unless sown at least by late September, it may prolong its vegetative phase without flowering. Podiwi is recommended for cultivation in Kurunegala, Kandy, Colombo and parts of Matara districts. It is a low yielder, and 50 bushels per acre is considered high. Its milling out-turn is average but grain weight is low.

Ptb 16

Ptb 16 is another long duration variety, recommended by the Department of Agriculture and known in certain villages as Riyan-wi on account of its exceptionally long panicle. It is an introduction from India which was released in Ceylon 12-15 years ago for the replacement of Kohumawi B-11.

Tall bulky culms growing beyond 130 cms., poor tillering, exceptionally long panicles measuring 35-39 cms., with medium narrow fine white grain, with good palatability are the more noteworthy features of Ptb 16.

It has high resistance to blast and moderately high nitrogen response up to 40 lbs. nitrogen per acre and fairly high resistance to stem-borer. Grain shedding, pre-harvest lodging and a low grain straw ratio can be listed as its chief defects. As in the case of Podiwi A8, Ptb 16 may run into leaf if excessively fertilized.

In sandy, ill-drained and degraded type of soils, a physiological decline has been observed after a period of vigorous growth. Yellowing and death of lower leaves is a manifestation of the onset of the decline. At that stage, most of the roots are found to be dead. Under such conditions nitrogen top dressings will not only be wasteful, but may also aggravate the decline.

Ptb 16 is a photo-sensitive variety although its optimum photoperiod is short and lies between 8.5-9.00 hours. For successful germination a dormancy period of 10-12 weeks is essential. Its rice is palatable and has a milling out-turn of 69% by weight. It has a sowing to harvest duration of 5½ months. Like Podiwi A 8, unless the variety is sown before the end of September, it may fail to flower. The exceptionally long panicle is often deceptive, leading to over estimation of acre yields on eye observation. An acre yield of 60 bushels per acre is considered good. Its cultivation is confined only to the Maha season and is recommended for Kandy, Kurunegala, Colombo, Ratnapura and Matara districts.

H 4

This is a recently evolved hybrid, released in late 1958. H 4 was the outcome of a cross between local Murungakayan 302 and Indonesian Mas. The main objectives of the cross were the elimination of the obvious defects of Murungakayan 302 such as bulkiness and awning. H 4 while eliminating the parental defects also combined several other virtues of great economic significance.

The characteristic features of H 4 are profuse tillering, short habit, seldom out-growing 100 cms., long heavy panicles, large, heavy, coarse, awnless paddy with red rice grains and a conspicuously erect flag leaf. At cooler temperatures H 4 culms are invariably less than 80 cms. in height. H 4 tillers freely yet bears long heavy panicles. Anthocyanin pigmentation is totally absent in H 4.

A wide range of adaptability is perhaps the most priced virtue of the variety. Resistance to *Piricularia*, and grain shedding, moderate resistance to stem borer, very high nitrogen response and fair lodging resistance are the additional virtues of H 4. H 4 is responsive up to 60 lbs. nitrogen per acre, even though at such high levels, the variety may manifest pre-harvest lodging. Moderate bronzing resistance has been reported. Compared to most recommended varieties, H 4 is credited with a higher grain straw ratio which is found to be constant even at high levels of fertilization. It also claims a high percentage of effective tillers. H 4 is a "period fixed" type with a sowing to harvest duration of 4-4½ months. A seed dormancy period of 5-6 weeks is essential for successful germination. It has been quite successfully cultivated even as an upland crop under rainfed conditions. A milling outturn of 72% by weight is possible.

The high shedding resistance is considered a drawback, particularly in tracts where foot and buffalo threshing are practiced. It has large, coarse, unappealing grain. Several basal grains of the panicle remain unfilled contributing to an increased sterility percentage which may exceed 20%. With proper timing of nitrogen top dressings, this can be reduced.

H 4 has the highest yield potentialities and acre yields of 120 bushels per acre are very common. A scientific study on its yield potentialities estimated the variety to be capable of producing 160 bushels per acre under optimum conditions. Under transplanted as well as broadcast sown conditions, H 4 has given high yields. The variety has a tendency for lodging under direct sown conditions. H 4 is recommended for practically all parts of the island and can be successfully cultivated during both Maha and Yala seasons. Since its release in 1958, it has gained wide popularity and has completely replaced its own maternal parent Murungakayan 302 which earlier completely wiped out the famous Vellai Illankalayan. H 4 is not a quality rice but a prodigous yielder, highly responsive to nitrogen .

H 501

This is also a recommended newly evolved variety isolated from a cross between Indian G.E.B. 24 and local Vellai Illankalayan. It is recognized by its compact low tillering, tall bulky habit, thick culms, medium long panicles with very dense grain arrangement. The grains are somewhat oval, medium sized, and awnless, with red rice. The earhead is a good example of a dense panicle. All parts of the plant are devoid of anthocyanin pigmentation.

Resistance to bronzing is listed as its chief merit and the only reason for its persistence. H 501 is quite responsive to nitrogen even up to 40-50 lbs. per acre. It is resistant to blast. Severe grain shedding is its chief drawback. H 501 is photo-insensitive and matures in 4-4½ months. The milling recovery approximates 69% by weight. Seed dormancy period is 4 weeks.

It can be cultivated for both Yala and Maha seasons. H 501 is specifically recommended for peaty acid ill-drained soils of the low country wet zone, where bronzing, resulting from iron toxicity is prevalent. The yield potentialities of H 501 are high and acre yields of 80 bushels have been reaped in dry zone tracts but its yields in problem soils are bound to be less. It is generally recommended for Galle, Kalutara and Colombo districts where iron toxicity is the chief problem. However, the variety is not quite popular.

Murungakayan 302

Murungakayan 302 is a straight selection made from Dikwi. It was released in 1951 and within a very short period, completely wiped out the then famous Vellai Illankalayan.

The chief noteworthy features of Murungakayan 302 are moderate tillering, very long heavy panicles, measuring about 30 cms. large coarse red rice grains. The awning frequency and awn length vary widely under changing environmental conditions. The culms are tall, thick and bulky. The flag leaf is conspicuously erect and all parts of the plant are devoid of anthocyanin pigmentation. Murungakayan 302 resists shedding and *Piricularia*. Its response to nitrogen is very high, yet less than that of H 4. Moderate resistance to lodging has been observed. A wide range of adaptability is associated with this variety. The variety, though highly responsive to nitrogen yet is a good yielder even at low levels of fertility. Tall and bulky growth and awning are its chief defects.

Murungakayan 302 is practically insensitive to the photoperiod, and matures in 4-4½ months. It has a milling out-turn of 69% and a seed dormancy period of 4-5 weeks. Even as an upland crop it has fared quite well. Acre yields of 80-85 bushels per acre have been recorded with Murungakayan 302. It was cultivated practically in all parts of the island and enjoyed wide popularity till the appearance of H 4, which inherited most of the desirable qualities from its Murungakayan 302 maternal parent. Since the release of H 4, Murungakayan 302 has gradually passed in to oblivion making way for its more prolific and superior offspring.

Patchaiperumal 2462/11

Patchaiperumal 2462/11 is one of the oldest local pure lines, which is extensively cultivated and very popular. The characteristic features of this variety are short thin culms seldom out growing

85 cms. It tillers freely, has a short panicle with well filled heavy medium size grain. Rice colour is red. Several parts of the plant are pigmented.

The chief advantage of Patchaiperumal is its earliness which approximates 90 days from sowing to harvest. It is undoubtedly the earliest maturing recommended variety. Another virtue of Patchaiperumal is its fairly high yield potentialities in spite of its earliness. High susceptibility to blast, severe grain shedding and lodging are some of the chief defects in addition to low response to nitrogen. Patchaiperumal is also susceptible to the stem-borer. This variety is not responsive to levels of nitrogen beyond 20-25 lbs. per acre.

This is a "period fixed" variety with a seed dormancy period of 3-4 weeks. The variety has a milling out-turn of 72 % on a weight basis which is considered high. In view of its earliness, it is ideally suited for the Yala season in dry zone areas, where the chief limitation is the restricted water supply. It has been tried as a late Maha-crop but its yields during the Maha season have been disappointingly low. Hence Patchaiperumal is essentially a Yala season variety. It has yielded up to 80 bushels per acre in Anuradhapura and Polonnaruwa districts. In addition to the above areas, it is also recommended for Kurunegala, Chilaw, Puttalam, Batticaloa and Jaffna districts.

Deveredderi 26081

Deveredderi, is an old variety but not a popular one. Poor tillering, medium long panicles with large heavy grain and tall culms about 120 cms. are the characteristic features of Deveredderi. The grains are very heavy. Anthocyanin pigmentation is absent.

The chief economic character of Deveredderi is its flood resistance, which is also the only justification for it to be listed as a recommended variety. Grain shedding, *Piricularia* susceptibility and lodging are its chief defects. It matures in five months and has a milling recovery of 70 %. Deveredderi is recommended for tracts around Colombo such as Muturajawela which are subjected to floods during the growing season. It is a definite Yala season variety but unfortunately is a poor yielder.

Pokkali

Pokkali is supposed to be an introduction from India. Morphologically it resembles Deveredderi in many of its features.

The only virtue of Pokkali is its saline resistance. Apart from that Pokkali claims no other advantages. It is also a Yala season variety specifically suited and recommended for those tracts where salt accumulation is a problem. Like Deveredderi, Pokkali is also a poor yielder and is not widely grown.

Summary of varietal characters

Variety	Age in months	Reaction to day length	Reaction* to blast	Shedding %	Sterility %	Nitrogen Response
Podiwi A 8	6	Sensitive	SS	8·0	6·6	Poor
Ptb 16	5½-6	,,	R	6·2	9·1	High
H 4	4 -4½	Insensitive	R	0·03	27·0	Very High
H 501	4 -4½	,,	R	14·3	6·4	High
Murungakayan 302	4 -4½	,,	RR	1·1	6·2	High
Patchaiperumal 2462/11	3	,,	SS	5·4	9·0	Poor
Deveredderi	5	—	SS	9·1	21·7	Low

*RR=Very highly resistant R =highly resistant SS=Very susceptible

Variety	Mean Panicle Length in cms.	Mean Panicle No. per hill	Grain Length in mm.	Grain Breadth in mm.	1000 grains grain wt. in grms.	Milling %	Yield Potentialities
Podiwi A 8	29·0	14·0	5·97	3·31	18·1	68·0	Low
Ptb 16	37·1	12·1	8·19	2·76	19·1	68·2	High
H 4	28·4	17·08	9·23	3·91	28·8	72·4	Very high
H 501	26·1	11·4	7·45	2·92	21·5	69·0	High
Murungakavan 302	32·1	10·5	8·33	3·07	27·2	69·0	High
Patchaiperumal 2461/11	25·8	23·0	8·0	3·50	27·5	72·4	Good
Deveredderi	27·2	10·6	8·28	3·56	32·5	70·2	Very poor

Nitrogen response

Variety	No Nitrogen		30 lbs. Nitrogen per acre		60 lbs. Nitrogen per acre	
	Yield in pounds/ acre	control	Yield in pounds/ acre	Percentage of control	Yield in pounds/ acre	Percentage of control
Podiwi A 8	1822	100%	2048	112%	2382	130%
Ptb 16	2216	100%	2870	129%	3470	156·6%
H 4	2032	100%	3160	155%	3948	194·0%
Murungakayan 302	1966	100%	2862	139%	3888	170%
H 501	2258	100%	2784	123%	3626	160%
Patchaiperumal 2462/11	2272	100%	2632	115·8%	2728	120·0%

CROP PHYSIOLOGY

Growth

Since yield integrates all factors affecting a crop, any attempt to analyse the factors contributing to final yield, must include a detailed study of the development of the plant.

Germination and seedling growth

Some of the physiological processes which accompany germination are known. Increased respiration, enzyme activity, chemical changes in the endosperm and embryo growth are among these. Each type of seed possesses an internal mechanism for releasing germination forces which are sensitive to one or several external conditions. In this regard rice is unique. It is possibly the only crop plant which can germinate under high or very low oxygen pressures as it possesses a strong mechanism for anaerobic respiration. The nature of the resulting seedling varies with oxygen availability. With abundant oxygen rice first produces a well developed coleorhiza and a diminutive coleoptile. Under low oxygen pressures, a strong growth of coleoptile results with reduced root growth.

Tillering phase

Tillering commences soon after seedling establishment 5-6 weeks from sowing in a 5 month variety. The "grand period" of tillering is short and extends from the 39th to 49th day. The tillering stage itself is divided into the valid-tillering stage and the invalid-tillering stage. Only those tillers produced during the valid-tillering phase bear panicles. (Table 20) (21).

TABLE 20

Seasonal increase in number of tillers and incremental change. (Based on a sample of 50 plants) (Senewiratne, 1957)

Age of Plant in days	Number of Tillers	Incremental change
25	0	—
32	1	1
39	68	67
49	193	125
53	212	19

Tillering is closely associated with the nutritional status of the mother culm, because a tiller receives carbohydrates and nutrients from the mother culm up to the 3 leaf stage.

Post-tillering to harvest

The title post-tillering is not meant to indicate a total absence of tiller production but merely the phase commencing after the "grand period" of tillering. The period extends over 100 days and includes the phases, involving the rapid development of a photosynthetic surface, active carbohydrate elaboration, storage and finally translocation of the stored material to the developing grain. These phases also overlap the change from the vegetative to the generative phase, growth in height, exertion of the inflorescence, ripening of the grain and senescence of the plant as a whole.

Leaf growth

Changes in leaf growth deserve close study as it is the main avenue through which the plant elaborates carbohydrates. However, the paddy plant consists of a colony of tillers, some productive, others not, and is a cumbersome unit for detailed examination. The main stem is less liable to variation from plant to plant and the data presented on leaf growth and leaf area pertains to this part of the plant.

Leaves 1-5 were small and their values are not reported. The pattern of growth indicates a gradual weight increase, a steady state and a decline with the onset of senescence. The values underlined in the table indicate the time when senescence, commenced. (Table 21).

Table 22 gives the seasonal changes in the weight of all leaf sheaths and blades on each main stem. These values indicate clearly that leaf sheaths decline in weight at the time of filling and maturity of the grain, indicating translocation of stored material out from the leaf sheaths. This occurs only to a small extent in the case of leaf blades.

Leaf area

The mother tiller had a total of 15 leaves. Of these the first two had no leaf blades, and the photosynthetically important leaves were leaf 3 onwards. The leaf that has just completed elongation is considered the "active centre leaf" and this leaf carries out photosynthesis vigorously and accumulates nitrogen, phosphorus, potassium and sulphur markedly. The active centre leaf is the most important leaf at any stage of growth, as it makes the greatest contribution.

Experimental evidence with $C^{14}O_2$ experiments carried out by Kasai and Asada have shown that the bulk of the carbohydrates in the grain come in as sucrose from the uppermost leaf via leaf sheath, node and stem. They suggested that the driving force of translocation was the difference in sugar concentration between leaf blade and grain. (15).

TABLE 21

Seasonal Change in Weight of Leaves (Senewiratne 1957)

Age of Plant in days	Dry Weight of Leaves (in gms.) According to Leaf Number									
	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15
12										
18	T*									
25	·003	T								
32	·019	·015	·017	T						
39	·022	·037	·048	·041	·009					
46	·024	·049	·065	·074	·053	·020	T			
53	·021	·046	·070	·099	·123	·121	·061	T		
60	·019	·039	·076	·101	·153	·210	·187	·070		
67	·019	·036	·072	·101	·152	·210	·256	·176	T	
74	·019	·039	·070	·100	·168	·233	·328	·315	·105	
81	·019	·039	·076	·117	·180	·270	·367	·389	·255	
88	·019	·039	·067	·101	·180	·300	·397	·483	·342	·085
95	·019	·039	·064	·101	·172	·310	·465	·513	·403	·176
102	·019	·039	·064	·088	·170	·326	·481	·509	·424	·291
109	·019	·039	·064	·095	·147	·246	·477	·479	·425	·353
116	·019	·039	·064	·100	·149	·284	·499	·550	·420	·328
123	·019	·039	·064	·095	·154	·290	·483	·489	·381	·319
136	·019	·039	·064	·095	·148	·277	·376	·400	·358	·344
149	·019	·039	·064	·095	·144	·270	·364	·406	·368	·334
160	·019	·039	·064	·095	·147	·267	·379	·393	·323	·315

* T indicates newly exerted leaf too small for measurement.

TABLE 22

Seasonal Changes in the Weight of Leaf Sheaths and Blades of Leaves on the Main Stem of Plants (Senewiratne 1957)

Age in Days	Total Leaves		
	Weight in gms.		
	Sheaths	Blades	Total
12	0·002	0·001	0·003
18	0·006	0·005	0·011
25	0·009	0·008	0·017
32	0·024	0·039	0·063
39	0·071	0·096	0·167
46	0·121	0·174	0·295
53	0·266	0·285	0·551
60	0·436	0·429	0·865
67	0·533	0·499	1·032
74	0·754	0·633	1·387
81	1·005	0·717	1·722
88	1·172	0·851	2·023
95	1·403	0·869	2·272
102	1·538	0·883	2·421
109	1·454	0·900	2·354
116	1·492	0·970	2·462
123	1·428	0·915	2·343
136	1·261	0·869	2·130
149	1·239	0·874	2·113
160	1·180	0·871	2·051

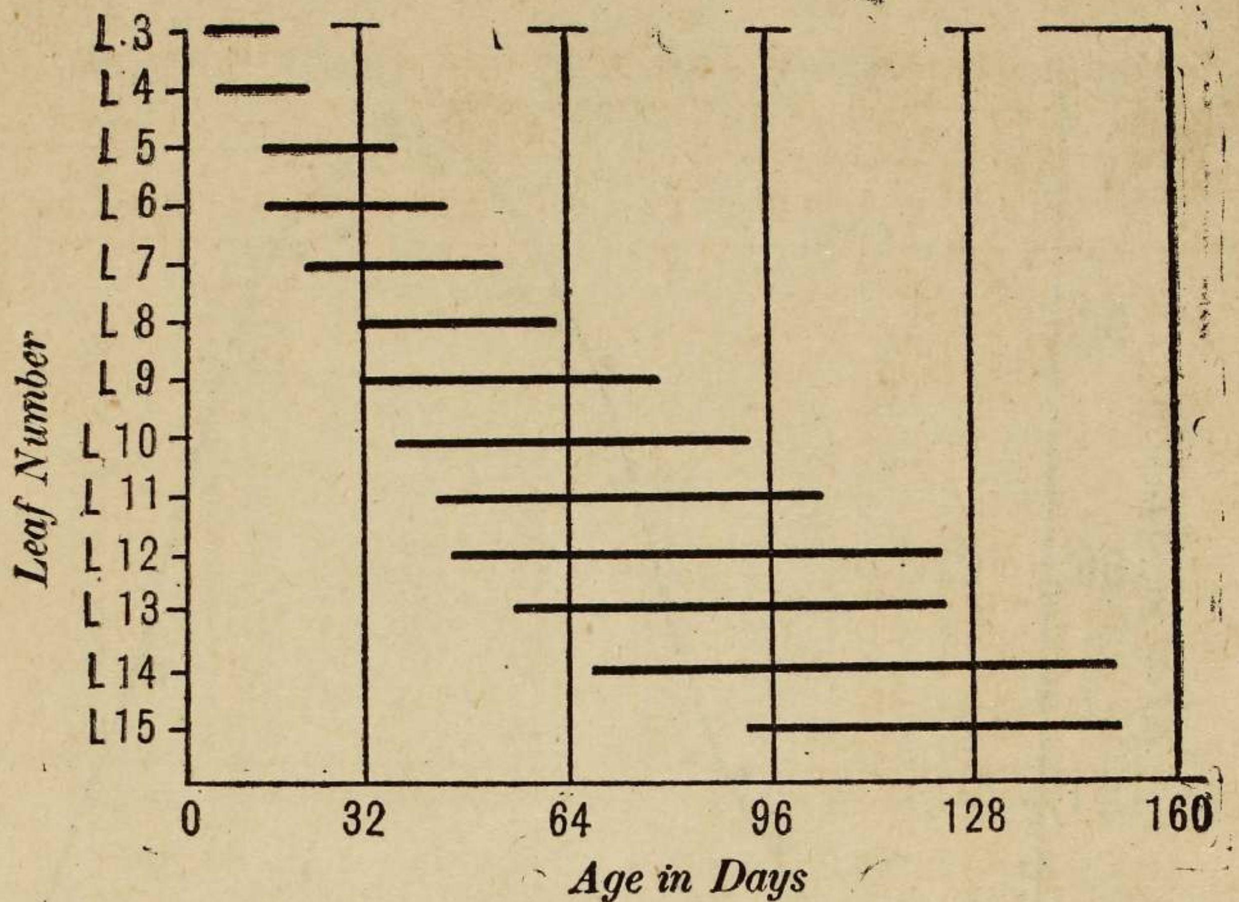


Figure 3. Period of Photosynthetic Activity of leaves on Main Stems (Senewiratne 1957)

The period of active photosynthesis of leaves has a material bearing on the total photosynthetic area of the plant. (Figure 3). However, the increase in total photosynthetic activity is not proportional to increases in the total leaf area, while total respiration does increase proportionally. It would appear that there is an optimum total leaf area which results in a balance between photosynthesis and respiration.

The effective photosynthetic area reached a maximum about the 95th day, and a decline set in shortly afterwards as a result of senescence of the larger leaves. (Figure 4). Under conditions of normal carbon dioxide supply and light saturation, photosynthetic activity on a leaf area basis is closely related to nitrogen supply, is dependent on variety and is considered to be a heritable character. (15).

Growth of culms

Elongation of culms usually follows floral induction and the first measurable changes in culm length are noticed about half way through the growth period. The internodes that subtend the lower leaves never elongate appreciably. The upper internodes elongate and finally result in the exertion of the inflorescence. Panicle formation begins 30-35 days prior to exertion. The booting stage, the stage when the panicle is just about to be exerted, coincides with reduction division or meiosis.

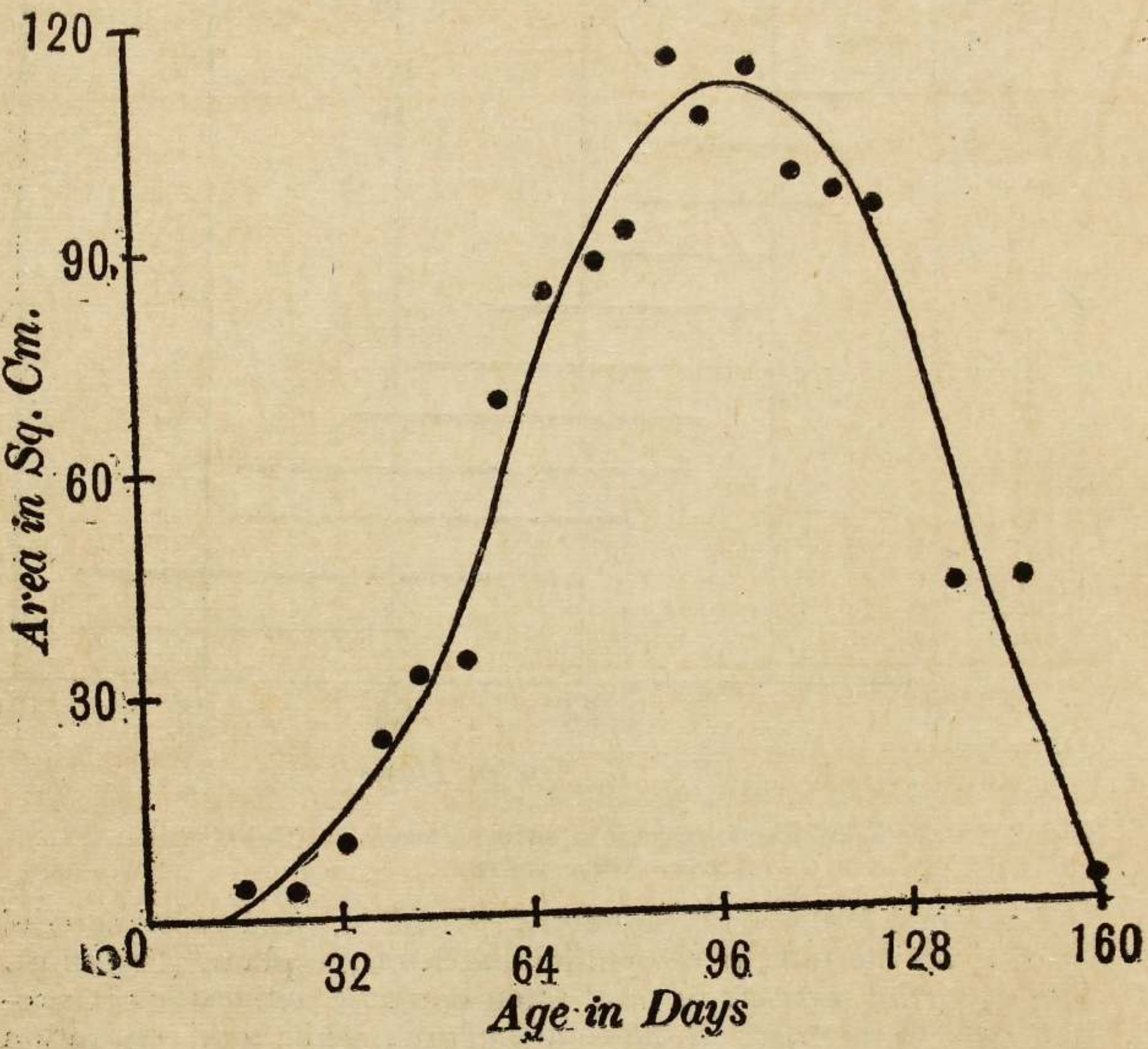


Figure 4. Effective Photosynthetic Area of ears on Main Stems (Senewiratne 1957)

The change in weight of the culm is marked. The culms increase in weight indicating storage of food and then decline when the reserves move out to the developing grain. The extent of stored food moving out from leaf sheaths and culms into the grain is estimated to vary up to 40 %. Table 23 indicates the weight changes that occur in each internode throughout the life of the plant.

Dry matter accumulation

Table 24 gives details of the pattern of growth of the rice plant, indicating the differences between main stems and tillers taken collectively. Although each plant produced 3 valid tillers on an average, the total weight of tillers only amounted to about twice the weight of the main stem. This would emphasize the greater growth of the main stem as opposed to the tillers.

TABLE 23
Seasonal Change in Internode Weight (in gms.)
(Senewiratne 1957)

Age in days	Internode Number*						
	L1-9	L10	L11	L12	L13	L14	L15
53	0·040						
60	0·071						
67	0·077						
74	0·115	0·027					
81	0·173	0·040	0·073	T			
88	0·185	0·040	0·161	0·029	T		
95	0·229	0·040	0·198	0·061	0·051	T	
102	0·251	0·040	0·200	0·174	0·114	0·042	T
109	0·245	0·040	0·205	0·259	0·214	0·104	0·112
116	0·237	0·040	0·215	0·261	0·322	0·214	0·218
123	0·250	0·030	0·220	0·270	0·364	0·286	0·240
136	0·247	0·030	0·160	0·200	0·234	0·160	0·185
149	0·239	0·030	0·125	0·144	0·187	0·145	0·200
160	0·233	0·030	0·125	0·175	0·184	0·149	0·202

*Internodes numbered in relation to the respective leaves

The growth of the entire plant, (Table 25) indicates that about 35% of all the final dry weight is in the form of leaves and that nearly 45% is grain. The grain/straw ratio varies with varieties and with cultural conditions. In general the *japonicas* give a more favourable grain/straw ratio, whilst the *indicas* tend to be leafy and produce less grain in comparison. The characteristics of a desirable plant type have been defined as a plant with small, thick, erect dark green leaves.

Yield components

Yield is determined by the number of panicles per unit area, the number of spikelets per panicle, the degree of sterility and the weight per 1000 kernels. The number of panicles per unit area is a function of the extent of tillering, particularly the tillers in the valid tillering stage. This is strongly influenced by environmental conditions. Table 26 gives the classification of a sample of plants according to the number of tillers. 16 per cent of the plants had only 1 tiller each, 50 per cent had 2 tillers each, 20 per cent 3 tillers each and 12 per cent 4 tillers each.

The number of spikelets depends on environmental conditions particularly before the spikelet primordium differentiation stage. The variation in the number of spikelets changes with the extent of tillering and the number of tillers per plant. The spikelet number on main stems increased with the extent of tillering. Plants with one tiller had on an average only 93.1 spikelets whereas plants with 4 tillers had 108.1 spikelets. A comparison of the number of spikelets on the main stem and tillers always indicated that individual tillers had fewer spikelets than the main stem. (Table 26).

Table 24
Seasonal Change in Weight of Main Stem and Tillers (in gms.)
(Senewiratne 1957)

Age in Days	Main Stem				Tillers			
	Leaves	Culm	Grain	Total	Leaves	Culm	Grain	Total
12	0·003	T		0·003				
18	0·011	T		0·011				
25	0·017	T		0·017				
32	0·063	T		0·063				
39	0·167	0·014		0·181	0·021	T		0·021
46	0·295	0·021		0·316	0·165	0·009		0·174
53	0·551	0·040		0·591	0·747	0·036		0·783
60	0·865	0·071		0·936	1·540	0·085		1·625
67	1·032	0·077		1·109	1·490	0·108		1·598
74	1·387	0·142		1·529	2·014	0·196		2·210
81	1·722	0·286		2·008	3·155	0·460		3·615
88	2·023	0·415	T	2·438	4·286	0·844	T	5·130
95	2·272	0·579	0·010	2·861	4·653	1·292	T	5·945
102	2·421	0·821	0·222	3·464	4·774	1·658	0·277	6·709
109	2·354	1·179	0·444	3·977	5·675	2·090	0·580	8·345
116	2·462	1·507	0·401	4·370	5·874	3·844	1·218	10·936
123	2·343	1·660	0·793	4·796	5·200	3·392	2·112	10·704
136	2·130	1·216	1·600	4·946	4·854	1·716	2·946	9·516
149	2·113	1·070	2·400	5·583	4·697	1·505	4·912	11·114
160	2·051	1·098	2·540	5·689	4·317	1·719	5·851	11·887

Table 25
Seasonal Change in Weight of Whole Plants (in gms.)
(Senewiratne 1957)

Age in days	Weight in grams				
	Leaves	Culm	Grain	Roots	Total
12	0·003	T		0·002	0·005
18	0·011	T		0·004	0·015
25	0·017	T		0·010	0·027
32	0·063	T		0·025	0·088
39	0·188	0·014		0·068	0·270
46	0·460	0·030		0·165	0·655
53	1·298	0·076		0·327	1·701
60	2·405	0·156		0·490	3·051
67	2·522	0·185		0·535	3·242
74	3·401	0·338		0·580	4·319
81	4·877	0·746		0·738	6·361
88	6·309	1·259	T	0·880	8·448
95	6·925	1·871	0·010	0·880	9·686
102	7·195	2·479	0·499	0·891	11·064
109	8·029	3·269	1·024	0·900	13·222
116	8·336	5·351	1·619	0·900	16·206
123	7·543	5·052	2·905	0·900	16·400
136	6·984	2·932	4·546	0·900	15·362
149	6·810	2·575	7·312	0·900	17·597
160	6·368	2·817	8·391	0·900	18·476

TABLE 26

Yield of Rice as influenced by number of Tillers per Plant with Main Stem (MS) and Tiller (T) contributions to the total yield

(Senewiratne 1957)

		Average of 50 plants						
No. of Tillers per Plant	% Plants in each Group	Main Stem Number of Grain		Tiller Number of Grain		Total No. Grain		% Empty
		Filled	Empty	Filled	Empty	Filled	Empty	
0	0	0	0	0	0	0	0	
1	16	89·0	4·1	56·8	1·3	145·8	5·4	3·6
2	50	85·9	3·7	68·1	3·3	222·1	10·3	4·4
3	20	91·0	4·9	70·0	3·4	301·0	15·1	4·8
4	12	103·3	4·8	77·8	3·4	414·5	18·4	4·3
5	2	131·0	5·0	76·2	5·8	512·0	34·0	6·2
Wt. of 100 seed in gms.		3·00		3·03				

Not all the differentiated spikelets develop. A certain number of spikelet primordia degenerate at the reduction division stage.

Table 26 also lists the extent of filled grain and empties. The number on each panicle whether main stem or tiller showed hardly any variation. The total empties per plant increased with the increase in number of tillers and ranged up to 6.2%. This value only reflects the empty grain. Bad weather at flowering can result in a high percentage of empties.

Grain size depends on two main characteristics. 1. Size of the glumes. 2. Extent of filling up of the glumes. Possibly the second factor has a greater bearing on grain weight, and is conditioned largely by the extent of stored carbohydrates in the culms and leaf sheaths and also photosynthesis in the flag leaf. The optimum number of spikelets per unit area would be the number that could be efficiently filled by the available carbohydrate.

RICE NUTRITION

Along with varietal variations one of the most important factors determining growth and yields is nutrition. Vast strides have been made in this field and recent work has adduced evidence to explain the mechanism of nutrient uptake for paddy. Mitsui is reported to have linked phosphorus uptake with oxidative phosphorylation, potassium accumulation with nucleic acid metabolism and nitrogen absorption with the TCA cycle. He has further indicated that his preliminary findings hold promise for the use of chemicals mixed with fertilizers to enhance the absorption of nutrients by plant roots. (15).

Nitrogen Nutrition

The paddy plant can use both nitrate and ammonia nitrogen. Solution culture studies have demonstrated that nearly equal growth has been obtained with both sources of nitrogen. (Plate 1)

Nitrogen is present largely in the form of ammonia nitrogen in flooded soils. The absorbed ammonia is rapidly synthesized in the roots to amino acids and then translocated into the leaves where it is converted into protein. Small amounts of protein are also produced in the roots.

Nitrogen also promotes photosynthesis per unit leaf area. Excess nitrogen however leads to rapid vegetative growth, mutual shading and an imbalance between photosynthesis and respiration.

Deficiency in nitrogen decreases leaf length, number of tillers, panicles and number of grains per panicle. Symptoms of deficiency appear on the lower leaves due to the migration of the element to the upper leaves. Excess nitrogen is stored in all organs.

The nature of nitrogen distribution within the plant is shown in Table 27. The nitrogen located in the leaves and culm gradually decrease with translocation into the developing earhead. About 65-70 per cent of the nitrogen taken up by the plant is finally removed along with the grain.

The values reported for roots is not always accurate as there is a considerable sampling error caused by poor recovery of roots.

Studies on the influence of nitrogen supply at different stages of growth, have indicated that nitrogen is required at four important stages as follows : 1. At active tillering to increase the number of valid-tillers. 2. At neck node initiation to increase the number of spikelets. 3. At reduction division to prevent degeneration of differentiated spikelets and to increase size of hulls. 4. At full heading to increase the percentage of ripened grain.

Potassium Nutrition

The paddy plant takes up more potassium than most of the other elements. Potassium is present in water soluble form and is mobile within the plant. As a result of its great mobility potassium deficiency shows up on the older leaves. Deficiency causes a decrease in photosynthesis and increased respiration. Deficient plants are darker green, shorter, more susceptible to blast disease, and when potassium content falls below 0.5 % reddish brown spots appear on the leaves.

Potassium deficiency depresses yields by lowering the number and size of seed. When excess of potassium is absorbed it is stored in the culms.

The pattern of potassium distribution within the plant is indicated in Table 28. The early storage is in the leaves and this is followed by translocation to the culms and the grain. Finally only about 25 % is located in the grain, about 75 % remaining with the leaves and culms. The straw that is returned to the fields is a rich source of potassium.

Phosphorus Nutrition

Phosphorus is concerned with the synthesis of starch and cellulose and the formation of energy rich bonds. Phosphorus promotes tillering and is mobile within the plant. Deficiency symptoms first appear on the lowest leaves and lead to dark green or bluish leaves, decreased leaf length, leaf number, number of panicles and grain per panicle. Solution culture studies have indicated that plants grown in media with three parts per million of phosphorus were healthy and showed normal growth. (Plate 2).

About 80 per cent of the phosphorus taken up by plants is located in the seed. The phosphorus retained in the leaves and the culm moves out into the developing grain during the last month of growth. (Table 29). The straw is particularly poor in this element.

TABLE 27

Seasonal Change in Nitrogen Content of Whole Plants (Senewiratne 1957)

Age of Plant in days	in mg. per plant				
	Leaves	Culm	Grain	Roots	Total
18	0·46	—	—	0·09	0·55
25	0·43	—	—	0·21	0·64
32	1·77	—	—	0·41	2·18
39	5·74	—	—	1·08	6·82
46	13·69	0·40	—	2·23	16·32
53	25·14	0·55	—	3·43	29·12
67	38·24	0·69	—	4·92	43·85
74	37·99	3·01	—	4·64	45·64
81	46·52	4·05	—	4·65	55·22
88	58·41	5·71	—	6·60	70·72
95	60·15	6·78	—	5·63	72·56
102	53·70	8·68	6·95	5·61	74·94
109	57·92	12·28	9·48	5·22	84·90
123	49·05	15·83	28·18	5·13	98·19
149	25·73	7·16	59·73	4·50	97·12
160	26·42	9·51	74·42	5·31	115·66

Iron Nutrition

Iron is immobile and not distributed within the plant. Deficiency shows up on the upper leaves and is also associated with dwarfed plant growth, bleaching of leaf tips with subsequent yellowing of other parts of the leaf. (22), (23). The results obtained from solution culture studies do not support the view that the rice plant needs high levels of iron. (18). Plants grown in solutions with only 0.1 parts per million iron showed normal growth. (Plate 3).

TABLE 28

Seasonal Change in Potassium Content (Senewiratne 1957)

Age of Plant in days	in mg. per plant				
	Leaves	Culm	Grain	Roots	Total
18	0·48	—	—	0·09	0·59
25	0·54	—	—	0·28	0·82
32	1·83	—	—	0·65	2·48
39	5·86	—	—	1·84	7·70
46	15·52	0·54	—	4·29	20·35
53	39·73	0·96	—	7·85	48·54
67	62·93	1·73	—	10·17	74·83
74	78·85	8·93	—	9·86	97·64
81	107·04	16·59	—	10·70	134·33
88	145·20	26·66	—	11·26	183·12
95	146·98	23·39	0·38	11·88	182·63
102	136·78	52·07	10·37	11·14	210·36
109	142·71	53·38	7·34	13·05	203·43
123	133·07	70·43	20·18	9·27	232·95
149	89·13	87·04	52·86	7·65	236·68
160	64·34	102·82	62·42	6·75	236·33

Plate 1. A comparison of plants grown in a solution culture with nitrate nitrogen and ammonium nitrogen. Note the nearly uniform growth. (21)

Plate 2. A comparison of plants grown in solution cultures with 0.3 and 18 p.p.m. phosphorus, showing normal growth with 3 p.p.m. phosphorus. (21)

Table 29

Seasonal Change in Phosphorus Content (Senewiratne 1957)

Age of Plant in days	in mg. per plant				
	Leaves	Culm	Grain	Roots	Total
18	0·047	—	—	0·015	0·062
25	0·023	—	—	0·045	0·068
32	0·144	—	—	0·107	0·251
39	0·463	—	—	0·120	0·583
46	0·883	0·059	—	0·175	1·117
53	2·841	0·170	—	0·363	3·374
67	5·200	0·387	—	0·491	6·078
74	6·483	0·872	—	0·629	7·984
81	9·527	1·601	—	0·666	11·794
88	12·391	2·687	—	0·491	15·569
95	12·922	2·684	0·020	0·611	16·237
102	11·159	4·876	0·377	0·528	16·940
109	12·499	6·538	1·580	0·450	21·067
123	10·381	9·938	5·969	0·600	26·888
149	5·047	1·953	22·907	0·525	30·432
160	3·807	2·253	26·012	0·225	32·297

Sulphur Nutrition

The symptoms of sulphur deficiency are a general yellowing of the plant, reduction in size, leaf area, number of panicles and number of grains per panicle. Excess of sulphur if taken up is stored in all organs.

Manganese Nutrition

Toxicity symptoms appear to include the premature death of leaves and tillers and bleaching of chlorophyll. (23). Manganese nutrition is a controversial subject. It has been shown that manganese uptake is depressed in the presence of ammonia nitrogen as in the case of lowland rice. Under upland conditions, with nitrate nitrogen, manganese uptake is favoured and has been cited as the cause for the poor performance of upland rice. (18).

Silica Nutrition

Paddy is a typical silica plant containing as much as 10-20 per cent silica in the stems and leaves. The plant has shown marked responses to added silicate slags in silica deficient soils. There is no recognized physiological role for silica, but the following benefits are claimed for silica applications. (15).

1. Increased availability of phosphorus. 2. Increased resistance to diseases and pests. 3. Increased resistance to lodging.

4. Promotion of an erect growth habit. 5. Reduction of transpiration losses.

In solution culture experiments the following results have been obtained: 1. Silica markedly increased straw and grain. 2. Deepened the green colour of leaves and narrowed their angle in the earlier stages of growth. 3. An increase in S_1O_2 concentration in the culture solution from 0-100 p.p.m. progressively increased height, fresh and dry weight, number of panicles, number of spikelets per panicle and percentage of ripened grain, and hastened flowering. 4. Silica markedly retarded iron and manganese uptake. Silica retarded uptake of phosphorus when phosphorus was present in excess but promoted its translocation in the rice plant.

CHARACTERISTICS OF FLOODED SOILS

The current understanding of the characteristics of submerged soils arose from the studies conducted by several workers in Japan and elsewhere. Mitsui has summarized many critical experiments in this field (24).

These workers have shown that the fundamental difference leading to the numerous changes in soil properties on submergence depend on the scarcity of oxygen. The changes occurring in a flooded soil include increased concentrations of carbon dioxide, disappearance of nitrate, accumulation of ammonia, increase in solubility of iron, manganese, phosphate, silica and the displacement of cations into the soil solution.

The ability of rice roots to grow in an environment so poor in oxygen is explained by the fact that the plant translocates oxygen from the shoot to the root and even excretes oxygen into the soil to create an oxidative rhizosphere. Carbon dioxide concentrations rarely reach toxic levels.

One of the numerous significant changes occurring on submergence relates to the nitrogen relationships of the soil. The soil profile under flooded conditions exhibits a thin surface oxidized layer superimposed over a reductive zone. Nitrogenous fertilizers applied to such a soil first reaches the oxidised layer and is converted to nitrate by bacterial activity. Nitrate nitrogen readily descends to the reduced layer where it is rapidly denitrified and changed into nitrogen oxide or nitrogen gas which in turn bubbles out into the atmosphere. As a result, nitrogen fertilizer applied to the oxidative zone could be largely lost. Ammonia applied to the reductive zone is retained in available form. These findings point to the importance of a number of cultural practices.

1. The continuous submergence of soils once wet preparatory tillage is commenced. Alternate wetting and drying will lead to increased nitrogen loss.

2. The beneficial effects of deep placement of ammoniacal fertilizers in the reductive zone of the soil.

3. The application of top dressed nitrogen in small doses as split applications for rapid absorption by surface roots. This minimizes nitrogen losses through denitrification.

WATER REQUIREMENTS OF RICE

As early as 1912 Briggs and Shantz (25) showed that the water requirement of rice was not much higher than that of rye and lower than that of many other plants. These findings were later corroborated by Indian workers. Although the water requirement of rice was not greater than that of other crops, the benefits occurring from flooded culture have been universally recognized. Much research has been completed to elucidate the reasons why rice a morphologically non-acquatic plant can germinate and flourish under flooded conditions but few substantial efforts have been made to investigate the factors that limit the growth of rice under upland conditions.

Senewiratne (21) studied variations arising from flooded and unflooded culture. He pointed out that rice varieties, though they may be of diverse genetic make up, respond alike to flooded culture and that they make better growth on such soils. Hence it could be assumed that the rice plant had no genetic adaptation in any known variety, capable of combating the adverse environmental conditions resulting from unflooded rice culture. With the elimination of probable genetic interactions, one was restricted to the direct effect of external factors on the physiological processes of the plant, in the search for an explanation of the growth response obtained.

Senewiratne further reported that standing water hinders stand establishment, tiller production, weakens culms and that muddy water may interfere with stomatal function. Its only direct virtue appears to be a buffering action against temperature variations and some benefit with regard to weed control. Soil saturation alone seemed to suffice for good results. He evaluated the effect of the chemical changes that occurred in a saturated soil on plant growth. It was demonstrated that the benefits from soil saturation were related to changes in nitrogen and manganese nutrition among other considerations and the related physiology of the plant. He supported the findings that the benefits from abundant water arose from soil saturation.

The practical significance of this study arises from the fact that only soil saturation is required for the better growth and development of the plant. Standing water is a luxury and confers only marginal benefits such as temperature regulation which is hardly of any use in Ceylon, and weed control which can be achieved by other means. Ghose (8) whilst discussing water use states that "very little information is available regarding the rice crop, and whatever we have is empirical, and is not based on comprehensive research." This is also true of Ceylon and an exhaustive study of water use in rice production is an urgent need. Such a study may indicate that a crop could be raised with less water utilization, thereby extending the area now cultivated under each irrigation tank.

METHODS OF PADDY CULTIVATION

There is considerable variation in the methods of paddy cultivation practised in various parts of Ceylon. The variations arise largely from water availability. There are three well defined systems of paddy growing, namely, upland culture, the semi-dry system and lowland culture. These three systems are considered separately.

LOWLAND CULTURE

Season of Cultivation

Paddy growing seasons differ in various parts of Ceylon. Generally the crop is grown in the Maha season in all the 22 districts and during Yala in the wet zone or under irrigation in the dry zone. An intermediate season or late Maha known as the "meda" season is recognized in the Kurunegala district. In areas such as Chilaw where long aged paddies are sown for the Maha season, cultivation commences much earlier than in the other areas. Actual sowing or planting dates vary a great deal depending on the availability of water and the age of the paddy grown.

Rotations

In most areas one paddy crop follows another wherever double cropping is practised. When this system is not adopted one paddy crop is followed by a fallow season during which the stubble is grazed or the land is cropped with vegetables. Rotation with vegetables is done quite frequently in the Western and Central provinces amongst others. Such a rotation needs well drained land. In heavy soils the vegetables are grown on raised beds. This rotation gives higher economic returns and in the period between paddy crops as many as two or sometimes three vegetable crops are harvested. Popular rotations include snake gourd, luffa and bitter gourd followed by crops like beans, bandakka and tomatoes. Numerous other crops are grown depending on the area. Recently potatoes have replaced traditional vegetables like cabbage in the up-country areas and paddy-sugar cane rotations are contemplated at Gal Oya and Kantalai.

The advantages of rotations may be well known but poor drainage in some cases and pressure on the land in others, tends to favour continuous rice culture, wherever water is available.

Land preparation

Fields usually carry an assortment of weeds and stubble at the commencement of preparatory tillage. Bunds and irrigation channels are similarly covered with weed growth. The actual operations of preparatory tillage vary with the availability of water, tractors, buffaloes and manual labour. Whatever the method used one of the preliminary operations is the weeding of channels and bunds. This enables the weeds and weed seeds to be destroyed and also eliminates alternate hosts for many paddy pests. Preparatory tillage is either done by manual labour, with the help of buffaloes, by mechanized methods or with a combination of these.

Land preparation with manual labour

Water is impounded in the field a few weeks ahead. When the fields are well soaked, they are drained off leaving only 1-2 inches of water and tilled with mamoties. Special broad and light weight mamoties are used for this purpose. The object of this operation is to bury the weeds so that they may be killed. Water is again impounded into the field and allowed to remain for about 2 weeks. The purpose of having standing water is to kill the weeds and to keep the soil anaerobic, so that soil nitrogen will be retained in the ammoniacal form and not converted to nitrate. During this period the clods slacken and weeds rot.

A second mamoty tillage is necessary for the complete destruction of weeds and proper pulverization of clods. This is done as before, after draining the fields. At no time should fields be drained when water is turbid as the suspended clay and organic matter will be lost. At about this time the bunds are also plastered with mud, cracks sealed off and bunds strengthened. After this second operation water is impounded into the field for about one week.

The next operation is levelling. This is done in two stages. The initial rough levelling is intended to even out the gross irregularities in the field. It is done by dragging something like a headpiece of a tooth harrow or a log across the field, or with levelling boards. Water is again let in and allowed to stand for a few days. The final levelling and creation of shallow surface drainage channels is done with levelling boards after all the water is drained. Small puddles of water on the surface of the field leads to a poor stand in these patches and should be levelled off. This precaution is not necessary if the field is to be transplanted. The operations of preparatory tillage should be well spaced out. Weeds will not be killed in a hurried operation. A field so prepared with bunds replastered and channels cleared is ready for sowing.

Land preparation with buffaloes

Mudding with buffaloes is quite popular wherever animals are available, and the land is not too swampy. The animals are driven round and round the fields and the soil is puddled, weeds are destroyed and the soil slackened. All other operations are the same as those described for manual labour, except that the two operations of tillage are replaced with buffalo mudding.

In some instances the soil is ploughed by buffaloes, using either a light mould board plough or a wooden plough. A second tillage operation is also done about 2 weeks after the first.

Mechanized land preparation

A lack of adequate labour during seasons of preparatory tillage and the scarcity of work buffaloes has made tractor tillage increasingly popular in the dry zone colonization areas. The limitations to this type of tillage arises from the scarcity of tractors for this purpose. Cultivators depend on a custom service which is provided by the Department of Agriculture at reasonable rates or on private agencies that make higher charges. Another factor that limits the usefulness of tractor tillage is the small size of the liyadda which restricts the manœuvrebility of these machines on such fields. Wikramanayake considered the subject in detail and outlined the virtues of two wheeled and four wheeled machines for rice culture. (26). Both types are in use in Ceylon, the four wheeled types being fitted with specially designed wheel extensions which enable them to work in muddy fields.

Wherever tractors are used, tractor tillage is adopted instead of mamoty tillage. In some instances where the soil is easily puddled and where weed growth is not heavy one operation is considered adequate, and levelling follows after a time lapse of 2-3 weeks, during which time the fields are kept flooded.

Depth of preparatory tillage

There is little local information on the depth of cultivation. A large percentage of the plant roots are in the surface layers and a depth of 8″-10″ appears adequate. Mamoty and buffalo puddling seldom go deeper than this, except in swampy fields, but mechanized tillage works the soil to a greater depth. Grist considers deep ploughing for paddy unnecessary and inadvisable. (14).

Selection of good seed

The importance of good seed paddy cannot be overemphasized. The Department of Agriculture produces limited quantities of foundation seed which is multiplied on seed farms to give certified seed. The accepted standards for certified seed are as follows:

Purity (minimum) 97 %
Viability (minimum) 85 %
Inert matter (maximum) 5 %
Moisture (maximum) 14.5 %
Weed seeds per pound of seed paddy (maximum) 100.

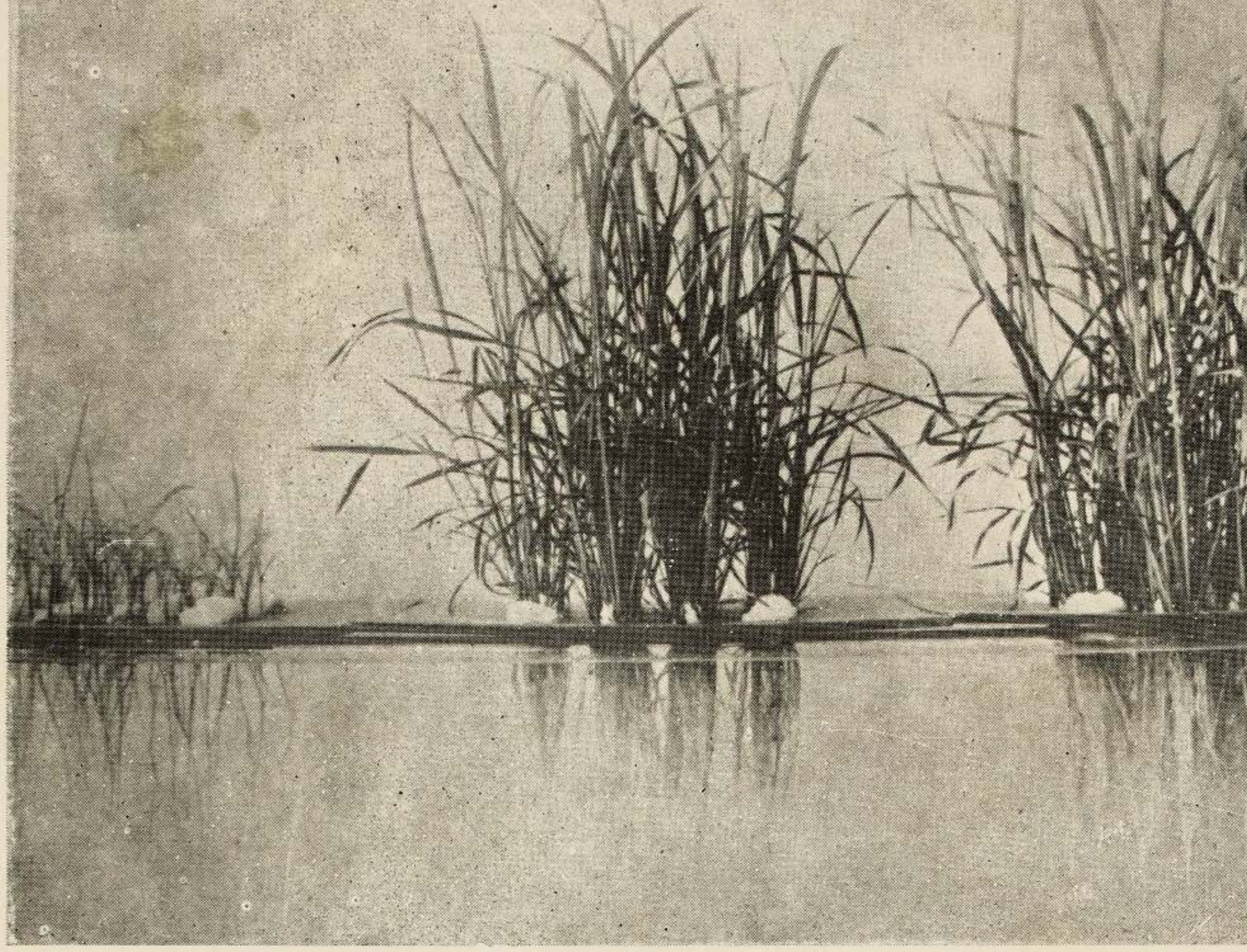
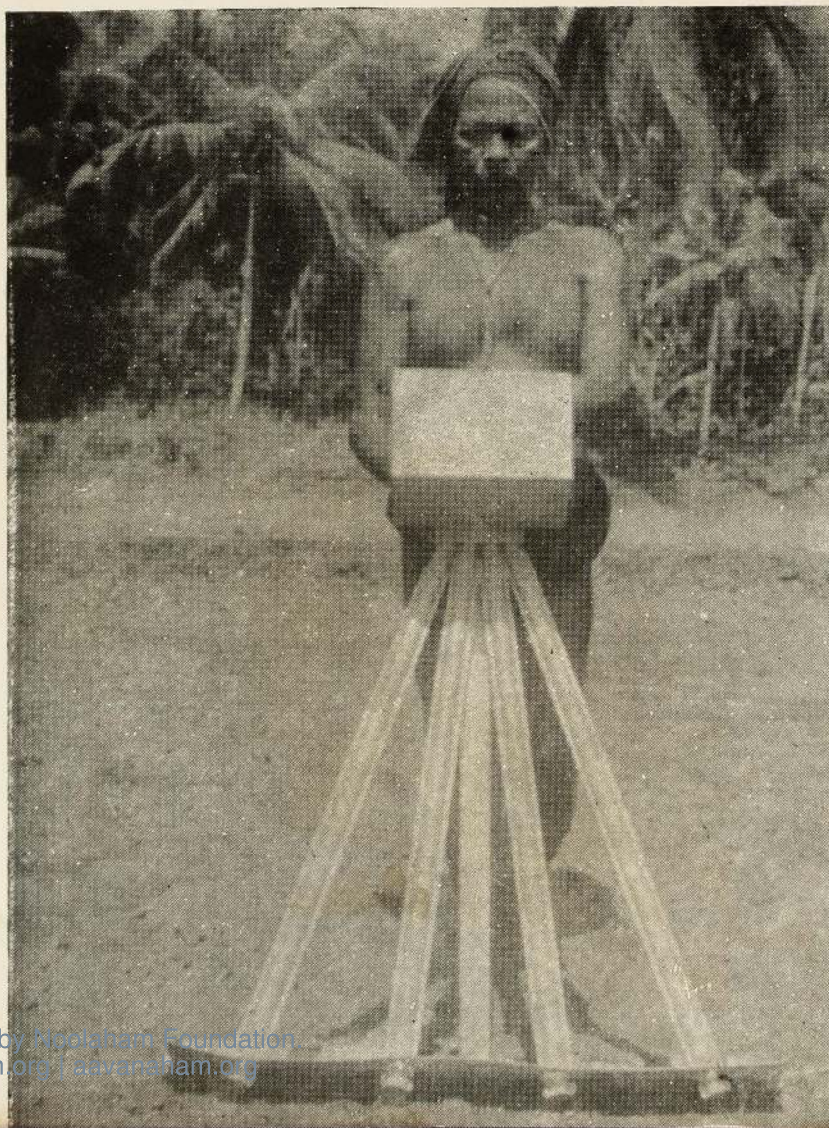


Plate 3. A comparison of plants grown in solution cultures with 0, 0.1, and 3.0 p.p.m. iron, showing normal growth with 0.1 p.p.m. iron (21)

Plate 4. Row seeding of paddy using a row seeder



All growers are expected to obtain supplies of certified seed at regular intervals of four to five years, and save their own seed paddy for the intervening years.

All lots of seed paddy saved by cultivators should be carefully inspected and tested before use. They should meet the following specifications :

1. They should be of the desired variety.
2. They should contain pure seed. Purity connotes a number of widely different contaminants—(*a*) Freedom from admixture with other paddy seed. (*b*) Freedom from weed seeds. (*c*) Freedom from extraneous matter. Standards are set for the limits of contamination and the sample of seed should conform to these limits.
3. Seed should have a high germination percentage, 85 per cent is acceptable.
4. Seed should be well developed, uniform in size and heavy. It is common practice in Japan to select seed on this basis. Three methods of selection are generally adopted, namely, sieve, wind and specific gravity selection. Specific gravity selection is done using a salt solution. Optimum specific gravities should be established for *indica* varieties. A specific gravity of 1.08-1.10 is usually considered suitable in Japan. When a fresh egg is dropped into such a solution it rises a little from the bottom. This is a rough test that is used when a hydrometer is not available. (16). After steeping the seed in the salt solution the sinker fraction is washed, dried in the shade and stored for use as seed paddy. The floater fraction is used as consumption paddy. Local trials did not show any significant yield increases from the use of heavy seed separated out with the use of salt water. (27).
5. Seed should be free from pest and disease. Seed treatment has been developed to disinfect seed paddy against disease contamination.

Seed treatment

Seed treatment is carried out to achieve various purposes.

(*a*) Seed treatment has been used to induce drought resistance and to increase yields. The treatment includes seed soaking, holding the seed in a wet condition and air-drying the seed till it is completely dry. This treatment is claimed to cause an increased rate of growth and development of the plant resulting in increased yields. (28). Treatment involving the soaking of seed paddy repeatedly in water for 8, 10, 12 and 14 hours produced no significant yield benefits. (27). Seedling stimulation has also been attempted with the use of hormones and chemicals.

(*b*) Seed disinfection with fungicides is a common practice against various diseases, for example foot rot of paddy. (Details are given under disease control).

(*c*) Pre-sprouting of seed. Prior to sowing, paddy is pre-sprouted and this could well be considered a method of seed treatment. The selected seed is soaked in water either in sacks or in some convenient receptacle for about 24 hours. The seed is then drained of the water. The soaked seed is unbagged and laid out in layers 3-6 inches thick covered over and weighted down. Thicker layers lead to excessive heating which may cause injury to the seed. Further, lack of oxygen at the bottom of the stack may retard sprouting. The seed is well pipped in about 24 hours and is used at this stage for row sowing.

For broadcast sowing the seed is allowed to sprout further. The seed is seen as an entangled mass of plumules and radicles. The seed mass is untangled carefully and used for sowing. If it is desired to encourage sprouting still further the untangled mass is restacked about 12″ deep and allowed to germinate further. Extensive sprouting is desired on land where less sprouted seed tends to sink. Seed that sinks in the seed bed fails to grow and a poor stand results. The problem of using well sprouted seed is that it is difficult to sow such seed uniformly.

Adverse weather conditions like excessive rain may make it necessary to postpone sowing after the seed has been sprouted. Under these circumstances, the sprouted seed can be dried out slowly in the shade and stored for later use when conditions are more favourable for sowing. Such dried out seed is soaked in water prior to use.

Seed of the desired variety, properly selected, tested for germination, treated with fungicide if necessary, and pre-sprouted, is then ready for sowing in the field or in nurseries.

Methods of sowing and planting

The common methods of sowing or planting a rice crop are broadcast sowing, row sowing or transplanting. Each method has its own advantages and disadvantages. The relative usefulness of the three systems varies, with respect to important cultural practices and other considerations.

1. Effect on yield. Numerous cultural trials in Ceylon and abroad have indicated that yields obtained from transplanted crops have been higher than those secured from broadcast sown crops. This is so in varieties of over four month duration. Comparisons between row sown and transplanted crops indicate that

there is not much yield difference between these cultural methods, whereas row sown or dibbled crops outyielded broadcast sown crops. Results of experiments carried out at Bombuwela show the variations in yield that were obtained from these cultural practices. (29). (Table 30).

TABLE 30

The effect of method of planting on rice yields
(Bushels per acre)

Method of planting	Handweeded
Broadcast sown	41·5
Dibbled (Row sown)	49·0
Transplanted	54·4

2. Water consumption. No accurate estimates of water consumption have been made, but since transplanted crops occupy the field for shorter periods of time, a saving of water can be expected from transplanted culture. This advantage is not material in rainfed areas.

3. Labour requirement. The least labour is utilized in broadcast sowing (1/3-½ man day per acre), very little extra is used for row sowing (1 man day per acre) and considerably more labour is used for growing nurseries and transplanting (8-15 women and 2-3 man days per acre). Transplanting is suited to areas where labour is plentiful.

4. Climatic conditions. Climatic conditons at planting, particularly rain, limits the areas where row sowing can be done effectively. Rain shortly after sowing, leads to displacement of the row sown seed. This is one of the factors limiting the expansion of the acreage row sown. Rain at this time also interferes with broadcast sowing but to a lesser extent. Transplanted crops are not adversely affected by rains at planting time.

5. Seed bed preparation. Both row and broadcast sowing need well prepared seed beds which include fine levelling. A rough seed bed is adequate for transplanting.

6. Age of the variety. Short aged varieties do not respond to transplanted culture, but row sowing gives yield increases over broadcast sowing. With long aged varieties both row sowing and transplanting are superior to broadcast sowing.

7. Double cropping. When long aged varieties are sown it is often difficult to double crop a field except where transplanting is adopted. This becomes possible since part of the growing period is spent in nurseries.

8. Seed rate. Broadcast sowing requires the highest seed rate, which varies from 2 to 5 bushels per acre.

9. Weed control. One of the most significant differences between these methods of sowing is in respect of weed control. In a broadcast sown crop weed control could be done only by hand or with chemicals. Both these methods of weed control are expensive. In a row sown or row transplanted crop, weeds can be inexpensively controlled by row weeding. Hand weeding a transplanted field that has not been grown in rows is more expensive than weeding a row sown crop but still cheaper than weeding a broadcast sown field.

10. Relative costs. Taking all financial considerations into account such as saving in preparatory tillage, seed rate, weeding and planting costs, a row seeded crop is the cheapest and is nearly as efficient as a transplanted crop. The one obstacle that hinders the widespread use of this method of sowing, is the uncertain weather conditions that prevail at planting time.

Broadcast sowing

This is by far the most popular method of sowing in Ceylon. Sprouted seed is untangled and sown by hand. On fields that have been prepared to a very soft puddle, well sprouted seed is used to stop the seed from sinking too deep into the mud. The usual seed rate is two bushels per acre but as much as five bushels are sown in some areas. Experiments with broadcast seed rates from 1½ to 2½ bushels per acre showed no significant differences within this range. (27).

Differences in seed rate arise from variations in age of the variety, tillering capacity and soil fertility, amongst other considerations. Experiments designed to evaluate the effect of population density have been carried out by broadcasting seed at the rate of 1, 2, 6, 18, 54, 162, 486 and 1458 seed per square foot. At densities between 1 and 18 plants per sq. foot there was a linear decrease in the number of tillers per plant with increasing density. Tillering ceased when the density reached 54 per square foot. Grain yield appeared to be related to the panicle number per unit area rather than to seed rate and yields tended to be maximal when the panicle number was 20-35 per sq. ft. (30).

Sowing should be timed so as to avoid heavy rain immediately afterwards as this washes seed into pockets causing an uneven stand. One man can sow two to three acres per day.

Row sowing

Thambiyah (31) has described 18 row seeders that have been designed for Ceylon. Some of them are cheap to manufacture and are efficient. (Row seeders manufactured by the Department of Agriculture were available for sale through the Agriculture

Extension Service at the subsidized price of Rs. 12.00 each, the actual cost being about Rs. 20.00).

Pipped seed is used for row seeding. Well sprouted seed chokes the seeders now in use. A seed rate of one bushel is adequate. One man can sow about an acre per day. Sowing should be timed to avoid heavy rains shortly after sowing, as this disturbs the rows and makes row seeding worthless. Spacing trials have indicated that a spacing of 10″ between rows was superior to a spacing of 12″ (32). The spacing adopted should permit the use of row weeding equipment.

Immediate aftercare of broadcast and row sown fields

The sprouted seed takes a few days to strike root and grow. During this time the surface of the field should not dry out nor should there be standing water in the field. Water should be let in and drained after a few hours. If the field is allowed to dry out and crack on the surface, serious losses of soil nitrogen could result on reflooding.

Transplanting

Transplanting is popular in the Kandy, Matale and Kegalle districts where skilled labour is available. The labour requirement for transplanting is high and varies between 8-15 women and 2-3 man days per acre. Transplants are generally raised in nurseries which may be either upland or lowland nurseries. The prevailing practice in Ceylon is to establish lowland or wet nurseries. Japanese work has however demonstrated that plants raised in upland nurseries are superior. They appear to have better rooting ability and show higher starch and nitrogen content. These upland plants when transplanted into lowland fields have performed better under conditions of high soil fertility. (16).

Under Ceylon conditions upland nurseries could be of great use in the dry zone where they could be established well ahead of time with the early rains supplemented by water from wells. This procedure may make it possible to increase the areas transplanted in the dry zone, wherever labour is available.

Lowland nurseries

A conveniently located portion of the field is selected and thoroughly prepared as indicated earlier. About 10-20 pounds of seed is pre-sprouted and sown broadcast on 1/10th of an acre to raise sufficient plants for one acre. Indian experience has indicated that heavy nursery fertilization does not increase yield of the transplanted crop to any appreciable extent. Manuring at the rate of 20 pounds nitrogen and 16 pounds phosphorus is considered adequate per acre. (8). Local information indicated that there appears to be no advantage in heavy nursery manuring. (27).

After-care of the nursery amounts to weeding, pest and disease control and irrigation. Water is held at about 1" depth. Plants are ready for transplanting when they are 3-6 weeks old and they should be lifted with care. Transplanting should be done soon after removal. If it is necessary to keep plants for a day or two they should be allowed to stand in shallow water.

Upland nurseries

These nurseries should be suitably located where water is available for supplementary irrigation. The soil is well worked to destroy weeds and thrown up into raised beds 6½ high and 3-4 feet wide and of any convenient length. Ungerminated seed is sown in rows 4-6 inches apart. A seed rate of 10-20 pounds of seed sown in 1/10th of an acre would be sufficient to raise seedlings for one acre. Japanese work has indicated that thin nursery sowing produced better transplants. (16). After-care includes weed, pest and disease control and watering when necessary. Seedlings are ready in 3-6 weeks time and should be removed carefully after the beds are watered thoroughly.

Upland nurseries used at Labuduwa, Kalutara and Homagama are reported to have proved very successful. Uprooting of seedlings was found particularly easy, in contrast to the removal of seedlings from a wet land nursery. (33).

Field planting

Planting out is generally done by women. The traditional method of planting was to plant at random, the current recommendation is to plant in rows so as to enable row weeding. The advantage of row planting was first demonstrated in Japan and along with fertilization this is sometimes referred to as the Japanese method of rice culture.

Row transplanting is done with the aid of a stretched rope. Several persons line up along the rope and each plants a certain number of hills. When transplanting in the first row is finished the workers move backwards and the rope is shifted to a fresh position according to the desired spacing, and the procedure is repeated.

Spacing and number of seedlings per hill

Spacing has an important bearing on the number of ear bearing tillers and yield, and varies according to the age of the variety and soil fertility among other considerations. No optimum spacing can be given for all conditions and local trials have to be carried out with the variety concerned to determine optimum spacings.

In an experiment carried out at the Ceylon University the effect of plant density on yields of transplanted paddy was studied with the variety Murungakayan 302. Spacings between plants in the row and the number of plants at each hill were varied to give 2.5, 5, 10, 15, 20 and 25 plants per square foot. The spacing between rows was kept constant at 10″. The number of tillers produced per plant and grain yields per tiller were depressed as plant density increased. There was no marked variation in grain size. Grain yields obtained are shown in Table 31. (34).

TABLE 31

Plant density and grain yields
(Senewiratne 1959)

Number of plants per square foot	Yield in Bushels per acre
2·5	37·30
5·0	39·55
10·0	54·22
15·0	56·16
20·0	60·75
25·0	52·64

Plant densities as low as 2.5 and 5 plants per square foot depressed yields whereas there was no significant variation in yields between the other plant densities.

Indian experience has shown that 2 to 3 seedlings at a spacing of 6 x 6 inches for early varieties and 9 x 9 inches for late varieties is the optimum (8).

Depth of planting

Shallow planting is claimed to give better yields compared to deep planting. The depth of planting determines the locus of tillering, increases the height at which tillers appear and may also influence lodging. In practice plants are set about ½-1 inch deep. Experimental evidence also supports this practice adopted in peasant holdings. (29).

TABLE 32

The effect of depth of planting on yields
(In bushels per acre)

Depth of planting	Yields	
	Maha	Yala
Surface planting	57	46
Planting at 1″ depth	46	54
Planting at 2″ depth	45	50
Planting at 3″ depth	36	44

Angle of planting

Most plants are set erect. In windy areas plants are set at an angle to overcome the effect of the wind. Plants set at an angle straighten up when they strike root.

Age of seedlings

The correct age of seedlings for transplanting varies with variety and growth. Results of trials have indicated that 20 day old plants are superior to 10 and 30 day old plants. (19). Rhind suggested that nursery plants from 3 month varieties should be transplanted at 15 days, 4 month varieties at 21 days and 5-6 month varieties at 30-35 days. (35)

Immediate after-care of a transplanted field

Plants establish themselves in about one week. Up to this time the field is kept moist without standing water. After a week standing water is allowed to remain in the field and this is progressively increased.

Paddy Transplanters

The yield increases obtained from transplanting are well recognized, but the extents transplanted are meagre and largely confined to the Kandy, Kegalle and Matale districts. Efforts at popularizing transplanting in other areas have met with resistance as transplanting is a laborious operation for unskilled workers. The solution to this problem appears to be the development of a mechanical transplanter.

In the last ten years over 90 different types of mechanial transplanters have been designed and tested out in China. Of these, three machines have been demonstrated with success at Hingurakgoda. (36). However, little progress has been made at popularizing the use of these machines on a field scale in Ceylon.

Transplanting and paddy yields

It is generally accepted that transplanted rice outyields broadcast sown crops, when medium and long aged varieties are grown. Numerous explanations have been offered to account for the superiority of transplanted rice. It is often suggested that weed control is better under transplanted culture. This is evident and is possibly one of the factors responsible for the variation in yield. Other reasons adduced for this yield increase include the effect of root pruning, shock and the benefits gained from uniform plant spacing. An experiment designed to evaluate the effect of spaced planting and broadcast sowing at the same plant densities did not support the view, that uniform plant spacing alone could account for the yield increases obtained under transplanted culture (34).

Senewiratne suggested that the transplanting response could be related to the nitrogen nutrition of the plant (37). The plant has two peaks of nitrogen requirement. The first peak is observed early in the growth of the plant, usually at the grand period of tillering which occurs during the second month. The second flush of nitrogen uptake occurs later in the season at panicle formation.

On the other hand it is interesting to study the curve of mineralization of organic matter in flooded soils. The period of rapid nitrogen release lies between the 30th and the 60th day after incorporation of organic matter and weeds. At the same time it should be remembered that a period of about four weeks would lapse from the time of organic matter incorporation to final land preparation. Thus the period of high nitrogen release would commence at about the time when tillage operations are completed, and the field is ready for sowing.

Both processes should be viewed together. Whatever the method of culture whether broadcast or transpanted, peak nitrogen availability occurs during the month right after the completion of preparatory tillage. In the case of a broadcast sown crop, the young seedlings will not be in a physiological condition to assimilate the nitrogen that is released during this period of high availability, as a result, some of the nitrogen may be lost by denitrification or through weed growth. If 4-6 week old transplants were used, instead, they would be in a position to utilize this available nitrogen. The first peak of nitrogen requirement, which occurs at the tillering phase, would coincide with the peak period of nitrogen availability. This will mean more ear bearing tillers which could lead to higher yields. This will be particularly so under conditions of low soil fertility.

This observation is further supported by the behaviour of the early varieties which do not give a worthwhile yield response with transplanting. In these short aged varieties, the tillering phase and flower primordia initiation occurs early and some of this period coincides with the period of high nitrogen availability irrespective of the method of culture. As such neither cultural technique has any advantage over the other.

These studies indicate that the higher yields from transplanting could arise from the better utilization of available soil nitrogen, particularly through the initiation of a larger number of ear bearing tillers. If this assumption is correct yields from broadcast sown crops should approximate those of transplanted crops, if the nitrogen requirements of the crop are fully satisfied. This is in fact so, and high yields have been obtained from broadcast sown crops when split applications of nitrogen have been used at the time of tillering and flower primordia initiation.

If the main virtues of this transplanting response arises from considerations of nitrogen nutrition and possibly weed control, the efforts of agricultural extension may well be oriented in this direction, rather than in attempting to promote transplanting, which technique cultivators are slow to accept.

Irrigation

It is customary practice in Ceylon to flood paddy fields after the plant is established and to gradually increase the depth of flooding as the plant grows. No accurate estimate of consumptive water use is available for Ceylon nor is there any indication of percolation and distribution losses.

Rhind (35) reports that "...yields increase as the interval between irrigation decreases but not proportionally, while water consumption increases as the interval between irrigation decreases, again not proportionally". He provides water use data from actual trials on Government Farms and these compare very favourably with the estimates of irrigation water generally made, on the basis of two acre feet for land preparation and one acre foot per month of irrigation. (Table 33)

Table 33

Quantities of Irrigation and Rain Water used on Government Farms for Paddy (In acre ft.)
(**Rhind 1950**)

Farms	YALA			MAHA		
	Irrigation	Rain	Total	Irrigation	Rain	Total
Batalagoda	2·2	2·2	4·4	1·6	3·4	5·0
Paranthan	4·1	0·3	4·4	0·9	2·7	3·6
Anuradhapura	1·7	1·3	3·0	1·3	2·5	3·8
Tabbowa	—	—	—	2·4	3·2	5·6

Continuous and Intermittent Irrigation

The importance of continuous anaerobic soil conditions has been discussed elsewhere, particularly with reference to the maintenance of soil nitrogen. From this point of view, the impact of intermittent irrigation must be considered not only as the presence or absence of standing water but also with regard to the state of oxidation or reduction of the soil. Most experimental data on this subject, do not include information on the latter aspect and as a result, are difficult to interpret.

Ota *et al* (38) studied the effects of continuous and intermittent irrigation along with plant density. They concluded from preliminary investigations that a low density of plants is preferable under conditions of continuous standing water and that a higher density of plants is required with intermittent irrigation.

Plate 5. Transplanting of paddy using a hand-operated transplanting machine.

Plate 6. Row weeding of paddy using a row weeder.

Indian experience showed that there was no difference in drying and irrigating the field every third day as compared with continuous irrigation. Other Indian work indicated that the application of two inches of water every three or four days was best, approximating very closely a saturated condition.(8)

Depth of Irrigation

There is considerable evidence to show that standing water inhibited the development of lower tillering primordia, suppressed tillering and that a rise in water level above soil saturation adversely affected both number of tillers and yield. (39)

The general practice is to increase the depth of submergence as the plant grows in height to a maximum of about 4-6 inches. Water is held at that height till the grain fills after which water is drained to permit maturity of the crop.

Water Economy in Rice Production

All available evidence indicates that a saturated soil is desirable, that standing water helps to control weeds but there is no justification for growing rice in flowing water. This however, is invariably the case in most peasant holdings. Water moves through the fields and overflows into drainage canals. A proper evaluation of actual water needs will minimize such extravagant use of water and help extend the area under irrigation.

Drainage

The importance of drainage is often overlooked in tracts asweddumized for paddy cultivation. Ill drained lands soon turn out to be problem areas. The appearance of salinity is a common feature in such fields. The poorly drained lands in the Colombo District cause "bronzing" of the plant with resulting low yields. Even weed problems like salvinia infestation are aggravated by lack of drainage. All irrigation facilities should be accompanied by drainage schemes to keep lands productive over long periods of time.

WEED CONTROL

The total extent of the crop weeded is reported to be about 300,000 acres in Maha and 200,000 acres in Yala. These are alarming figures as it represents only 30 per cent of the cultivated extent. All measures aimed at reaching the declared objective of self-sufficiency in rice, will fail if this basic cultural operation is not adopted on a wider scale.

A large number of methods of weed control are available to the cultivator and some method or another suit the particular conditions under which cultivation is carried out. Methods of weed control may be broadly grouped into three categories, namely, cultural, mechanical and chemical.

Cultural methods

Preparatory tillage is in itself an excellent method. Careful tillage and complete inversion of the furrow slice followed by submergence will ensure good weed control. Clean weeding of bunds and irrigation channels removes another troublesome source of weeds. The use of clean weed free seed is still another method of minimizing weed populations.

One of the chief objectives realized by maintaining standing water in rice fields is supposedly weed control. This is of doubtful importance in broadcast or row sown crops as the germinating paddy will not take standing water and during this period both paddy and weeds grow alike. Finally when the crop does take standing water, the weeds are ahead and will offer the crop severe competition. If standing water is to be useful to such a crop, the field should have a preliminary weeding by manual, mechanical or chemical means. Standing water can be applied earlier to a transplanted crop and can be more useful under these conditions. Water alone seldom provides adequate control and it will be worth evaluating what extra acreage could be cultivated with the water that is now inefficiently utilized to control weeds.

Mechanical methods

In a broadcast sown crop hand weeding and harrowing the standing crop are two possible methods of weed control. Many man hours are spent on the laborious task of hand weeding. This is possibly not a serious consideration in areas where underemployment is widespread. The valid consideration is that by the time weeds have grown sufficiently to make hand pulling possible, they have utilized valuable plant food and offered competition at a critical stage in the life of the rice plant. This practice is however better than none at all, as profuse weed growth could choke the crop completely.

Harrowing the standing crop

This practice is adopted to stir the soil, control weeds and thin out the crop when it is 3-4 weeks old. It is done with a wooden toothed harrow drawn over the field by a pair of muzzled buffaloes. Except when going over fairly marshy patches the harrow should be weighted down by riding on it or by other means. When necessary the harrow should be lifted up to remove weeds and plants collected on the tines. The following day water is let in to cover the soil, the field is lightly weeded and vacancies filled in. In rainfed areas the crop is harrowed in about 3″ of water and this water depth is maintained. This is an useful method where labour is scarce and expensive.

Reports from the Northern Province indicate that there are limitations to the widespread use of this practice in those areas. (19). 1. The operation on heavy clays does more damage than good. 2. Appreciable increases in yields are not obtained on land sown dry and when the age of the paddy is less than three months. 3. Best results are obtained only on loamy rich soils. 4. Shortage of animals for harrowing.

Row weeding

Row weeding using row weeders can be easily, economically and efficiently carried out on all row seeded and row transplanted crops. The labour requirement is small, usually 2 man days per acre and the operation can be repeated at all stages of the crop when weeds prove to be troublesome. Row weeding can also be adopted when weeds are small before they offer much competition to the crop. (Row weeders are marketed by the Department of Agriculture at the subsidized price of Rs. 12.00 each).

Chemical weed control

The method of control equally applicable to broadcast, row sown or transplanted crops appears to be chemical weed control. Ideally the weed killer should control all weeds both monocots and dicots, without damaging the rice. The popular chemicals, 2, 4, dichloro phenoxy-acetic acid (2, 4-D) and 2 methyl—4 chloro phenoxy acetic acid (MCPA) are effective against some paddy field weeds but they are ineffective against graminaceous types.

Recent developments in this field have shown that the chemical 3, 4-dichloropropion anilide (3, 4—DPA), a contact herbicide of the non-hormone type is capable of killing all weeds in a field, without being injurious to the rice plant. This chemical is widely used as a post-emergence foliar spray and is very useful for broadcast or row sown crops. Best results are obtained when applied at the time when weeds are at the two leaf stage and the chemical causes no phytotoxicity to the crop when sprayed 10-14 days after sowing. The usual concentration is 3 pounds active ingredient per acre in 40 gallons of water, using a high volume sprayer with a boom of jet nozzles. The weedicide could also be sprayed with a low volume sprayer of the mist blower types using 1½ pounds active ingredient per acre in six gallons of water.

List of Common Paddy Field Weeds (40)

Botanical Name	*Sinhalese Name*	*Tamil Name*
Asteracantha longifolia	Katu-Ikiri	Neer-mulli
Limnocharis flava	Diya-Gova	
Eclipta alba	Kikirindiya	
Epaltus divaricatus	Hin-Mudamahana	
Spilanthes acmella		
Sparganophorus vaillantii		
Sphaeranthus indicus	Mudamahana	
Cyperus iria	Wel-Hiri	
Cyperus tenuispica		

Botanical Name	*Sinhalese Name*	*Tamil Name*
Cyperus pilowus		
Cyperus procerus		Kokunarai
Eleocharis dulcis		
Fimbristylis miliacea	Kudumetta	
Fimbristylis quinquangularis		
Lipocarpa argentea		
Ceratropteris thalictroides	Kudamhu pala	
Coix gigantea	Kirindi	
Echinocloa colona		
Echinocloa crus-galli		
Echinocloa frumentacea		
Echinocloa stagnina	Wel Maruk	
Eragrostis japonica		
Elytrophorus spicatus		
Eragrostis unioloides		
Isachne globosa	Batadella	
Ischaemum rugosum	Gojera walu	Kudikedu
Leersia hexandra		
Leptochloa chinenii		
Oryza fufipogon	Uruwi	Pandi nel
Oryza derennis Moench	Uruwi	
Sacciolepis myesuroides		
Blyxa zeylanica	Diya Hawari	
Ottelia alismoides		
Hydrolea zeylanica	Diya Kirilla	
Ammania baccifera		
Rotala indica		
Rotala leptopetala		
Marsialia quadrifoliata	Diya embul-embiliya	
Aeschynomene indica	Diya-Siyambala	Kidaichchi
Eichornia crassipes		
Monochoria vaginalis	Diya-Habarala	
Pistia stratiotes	Diya-Paradella	
Jussiaea repens	Beru-Diyanilla	
Jussisea tenella		
Ludwigia perennia		
Salvinia auriculata	Japan-Pasi	
Bacopa moniera	Lunuwila	
Dopatrium junceum	Bin-Sewan	
Limonophylla conferta	Ambawila	
Lindernia antipoda	Wila	
Lindernia cordifolia		
Lindernia hyssopiodes		
Xyris Indica		

Fertilization of Paddy

Paddy yields of 20-30 bushels per acre have been obtained on fields that have been cultivated for centuries without any organized fertilization. This has been observed in other parts of the world as well. De, working on blue green algae, demonstrated that the algae were capable of fixing atmospheric nitrogen and that this could well be a good source of nitrogen for rice. (41). Some workers were of the opinion that the nitrogen arises from contaminating bacteria such as *Azotobacter*, that live within the gelatinous sheath that covers the blue green algae. De was of the opinion that nitrogen fixation was associated with the algae themselves.

Local surveys showed that these blue green algae were widely distributed in rice soils in Ceylon. About 10 species of *Nostoc* were found in the North Western, Western, Southern, Eastern and Northern provinces. Eight species of *Lyngbya* occurred in the North Western, Eastern and Uva provinces, and three species of *Oscilla toria* predominated in the Central and Sabaragamuwa provinces. (29). The work done by Watnabe has shown that the three species *Tolypothrix tenuvis* from Borneo, *Calothrix brevissima* and *Anabaenopsis* sp. from Sumatra have extraordinary high nitrogen fixing ability. (42).

De and Pain (43) also suggested that in some instances the nitrogen fixed in the soil was greater than that actually removed by a rice crop. The size of the crop would be of importance in this comparison. The precise contribution from blue green algae is not known. A high estimate is considered to be about 50 pounds nitrogen per acre in high pH soils well supplied with phosphorus and potassium. (15).

Local experience has indicated that improved paddy varieties have shown a marked response to nitrogen application and that high yields cannot be harvested from unfertilized fields. Nitrogen, phosphorus and potassium are found inadequate in most rice soils. These plant nutrients can be added to fields in either inorganic form as fertilizers or in the form of green manures, compost or other organic manures.

Inorganic fertilizers for rice

Most of the work done on rice nutrition has centred round the use of chemical fertilizers. These fertilizers are convenient to use, can be applied at any particular stage of growth and are immediately available to the crop.

The prediction of fertilizer needs for the various rice growing areas has however proved to be a problem. Ponnamperuma (15) summarizes the discussions of the International Rice Research Institute on the usefulness of soil analysis as a method of determining fertilizer needs, as follows :

"For more than a century, soil and plant scientists have attempted to use soil analysis to predict fertilizer needs of crops. But in spite of advances in extraction and analytical procedures and the experience gained by the wide use of soil tests, satisfactory quantitative correlations between soil tests and yields or fertilizer response are not common." The results obtained from the recent All Island Rice Soil Fertility Survey and the latest fertilizer recommendations released by the Department of Agriculture (44) would also support the views of Ponnamperuma. Table 34 gives the information obtained from the All Island Fertility Survey for a few districts. These values indicate that the range of phosphorus in soils varied between 0-30 lb. P_2O_5 per acre in the Trincomalee, Vavuniya, Anuradhapura, Moneragala and Polonnaruwa districts, which have amongst them 225,000 acres of asweddumized land. But the fertilizer recommendation is the same for this entire area—namely 112 lbs. saphos per acre for fertilizer responsive varieties and 84 lbs. saphos per acre for other varieties. The position is identical in the case of potassium, the fertilizer recommendation being the same for all these districts although the Fertility Survey indicated wide variations in potassium.

Fertilizer experiments in cultivators fields, were commenced in 1955, in the hope that fertilizer recommendations could be based on such information. Over 20,000 such plots have been laid down and they have provided valuable information on the fertilizer needs of rice soils. The programme is still being carried as a Freedom From Hunger Campaign Soil Fertility Project under the sponsorship of the Food and Agriculture Organization, financed jointly by the Australian and Ceylon Governments.

Nitrogen fertilization. Nitrogen fertilization of lowland rice depends to a large extent on the variety grown and its efficiency varies with the form of nitrogen used, time of application, depth of placement, and quantity of nitrogen applied.

Variety — nitrogen relationships. Improved varieties with high fertilizer response should be fertilized with higher levels of nitrogen than varieties with low fertilizer response. Another factor that needs to be taken into consideration is the effect of nitrogen levels on the incidence of blast disease. High levels of nitrogen nutrition predisposes the crop to attack from blast, and varieties that do not have good straw strength tend to lodge severely. The varieties H4, H7, H501, H105, Murungakayan 302 and Ptb 16 respond to high levels of nitrogen fertilization, Podiwi a8 is intermediate, Patchaiperumal, Dewareddiri, Pokkali and village varieties do not show a marked response. (44).

Form of nitrogen used. The rice plant can use both ammonia and nitrate forms of nitrogen. However, under flooded cultural conditions, nitrates are partly denitrified and lost and ammonia forms of nitrogen have proved to be superior.

TABLE 34

A comparison of the results obtained in the Fertility Survey and the Fertilizer Recommendations for Paddy.

District Fertilizer Recommen dations.(lb.Saphos/ac)	Phosphorus			Potassium		
	Fertility Survey Modal Range Values (lb. P_2O_5/ac)	Fertilizer Recommendations (lb. Saphos/ac.)		Fertility Survey Modal Range Values (m.e. % K)	Fertilizer Recommendations (lb. Muriate of Potash/ac.)	
		For Fert. Responsive Varieties	For Other Varieties		For Fert. Responsive Varieties	For Other Varieties
Trincomalee	0—5	112	84	0·10—0·15	56	28
Vavu iya	5—15	112	84	0·10—0·15	56	28
Anuradhapura	5—15	112	84	0·15—0·20	56	28
Moneragala	5—15	112	84	0—0·10	56	28
Polonnaruwa	15—30	112	84	0·10—0·15	56	28

The use of ammonium sulphate under acid soil conditions could predispose the crop to hydrogen sulphide toxicity and thereby depress yields. (44) Urea is a better form of nitrogen than ammonium sulphate for these wet and intermediate zones and the acid sandy soils of the dry zone, (parts of Jaffna and Batticaloa). Ammonium sulphate can be safely used on the remaining soils of the dry zone. (4).

Time of application. A number of factors should be taken into consideration in determining the proper time of nitrogen application. 1. The tendency in many parts of the world is to apply all of the nitrogen as a basal application when the variety is early maturing. This could lead to excessive vegetative growth and mutual shading in leafy *indica* varieties. 2. The peak nitrogen requirements of the crop are at tillering and at panicle initiation. 3. Both urea and ammonium sulphate are quick acting fertilizers.

The recommended practice is to withhold nitrogen from the basal dressing of fertilizer and to apply it in split doses at tillering, flower primordia initiation and at heading. Since Podiwi a8 is susceptible to blast disease it is suggested that the first top dressing be withheld and that only the other two dressings be given. In the case of low fertilizer response varieties only one top dressing at tillering is recommended. (44).

Placement of nitrogen fertilizer. The significance of the oxidised and reduced layers in the soil profile of a lowland rice field has been discussed. It would appear that placement of ammoniacal fertilizers in the reducing zone would be most desirable. Experimental evidence has confirmed this view. Average increases in yield of 13-15 per cent were obtained with shallow placement (1″-2″ deep) and 21 per cent with deep placement (4″-5″ deep) over surface application. (46).

In practice it is difficult to make sub-surface applications during the growth of the crop, unless the fertilizer is available in "ball" form and each pellet is pushed into the soil as is done in Japan. (24). Under local conditions it is recommended that the first top dressing should be lightly worked into the soil to get maximum benefit from the fertilizer and that subsequent top dressings should be applied to the soil surface. (44).

Quantity of nitrogen fertilizer. One of the main aims of fertilizer trials in cultivators fields has been to get some quantitative evaluation of the amount of nitrogen required for the various rice tracts in Ceylon. These requirements have been presented in detail in the Department of Agriculture publication on Fertilizer Use. Table 35 attempts to present the total quantity of nitrogenous fertilizers recommended, in a general manner, based on this information. (44), (4). Variations occurring in small areas are not included in the table.

TABLE 35

Nitrogenous fertilizer recommendations for paddy

	Soil type	Fertilizer Responsive varieties	Other varieties
Dry zone	Normal soils	224 lb. ammonium sulphate	112 lb. ammonium sulphate
	Acid sandy soils	112 lb. urea	56 lb. urea
Wet sone	Most soils	84 lb. urea	56 lb. urea
	Rich soils	56 lb. urea	42 lb. urea

These quantities are applied to the field in split applications. In most instances three applications are recommended, when improved varieties are grown. Half the quantity of fertilizer is given at flower primordia initiation and the balance applied at tillering and heading. Variations from this practice are discussed under variety-nitrogen relationships.

Phosphorus fertilization. Flooding is known to increase availability of soil phosphorus, and enhance the utilization of phosphate fertilizers. Responses to phosphate applications are not as striking as the results obtained from nitrogen applications but phosphorus applications are required for all districts in Ceylon.

Variety-phosphorus relationships. Due to the better growth and yields obtained from improved varieties, the recommended levels of phosphorus are higher for these types. The recommendations indicate a 50% higher application of phosphate fertilizers for the fertilizer responsive varieties.

Form of phosphorus used. Fertilizer trials carried out indicate that there were no significant differences between the phosphatic fertilizers, soft rock phosphate, ordinary superphosphate, concentrate superphosphate, basic slag and bone meal (3/32" grade) when applied at 40 lbs. P_2O_5 per acre, over a basal dressing of 200 lb. per acre ammonium sulphate and 100 lb. per acre muriate of potash. (45). Saphos (ground rock phosphate) is the cheapest. It is the recommended source of phosphorus.

Time of application. The time of application depends on the requirements of the plant and on the availability of soil phosphorus. The plant absorbs phosphorus continuously, more or less in keeping with the increase in dry matter accumulation. (Table 29). Phosphorus availability increases on flooding but because of poor phosphorus utilization in the early stages, phosphorus application is recommended as a basal dressing during preparatory tillage.

The favourable effects of phosphorus on nitrogen uptake has also been stressed. Work with *japonica* varieties has shown that nitrogen uptake was nearly trebled by the end of the 42nd day after sowing, as a result of phosphorus applications as a basal dressing. (47).

Placement of phosphorus fertilizer. Little information is available on the placement of phosphorus fertilizers. In areas where preparatory tillage is carried out dry, as in California, the phosphate is drilled into the soil. In Ceylon the recommended practice is to apply the fertilizer at the latter stages of preparatory tillage and to work it into the soil. (44).

Recent work using P^{32} seems to indicate that surface broadcast application with or without mixing was superior to deep placement. (15). It is premature to utilize this method of placement in Ceylon, without confirmation from local trials.

Quantity of phosphorus. The optimum application over most of the Island is 1 cwt. of saphos per acre. On soils very deficient in phosphorus the recommendation is 168 lbs. per acre and on soils with good phosphate status 84 lbs. per acre. These values are for improved varieties of paddy, smaller quantities are used when low fertilizer response types are grown, as indicated earlier (44), (4).

Potassium fertilization. Rice straw and in some cases irrigation water, can be rich sources of potassium. Most of the potassium removed by a crop of paddy is located in the straw which can contain about 80 lbs. potassium per ton. Losses of potassium from soils can occur through immobilization or could be removed with drainage water.

Variety - potassium relationships. As in the case of phosphorus, the recommended levels of potassium fertilization for improved varieties is higher than that for low fertilizer response types. In most cases the latter group get only 50% of the fertilizer recommended for high yielding paddy varieties. (44).

Form and placement of potassium fertilizers. Muriate of potash is the best source of potassium and can be used safely over the entire Island (4). The potassium can be incorporated with the saphos in the basal dressing except in some instances where it is recommended that a part of the application be applied as a top dressing prior to heading.

Quantity of potassium fertilizer. The general recommendation is 56 lbs. muriate of potash per acre. On soils very poor in potash, applications of 84 lbs. are recommended and in rich soils the quantity may be reduced to 28 lbs. Detailed recommendations for the various districts are presented in the publication on Fertilizer Use. (44).

Liming of Rice Soils. Marked yield responses have been obtained from liming strongly acid lateritic soils, which predisposes the crop to the physiological disease "bronzing".

Form of Lime. Three forms of lime were tried out on the strongly acid soils in the Mirigama area. The responses to slaked coral lime, ground coral limestone and dolomite applications were 707, 486 and 319 lbs. paddy per acre, when tried out at the lime equivalent of 6 tons slaked lime per acre. (45). The current recommendation is to use ground limestone. (44).

Quantity of lime. Four levels of lime, 0, 2.7, 5.4, and 8.1 tons per acre ground limestone were tested out in 5 districts during the Maha 1958-59 season. The response was variable. It was most marked in the strongly acid soils of the Mirigama Range, appreciable in the mid country and least in the Kalutara district. (45). However liming trials carried out at Paiyagala and Mirigama in the Yala season of 1962 are reported to have showed no response to lime. (30).

The current recommendation is to apply half a ton of ground limestone per acre, two weeks before planting or sowing wherever severe symptoms of "bronzing" occur in the low country wet zone. Such applications to be continued every season till no further symptoms of "bronzing" are noticed. (44).

Addition of Silica to rice soils. The advantages gained by having a liberal supply of silica for paddy is well recognized. The strongly acid lateritic soils of the low country wet zone are considered to be deficient in silica and trials were laid down to test the usefulness of silica. The silica was supplied in the form of Portland Cement. Yield observations suggested a marked response to silica. (45). The current recommendation is to apply repeated seasonal applications of rice-husk ash as a basal dressing up to 4 cwt. per acre to these silica deficient soils. (44).

Organic manures for paddy

Green manures, composts and farm yard manures have been widely used in paddy fields and they were the chief source of plant nutrients before the use of fertilizers. Apart from their beneficial role in some soils, green manures could aggravate physiological diseases associated with reduction of the soil and prove to be harmful to the crop.

The non-availability of composts and farmyard manure restricts their use in paddy cultivation and the main source of organics is green manure. The nitrogen contained in the green manure is in the form of protein and is not directly available to the plants. The green manure will first need to undergo mineralization before it can be of use to the crop. The rate of mineralization is dependent on the C/N ratio of the added material among other considerations. Green material with a favourable C/N ratio will decompose rapidly and nitrogen release in usable form will commence in 20-30 days depending on the conditions prevailing.

The time of green manure incorporation, the source of green manure and the type of sowing adopted have some bearing on the efficiency of green manuring in rice production. Green manures could either be grown *in situ* or introduced from outside.

The cultivation of green manures *in situ*. The practice in some parts of the world is to sow down the green manure seed in the standing crop shortly before harvest. The plant grows rapidly after harvest and is ploughed under with the commencement of preparatory tillage for the next season. Another method is to sow down a green manure crop after some soil preparation. This system of cultivation *in situ* is possible only in areas where the land is cropped for one season.

Introduced green manures. There is no restriction with regard to the type of plant material introduced into the fields. In most cases the green material is obtained from trees growing on the adjoining lands. The quantity of material available is generally inadequate for a large extent of land. The loppings are spread out in the field and any branches that were used are removed after leaf fall. One advantage in this system, is that introduced green manures could be applied to the fields during the latter part of preparatory tillage. They need not necessarily be applied at the commencement of land preparation.

Relationship between time of incorporation and method of sowing. Green manure crops grown *in situ* are turned into the soil at the commencement of preparatory tillage. Mineralization occurs and the nitrogen released becomes available to the crop in 30-40 days. This period is shortly after the time when preparatory tillage is over. A broadcast sown crop cannot use this nitrogen efficiently whereas a transplanted crop will respond favourably, with an increased number of ear-bearing tillers.

In the case of introduced green manures they can be applied late at the tail end of preparatory tillage and this would suit a broadcast or row sown crop of paddy. The nitrogen release in this case would more or less coincide with the tillering stage resulting in a larger number of "valid" tillers.

Quantity of green manures. Good green manures contain 3-4% nitrogen on a dry weight basis. A crop of green manure weighing 6000-8000 lbs. fresh weight will give 40-50 lbs. nitrogen and be equivalent to 2-2½ cwt. of ammonium sulphate per acre.

This is about the recommended level of nitrogen for most soils in Ceylon.

In a system of double cropping the cultivation of green manures *in situ* will be difficult if not impossible. In other areas, fields are used as grazing grounds in the off season and if they are to be sown to green manures, fencing or some other method will have to be used, to protect the crop.

It is claimed that green manures are an uneconomic source of nitrogen. This objection can hardly be raised in Ceylon, where, the need to conserve foreign exchange cannot be overemphasized. In actual practice, in areas where green manuring can be used efficiently, it may pay to divert the subsidy now paid for the purchase of nitrogenous fertilizers to a subsidy for the cultivation of green manures. If the yields obtained from green manured fields can match the yields obtained from fertilizer use, this change will mean a saving in scarce foreign exchange.

The current recommendation on the use of green manures, states that: "Green manures may be used safely in fields that are well drained and not boggy". (44).

Pest Control

The loss of crop from pest attack is difficult to estimate, but such losses must be of a considerable magnitude. Some pests are widely distributed and cause severe damage whilst others occur in isolated pockets.

The practice of double cropping, with varieties of varying ages, which tend to overlap from one season to another makes pest control difficult. The pests merely start off in one season, multiply and move on to the next crop. The last harvests in the tract are often worthless due to pest attack.

It is difficult for individual farmers to control pests effectively in small isolated holdings. Pest control has to be a team effort which embraces the entire tract. Proper weed control to eliminate alternate hosts, fixed sowing periods, the cultivation of varieties in the same age group, and collective action when a pest does occur are all sound agricultural practices that minimize losses. Unlimited latitude amongst cultivators in these matters provides a continuous food supply for insect pests and ideal breeding conditions resulting in heavy losses of crop. A paddy tract is made up of a multitude of fragmented holdings and extension workers should aim at introducing uniformity by persuasive means, failing which cultivation committees should enforce such measures compulsorily.

These cultural practices cost nothing. Failure to observe these, increases the need for insecticidal control which involves the use of expensive spray equipment and chemicals. Insecticidal and other control measures with an exhaustive description of spray equipment has been presented by Fernando and co-workers. (48). The effectiveness of insect control can be increased by proper forecasting of insect pest occurrence. However such forecasting can be done only with data collected over a number of years and with the assistance of a large staff. There are three methods of forecasting commonly used—1. Field observational forecasting method. 2. Statistical forecasting method. 3. Theoretical forecasting method.

Pests of paddy are conveniently grouped into categories based on the types of damage caused: I. Leaf eating caterpillars. II. Stem borers and gall formers. III. Plant sucking types. IV. Pests of stored grain. These pests have been elaborately discussed by Manickavasagar (49).

Leaf eating caterpillars

1. The Swarming Caterpillar. *Spodoptera mauritia.* Boisd.

The pest occurs all over Ceylon and a badly damaged field looks as though it has been grazed by cattle. The crop could be eaten down to water level, and in the absence of water, to ground level.

The caterpillars emerge from a mass of eggs laid by a brownish black moth on either paddy plants or weeds. The pale green caterpillars feed voraciously on the crop, turn a dark brown colour in 10-15 days and attain maturity within a month. They migrate to the bunds or highlands and pupate in the soil in earthen cells. Moths emerge in two weeks and the cycle continues. The crop is by then too fibrous and unpalatable for the young caterpillars.

Birds act as predators and the Tachinid fly parasitizes the caterpillars causing fair control of the pest. Heavy rain also washes the caterpillars into the standing water and they drown. A light top dressing of nitrogen often helps the crop to revive without a serious loss of yield. Insecticidal control is discussed at the end of the group.

2. The Paddy Case Bearer. *Nymphula depunctatis.* Guen.

The pest occurs in isolated areas and attacks the plants when they are 2-6 weeks old. Damage could be easily spotted by the rice leaf tubes which float in the water once they are cut off the plants by the caterpillars.

The pale green caterpillars emerge from eggs laid singly on leaves by a white moth with pale brown marking and dark specks on the wings. The caterpillars cut sections of leaves, roll them up into tubes and live in them. They feed on the epidermis of the leaves which turn white in patches where feeding occurs. As the caterpillats grow they construct fresh tubes and pupate in the last larval leaf tube which is attached to the base of the plant. The moth emerges in about a week.

The cheapest method of control is to drain the fields, if water is assured. Insecticidal control is discussed at the end of the section.

3. The Paddy Leaf Roller. *Marasmia trapesalis.*

The pest attacks the crop at all stages of growth and the damage could be severe if the uppermost leaves or the flag leaf is attacked. The pest is severe when nitrogenous manures have been used excessively.

The caterpillar hatches out from eggs laid by a small yellowish moth with wings fringed with blackish brown markings. The pale green caterpillars roll up the leaves by glueing the margins. They feed on the inner epidermis and pupate within these rolled up leaves. The leaves turn whitish and appear parched up.

The caterpillars are heavily parasitized. Rain also helps in the control of this pest.

4. The Borollia Caterpillar. *Borolia venalba.* Mo.

The moths lay about 600 eggs and the young caterpillars, greyish when young and reddish with grey stripes when mature, web together a few leaves to serve as shelters, within which they pupate in whitish silken cocoons. The pest feeds on the plant, eating the entire leaves and sometimes even stems.

5. *Parnara* sp. Caterpillars from Hesperid butterflies with large broad heads and narrow elongate bodies. They feed on portions of rice leaves.

Insecticidal control of Leaf Eating Caterpillars

All the leaf eating caterpillars could be controlled by using 0.5 lb. of actual D.D.T. per acre, in the form of a spray. The D.D.T. is available as either 50% D.D.T. water wettable formulation or 25% D.D.T. emulsion concentrate and could be sprayed by using either knapsack or power driven sprayers.

Gamma BHC dust could also be used at the rate of 0.25 lb. of actual gamma BHC per acre.

Spray applications

Formulation	Hand operated knapsack sprayer	Power driven mist blower
1. DDT 50 % water wettable powder	1 lb. in 40-60 gallons 1 oz. in $2\frac{1}{2}$-$3\frac{1}{2}$ gallons	1 lb. in 3-5 gallons
2. DDT 25% emulsion concentrate	30 fl. oz. in 40-60 gals. 1 fl. oz. in $1\frac{1}{3}$-2 gals.	30 fl. oz. in 3-5 gals.

Dust applications

0.65 % gamma BHC dust use 45 lbs. per acre
0.7 % gamma BHC dust use 35 lbs. per acre
1.3 % gamma BHC dust use 20 lbs. per acre

Paddy Stem Borers and Gall-formers

6. Paddy Stem Borer. *Schoenobius incertellus.* Wlk.

The pest occurs all over Ceylon and results in the death of the central growing shoots and in older plants the formation of white panicles with empties. They are easily recognized in a field. This is a major pest and damage is extensive often amounting to 20-40 % of the crop. About 2-4 generations are produced in a single season and plants are attacked in all stages of growth.

The moth is yellowish orange with a characteristic dark spot in the middle of each fore wing. Egg masses are deposited on leaves, hatch in 2 weeks and the creamy white caterpillars bore down the plants feeding on the internal tissues. A single caterpillar has to feed on 3-5 seedlings in order to complete its life cycle. In each case the central tissue is destroyed whether it be leaf or panicle.

In nature the egg masses are parasitized on by *Tetrasticus schoenobbi* and *Telenomus dignus*, both wasp parasites. The effectiveness of various insecticides for control of stem borer was measured by estimating reduction in dead heart incidence as an index of stem borer damage.

Results were as follows : (50)

Gammexane BHC	2 % dust	83 %
Endrin	2 % dust	60 %
Endrin	1 % dust	71 %
Sumithion	2 % dust	34 %
Endrin	2 % pellets	43 %

Twenty fluid ounces of endrin 20 % emulsion concentrate in 40 gallons of water also gives good control.

A faulty timing of application could result in heavy infestation. Applications should be made at regular intervals as long as the problem lasts.

7. Rice Stem Fly. *Altherigona exigua.*

The pest occurs in isolated areas during dry seasons or in upland rice. The attacked plants die, but usually tillers appear before this occurs. If no control is effected the tillers will also be lost.

The stem fly is greyish brown in colour with one pair of wings, the other is reduced to a pair of halters. Eggs are deposited on plants 2-3 weeks old. The maggots move to the growing shoot and attack it. The bright yellow mature maggot pupates in the attacked plant or in the soil around the plant if it is dry. The life cycle is 3-4 weeks and when the second generation of flies appear the unattacked crop is too mature.

Control is effected by a drenching spray of dipterex using 10 fluid ounces of a 50% emulsion concentrate or 7 oz. of a 80 % water wettable powder in 40-50 gallons of water per acre.

8. The Paddy Gall-fly. *Pachydiplosis oryzae*. W.

The pest attacks the plant at all stages of growth and severe damage could be caused in the seedling stage. Tillers produced by these plants are also liable to be attacked. Late cultivation, lack of water and poor fertilization favour gall-fly incidence.

Small pinkish to red flies deposit the eggs on leaves and the maggots on emergence bore into the shoot and reach the growing point. The attack stimulates the production of a light green coloured leaf tube with a silvery sheen, known as the "silver shoot". This prevents further growth of the plant. Maggots pupate in the "silver shoots" and the fly emerges through a small hole in the tube. The life cycle takes 2-3 weeks.

Fair control is obtained with DDT sprays. Eighty fluid ounces of 25 % emulsion concentrate in 40 gallons of water is adequate for one acre, or 24 ounces of 50 % water wettable powder in 40 gallons of water. The egg parasite *Platygaster oryzae* has been observed parasitizing eggs of this pest. (32).

9. *Sesamia inferens*. A pinkish caterpillar from a straw coloured moth has been recently found to be a pest on paddy.

Plant sucking pests

10. Rice Leaf Hoppers. *Nephotettix* species, *Nilaparvata* species, *Tettigoniella spectra*. The pest mainly occurs during dry periods, in localized areas. The minute bugs feed on leaves causing white to yellowish spots and streaks on the leaf surface by their feeding action. On older plants they feed at the base of the plants and this could lead to the collapse of the actively growing plants. Both nymphs and adults feed on plants and they migrate from plant to plant.

Control could be effected by spraying with DDT 1/3 pound active ingredient per 40 gallons of water or by using gamma BHC dust at the rate of ½ pound active ingredient per acre.

11. The Paddy Pentatomid Bug. *Scotinophara obscura*.

The pest is widespread but is severe in the southern areas. The dark coloured bugs feed by sucking plant sap and lay their eggs on growing rice plants or weeds. The brown to yellow nymphs on emergence feed on paddy plants in the same manner as the adults. They are active at night and at harvest time they hibernate in the cracks in the field, under plant trash and in such places. They migrate back to the paddy plants during the next season.

The damaged leaves in the stem show white or creamish chlorotic patches as soon as they exert and if the patches extend across the leaves the upper portion could wither and drop off.

Control is effected by Malathion sprays at the rate of 1/5 pound of active ingredient per acre, or dipterex at the rate of 1/8 pound of active ingredient per acre in 30 gallons of water.

12. The Paddy Bug. *Leptocorisa* sp.

A most serious pest during the milky stage of the crop. The bug lives on graminaceous weeds and multiplies rapidly when the earheads are in the milky stage particularly in cool, cloudy and still weather. Hot windy weather does not favour the pest. The bug lays its eggs on leaves and stems of paddy plants and weeds. The nymphs are greenish on emergence and both these and adults feed by piercing the plant tissue and sucking the sap. Attacked grain is either half full or empty.

Gamma BHC dust used at the rate of ¼ pound of actual gamma BHC per acre, using a power operated dusting machine gives good control.

13. Paddy Thrips. *Thrips oryzae.*

Thrip attack is severe during periods of drought. The minute black adults and cream to yellow young thrips live and feed on leaves. They attack the surface of leaves and suck the exuding sap. These damaged leaves turn yellow to brown, wither and roll up.

Control is effected by using DDT sprays using ½ pound of actual DDT, or ¼ pound of actual gamma BHC per acre.

Other pests of the crop

Rats

Rat damage is severe during the latter part of the crop. They cut the plants and drag them into their burrows.

Rats are controlled by baiting them with 0.5% or 1% Warfarin. If the 1% formulation is used, mix 1 part with 39 parts rice bran or maize meal. Addition of burnt coconut makes it more attractive. The bait is spread out each evening at the rate of one to two ounces at each site till the attack is controlled.

Crabs

Crabs damage bunds and they are controlled by squirting small quantities of endrin solution into their breeding holes, one fluid ounce of a 20% endrin emulsifiable concentrate in two gallons of water is a suitable concentration. Repeated use of endrin makes the crabs completely resistant to this chemical. These endrin resistant crabs could be controlled by sumithion, lebaycid and parathion (4).

Pests of Stored Grain

The three common and serious pests are *Sitotroga cerealella* a moth, *Sitophilus oryzae* a weevil and *Rhizopertha dominica* a beetle.

The following control methods are recommended :

1. Store and bag treatment. Two fluid ounces of a 20% gamma BHC or 50% Malathion emulsifiable concentrate in one gallon of water for store and bag sprays.

2. For seed paddy. Mix four ounces of 0.6% gamma BHC dust or two ounces of a 4% Malathion dust per bushel of seed paddy.

3. Consumption paddy should not be treated with dusts, only bag sprays being used.

Paddy Diseases

Paddy diseases depress yields to varying extents. The magnitude of such reduction in yields depends on the variety grown, extent of fertilization, and climatic conditions among other factors. The most profitable approach to disease control would be to use disease resistant varieties. However such resistant varieties do not remain resistant for all times, as various new races of fungi appear which differ in pathogenicity. For instance over 12 races of blast fungi have been reported in Japan alone. Most local unimproved varieties of paddy are very susceptible to disease and they break down distressingly at high levels of fertilizer application.

The cheapest method of control is to use resistant varieties, but the crop often needs fungicidal spray as well. Such sprays are most effective when they are applied before severe damage occurs and this is facilitated by proper disease forecasting. Such a forecasting service needs the help of a number of pathologists and is based on regular survey data collected throughout the country, from a network of spore traps and other devices. For lack of staff and other reasons this forecasting service is not available in Ceylon and most control measures are initiated on the appearance of the disease.

The use of good cultural measures such as the use of clean seed, seed treatment, proper destruction of crop stubble and weed control all help to minimize the damage caused by disease. The common diseases of paddy may be broadly classified as follows: 1. Fungal diseases. 2. Bacterial diseases. 3. Nematode diseases. 4. Physiological diseases. (51).

Fungal Diseases

1. Paddy blast. *Piricularia oryzae*

The disease attacks the crop at all stages of growth and cause leaf blast, neck rot, panicle blast and nodal infection. High fertilizer applications predispose the crop to infection.

Leaf blast. Usually severe at low elevations below 1000 feet. The spots formed on the leaves vary in colour and size and have been classified according to the resistance of the host to the fungus.

(*a*) Minute brown spots the size of pin points. These are found on very resistant varieties.

(*b*) Small diamond shaped lesions 1-1.5 mm. uniformly brown in colour. Not serious on leaves.

(*c*) Larger lesions very irregular in shape and varying in size from 2.0-10.0 mm. At the initial stages they are blue -green in colour but subsequently turn brown and may have a yellow margin. Varieties with these lesions are considered susceptible to blast.

(*d*) Large creamy white lesions which slowly turn blue-green and finally brown. Usually found on very susceptible varieties.

When the attack is severe it leads to stunting and there is often destruction of entire leaves. Such crops may have to be destroyed in order to safeguard neighbouring fields.

Node blast, Neck Rot and Panicle blast. These forms of the disease are more severe at the higher elevations above 1500 feet. The parts attacked are the nodes, neck of the panicle or the spikelets. The portion of the plant above the point of attack usually dries up and if the panicle is involved the grain may be partially filled or the glumes completely empty.

A variety resistant to leaf blast is also considered resistant to neck rot as it has been established that there is a positive correlation between these phases. A large number of varieties have been screened for resistance and the following rating has been allocated, varying from highly resistant to very susceptible.

LIST OF PADDIES AND THEIR DEGREE OF RESISTANCE TO BLAST DISEASE

Key to symbols used

Highly resistant	†††
Very resistant	††
Fairly resistant	†
Rather susceptible	@
Susceptible	@@
Very susceptible	@@@

3 3½ month paddy		**3½-4 month paddy**	
Br. 4	†††	H. 105	†††
Dahanala 2014	@@	SR. 26 B	†††
Heenati 309	@@	Sinnanayan 398	†
Heenati 310	@@	Sulai 301	@

Ch. 1007	@@
Ch. 1039	@@
Waner	@@
H. 2	@@@
Murunga 307	@@@
Murunga 308	@@@
Murunga 137	@@@
P.P. 2462/11	@@@
Suduwi 305	@@@
Suduwi 306	@@@
2-2-18	@@@
Ptb. 10	@@@

4-4½ month paddy

H. 4	†††
H. 5	†††
Murungakayan 101	†††
Murungakayan 302	†††
Murungakayan 3	†††
Murungakayan 304	†††
Murungan samba 3081	†††
Sigardis 3443	†††
Myae 104	†††
V.I. 28061	†††
H. 501	††
Murungakayan 104	†
Murungakayan 303	†
Pokkali	@
Perillanel 26014	@@
Madael 137	@@@
Oddavalan 2449-20	@@@
Chuban 18	@@@
H. 106	@@@
H. 103	@@@
Mas. M 24	@@@

Rathkarayal 3753	@@
Samo	@@
Kalu Heenati 3254	@@@
Sinnanayan 2208	@@@
Suduheenati Hf. 9	@@@
Suduheenati 1 CPY 15	@@@
Sulai 27614	@@@
Vellai Perunel 28724	@@@
Wanni Dahanala 1	@@@
GEB 24	@@@
Adt. 18	@@@

4½-5 month paddy

Remadja	†††
Co 25	†††
C. 20	@@
Uvar Vellai	@@
Pebifun	@@
C. 12	@@@
Hondarawela 538	@@@
Gendah Beton	@@@

5-5½ month paddy

Tjahaja	†††
Bengawan B. 27	†††
Peria Vellai 538	††
Dewareddiri 26081	@@@
Siam 29	@@@
Brondel Putih	@@@

5½-6 *month paddy*

Ptb 16	†
Mawi B. 11	@@
Molagusamba g 18	@@
Kurulutuduwi B 13	@@@
Podiwi a 8	@@@

Numerous hybrid progenies have also been screened against blast and a few have been found to be highly resistant, such as 61-1478 (57-56 x H5), 61-1491 (57-562 x H5) and 14 (H 501-H4). (4).

Fungicidal control. This method of control should be used only when others fail. Fermate or Niagara Carbamate (Ferric dimethyl dithio carbamate—76% active ingredient) can be used with success at the rate of 1 ounce per 10 gallons of water. Recent work has indicated that Triphenyl—tin, Acetate (Brestan 60) and Verdasan organo-mercurial gave excellent control being superior to Niagara Carbamate. Organo-mercurials are usually considered toxic to *indica* rices but at concentrations of 4 ounces in 5 gallons practically no toxic effects have been observed. (4).

Usually 100-200 gallons of spray are required per acre and the application should be timed so that it is followed by a short dry spell which permits the spray to dry on the leaf. Dusts should be applied preferably with power dusters to ensure good results.

If fungicides are given as protective treatment they should be applied at ear emergence. Such a spray may also be used where leaf blast was serious earlier or where such a crop has been top-dressed with nitrogen.

2. Brown Spot. *Helminthosporium oryzae*

The disease is of less importance than blast. Poor soil conditions predispose the crop to Helminthosporium attack. The lesions are large, oval, uniformly coloured chocolate brown and evenly distributed on the leaf. The spots may vary up to 6.0 mm. in size.

Good cultural methods are useful in the control of this disease. Improved drainage, removal of standing water and proper nutrition all help to limit the damage caused. The addition of potash and organic manures like composts and farmyard manure are recommended in Japan.

A mercurial seed disinfectant like Agrosan (dry) or Ceresan (dry) used at the rate of 4 ounces per 112 pounds of seed gives effective control. When using a wet seed dressing like Ceresan (wet) or Tillex liquid, 1 pound of fungicide in 100 gallons of water may be used. This is adequate for 1000 pounds of seed. Seed should be soaked in this solution for 12 hours.

Fifty varieties of paddy were screened for resistance to brown spot disease, and the following rankings were obtained:

Resistant. Sinnanayan 398, Sudu Heenati H.F. 9, Sinnanayan 2208, Sulai 304, and Uvarvellai.

Susceptible. H5, Rathkarayal, M-3, M-104, Siam 29, M-101, M-304, H-501, H-6, H-105, H-4, and Devareddiri. (4).

3. Bakanae or Foot Rot. *Fusarium moniliforme*

The disease is mostly confined to the Kegalle and Kandy districts during the Yala seasons. The disease attacks young seedlings causing seedling blight and later even kills transplants. When a more mature crop is attacked it encourages tall light green growth which makes it easy to spot the diseased plants in the field. Sometimes a pinkish bloom is seen on the nodes.

The most effective method of control is seed disinfection, similar to that used for the control of Helminthosporium.

4. Narrow Leaf Spot. *Cercospora oryzae.* Miyake.

This is not a serious disease. Narrow elongated lesions are formed, light brown in colour and about 3-4 mm. long. These lesions are uniformly distributed on leaves. Leaf sheaths and heads may also be attacked. The disease may be mistaken for blast or brown spot.

5. Leaf Scald. *Rhynchosporium oryzae*

Usually lower leaves are attacked. Large irregular greyish brown patches are found and the leaves appear dirty and brown. The lesions appear near the apex of leaves. The variety M 302 appears to be very susceptible to the disease.

6. Sheath Blight. *Corticium sasakii*

This disease was formerly called Rhizoctonia solani. The disease occurs all over Ceylon and is severe in very wet areas. The plant is weakened and the disease predisposes it to lodging. The damage is enhanced under conditions of high nitrogen nutrition.

The lesions on the leaf sheaths are first greyish green and turn greyish white with a well defined blackish brown margin. This leads to the death of the corresponding leaf. Yields can be greatly depressed if the flag leaf is attacked.

Eighty-seven varieties were screened for resistance and none of these showed resistance to the disease. Greenhouse trials indicated that the most efficient control was obtained with a fungicide containing Tetra methyl dithocarbamic acid methyl arsene at a concentration of 1 gram in 2000 c.c. (52).

7. Stem Rot. *Helminthosporium sigmoideum*

The disease is also called Leptosphaeria salvinii, and is soil borne occurring in all parts of Ceylon. The damage can be severe and it also predisposes the plants to lodging. The base of the diseased culm is blackened and on splitting it open small round blackish bodies may be found (sclerotia) on the inner surface of the culm. The lower leaf sheaths are also attacked and in severe cases the grains are only partly filled. The disease results in excessive tillering and the emergence of adventitious roots from the lower nodes.

Control can be achieved by the application of balanced fertilizers. Excess nitrogen and or phosphate and low potassium heavily predisposes the plants to disease.

Bacterial Diseases

8. Bacterial Leaf Blight. *Pseudomonas oryzae*

The disease attacks older plants causing irregular cream coloured streaks which darken and dry up later. There can be considerable destruction of the photosynthetic area of the leaf. The disease is severe when high levels of nitrogen have been used. Seed treatment and the use of resistant varieties are adopted for the control of this disease in Japan.

Nematode Diseases

9. White tip disease. *Aphelencoides bessyii*

The disease is seed borne and appears to be widespread in Ceylon. The disease can be noticed when the culm begins to elongate. The terminal portions of the leaves become yellowish cream to white or transparent, they are shorter than normal with twisted tips. The ear length is reduced and some grain does not set.

Control with hot water treatment is difficult with large quantities of seed. A most effective control measure is to use 0.1 percent Dipterex solution. Various techniques of treatment have been tried out and the spraying of germinated seed with a 0.1 % solution has given the best results. (30). Trials have also been carried out to select resistant varieties. Thirty-nine varieties were screened and it was found that H 6 had no infection and that Remadja was very slightly infested. M 302 was the poorest of the varieties tested. (4).

Physiological Diseases

10. "Bronzing" or "browning". This physiological disease occurs in poorly drained, strongly acid soils contiguous with laterite highlands in the wet zone of Ceylon. The disease is aggravated by using acidic fertilizers. The chief cause appears to be excess soluble iron.

The foliar symptoms vary depending on the variety grown. Generally the symptom is a deep orange discolouration of the leaf tips and these leaves sometimes die prematurely. In some cases the leaves turn deep blue-green and finally show brown patches. Plants remain stunted and there could be considerable death of roots. Control measures include liming, improvement in drainage and withholding water to the affected fields.

HARVEST

When the grain is mature and the panicles turn yellow the crop is ready for harvest. It often happens that some varieties with a protracted tillering period have a few immature heads at this time. A delay in harvest until these mature may lead to loss of crop through rain damage or lodging. When the crop is ready for harvest the grain has about 18 % moisture and the straw over 50 %. Delayed harvesting till the moisture content in the straw drops may expose the crop to damage by wild life and even increase sun cracking leading to a poor outturn of head rice on milling. The best procedure is to harvest at maturity and sun-dry the crop to reduce moisture in the straw, prior to stacking. The use of chemical desiccants is popular in some parts of the world to reduce moisture content in the harvested crop. Sodium ethyl-xanthogenic acid a non-hormone quick acting contact type herbicide has been used as a grain desiccant in Japan. (16).

Harvesting is generally done with hand labour using sickles. Generally 6-8 units of labour are required to harvest an acre. Mechanized harvesting has not been attempted on a large scale and is unlikely to be of much importance in the near future as the liyaddas are too small for large combine harvesters. Small harvesters have hardly been tried out in Ceylon.

The harvested crop is generally laid out on bunds, if the field is wet, and allowed to dry out for 3-4 days. It is then collected, transported to the threshing floors and stacked. If the stacks get heated up this is an indication that the harvested crop was too wet for stacking. Such stacks should be broken, the crop dried further and restacked.

Threshing and Winnowing

The crop is usually threshed under the feet of bullocks. Tractors are also used for this purpose. The stacks are broken and the sheaves piled up in the middle of the threshing floor, which is generally located on a patch of high ground close to the field. The sheaves are then trampled by bullocks walking over them in a circular fashion or by a tractor working in a similar way. The sheaves are turned over from time to time till the grain is finally shed. In some areas the crop is also threshed under the feet of men. Varieties that are easy to thresh are grown in these areas.

After threshing the paddy is sepai ated out and ready for winnowing which is usually done on the following day. The winnowed paddy, free from pieces of straw and empties should be dry or else it will deteriorate during storage. If not sufficiently dry the crop is spread out in the sun and stirred from time to time till it is adequately dry. Well dried paddy has 12-13 percent moisture. The dried paddy is then bagged for storage. Bag spraying with insecticide is useful to minimize damage done to the paddy by pests of stored grain.

Mechanical threshers and winnowers are in use in Ceylon to a limited extent. The pedal thresher and the small power driven threshers are easy to handle and economical. They are very useful in areas where buffaloes are scarce.

Yields

The yields obtained in the various Districts of Ceylon over a period of about 5 years, have been presented in Table 10. It has been pointed out earlier that these yields are disappointing and various reasons have been advanced to explain these poor results.

The reluctance to use improved methods of culture and the non-availability of agro-chemicals as and when required could very well be the prime causes depressing rice yields in Ceylon.

Numerous instances are known where yields of over 120 bushels per acre have been obtained from fair extents of land. Yields of 60 to 80 bushels are within the reach of most cultivators except those farming in problem areas.

Costs of Cultivation and Returns from Lowland Rice Culture

Due to the large diversity of cultural techniques and the wide variation in yields it is not possible to give a statement of costs and returns for lowland rice culture. Variable wage rates, tractor and buffalo hire charges makes the picture further complicated. It is generally accepted that costs per acre range between Rs. 200.00 to Rs. 250.00. This value is contested by many who claim that total costs exceed Rs. 300.00 if all operations are carried out by hired labour and machinery.

The average yield in Ceylon is 40 bushels and at the guaranteed price of Rs. 12.00 this amounts to Rs. 480.00 per acre. On this basis the actual return from an acre would amount to about Rs. 230.00 to Rs. 280.00 from which marketing costs should be deducted.

The peasant cultivator provides most of the labour utilized on his own fields, but even on this basis he secures only a meagre income as his holding rarely exceeds one acre in the wet zone areas. The position is certainly more favourable in the dry zone colonization schemes where each colonist farms two or three acres and double crops his land.

The guaranteed price of Rs. 12.00 which is twice the value of paddy in the world market is attractive, fertilizer subsidies and credit are available, but yields are still low. This could possibly be the result of a lack of incentive which stems from the low incomes derived from small fragmented holdings.

Ratoon Cropping of Paddy

Ratoon cropping of paddy is not practised in Ceylon. However it is a recognized method of culture in some parts of the United States and fair yields up to 30-40 bushels have been obtained from ratoon crops. There may be some scope for this technique in certain areas in Ceylon.

The procedure adopted is to harvest the crop which in most cases would be the Maha crop, in the usual manner, fertilize the stubble to stimulate tiller production, flood the field and harvest the regenerated growth on maturity.

This cultural technique could have particular usefulness under Ceylon conditions. In some single cropped tank irrigated tracts at the end of the Maha season there is invariably sufficient water in the tank for further irrigation but this quantity is inadequate for the Yala, as evaporation losses between the last irrigation after the Maha and the commencement of the Yala are high and the residual water insufficient for a Yala cultivation. Under these conditions it is possible that this water could be used for raising a ratoon crop of paddy from the stubble of the Maha crop.

Preliminary investigations (10) carried out during the last two years has indicated that there are a number of problems that merit investigation before this technique could be used on a field scale. The following considerations deserve attention. 1. The weed growth that accompanies the Maha crop is mature at the end of the season and is difficult to control by chemical means without damage to the rice stubble. It is even difficult to control it manually if it is dense. Thus to make ratoon cropping possible the Maha crop should preferably be row sown and maintained with good weed control.

2. A comparison between a transplanted crop and one raised from seed has indicated that ratooning is poor in a transplanted crop. Crops to be ratooned should therefore be raised as row sown crops in the Maha season .

3. There is also considerable variation between varieties. A proper evaluation of suitable varieties will also have to be undertaken.

4. The height of cutting a standing crop also needs further study, this may be dependent on variety and fertilizer practice as well.

5. General indications are that the Maha crop should be harvested at the first possible opportunity and not allowed to remain in the field after maturity as the root system tends to die out if the harvest is unduly delayed.

6. The extent of fertilization and the time lapse between cutting and irrigation needs to be determined.

7. Tillering over a long protracted period after the crop is harvested should be avoided, as this makes harvesting of the ratoon crop difficult. Variety and fertilizer practice will determine this character.

8. Pest and disease control must be efficiently handled in the Maha crop, or else the ratoon crop will be worthless.

Much research has to be conducted along these lines before this technique can be used on a field scale, but its potential value cannot be overlooked. It is about the only way in which tracts in the dry zone could be double cropped in seasons when there is inadequate water for a normal Yala crop. It is also essential to point out that efforts to ratoon crop a field should commence with the planting of the Maha crop in which row seeding, proper weed, pest and disease control should be enforced throughout the season. The requirements of the main crop which is to be subsequently ratooned are nothing exceptional. They are merely the same considerations that are urged as improved techniques of cultivation.

Semi-dry Method of Rice Culture

The semi-dry method of rice culture is adopted in areas where water supply is restricted. The system is in use in the Northern and Eastern Provinces.

Method of culture

The land is prepared dry. Ploughing, harrowing and other operations are carried out as for any other highland crop. Ungerminated paddy is sown down either drilled in rows or broadcast and the seed germinates and grows with the rains. As the rains get heavier and more water is available, water is allowed to stand in the field and from this time onwards cultural operations are similar to those carried out in lowland rice culture.

Some features of this semi-dry method of culture

At the moment this method of culture is used where water supplies are restricted. However the virtues of this system and its potential, should be examined in greater detail. With small modifications, this method of semi-dry culture could be adopted on an extended area and it appears most suitable for large tank irrigated dry zone tracts in Ceylon. The following are some of the advantages that could accrue from a system of semi-dry culture.

1. Water conservation. It is estimated that two acre feet of water are required for preparatory tillage in lowland rice culture and one acre foot for each subsequent month of irrigation. On this basis a 4½ month crop of paddy would require about 5½ acre feet of water to bring it to maturity. In the semi-dry method of rice culture, the preliminary dry preparatory tillage would have two acre feet of water and another one acre foot during the first month, as the crop could be grown rainfed during this period. This would amount to a saving of three acre feet and the actual consumption of water would amount to only 2½ acre feet, or less than 50% of the water utilized in lowland rice culture. Looking at this result from another point of view, the extent of paddy cultivable could be increased twofold with the same quantity of irrigation water, if the semi-dry method of rice culture was to be used. Irrigation water is a scarce commodity and on this score alone the semi-dry method of rice culture merits serious consideration.

2. Mechanization. The lack of adequate labour at periods of peak requirement has often led to delayed sowing and low yields

in some instances. This is particularly true in the paddy areas of the dry zone. In these tracts there is a big demand for tractor tillage, but in some areas machines cannot be used as the fields are too swampy for mechanization. Under these conditions dry preparatory tillage would extend the area that could be mechanized.

It is also possible, that the rate of depreciation of machines will be greater under wet land conditions and this will also reduce the life of a tractor considerably. Dry soil preparation in tractor cultivated areas appears most desirable, as this will also help to save the water now used during preparatory tillage.

3. Weed control. The discussion on weed control in lowland rice culture, stressed the fact that a large quantity of irrigation water was used in rice culture, in the hope that it would control weeds. It was also pointed out that such weed control with water alone would be quite inefficient. Under semi-dry culture, weeds could be controlled most effectively. If the crop is row sown it could be inexpensively row weeded at about 18-25 days after sowing, or a broadcast sown crop could be weeded using the weedicide 3, 4-DPA as discussed under weed control in upland rice culture. Thereafter the crop could be flooded immediately and standing water 2-3 inches deep could be applied at once and maintained continuously as the plants will be 5-6 inches tall by this time. This standing water applied to a weed free field will suppress weeds most efficiently. This technique of weed control is as good or superior to any other that could be used in lowland rice culture. It can, however, be adopted only in areas with an assured supply of irrigation water.

4. Plant nutrition. In lowland rice culture all preparatory tillage is carried out under anaerobic conditions and available soil nitrogen is in the form of ammonia nitrogen. At sowing the fields are drained and they are retained in this condition till the young plants grow up and are capable of taking standing water. During this time a part of the soil nitrogen could be converted into nitrate nitrogen, which may be subsequently lost on flooding. Further, any top dressing of nitrogen given at one month after planting will be largely applied to the oxidative surface layer and may be partly lost through denitrification.

In the semi-dry cultural system the nitrogen dressings recommended for application at 4-5 weeks, can be drilled into the soil, placed below the soil surface, and immediately flooded so that the nitrogen will be retained in the reductive zone in ammonia form without loss through denitrification. Effective fertilizer placement is possible by utilizing this technique and full benefits can be obtained from the applied nitrogen. Flooding at this time is also most suitable from the point of view of weed control.

5. Effect on Yields. The results obtained from an experiment laid out to compare the two cultural techniques of wet preparatory tillage and mud-sowing with dry preparatory tillage and dry-sowing (kekulan) in combination with other cultural practices are presented in table 36. (29).

TABLE 36

Paddy yields as influenced by cultural practices
(in lb. per acre)

Method of Sowing	Method of Weeding	
	Japanese weeder	Hand weeder
Dry sowing in rows	2721	—
Mud sowing in rows	2571	—
Dry sowing broadcast	—	2460
Mud sowing broadcast	—	2404

These yield figures would indicate that dry preparatory tillage and dry sowing is as efficient as mud sowing if not superior. The possibility of saving irrigation water without an adverse effect on yields is clearly demonstrated.

The advantages that can accrue from this semi-dry method of rice culture in respect of water conservation, weed control and proper fertilizer use commends this form of culture as deserving of proper evaluation in areas with an assured water supply. The recommended improved methods of culture can be efficiently incorporated in this system. It should not be considered merely as a method of culture for areas with an inadequate supply of irrigation water.

UPLAND RICE CULTURE

Economic Importance

Lowland rice culture necessitates an assured supply of irrigation water. This includes the construction of reservoirs or tanks in most cases, irrigation channels, drainage schemes and numerous other items of capital expenditure such as land levelling. As a result, the capital requirements for opening up land in irrigated paddy is high. Upland rice needs none of these investments.

In view of the pressing need for increased production and the scarcity of foreign exchange for rice purchases, the entire question of the cultivation of upland rice should be reviewed. With intensive research and detailed investigation it might well prove to be one of the most remunerative unirrigated field crops in Ceylon, both for the dry and wet zones.

Areas of production

Unirrigated rice is grown mainly in the Dry Zone chenas. To a large extent it has replaced traditional chena crops like maize. Recently paddy has been tried out as a rainfed crop in the low country wet zone under mature coconut. In Yala 1964, 60 plots were established under coconut in the Colombo district. Some of the plots gave very encouraging results and rice culture under coconut merits further investigation.

Physiology

It is clear that paddy can use both nitrate and ammonia forms of nitrogen. Senewiratne and Mikkelsen (18) investigated the physiological differences between upland and lowland rice and they showed that the plant under lowland conditions, with ammonia as the predominant form of nitrogen and in the presence of adequate iron and phosphorus, accumulated comparatively small quantities of manganese. Under upland conditions with nitrate nitrogen as the main source of nitrogen, plants accumulated high levels of manganese. The accumulated manganese possibly altered catalase and peroxidase activities, which in turn determined indole acetic acid levels in the plant. These findings linked excessive manganese accumulation which occurred under upland culture, with higher rates of auxin destruction, which in turn resulted in poor growth and yields. The selection of a suitable upland variety appears to depend on the isolation of a plant type that either excludes manganese by selective absorption or tolerates high levels of manganese.

Culture of Upland Rice

Season

Planting should commence with the first rains. The crop could be cultivated in the Maha season in the dry zone and in both seasons in the low country wet zone. The Yala season has a better distributed rainfall in the low country wet zone and would be the preferred season.

Varieties

A number of selections have been made for the dry zone—Dikwee 328, Bikom 11, Allagollawe, Godawee, Warner and Bahadus Nigeria 5 are among the best. (32). H4 has performed well in the low country wet zone under coconut.

Preparatory tillage

Soil preparation should aim at the destruction of weeds. Ploughing followed by disking will give the necessary clean seed bed.

Experiments comparing cultivation on the flat and in furrowed land indicated that furrow planting gave 19% increases in yield (30).

Seeds and sowing

Unsprouted seed is dibbled or drilled in rows. The optimum spacing has been found to be 12″ and a suitable seed rate 80 lbs. (32). Broadcast sowing is not advocated as it is difficult to control weeds in such a crop.

Fertilization

Marked responses have been obtained to applications of nitrogen and moderate response to phosphate. An application of 30 lbs. nitrogen (150 lbs. Ammonium sulphate) applied in split doses, at tillering, and flower primordia initiation appears adequate. Results did not indicate any advantage from the use of compost. (32).

Weed control

One of the chief objections raised against the culture of upland rice is the difficulty to control weeds. This is more imaginary than real since weed growth could not be any different in a crop of paddy than it would be in any other erect growing field crop.

Investigations carried out on weed control in upland rice have shown that weed competition in the early stages of growth can depress yields to the extent of 20 per cent if weeding is delayed until the crop is 18 days old. Chemical weed control has been most effective. A pre-emergence spray of pentachlorophenol (PCP) at the rate of 4 pounds active ingredient in 80 gallons of water sprayed over one acre, followed by a spray of 3-4-dichloro propion anilide (3,4 DPA) at 2 pounds active ingredient in 20-40 gallons of water applied post-emergence, when the weeds are in the two leaf stage, have been found to be most effective. However, chemical weedicides are expensive in terms of foreign exchange and row sowing followed by row weeding with an inter-cultivator will effect this saving whilst achieving the object of weed control. Pest and disease control and harvest are the same as that for lowland rice culture.

Yields

Dry zone yields with adequate fertilization and weed control have exceeded 70 bushels per acre. Average chena yields vary between 20-40 bushels. Yields obtained from quarter acre trial plots under mature coconut in the low country wet zone varied up to 40 bushels per acre, steady yields of 30-40 bushels could be expected from such cultivation.

Costs of cultivation and returns from upland rice (53).

	Rs. cts.
Preparatory tillage	29.50
Seed and sowing	31.50
Fertilizer and application	42.00
Weedicide and application	92.50
Pest and disease control	11.00
Harvesting	37.50
Bundling and transporting	39.00
Threshing	37.50
Winnowing, drying and bagging ...	16.50
Supervision and watching	28.50
Incidentals	9.00
	374.00

Labour :	Casual rates —men	Rs. 2.50 per day
	women	Rs. 2.00 per day
	Monthly paid rates: men	Rs. 5.00 per day
Yield — 40 bushels at Rs. 12/-		Rs. 480.00
Profit		Rs. 106.00

REFERENCES

1. International Rice Year Book (1957).

2. Administration Report of the Commissioner of Agrarian Services. 1964.

3. Short Term Implementation Programme. 1962.

4. Administration Report of the Director of Agriculture. 1964.

5. Von Uexhuell. Obstacles to using fertilizers for rice in S. E. Asia. World Crops. Vol. 16. 1964.

6. Ike, Takashi. Year Round Rice Cultivation. A diagnostic Review of Japanese Method—1963.

7. Bansil, P. C. Peasant Agriculture in Ceylon. Journal of the National Agricultural Society of Ceylon. Vol 2. No. 1. 1965.

8. Ghose, R. L. M. *et al. Rice in India.* 1960.

9. Chandraratna, M. F. *Genetics and Breeding of Rice.* 1964.

10. Seneviratne, S. T. Unpublished data.

11. Ramiah, K. Rice in Madras. 1937.

12. Studies on Rice Breeding. A separate volume of the Journal of Breeding. Volume 4. 1954.

13. Herath, W. The Effect of Water Temperature on Rice (*Oryza sativa* L) and its influence on Cold Tolerance and Disease Resistance. Journal of the National Agricultural Society of Ceylon. Vol. 2. No. 1. 1965.

14. Grist, D. H. *Rice.* Longmans Green & Co. London. 1955.

15. Ponnamperuma, F. N. Review of the symposium on the Mineral Nutrition of the Rice Plant. International Rice Research Institute. 1964.

16. Matsubayashi, M. *et al.* *Theory and Practice of Growing Rice.* Fuji Publishing Co. Ltd. 1963.

17. Sakai, K. and Rodrigo, Manel. Studies on a Laboratory Method of testing Salinity Resistance in Rice Varieties. Tropical Agriculturist Vol. CXVI No. 3. 179-184. 1960.

18. Senewiratne, S. T. and Mikkelsen D. Physiological Factors Limiting growth and yield of *Oryva sativa* under unflooded conditions. Plant and Soil. Vol. XIV. No. 2. 127-147. 1961.

19. Administration Report of the Director of Agriculture. 1951.

20. Weeraratne, H. Private communication 1964.

21. Senewiratne, S. T. Ph.D. Thesis. University of California and other related unpublished data 1957.

22. Tullis, E. C. *et al.* Chlorosis of iron induced by iron deficiency. Phytopathology. 26: 111. 1936.

23. Aiyar, S. P. The role of minor elements in rice growing. Indian Farming 7: 11-14. 1946.

24. Mitsui, S. Inorganic Nutrition Fertilization and Soil Amelioration for Lowland Rice. 1954.

25. Briggs, L. J. and Shantz H. L. Relative water requirements of plants. Journal of Agr. Res. 3: 1-63. 1914.

26. Wikramanayake, V. E. A. The Mechanization of Rice Culture in Ceylon. Journal of the National Agricultural Society of Ceylon. Vol. 1. No. 1. 1964.

27. Administration Report of the Director of Agriculture. 1954.

28. Ariyanayagam, D. V. Growth and Developmental Changes caused by pre-sowing treatment of seed paddy. Tropical Agriculturist Vol. CIX. No. 1. 1953.

29. Administration Report of the Director of Agriculture. 1956.

30. Administration Report of the Director of Agriculture. 1963.

31. Thambiyah, S. Mechanical devices for row seeding swamp rice. Tropical Agriculturist Vol. CXV. No. 2. 1959.

32. Administration Report of the Director of Agriculture 1962.

33. Administration Report of the Director of Agriculture. 1953.

34. Senewiratne, S. T. The effect of plant spacing and cultural method on the Yield of Rice. Paper presented at the Ceylon Association for the Advancement of Science. 1959.

35. Rhind, D. Notes on the Improvement of the Yields of Paddy in Ceylon. 1950.

36. Rice—Transplanters. Tropical Agriculturist Vol. CXVI. No. 3. 1960.

37. Senewiratne, S. T. Nitrogen uptake by the rice plant and a comparison of cultural practices with regard to their efficiency in meeting the nitrogen needs of the crop. Paper presented at the Ceylon Association for the Advancement of Science. 1958.

38. Ota, Y., Devasundarajah, N., and Emerson, B. N. A comparison of the effects of continuous and intermittent irrigation and a study of optimum plant density. Report of the Experimental Results on Rice Agronomy and Physiology. 1964.

39. Ghosh, B. N. Studies on the physiology of rice. VII. Effect of varying water levels on growth of rice in relation to nitrogen absorption. Proc. of the Nat. Inst. of Science of India. 20 (4): 371-387. 1954.

40. Manickavasagar, P. Rice Protection—Weed Control. 1963.

41. De, P. K. Indian Jn. of Agricultural Science. 6. 1237-1245. 1936.

42. Watnabe, A. Miscellaneous Reports of the Research Institute for Natural Resources No. 17, 18. 1950.

43. De, P. K. and Pain, A. K. A biochemical study of the paddy soils of Bengal with special reference to their nitrogen fixing capacities. Indian Journal of Agl. Science. 6. 746-755. 1936.

44. A guide to Fertilizer Use in the Cultivation of Wetland Rice. Department of Agriculture. 1965.

45. Ponnamperuma, F. N. Fertilizer experiments in cultivators fields in Ceylon Tropical Agriculturist Vol. CXI. No. 4. 253-266. 1960.

46. Administration Report of the Director of Agriculture 1955.

47. Senewiratne, S. T. Phosphorus nutrition of the Rice plant. Paper presented at the Ceylon Association for the Advancement of Science. 1959.

48. Fernando, H. E., Weerawardena, G. V., and Manickavasagar, P. Paddy Pest control in Ceylon. Tropical Agriculturist Vol. CX. No. 3. 159-174. 1954.

49. Manickavasagar, P. Rice Protection (Pests) 1963.

50. Administration Report of the Director of Agriculture. 1960.

51. Diseases of paddy and their control. Division of Plant Pathology. Department of Agriculture, Peradeniya.

52. Administration Report of the Director of Agriculture. 1958.

53. Costs from Dry Zone Research Station. Maha Illupalama.

3. MAIZE

Economic importance

Maize is one of the more important cereal crops of the dry zone chenas. It ranks second in importance to kurakkan in these areas. A small quantity is consumed as food. The bulk of the maize produced in Ceylon, however, has been traditionally utilized as poultry feed. Even so, the expansion in maize cultivation has not kept pace with the rapid development of the poultry industry, and the increasing demand for maize as poultry feed. Chena paddy has increasingly replaced maize in these areas, because it has proved to be more paying. Consequently imports of maize have steadily increased and in 1962 the imports amounted to 3000 tons costing over Rs. 1 million in foreign exchange.

Maize is one of the crops brought under the guaranteed price scheme as an incentive to local production. The guaranteed price which was Rs. 14.50 per cwt. for Grade I and Rs. 10.50 per cwt. for Grade II maize in 1958, has been increased over the years, and was Rs. 17.00 per cwt. for both grades in 1963 (1). Present rates are Rs. 19.00 per cwt. In spite of these incentives production has been meagre, and the crop has continued to remain essentially a chena crop, without any organized large scale cutivation, except on a few Government farms.

Average yields of locally produced maize, have been deplorably low, and the incidence of bird damage relatively high. These factors are reflected in the low quantities offered for sale under the guaranteed price scheme. (Table 1).

TABLE I

Purchase of Maize under the guaranteed price scheme (in cwt.) (**2**)

Province*	1960	1961	1962	1953
Western	428	—		
Eastern	661	32		
North Western	16	18		
North Central	6,821	—		
Uva	4,677	2,064		
	12,603	2,114	2,635	1,858

*Includes outstation produce for which payments had been made at the Head Office.

In World production, Maize ranks with wheat, rice and oats. It is the premier crop of the United States, occupying a fourth of the entire cultivable area. Other main producers of maize are Argentina, China, Brazil, U.S.S.R., Yugoslavia, and the Union of South Africa.

BOTANICAL CHARACTERS

Maize is the most completely domesticated of all field crops, and is not known to exist in the wild state. Distinguished botanically as *Zea mays*, it belongs to the family Gramineae, and the Tribe Maydeae, which is characterized by the presence of separate staminate and pistillate inflorescences.

Vegetative characters

The culm or stalk of the maize plant ranges in length from 2' to 10' depending on the area, and the cultural conditions under which it is grown. The diameter of these stalks varies from ½ to 2 inches. The internodes are straight and nearly cylindrical in the upper part of the plant, and alternately grooved in the lower part. A bud is present at the base of each node, save the terminal one. The leaves of maize are similar to those of sugar cane. At intervals along the upper epidermal layer, the leaves contain groups of large bulliform cells, that regulate transpiratory loss of moisture from the plants. The maize plant has 3 types of roots. These are the seminal roots, crown roots, and brace or buttress roots. The seminal roots numbering 3 to 5 grow downward at the time of germination. The crown roots arise 1-2 inches below the soil surface at the nodes of the stem, after the plumule has emerged. Brace roots arise from the nodes above the ground, and function similarly to crown roots once they enter the ground. In good soils 75% of the maize roots remain within the first foot of soil, and 25% go deeper. In poor soils only 5% of the roots reach into the lower layers.

Reproductive characters

The maize plant is monoecious. Staminate and pistillate flowers occur in separate inflorescences on the same plant. The staminate or male inflorescence is borne in the tassel at the top of the stalk. The pistillate or female inflorescence is located in the axils of lower leaves. The mature pistillate inflorescence is called the ear.

The main vegetative stem continues as the staminate panicle. The panicle is branched, the branches being spirally arranged around the axis. Each spikelet consists of two florets; the upper one being generally more advanced in development. The spikelets are arranged in pairs on the panicle, one sessile and the other pediceled.

The ear is a spike with a thickened axis. The pistillate spikelets are borne in pairs in several longitudinal rows (3). This is the reason why the maize ear, has generally an even number of rows of grains. Each spikelet has two flowers, only one of these being generally fertile. The single ovary in each fertile floret, bears a long style, about 4-12 inches long and usually called the silk, which is forked at the tip. The silk is receptive to pollen all along its length, and the receptivity of the stigma lasts for about two weeks.

Maize is normally cross pollinated, being suitably adapted for wind pollination. The normal ear of maize contains from 8-28 rows of grains, each regular row having between 20-70 grains. American varieties may have 14, 16 and even 18 rows in each ear. The average ear weighs between 6-7 oz., and may contain about 400 grains. To obtain a bushel of shelled maize, about 70 pounds of ears, is required assuming a shelling percentage of between 80-85%.

Groups or Types of Maize

Maize may be broadly grouped into seven types or groups, on the basis of the endosperm and glume characteristics. There is also the view that these groups should be considered as sub-species. The groups are as follows:

1. **Dent** (*Zea mays indentata*). This is the popular type of maize. On drying the soft endosperm of the grain shrinks, and forms a dent, which is clearly visible.

2. **Flint** (*Zea mays indurata*). In this type, the endosperm is soft and starchy in the centre, but is completely enclosed by a corneous outer layer. All local varieties belong to this group.

3. **Flour** (*Zea mays amylacea*). This type is not generally grown. There is no commercial production of this type in the United States, but American Indians are said to still grow this type.

4. **Pop** (*Zea mays everta*). This type is similar to the Flin type, and is extremely popular. The endosperm of this type has 2-4% more moisture than the other types. The starch particles are small and compact. When heated to steam point the seed blows inside out and gives what is popularly known as pop corn.

5. **Sweet** (*Zea mays saccharata*). The endosperm in this type contains sugar as well as starch, as such before it is fully ripe it has a sweet taste. This type is believed to have arisen as a mutant from the dent type. It is used primarily for human consumption. It is often canned on account of its sweetness. It is also used in the making of silage:

6. **Pod** (*Zea mays tunicata*). In this type each grain has its own husk. The grains are small with large fibres. Not commercially grown.

7. **Waxy** (*Zea mays ceratina*). This type has a uniformly soft endosperm. The endosperm breaks with a wax like fracture. The starch which resembles tapioca starch is used in the making of adhesives.

Varieties

All the maize grown locally are open-pollinated varieties. In chenas which are spaced far apart, and where only one particular variety is grown, the variety is highly inbred. On the other hand, where adjacent chenas grow different varieties, the variety may be highly mixed. Varietal names in maize, in any case, mean less than those of almost any other crop. Selection and local adaptation produces numerous strains and types within varieties. Sometimes, differences among strains within varieties may be greater than the differences between the varieties themselves.

Crop Improvement

With a view to breeding varieties for maximum yield and for resistance to environmental hazards in the dry zone, a planned programme of introduction and evaluation of local and foreign varieties was begun in Maha Illupalama in the Maha of 1955/56 (4). In addition to nearly 50 varieties collected from the villages in the North Central province, a large number of introductions were made from the U. S. A., Australia and over 16 tropical countries in South America, Africa and South East Asia. Some of the varieties that have performed well in yield trials, and outyielded the standard variety yellow maize are as follows:

ZM—T 34
ZM—T 53
ZM—T 48 } Top crosses evolved at Katugastota.
ZM—T 99
ZM—T105

Cuban Yellow, A 103, OP 1, Improved yellow dent,
College Yellow, Hawaiian Yellow and Creole Yellow Flint.

In subsequent yield trials T 48, proved to be the best of the varieties tested, and gave a yield of 3,600 pounds per acre, 20% higher than the control variety College Yellow. T 48 was being multiplied for distribution. (5).

Production of Hybrid seed for commercial planting

Hybrid seed of maize, has several advantages when used for raising a commercial crop, chief amongst which is the capacity to produce higher yields than open-pollinated varieties. In the

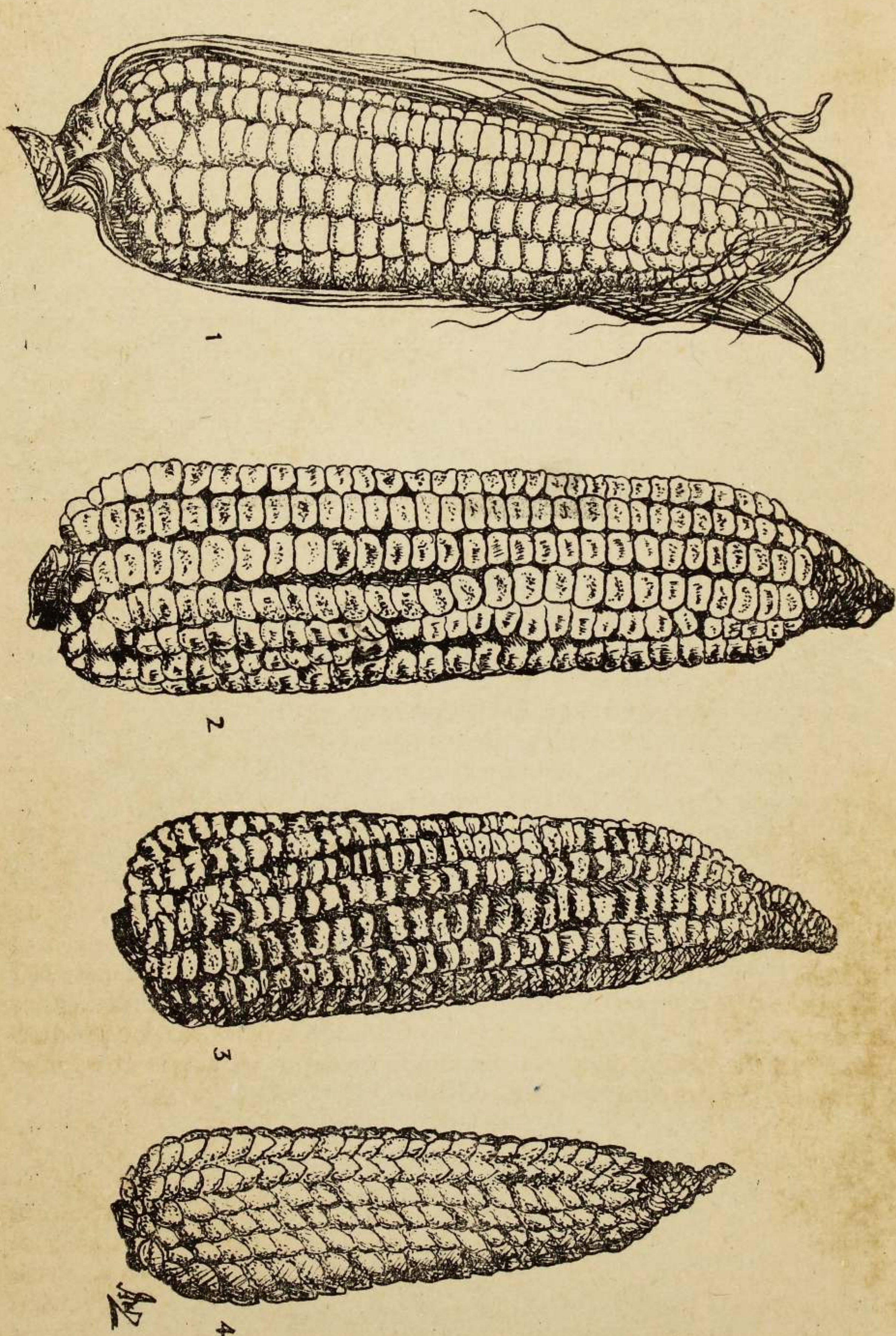


Figure 5. Types of Maize
1. Flint 2. Dent 3. Sweet 4. Pop

United States, the better commercial hybrids are reported to have given yield increases ranging from 15 to 35%. Many hybrids combine other desirable characters like stalk strength, and lodging resistance. Even so, first generation hybrid seed for growing the hybrid has to be obtained each year. Yields get progressively reduced when seed of hybrid crops, are used in following crop cultivations. Yield of the second generation of double crosses drops to 84% of that of the first generation. (6). Also maize hybrids, are rather specific about their soil and climatic requirements, and perform best only in their own localities. (7).

The production of double cross hybrids involves 1. Selfing and selection of lines that breed true for certain characters. 2. Selection of the best involved lines with best combining ability. 3. Making suitable single and double crosses to produce these hybrids.

The procedure adopted in the production of these hybrids is as follows. Firstly plants are selected among the varieties for selfing. By suitably bagging the tassel, the pollen that is shed is collected into these bags. The pollen is then transferred on to the silks of the shoots in the same plant. Prior to selfing the ear shoots themselves are bagged separately after trimming the silks to a uniform length. The seed from the better selfed ears is then planted in progeny rows. Selection and selfing is continued, for about 5 to 7 years till the inbred lines breed relatively true.

Sometimes, inbred lines produced after 2 to 3 years of selfing are grown in special blocks for crossing, and known varieties or hybrids are grown in every alternate, third, or fourth row as the pollen parent. Tassels are removed from the inbred lines, and all are pollinated by the same parent variety. This process of top crossing, enables the determination of inbred lines that have the best combining ability. The better of these lines can be retained and inbred till they become uniform. Some examples of top crosses evolved at Katugastota are ZM—T 48, ZM—T 99, ZM—T 105 and ZM—T 53. Lines with high combining ability can then be used to make single crosses, and tested for yield, grain quality and other characteristics. The performance of double crosses can be predicted from the performance of the single crosses. A single cross may be made by crossing two inbred lines.

e.g.: A×B single cross.

Single cross seed are not generally used for commercial production as yield is low. A three way cross involves a single cross and an inbred line e.g. (A×B) ×C., the doube cross involves a cross between two single crosses e.g. (A×B) × (C×D). Fields used for the production of double cross seed should be isolated. Inbred lines or single crosses are grown in alternate rows, or groups of rows. Seed parents are detasseled, while ears of male parents are not harvested for seed. One male parent row could be used for 3 or 4 female parent rows, depending on the capacity of the male parents to produce sufficient pollen.

ECOLOGICAL ADAPTATION

On account of the wide diversity in vegetative types, maize is adapted to a wide range of environmental conditions. Open pollinated varieties grown in particular localities for many years show remarkable adaptation to those localities. When grown in areas where there is a shortage of moisture, the maize plant adapts itself by reducing its vegetative growth, and thereby reducing its requirements for moisture (8). Maize is cultivated from 58°N latitude to 40°S latitude. It is best suited to areas with a rainfall of between 25-40 inches. Most of the best areas under maize in the United States, known as the corn belt, falls within such a rainfall regime. In Ceylon it is grown in the dry zone in the Maha season.

Maize is most suited to fertile, well drained loamy soils. Soils with a pH of between 5.5 and 8.0 are satisfactory. An abundance of readily available plant nutrients are required for optimum growth. (9).

Areas for Cultivation

A $3\frac{1}{2}$ month crop of maize can be cultivated successfully in most areas of the dry zone. Traditionally maize has been cultivated as a chena crop in these areas, and in small holdings in the wetter highland districts. Although its relatively high requirements for moisture, make it a suitable crop for the low country wet zone, the greatest scope for its extension lies mainly in the unirrigable highlands of the dry zone as a Maha crop.

Crop Physiology

The maize plant goes through the following stages of growth in its life cycle, and during each stage, its requirements for nutrients and moisture are specific.

Stage 1. Planting to knee-high
2. Stage of rapid elongation
3. Pollination and fertilization
4. Stage of the roasting ear
5. Physiological maturity.

Stage 1. Planting to knee-high

Time of planting is important in relation to soil moisture. Delayed germination results in weak seedlings. During this stage vegetative growth is initially slow, and the plant reaches knee-high in about 28 days from planting. Cell division then becomes rapid and this is also the period when the plant changes from the vegetative to the reproductive phase. As such the first critical period in its life cycle is around this time. Moisture and fertility requirements are critical, and determine the ultimate yield potential.

Stage 2. Stage of rapid elongation

The period of elongation follows the knee-high stage, and lasts for 3 weeks approximately. During this period dry matter accumulation in the maize plant proceeds essentially as a linear function of time. Nutrient uptake and requirements for moisture are also high.

Stage 3. Pollination and fertilization

This stage lasts for a period of 10-14 days. Yield can be affected in a short time by adverse conditions. The susceptibility to adverse conditions is also greatest during this period. High temperature causes pollen sterility and retards fertilization. Water consumption and nutrient uptake is at a peak during this period. About one half the seasonal intake of water is utilized during the 5 weeks following the attainment of maximum leaf area which is about the tasseling stage.

Stage 4. Stage of roasting ear

During this period the translocation of photosynthates to grain takes place. The stage of roasting ear is reached about 20 days after tasseling, about 90 days from planting. Higher temperatures are not detrimental at this stage, but the requirements for moisture and fertility remain critical.

Stage 5. Stage of physiological maturity

The grains reach physiological maturity at this stage, and all that is required is hot dry weather.

The maize plant continues to gain dry matter till it is mature. It produces more dry matter per acre, requires more moisture and fertility than most crops, and this requirement is critical at certain stages of its growth cycle. Hanway (10) has worked out the approximate average days from emergence for the different stages of growth of maize, which may be adapted to include the main stages described above.

	Stage	**Days**	**Identifying characters**
Planting	0	0	Plant emergence. Tip of coleoptile of plant visible at soil surface.
	1	14	Collar of 4th leaf visible.

Knee-high	2	28	Collar of 8th leaf visible. Leaves 1 to 2 may be dead.
	3	42	Collar of 12th leaf visible. Leaves 3 to 4 may be dead.
Tasseling and Silking	4	56	Collar of 16th leaf visible. Tips of many tassels visible. Leaves 5 to 6 may be dead.
	5	66	In 75% plants, silks visible. Pollen shedding.
	6	78	12 days after 75% silked. Kernels in blister stage.
Roasting ear	7	90	24 days after 75% silked. Very late roasting ear.
Early dent	8	102	36 days after 75% silked. Early dent stage.
	9	114	48 days after 75% silked. Full dent stage.
Maturity (physiological maturity)	10	126	60 days after 75% silked. Grain physiologically mature.

Planting season

In the unirrigable highlands of the dry zone, where maize is grown under rainfed conditions, planting should commence with the first Maha rains in October. Time of planting trials conducted at Rahangala commencing 17th October 1961, with fortnightly plantings till March 6th 1962, showed that planting on 17th October was superior to all other plantings. (5). In the wet zone areas where Yala cultivation is undertaken, planting should commence in April or early May.

CULTURE OF THE CROP

Seed bed preparation

In the dry zone where inversion tillage is not advocated, repeated working of the soil with a disc harrow would be required in order to ensure a seed bed, free of clods. The disc harrow, may be followed by the spring tooth harrow to remove any debris, as well as to level the land. The first four inches of the soil must be worked down to a fine tilth, and pulverized, to provide a soil free from large air spaces in which to plant the seed.

Seeds and sowing

The seeds are usually planted in rows, being either dibbled by hand after marking with a marker, or drilled using seed drills. When seed drills are used, it may be possible to attach a fertilizer cum seed drill attachment to the tractor, so that planting and initial fertilizing may be combined into one operation. The seed is buried to a depth of about 2 inches. The seed rate amounts to 15 pounds per acre.

Spacing

Plant populations per acre, and the optimum spacing for maize has been the subject of much study. With four Commercial hybrids and eight experimental hybrids of sweet corn varieties of maize planted to populations of 8,000, 12,000, 16,000 and 20,000 plants per acre, the 8,000 population gave significantly higher yields under conditions of reduced moisture. (Table 2). With more moisture, the 12,000 population could have been expected to perform better (11). At a trial set down at Bibile, with the variety Trinidad, maximum yields were obtained with a spacing of 2′×2′ (i.e approximately 11,000 plants per acre). (4). Spacing however, is determined by intercultivation practices, and the suitability for working with intercultivation implements, the fertility of the soil, and other factors. A recommended spacing when the seed is drilled in rows is 3 feet between rows and 6-9 inches within the row. With dibbled seed, a recommended spacing is 2×1 feet with one seed per hill or 2½×3 feet with 2 seeds per hill. (12).

TABLE 2

The yield of marketable ears in pounds per acre for populations and hybrids (Appadurai 1955)

Hybrid	*Plants per acre* 8,000	12,000	16,000	20,000	Mean
1. Prosperity	1980	1578	1241	1013	1453.0
2. Calumet	2427	2372	1513	1709	2005.2
3. Sweetengold ..	2689	3169	1634	1784	2319.0
4. Ioana	1709	2058	1111	1307	1546.2
5. 56101	2091	1490	1219	1359	1539.7
6. 56102	1588	1143	1065	784	1145.0
7. 56103	2143	1447	1578	947	1528.7
8. 56104	1228	836	523	379	741.5
9. 56105	1905	990	1163	711	1192 2
10. 56106	1535	1578	968	598	1169.7
11. 56107	836	359	238	229	415.5
12. 56108	1807	1718	719	686	1232.5
Mean	1828.1	1561.5	1081.0	958.8	

Nutrition

Experimental evidence shows that the uptake of the major nutrients is directly related to the stages of growth of the maize plant. (13. 14). The highest uptake of nitrogen takes place

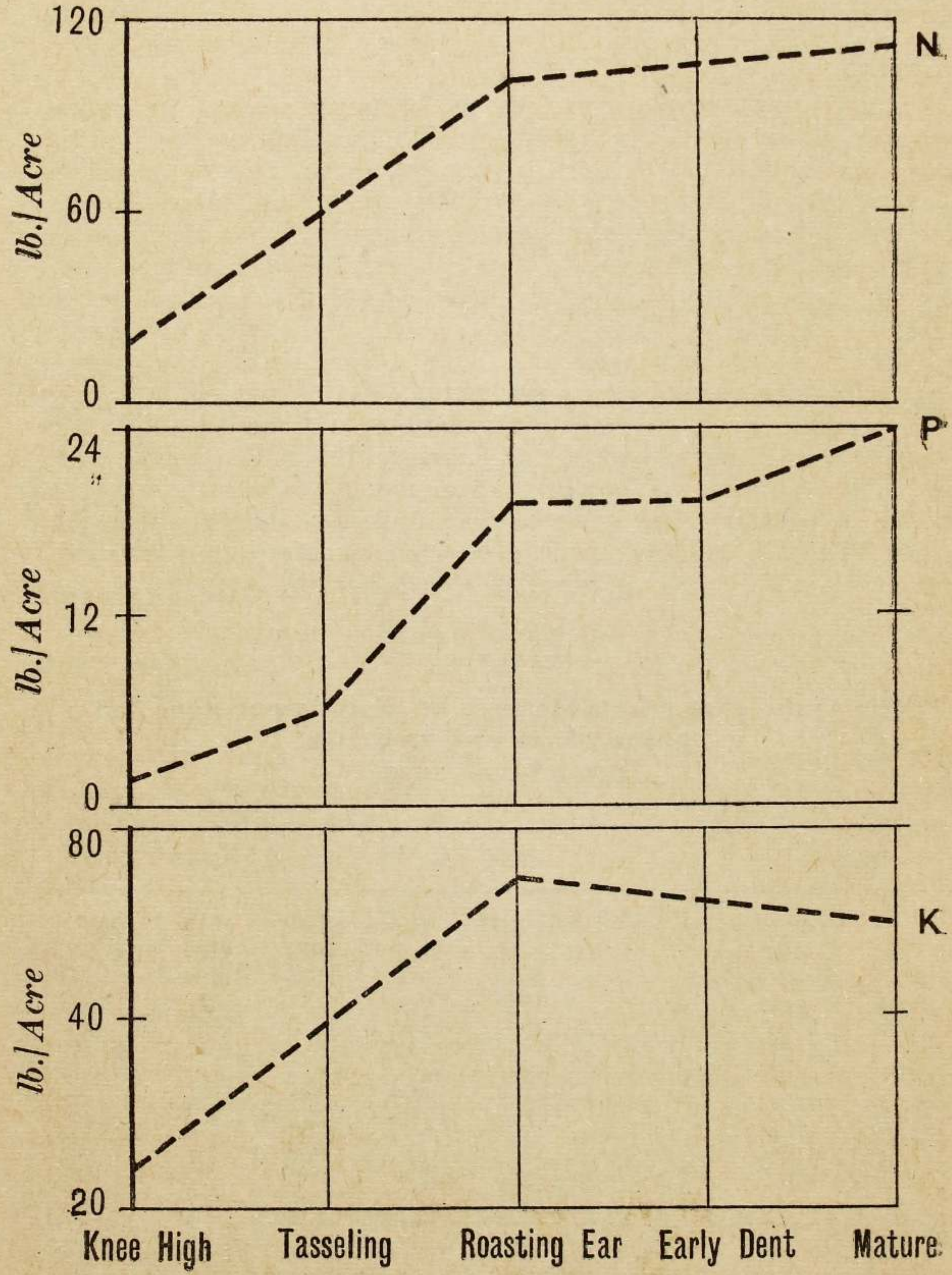


Figure 6. Nutrient uptake in Maize in relation to stage of growth.

between the knee-high stage and tasseling. Phosphorus uptake is high during two stages of growth, namely, between tasseling and roasting ear, and again between early dent stage and physiological maturity. Phosphorus has to be applied early. It is generally given as a basal dressing. The uptake of potassium increases from the knee-high stage, to that of roasting ear. (Fig. 6). It is estimated that a maize crop, producing 70 bushels per acre requires about 90 pounds of nitrogen, 35 pounds of phosphorus and 70 pounds of potassium.

Trials conducted at Maha Illupalama show that direct effects of the application of superphosphate is small, even when phosphate is applied at the high level of 126 pounds P_2O_5 per acre. Residual effects were however marked. Further, muriate of potash at the rate of 20, 40 and 80 pounds of K_2O to the acre, did not increase grain yield either when applied as a single application at planting or given as a split application, ½ at the time of planting and ½, 5 weeks later. (5). This experiment was carried out once in the Maha of 1961/62 and the results are not conclusive.

The recommended fertilizer rates for the different climatic zones are as follows: (12)

Dry Zone 1-1½ cwt. of ammonium sulphate
½-¾ cwt. of concentrated superphosphate

Wet Zone 1½-2 cwt. of ammonium sulphate
¾-1 cwt. of saphosphosphate or hyperphosphate

Ceylon soils are generally rich in potash except in the sandy areas. For sandy areas therefore an additional ¼ cwt. of muriate of potash is recommended.

Weed control

Intercultivation for the purposes of weed control may be initiated 2 weeks after sowing, when the plants are about 6-9 inches high. This may be followed by two further intercultivations, one 4 weeks after sowing and the other 6 weeks after sowing. In recent years, increasing use has been made of chemicals for the purpose of controlling weeds in a maize crop. Trials have repeatedly demonstrated the efficacy of a pre-emergence application of 1½ pounds active ingredient of simazine in 50 gallons of water for the effective control of all annual weeds during the growing season. (5). The approximate cost at the present time for simazine is Rs. 14/50 per pound.

CONTROL OF PESTS AND DISEASES

Pests

1. Stem borer. Attack by stem borer, results in the death of the top stock. Routine spraying with endrin at the rate of 1 fluid ounce in 2 gallons of water gives effective control.

2. Aphids and thrips cause a certain amount of leaf damage. Endrin spraying is effective in most cases.

3. Corn ear worm (*Heliothis obsoleta*)

This is the larva of a greyish brown moth. It attacks the tip end of the cobs, causing considerable damage to the grains. The larva can also destroy the leafy tissues near the cobs. Field sanitation, whereby the stubble is regularly ploughed in controls the infestation, by destroying the pupae that nest in the stubble and the soil. A more effective method of control is to grow resistant varieties. Resistant varieties have tight husks which completely cover the cobs.

Husk protection is particularly important from the point of view of ear worm resistance. The rapidity with which ear worms penetrate the ears depends primarily on the length and tightness of the husk. Lack of moisture causes unusually short husks, and when the drought is continuous, the husks are usually affected more than the cobs, which grow over a longer period and are therefore more likely to receive the moisture they need to complete their normal development. Appadurai (11) working with hybrid varieties of sweet maize, observed a high correlation between husk protection and ear worm resistance. (Table 3).

TABLE 3

Husk protection and ear worm resistance, graded from 1-5, 1 representing the most favourable grade, and 5 the poorest. Mean of four populations. (Appadurai 1955)

Commercial hybrid	Husk protection	Ear worm resistance
Prosperity	3.16	3.08
Calumet	2.41	2.41
Sweetengold	3.24	3.49
Ioana	3.57	4.08

Diseases

1. Corn smut (*Ustilago maydis*)

This disease is found on the grains, which are rendered useless by the presence of black spores. Rotation of crops is recommended as a measure of control.

2. Leaf blight (*Helminthosporium turcicum*)

This is a leaf spotting disease, which appears first as small spots which later coalesce to form large necrotic areas. Control measures adopted are the elimination of all infected crop residues and the adoption of a rotation. Seeds can be treated with manganese ethylene bisdithio carbamate, prior to sowing, as a measure of control.

Harvesting

Harvesting is done by snapping the ear from the standing stalk. The harvested ears are husked only after drying, about the time the ears are shelled. At other times, the cobs are husked and dried, before shelling. In the United States, mechanical corn pickers are used on a large scale to harvest maize. Combination huskers and shellers are also used to some extent.

When picked from the field the grain may contain about 30% moisture. The grain should be shelled when the moisture is 25% or less, but for storage the grain must be dried down to about 13 to 14% moisture, which can be achieved by sun drying. Shelling % of the local flint varieties averages between 50-60% which is very low compared to the shelling percentages of the American dents, which average between 70-80%. (12). Shelling is done either by the use of a corn sheller or by beating the dried ears, after packing them in a sack. The relation between the moisture content of the grain and the amount of ear corn required to produce a bushel of shelled maize of 15% moisture is shown in Table 4.

TABLE 4

Moisture content of grain and shelling percentage

Moisture in grain %	Ears for 1 bushel of shelled Maize at 15% moisture
15	70
20	75
25	80

Yields

Average yields under Ceylon conditions have been extremely poor amounting to between 15-20 bushels per acre (bushel weight—56 pounds). Compared to these, American varieties yield between 50-60 bushels to the acre. The improved varieties, however, have given promising yields. In yield trials at Maha Illupalama in 1961/62, T 48 gave a yield of 64 bushels per acre. (5). Thus with the use of more improved varieties, and the adoption of better cultural conditions, maize cultivation promises to augur well for the future.

Costs of cultivation and returns. (15)

	Rs. cts.
1st tillage	22.00
2nd tillage	22.00
Basal fertilizer: 1 cwt. superphosphate	
½ cwt. muriate of potash: 2 men ...	25.00
Cost of Seed and planting: 5 women	13.00
Cost of 4 pounds simazine at Rs. 14/50	58.00
Cost of spraying: 2 men	4.50
Cost of 2 cwt. sulphate of ammonia and 2 applications	
8 women	42.00
Bird scaring: 1 woman: 1 month	60.00
Pest control	20.00
Harvest: 4 women	8.00
Threshing winnowing etc. 6 women	12.00
	286.50

G. P. S. rate Rs. 19/- per cwt.

Approximate yield —	20 cwt. (40 bushels)
Value of Crop ...	Rs. 380.00
Expenditure —	Rs. 286.50
Profit	Rs. 93.50

REFERENCES

1. Administration Report of the Commissioner of Agrarian Services. 1964.

2. Statistical Abstract of Ceylon.

3. Mangelsdorf, P. C. The origin and nature of the ear of maize. Bot. museum leaflets. Harvard Univ. 12 (2) 33-75. 1945.

4. Sithamparanathan, J. Improvement of highland crops in the dry zone. Part I Cereals and Millets. Tropical Agriculturist Vol. CXIV No. 1. p. 19-28. 1958.

5. Administration Report of the Director of Agriculture. 1961-62.

6. Richey, F. D., Stringfield, G. H., and Sprague, G. F. The loss in yield that may be expected from planting second generation double crossed seed corn. Jour. Amer. Soc. Agron. 26. 196-99. 1934.

7. Jenkins, M. T. Corn improvement U.S. Dept. Agric. Yr. Bk. p. 455-522. 1936.

8. Kiesselbach, T.A. and Kein, F.D. Regional adaptation of corn in Nebraska Nebr. Agr. Exp. St. Res. Bul. 19. 1921.

9. Morgan, M.F., Gourley, J.H. and Ableiter, J.K. The soil requirements of economic plants. Soils and Men. U. S. Dept. Agr. Yr. Bk. p. 753-776. 1938.

10. Hanway, J. J. Growth stages of corn. Agron. J. Vol. 55. No. 5. 1963.

11. Appadurai, R. R. The effect of population on the performance of sweet corn hybrids. M.Sc. Thesis 1955. Texas A & M Univ.

12. Schokman, D. E. The breeding and cultivation of maize. Tropical Agriculturist Vol. CIX. No. 2. p. 103-110. 1953.

13. Research Report No. 248. College Station, Mississippi.

14. Krantz, B. A. and Chandler, W. V. Fertilize corn for higher yields. North Carolina Agric. Expt. Sta. Bull. 366. 1954.

15. Costs from Dry Zone Research Station, Maha Illupalama.

4. SORGHUM

Economic importance

Sorghum was introduced into Ceylon around 1930 and used as a food grain, and as a forage crop. As a world food grain, sorghum ranks third being exceeded only by wheat and rice. It is cultivated extensively as a food crop in China, India and North and South Africa. In Sudan and some countries of the African continent it constitutes the staple grain. In Australia, America and Southern Europe, the grain is used mainly for stock feeding.

As a food grain, sorghum is more digestible than maize, and ground into flour it can be used like rice flour. The mineral content of the grain as well as its calorific value is higher than the other cereals. (1). (Table 1)

TABLE 1

Analysis of Ceylon grown cereals (Joachim and Pandittesekera 1938)

	Moisture	Protein	Carbohydrate	Ether Extract	Fibre	Mineral	Calorific Value
Country Rice	13.24	7.44	77.28	0.73	0.33	0.98	345.5
Kurakkan	12.36	7.61	74.76	1.35	1.57	2.35	341.6
Maize	12.81	7.20	73.76	3.99	1.20	1.04	359.8
Sorghum	9.38	7.57	74.93	3.92	1.31	2.89	365.2

It can be used as a substitute cereal for rice and certain varieties produce small sized grains which can be cooked like rice. Sorghum can form an important component in the cereal ration for poultry.

A guaranteed price of Rs. 15/- per cwt. is offered for grain sorghum. Even so, there has been no striking expansion in the cultivation of grain sorghum. The heavy incidence of bird damage in this crop, has materially impeded the popularization and expansion of sorghum. In 1960 and 1961, a total of only 1,324 cwt. and 1,415 cwt. respectively were purchased under the guaranteed price scheme. (2).

Forage sorghums are used for making silage and hay, as well as for green fodder. Yields of green forage have averaged 15 tons per acre without fertilizers at Maha Illupalama. (3). These yields compare favourably with the yields of the best pasture grasses, and emphasize the value of these types in livestock feeding.

Botanical Characters

Sorghum, belongs to the family Gramineae and the tribe Andropogoneae. It is distinguished botanically as *Sorghum vulgare.* The plant is characterized by the presence of culms which may be from 2 to 15 feet in height. The sorghum plant can be distinguished from the maize plant, by the presence of saw teeth on the margins of the leaves.

The inflorescence is a panicle. The earheads may be compacted and dense, or loose and open. (Fig. 7). The stalk of the earhead may be erect or goosenecked. A well developed panicle in certain varieties may contain as many as 2,000 seeds, or 2 ounces of seed. Average panicles contain about 1½ ounces. Sorghums are about 95% self pollinated, but cross pollination can occur freely with other varieties of sorghum. Coloured sorghum seeds derive their colours from pigments present either in the pericarp or the testa, or in both.

Varieties

Sorghums may be broadly grouped into two main types. 1. Grain sorghum and 2. Fodder sorghum. (Sweet sorghum). This distinction is broad based, and is not absolute. The two types inter-cross freely. Grain types may have succulent sweet stems, and fodder types occasionally can give high grain yields. Hence the distinction is rather vague.

Grain sorghums may be of two types, dwarf and tall. Some types produce white or creamy grain which is used in human consumption, other types produce seed varying in colour from light to dark brown, and are used mainly for stock feeding. Fodder sorghums are very tall, from 6-12 feet, have juicy sweet stalks, and leaves, and a high sugar content in the sap. Seeds are coloured mahogany red to light brown, and are generally bitter and unpalatable. Varieties belonging to the three types are:

Dwarf grain types: (livestock feed)
e.g. Plainaman, Kaprock, Kalo, Martin

Tall grain types: (Human food)
e.g. Sanpyaung, Egyptian corn, Tambagalla, Hegari.

Fodder types:
e.g. Sweet sugar drip, Sweet Honey, Sweet Italian, Kavirondo.

Trials conducted at Maha Illupalama indicate that fodder sorghums for ensilage can be successfully grown in the Yala. Also, the variety Combine Shallu introduced from the U.S.A. in 1959, and which has a flowering duration of 45-50 days, enables it to be cultivated as a rainfed crop in the Yala. (4).

Milling out turn

The milling out turn of these varieties and quality of flour are as follows: (5).

Variety		Milling out turn %	Quality of flour
Egyptian corn	..	89	Attractive
Sandyaung	..	87	Attractive and good
Tambagalla	..	78	Rather gritty and astringent
Hegari	..	80	Greyish in colour and astringent

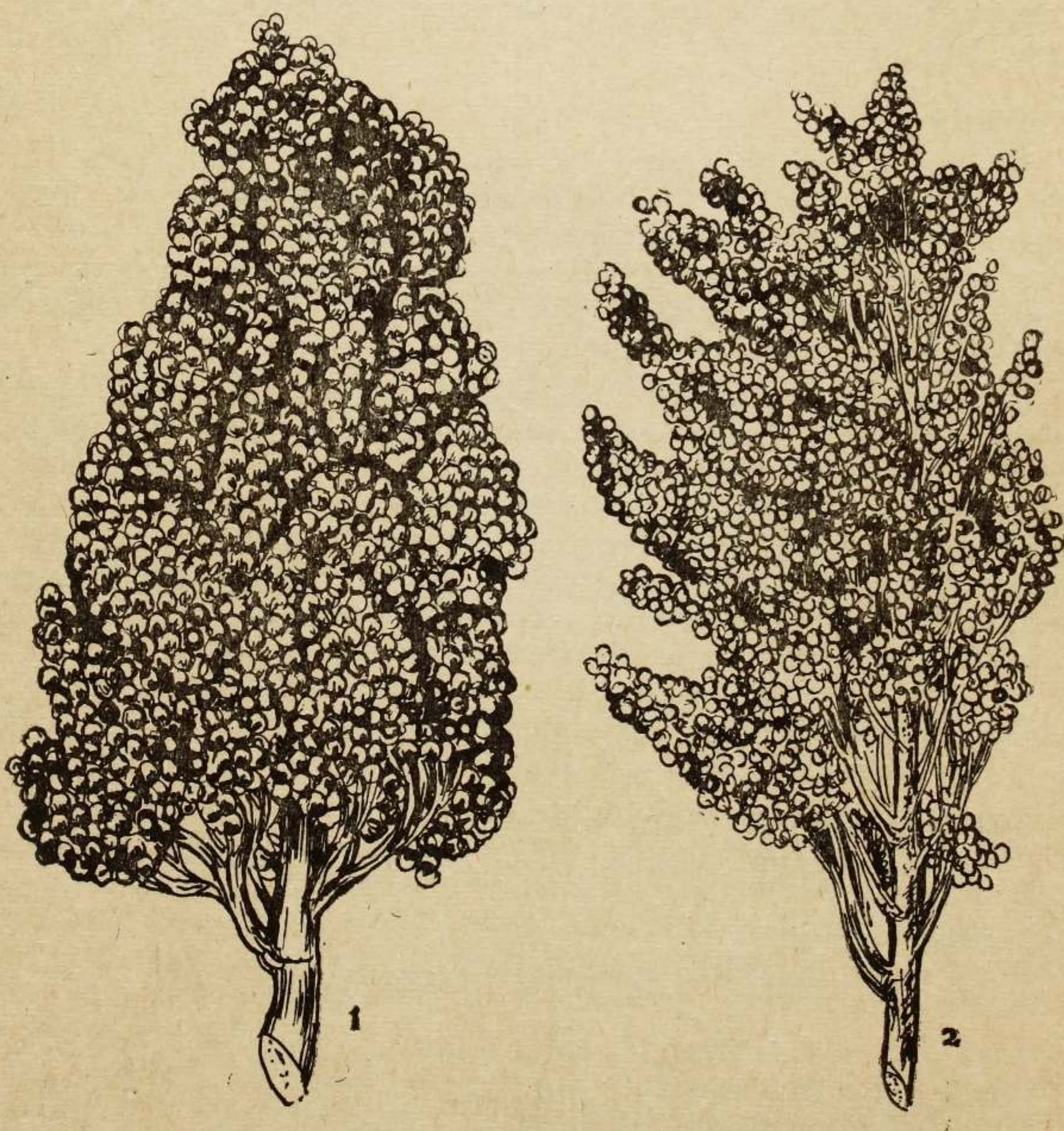


Figure 7. Two panicle types in Sorghum
1. Closed compact panicle 2. Open lax panicle

Photoperiodic response

Sorghum is a 3-4 month crop. The age of a variety varies markedly with the season. Length of day, affects age. Trials conducted at Maha Illupalama on the photoperiodic response of sorghum varieties indicate that Combine Black Kaffir, CBK 60, DD Shallu, and Tambagalla are photoperiod insensitive varieties, while Sanpyaung, IPI Jowar 3, and the local varieties from Moneragala and Maradankadawela are photoperiod sensitive. Maradankadawela variety when sown in March took 223 days to flower in a normal day length, but flowered in 103 days in a 9 hour photoperiod. When sown in November, however, it took 104 days to flower under both photoperiods. (4).

Crop Improvement

Crop improvement work in sorghum has been directed towards certain desirable attributes, in an ideal grain sorghum for the dry zone of Ceylon. These attributes are:

1. Dwarfness of habit.
2. Open or lax panicle.
3. White or pearly seeded grain.
4. Corneous endosperm.

The first two characters are related to the incidence of bird damage. Tall types with dense panicles, predispose to attack and damage by birds. A lax panicle also retards the development of mould formation, particularly during unseasonal rains. The last two attributes are related to the role of grain sorghums as substitutes for rice. White seeded varieties, do not possess the astringent principle which makes sorghum unpalatable. A corneous endosperm, promotes good milling quality, and a lower rancidity during storage.

In connection with the programme of improvement, work was commenced at Maha Illupalama in 1952, with the introduction of a large number of foreign varieties. (3). Lax panicle varieties, possessing all the other desirable characters of grain type did not possess dwarfiness, in the foreign varieties imported. Dwarf varieties, lacked grain qualities. Hence the breeding programme was designed to achieve this combination. Of a number of varieties tested for yield, Combine Black Kaffir a good yielder had dwarfiness but stiff panicles. A transfer of the genes for dwarfiness present in this variety into the otherwise desirable lax panicle varieties was therefore attempted. The cross between Combine Black Kaffir and a tall, semiperennial local variety collected at Maradankadawela, was particularly promising. The seed of the variety Maradankadawela is consumed locally as a substitute for rice. (4). Other lines of improvement undertaken were studies on the genetic correlation between plant height on the one hand and length and texture of the panicle branches, grain disposition, grain size and endosperm character on the other. (3).

ECOLOGICAL ADAPTATION

The most favourable mean temperature for the growth of sorghum is about 80°F. Sorghum can withstand heat well. It is quite suited to areas with an average annual rainfall of between 17-25 inches. The distribution of rainfall is important. Early rains, followed by a period of dry weather during the time the grains begin to mature is essential. Rain at the time of grain maturity results in germination of the grains on the earhead.

Wind is also an important environmental factor in sorghum areas. Strong winds are undesirable, particularly when tall sorghums are grown. Wind is not important with the dwarf types.

The crop can be cultivated on a wide variety of soils ranging from light loams to heavy clay soils. On soils of medium and poor fertility, sorghum offers better prospects than maize.

Drought resistance in Sorghum

Sorghum is extremely drought resistant. The plant can remain dormant during drought periods, and resume growth later with the onset of the rains. On account of this great adaptability the crop is often referred to as a 'crop camel'. The plant has an extensive secondary root system, which can more thoroughly permeate the soil, and a smaller leaf area than maize. Its adaptations for drought resistance include waxy cuticles on the leaves which retard drying, and the presence of bulliform cells, which enable the leaves to fold up like butterfly wings, during hot weather.

Areas for cultivation

On account of its drought resistance, and ability to produce fair yields even in the midst of environmental fluctuations, the crop is most suited to the dry zone of Ceylon. It can be successfully cultivated in the unirrigable highlands of the dry zone which have been traditionally under chena cultivation.

Rotations

The sorghum crop is considered to be hard on the land. Kansas experiments for a period of 15 years showed that where wheat followed sorghum, the average yield of wheat was 4.1 bushels less per acre, than when wheat followed maize. (6). Texas experiments with cotton sorghum rotations showed similar results, when compared to monoculture with cotton. In both experiments, the effect was marked whenever the crops followed sorghum immediately after. The ill effects were alleviated later in time.

Plate 7. A crop of Sorghum, showing the closed compact panicles.

Plate 8. A field stand of Kurakkan. Note the closed compact ear-heads.

The effects on the land are generally two fold. The first effect is a nitrogen deficiency, and the second effect is a moisture deficiency. The nitrogen deficiency does not occur when a well inoculated legume follows sorghum. When the legume is supplied with moisture, there is no further reduction in yield. The nitrogen deficiency occurring in the soil following a sorghum crop may be attributed to the increased bacterial population in such soils, which compete with the succeeding crops for the nitrogen in the soil. The increase in bacterial population is due to the high sugar content of sorghum roots which promotes bacterial growth. On a dry matter basis the sugar content of the roots of various varieties of sorghum has been estimated as ranging from 15-55%. (c.f. maize which has less than 1 to 4.5%). (7). The nitrogen deficiency lasts for a few months or until the sorghum residues have decayed.

The moisture deficiency occurring in sorghum soils may be attributed to the extensive secondary root system of the sorghum plant, which thoroughly permeates the soil depleting it of all available moisture. This can present problems in the drier areas. But again the effect is temporary. The detrimental effect of sorghum on the land can be overcome either by fallowing the land in the succeeding season, or including a legume in a rotation.

In India grain sorghum is sown mixed with dhal, green gram, cowpea, black gram, gingelly, horse gram, castor or deccan hemp. These are grown in rows which alternate with every 3 to 5 rows of sorghum. (5). In the chenas in the dry zone, sorghum is grown either as a pure crop or is mixed with other crops. In some Government farms sorghum is grown in mixture with dhal. The recommendation is to grow one row of dhal to every 3 rows of sorghum. (8).

CULTURE OF THE CROP

Seed bed preparation

Seed bed preparation is similar to that of maize. The soil has to be repeatedly worked in order to get a firm, fine seed bed.

Seeds and sowing

Grain sorghum seed may be drilled in rows, 2 feet apart using a mechanical seed drill. In the chenas, the seed is generally sown broadcast. The seed rate when the seed is drilled in rows amounts to 8-10 pounds per acre.

For fodder sorghum, a higher seed rate of 20-40 pounds per acre is required, and this may be drilled in rows 1 foot apart.

Spacing

Spacing in sorghum for optimum yields depends both on the variety and also the tillering habit. Spacings within the row, as well as between rows varies also according to the type of intercultivation practices adopted. In general close spacing results in better yields. In an experiment conducted on the University experimental plots at Peradeniya with six introduced dwarf varieties of sorghum, an increase in plant density resulted in a shorter head and a corresponding decrease in grain yield per head. (Table 2). But in all instances the increase in the number of heads per unit area more than compensated for the decreased yields of individual heads. The three plant densities used namely 12, 18, and 36 plants per square yard were obtained by growing two plants per hill at spacings of 4, 8 and 12 inches in the row. (9).

TABLE 2

Effect of plant density on the yield of six introduced varieties of sorghum (Senewiratne 1959)

Variety and age	Plant Density /Sq.Yd.	Height in feet	% Plants Tillered	% Immature Heads	Length of head inches	Average Grain per head in oz.	Yield lb./Ac.
Ryer 86 days	12	3.5-4.0	0	2.5	6-7	0.81	2564
	18	3.5-4.0	7.3	9.8	5-6	0.83	3020
	36	4.0-4.5	0	3.5	4.5-6	0.64	3886
Martin 89 days	12	3.5-4.0	3.75	3.75	11-12	1.48	4738
	18	4.0	1.90	1.90	10-11	1.20	5821
	36	4.0-5.0	0.90	2.40	8-9	0.71	6102
Norghum 93 days	12	3.5-4.0	33.3	28.3	11-12	1.10	3602
	18	4.0	16.6	22.4	11-12	1.10	4908
	36	4.5	1.6	8.1	10-12	0.81	5858
D.D.Y.S. 95 days	12	4.0	44.8	3.2	6-7	1.09	4672
	18	4.0	19.0	1.4	6-7	1.05	5385
	36	4.0-5.0	1.1	0	5-6	0.89	6237
D.D. 38 97 days	12	4.0-4.5	65.6	0.5	6-7	1.02	4752
	18	4.0-4.5	12.5	0	6-7	1.10	5412
	36	4.0-4.5	2.0	0.8	5-6	0.79	5863
Caprock 101 days	12	3.5-4.0	1.8	3.8	10-11	2.14	4950
	18	4.0	5.5	0.9	10-11	1.75	5468
	36	4.0-4.5	0.65	0	9-11	1.17	7250

Nutrition

The crop responds strikingly to the application of fertilizers. The Department of Agriculture recommends a basal dressing of 3-5 tons of cattle manure to the acre. Commercial fertilizers are recommended at the rate of 1 cwt. of sulphate of ammonia, and 1 cwt. of superphosphate per acre (8).

Where forage sorghum is grown, it is important to have the nitrogen content of the fertilizer mixture high. In fertilizer experiments conducted at the Alabama Agricultural Experiment Station, on forage sorghum, highest yields were obtained with a 6—10—4 or 6—20—4 fertilizer mixture. (10).

Weed control

Weed competition can become a serious problem in sorghum cultivation. When the crop is sown late, weeds come up with the heavy monsoon rains that follow, and seriously reduce yields. Early planting with early intercultivation between the rows, when the plants are about 3-4 weeks old, gives the crop a good start, and effectively controls weeds. Generally, at least 2-3 intercultivations are necessary.

Kirinde (11) reported the results of an experiment to test the value of combined chemical and cultural methods of weed control in sorghum. A pre-emergence treatment of DNBP (2, 4-dinitro-6-sec-butyl phenol) immediately after sowing at the rate of 1 gallon of 17% commercial formulation in 100 gallons of water, was followed by a number of mechanical weedings. Three mechanical weedings in combination with the pre-emergence treatment gave the best results. (Table 3.).

CONTROL OF PESTS AND DISEASES

Pests

1. Birds, chiefly parrots are the main pests of sorghum. Particularly on chena lands, where sorghum is grown in small allotments, the trees harbour these bi ds, which cause considerable damage to the crop. Peasants often control the extent of damage by breaking the stems after the grains have passed the milk stage, and allowing the earheads to droop. Sometimes, the plants are lodged mechanically for the same purpose.

2. Stem borer. *Chilo simplex*

The attack by the stem borer results in the death of the top stock. Rotation with resistant crops reduces borer damage.

Diseases

3. Smut (*Sphacelotheca sorghi*).

The sorghum grain is attacked by this fungus, when the crop flowers and ripens in humid weather. The seed may be dusted either with Copper carbamate or Ceresan or Agrosan at the rate of 2 oz. per bushel, so that the fungus may not be carried over to the next crop.

TABLE 3

Effect of combining a pre-emergence weed killer with mechanical weeding on yields of sorghum (Kirinde 1957)

Treatments		Yield lb./acre	Percentage of control
Chemical treatment			
* Without pre-emergence		3,915	100*
With pre-emergence		3,700	123
	Significant difference	370	
Weeding treatments			
No weeding		1,606	35
1 weeding		2,687	59
2 weedings at 10 day intervals		3,681	80
* 3 weedings at 10 day intervals		4,575	100*
4 weedings at 10 day intervals		4,237	93
	Significant difference	585	
Treatment combinations			
2 weedings only		3,300	74
* 3 weedings only		4,450	100*
Pre-emergence+2 weedings		4,062	91
Pre-emergence+3 weedings		4,687	105
	Significant difference	827	

(* Taken as a control representing present standard practice)

Harvesting

Sorghum may be harvested in 3-4 months depending on the variety. Harvesting should commence when the grain is dry. At this stage the grain does not dent when pressed with the finger nail. The general method of harvest is to harvest the earheads first. The stalks are cut later. In dwarf sorghums, both stalks and earheads are cut together. When harvested separately, the earheads may be dried, and threshed either by trampling with bullocks, or in power driven threshers. The stalks may be dried thoroughly for about two weeks, after which they make good fodder with a keeping quality which lasts nearly two years.

Fodder sorghum for silage purposes, should be harvested when the grain is in the milk stage, and not earlier, as otherwise there is a danger of prussic acid poisoning. After flowering, the prussic acid content is low, and the fodder can be harvested at this time.

Yields

Average yields of grain sorghum amount to 20 to 60 bushels per acre, depending on the cultural conditions under which it is grown.

Fodder yields average 10-13 tons of green material per acre, and should be considered as satisfactory.

Ratooning of sorghum

Sometimes, it should be possible to obtain a ratoon crop from sorghum. Immediately after harvest, the stubble is fertilized and regrows again, giving a reasonable yield in the beginning of Yala.

Storage of seed

Sorghum seed should be sun dried to about 14% moisture before storing. Grain in the ear stores better than threshed grain. The application of Gammexane reduces insect damage during storage. Sorghum grain can be stored satisfactorily in bissas of the type commonly used for storing paddy.

Costs of cultivation and returns (12)

	Rs. cts.
1st tillage	22.00
2nd tillage	22.00
Cost of basal fertilizer and application: 2 men ...	25.00
Cost of seed and planting: 8 women	20.00
1st intercultivation	22.00
Cost of top dressing, 1 cwt. sulphate of ammonia: 4 women	20.00
2nd intercultivation	22.00
Pest control	30.00
Harvest and processing: 15 women	30.00
	213.00

G. P. S. rate Rs. 15/- per cwt.
Approximate yield: 18 cwt.

Value of Crop	Rs. 270.00
Expenditure:	Rs. 213.00
Profit	Rs. 57.00

REFERENCES

1. Joachim, A. W. R. and Pandittesekera, D. G. The analysis of Ceylon foodstuffs II Tropical Agriculturist 1938.

2. Statistical Abstract of Ceylon 1962.

3. Sithamparanathan, J. Improvement of highland crops in the dry zone. Part I Cereals and Millets. Tropical Agriculturist Vol. CXIV. No. 1. 1958.

4. Administration report of the Director of Agriculture for 1960-61.

5. Karunaratne, C. R. Sorghum. Tropical Agriculturist Vol. CIX. No. 2. p. 92-102. 1953.

6. Laude, H. H. and Swanson, A. F. Sorghum production in Kansas. Kans. Agr. Exp. St. Bull. 265. 1933.

7. Conrad, J. P. The carbohydrate composition of corn and sorghum roots. Jour. Amer. Soc. Agron. 29. 1014-1021. 1937.

8. Sorghum. Department of Agriculture Circular No. 8.

9. Senewiratne, S. T. The effect of plant density on the yield of six introduced varieties of Sorghum. Paper read at the Annual Sessions of the Ceylon Association for the Advancement of Science. 1959.

10. Martin, J. H. and Leonard, W. H. *Principles of Field Crop Production.* The MacMillan Company, New York. p. 397-436.

11. Kirinde, S. T. W. Weed control in dry land farming. Tropical Agriculturist Vol. CXIII. No. 2. p. 131-146. 1957.

12. Costs from Central Experiment Station, Peradeniya.

5. KURAKKAN

Economic importance

Kurakkan or finger millet is the most important cereal crop of the Maha chenas in the dry zone. It is a grain of high nutritive value being higher in protein, fat and minerals, than rice, maize or sorghum. When consumed as food it provides a sustaining diet, suited to people who do hard work.

Kurakkan also has several other distinct characters, which differentiates it from other cereal grains. The crop is relatively free from pests and diseases, and the grain stores well for long periods, without undergoing damage. The straw makes valuable fodder for both working and milking animals. A guaranteed price of Rs. 15/- per cwt. for Grade I, and Rs. 13/- per cwt. for Grade II kurakkan is paid as an incentive to increase production. Being a chena crop, very little has been done however, in the way of organized cultivation, and only small quantities are produced annually. The quantities offered for sale under the guaranteed price scheme in 1960 and 1961 were only 4 cwt. and 2 cwt. respectively. (1).

Malaya and India are the countries in which kurakkan is cultivated on a larger scale. In India, it is the most important grain crop of the State of Mysore.

Botanical characters

Kurakkan (*Eleusine coracana*) belongs to the family Gramineae. The plant has flattened stems and round nodes. It is a profusely tillering dwarf plant, which bears at the end of the culms, earheads which consist of a whorl of finger like spikes ranging from 2-8 in number, in which the spikelets are arranged closely on both sides of a slender rachis. Spikelets contain 3-8 small seeds. In the cultivated varieties the seeds are displayed prominently. Kurakkan plants are largely self-fertilized.

The kurakkan plant tillers profusely. In addition it sends out branches at the nodes, which are pronounced in lodged or prostrate plants. Branches arise from nodes in succession, and this results in earheads, formed also in succession, and this in all stages of development, on the same plant. This tendency results in the presence of a large number of immature earheads at the time of harvest. The root system is fibrous and remarkably strong. It permeates the soil thoroughly and is capable of enabling the plants to withstand even severe drought, by its ability to absorb all available moisture in the soil.

Varieties

Varietal differences in kurakkan are based on the period of maturity, habit of growth, size, shape and colour of earheads, yielding capacity, size and quality of the grain. Some of the main differences are as follows:

Period of Maturity. There are early, medium and late varieties. The age varies from 4-5½ months.

Growth Habit. There are dwarf and tall types.

Type of Earheads. There are varieties with closed compact heads, and those with open lax heads. (Fig. 8). There is a third type with coxcomb heads, in which the spikes are branched, short and thick.

Yield. Long duration varieties yield better than short duration varieties.

Open types though better yielders have a tendency to break during harvest. They are brittle and have a tendency to shed. As such often, the closed types are preferred even though they are low yielders.

Local varieties are poor yielders when compared to the Indian varieties, some of which have been introduced and evaluated in yield trials. In yield trials, the varieties Ragi 958, and Ragi M-1 introduced from Madras, significantly outyielded the selection E43, by over 18%. (2). R 958, in subsequent trials, outyielded E43 by 24%. Another outstanding variety was AR 256. Varieties have also been introduced from Africa and are under study. (3).

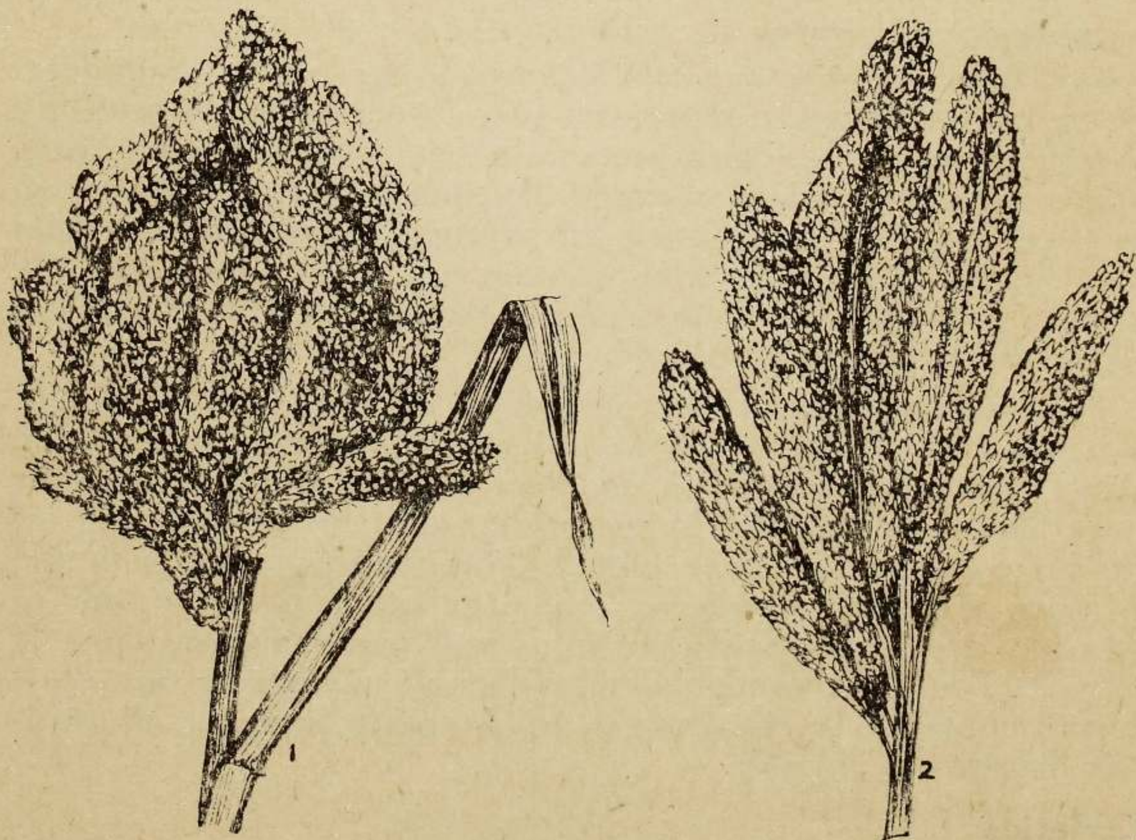


Figure 8 Kurrakkan ear heads
1. Closed ear head 2. Open ear head

Crop Improvement

Crop improvement work in kurakkan has been directed mainly towards achieving:

1. Increased yields
2. Resistance to lodging
3. Even maturity
4. A loose panicle

Most of the local and introduced varieties are susceptible to lodging and show uneven maturity. This results in a considerable loss of seed, as well as increased harvesting costs. Most of the local varieties in addition are poor yielders. With a view to achieving the objectives outlined in the improvement programme, a large number of introduced varieties from India and Africa are being evaluated at the present time particularly in respect of high yield potential, lodging resistance, and uniform maturity. A loose panicle which is an important characteristic in areas subject to unseasonal rains during maturation, is found in the varieties R958 and RM-1, but not in the local varieties. (2).

ECOLOGICAL ADAPTATION

Kurakkan does well in areas receiving between 20-35 inches of rain per season. In Jaffna it is cultivated also under irrigation. The crop is moisture loving, and is well adapted to the dry zone during the Maha season. It does well up to an elevation of 4,000 feet provided rainfall is moderate.

Red or light coloured loams or sandy loams are the most suitable for kurakkan cultivation.

Areas for cultivation

Kurakkan has been grown traditionally as a chena crop in the dry zone. In small holdings, it can be grown also in the low country wet zone. The main area for cultivation however, lies in the unirrigable highlands of the dry zone.

Planting season

Kurakkan is a Maha crop. As such planting should commence with the first rains in October during this season. In the Jaffna peninsula the crop is planted at different times during the dry season from February to September, under irrigation.

CULTURE OF THE CROP

Land preparation

Seed bed preparation should be fairly intensive as this is a small seeded grain. The soil should be worked to a fine tilth, by repeatedly working the soil.

Selection of seed for sowing

Kurakkan seed is generally mixed with immature or poor quality seed. As has been pointed out earlier, ununiform maturity due to late formed earheads, results in immature, shrunken and small seed being mixed with the well developed, plump good quality seed. Sometimes unseasonal rains result in poorly developed seed. As such seed selection to ensure good quality seed for sowing becomes important, and is in fact necessary to obtain a better germination and a good stand. Seed selection can be achieved either by the use of sieve meshes, capable of separating the larger better seeds from the smaller poor ones, or by the use of the salt water method whereby seed is separated on the basis of density.

Sowing methods

Broadcasting is the general method of sowing practised in the chenas. The seed may be mixed with sand or manure and sown to ensure an even stand.

Under better cultural conditions, the seed may be sown in rows, using seed drills. Simple seed drills which can sow from 6-12 rows at a time are common in India. (4)

Seed rate

The seed rate used in practice is generally much heavier than what is actually required. This is so because of the chances of poor germination when using highly mixed seed. In such cases a seed rate of between 6-8 pounds to the acre is used. The stand may be thinned down later if necessary.

Spacing

Th spacing adopted when the crop is row sown, is 10 inches between rows.

Nutrition

Very little fertilization is done in chena cultivation. Under better cultural conditions, a top dressing of 50 lbs. of ammonium sulphate gives good results. In some places, the practice is to grow a green manure crop like sunn hemp, and plough it in about two weeks prior to sowing. Such a practice, improves the organic matter content of the soil, thereby helping it to retain as much moisture as possible. Very little is known on the fertilizer requirements of kurakkan.

Weed control

Intercultivation for the purpose of weed control should commence about the 15th day. In many ways, weed fall is the chief limiting factor to the expanded cultivation of kurakkan. The initial growth of the kurakkan plant is so slow, that very often the crop gets smothered by weeds in no time. Regular and thorough intercultivation of the crop therefore assumes considerable importance, and also adds to the costs of cultivation. Occasionally kurakkan cultivation is abandoned half way due to this problem. The evaluation and use of a pre-emergence weedicide to control the annual weeds that are a bane in this crop, needs immediate attention.

Irrigated kurakkan

For irrigated kurakkan, the plants are raised in nurseries, and transplanted later. 6 pounds of seed sown on about 1/6 of an acre is adequate to raise enough seedlings for an acre. Seedlings are transplanted when 25 to 30 days old. One seedling is planted per hill at a spacing of 3 to 4 inches. Irrigation is withheld for about a fortnight after transplanting till the seedlings get established. Thereafter the crop is irrigated once every four days.

Control of pests and diseases

Kurakkan is relatively free from the attack of the major insect pests and diseases, common to other grain crops. The hairy caterpillar and sometimes even the grasshopper, can prove to be troublesome. The crop is sometimes attacked by a couple of fungus diseases. In seasons of heavy rainfall, the fungus disease *Helminthosporium nodulosum* can cause some damage. The disease occurs in patches in the fields, and infected plants show brown rusty spots on the leaves, and similar blotches on the nodes, leaf-sheath, rachis and spikelets. Grain development in infected plants is poor. The disease is carried over from season to season, through infected seed, as well as from plant to plant by wind borne spores. Seed disinfection by dusting with Ceresan gives some measure of control. Another fungus disease which occasionally attacks kurakkan is *Piricularia*. Grain filling in infected plants is poor. Remedial measures are similar to those described under rice.

Harvest. The crop is generally ready for harvest in about 4 months from sowing. Late varieties take about 5½ months to mature. Further, broadcast seed ripen about 2-3 weeks earlier than transplanted seed. Since ripening is uneven, at least two harvests should be taken at about 10 day intervals. Harvesting is generally done by hand by collecting the earheads. The grain may be threshed by the use of a mortar and pestle. Milling is done by the kurakkan handmill, the milling outturn is about 95%.

Yields. Yields under good cultural conditions average around 1,500 pounds per acre. The variety R 958 gave a yield of 1,740 pounds per acre in experimental plots. (3). Average chena yields are much lower, being about 500-700 pounds per acre. Under irrigation in Jaffna, yields amount to nearly 2,250 pounds. (5).

Storage. Earheads should be dried thoroughly in the sun prior to threshing. The earheads could then be stacked, and threshed for grain as required.

Costs of cultivation and returns (6)

	Rs. cts.
1st tillage	22.00
2nd tillage	22.00
Basal fertilizer and application: 2 men ...	25.00
Cost of seed and planting: 8 women	18.00
Intercultivation and thinning out: 4 women ...	30.00
Top dressing ½ cwt. sulphate of ammonia: 3 women	15.00
Harvest: 8 women	16.00
Processing etc.: 5 women	10.00
Rs.	158.00

G. P. S. rate Rs. 15.00 per cwt.
Approximate yield 15 cwt.

Value of crop ...	Rs. 225.00
Expenditure	Rs. 158.00
Profit	Rs. 67.00

REFERENCES

1. Statistical Abstracts of Ceylon 1962.

2. Sithamparanathan, J. Improvement of highland crops in the dry zone Part I. Cereals and Millets. Tropical Agriculturist Vol. CXIV No. 1. 1958.

3. Administration Report of the Director of Agriculture 1961-62.

4. Yegna Narayan Aiyar, A. K. *Field Crops of India.* p. 44-65.

5. Kurakkan (*Eleusine coracana*) Field production Leaflet No. 1. Leaflet No. 170. Department of Agriculture.

6. Costs from Dry Zone Research Station, Maha Illupalama.

6. THANAHAL

Economic importance

Italian millet or Thanahal is one of the more important minor millets, and is used widely as a substitute cereal for rice. It is a relatively quick growing crop, coming to maturity in a period of about 3 months, and providing as good a yield as some of the longer aged grain crops. The food value of Italian millet is as follows: (1).

Moisture %	Protein %	Carbohydrate %	Ether extract (Fat) %	Fibre %
12.80	12.95	68.77	2.90	0.21

Mineral matter %	Calcium %	Phosphorus %	Calorific value per 100 gm.
2.37	0.037	0.280	353.0

Italian millet has a wide range of cultivation being grown in many parts of the world, particularly China, Japan, South Africa, India, Southern and Eastern Europe and North America. In America the crop is grown mainly for hay purposes, the grain being used as livestock feed. (2). In Ceylon it is grown either as a chena crop in the dry zone, or on small holdings under more intensive management.

BOTANICAL DESCRIPTION

Italian millet (*Setaria italica*) is an annual grass with slender, erect, leafy stems. The plants attain a height of 3 to 3½ feet under cultivation. The leaves are about 12 to 18 inches long and lanceolate in shape. The peduncle is long and slender. The inflorescence is a spike, long, drooping and covered over with thin bristles. The spikelets occur in clusters of 40 or 50. Only the fourth glume contains a bisexual flower, which develops a grain. The small convex grains are enclosed in the lemma and palea. Italian millet is largely self pollinated, with 0-10% of natural crossing. (3, 4).

Varieties

Varietal differences are based on a number of characteristics, some of which are:

1. Period of maturity: Some varieties mature in three months, while others take four months.

2. Height of plants: May vary between 3-4½ feet, in height.

3. Length and appearance of earhead: Either compact and smooth or long, lax and with bristles.

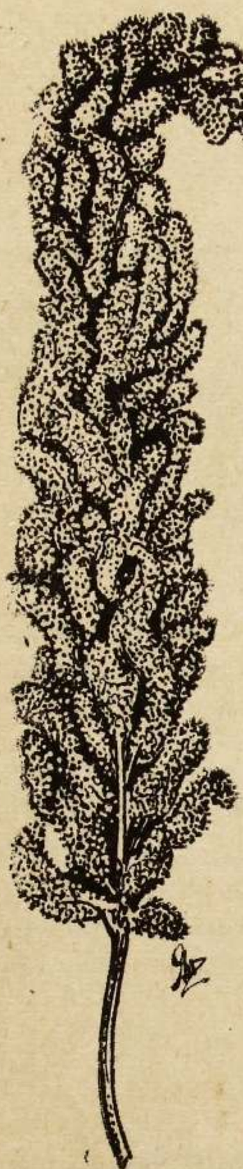


Figure 9.
Ear Head of Thanahal.

Length of earheads may be from 6 to 12 inches. Diameter from ½ to 1½ inches. (Fig. 9).

4. Colour of grain: May be yellow, white, cream coloured orange red, purple, black, greenish white.

Names of varieties are generally descriptive of the colour and appearance of the earhead.

ECOLOGICAL ADAPTATION

The crop is suited to areas of low rainfall although it does well even in the higher rainfall areas. It can be cultivated even at high altitudes of about 6,000 feet. (5). It is essentially a crop for the dry zone, where it can be cultivated either in the Maha or the Yala. It has also given satisfactory yields at Peradeniya.

Italian millet can be grown on a wide range of well drained soils. A fertile loam soil is best for this crop. It can be grown on very light soils as well as heavy clay soils, when rainfall is not heavy.

CULTURE OF THE CROP

Seed bed preparation

Thorough preparation of the soil is essential and this is usually achieved by one or two cultivations of the soil with the plough and disc harrow. The land can then be levelled using a spring tooth harrow, and at the same time cleared free of any trash or weeds.

Planting season

When grown as a chena crop in the dry zone, it is sown with the first Maha rains. In the wet zone it could be planted in both the Yala and Maha seasons, the crop being sown in both cases with the first rains.

Seeds and sowing

The seeds may be either sown broadcast or drilled in rows. When drilled in rows, the three coultered seed drill may be used. The seed rate amounts to about 7-10 pounds to the acre.

Spacing

Close spacing is advocated as this helps to suppress weeds. (6). The spacing between plants should not be more than 2 inches in the row, with rows 12 inches apart (7).

Weed control

At least one intercultivation is necessary for the purpose of weed control, and should be given a fortnight after sowing. No information is available on the chemical control of weeds in this crop.

Nutrition

A fertilizer application at the rate of 1 cwt. per acre of a mixed fertilizer analysing 16—8—8 given as a basal dressing, and a second application about a month later gives good yields.

Control of pests and diseases

The pests common to kurakkan and sorghum are found to attack thanahal as well. Remedial measures are similar to those described under these crops.

The 'green ear' disease, described under cambu, also attacks thanahal, and causes considerable damage.

Another disease of some importance is kernel smut. (*Ustilage crameri*). Treatment of the seed with a 0.5% solution of formalin for 5 minutes, affords effective control. Copper sulphate may also be used in seed treatment.

Harvest

When the crop is mature, harvesting is done by cutting off the earheads. The earheads are heaped on the threshing floor for about a week, before being threshed under the feet of bullocks, or by a stone thresher.

Yields

Average yields amount to between 600-900 pounds per acre. Under intensive culture yields can go up to 1,500 pounds per acre.

Costs of cultivation and returns (8)	Rs. cts.
Preparatory tillage (mechanical)	35.00
Cost of seed	1.80
Sowing (drilling) animal hire: 2 units	15.00
Intercultivations (two)	30.00
Fertilizers and application: ½ unit	17.50
Crop protection	20.00
Harvesting: 8 units	20.00
Threshing and cleaning	15.00
Drying and bagging: 4 units	12.00
	166.30

Yield 650 pounds		
Value of seed at 30 cts. per pound	Rs.	195.00
Expenditure	Rs.	166.30
Profit	Rs.	28.70

REFERENCES

1. Joachim, A. W.R. and Pandittesekera, D.G. The analysis of Ceylon Food Stuffs. Tropical Agriculturist Vol. XCIX No. 1. 1943. p. 13-17.

2. Martin, J. H. and Leonard, W. H. *Principles of Field Crop Production.* The Macmillan Company, New York. p. 605-619.

3. Li, H. W., Meng, C.J. and Liu, T. N. Problems in the breeding of millet. *Setaria italica* Jour. Amer. Soc. Agron. 27. p. 963-970. 1935.

4. McVicar, R.M. and Parnell, H.R. The inheritance of plant colour and the extent of natural crossing in foxtail millet. Sci. Agr. 22. p. 80-84.

5. Yegna Narayan Aiyer, A. K. *Field Crops of India.* Govt. Press. Bangalore. p. 90-94.

6. Curtis, J. J. Foxtail millet in Colorado. Colo. Agr. Exp. Stn. Bull. 461. 1940.

7. Li, H. W., and Meng, C. J. Experiments on the planting distance in varietal trials with millet, *Setaria italica.* Jour. Amer. Soc. Agron. 29. p. 577-583. 1937.

8. Costs from Central Experiment Station, Peradeniya.

7. MINERI

Economic importance

Mineri, is the most important minor millet of the Yala chenas in the dry zone. The extremely short age of this crop enables it to mature and produce reliable yields of grain during this season. It has been a popular chena crop for the Yala season for over 75 years (1). Mineri rice is rich in protein and fat, and is relished by the peasants. An acre of Mineri produces about 1,750 pounds of straw which is highly nutritious for cattle. The importance of this millet is due to its capacity to make good with very little moisture, the Yala rains being usually adequate to raise and mature the crop. It is cultivated in Egypt, Arabia, Japan, Southern Russia and in various parts of Northwest India.

BOTANICAL CHARACTERS

Mineri (*Panicum miliaceum* Linn), also called Panicum millet or common millet, is a grass, that grows to a height of about 2½ feet, and which can be readily recognized by its bright green foliage and spikelets of flowers arranged in lax drooping panicles. The plant tillers profusely, producing on the average about 10 tillers with 4 branches to each tiller. The leaves are large and acuminate. The panicle is much branched. Branches are long and spreading, ultimately drooping with the weight of the grain. The root system is fibrous and very shallow. The grain is oval, with longitudinal streaks.

Varieties

Varietal differences in Mineri are based on the colour of the grain, which may be grey, yellow, olive grey or ivory yellow.

CROP IMPROVEMENT

Work is in progress at Maha Illupalama to evolve an earlier maturing and high yielding variety for the Yala season. As a prelude to this programme, a representative range of varieties both locally and from abroad are under study. (2).

ECOLOGICAL ADAPTATION

Very little rainfall is required to raise a crop of Mineri successfully to maturity. About 8-10 inches per season is adequate.

The crop thrives best in sandy loam to loamy soils.

Areas for cultivation

Mineri is quite suited to the drier areas, on account of its highly drought resistant character, and short duration. It is one of the very few short duration crops that can be grown with the Yala rains, and matured before the soil dries out in June. It can be grown even in the low country wet zone.

CULTURE OF THE CROP

Seed bed preparation

Preparatory tillage is generally limited to one operation. The soil is lightly tilled and prepared for sowing. In the dry zone chena, where it is sown as a broadcast crop, a superficial tillage is all that is done.

Seeds and sowing

In more organized cultivation, the seed may be drilled in rows, using a seed drill. In the dry zone chena, the crop is broadcast as a pure crop for the Yala season.

The seed rate when broadcast is about 12 pounds to the acre. The seed rate when drilled in rows is about 8 pounds to the acre.

Spacing

When sown in rows, a spacing of 1 foot between rows is adopted.

Nutrition

With the addition of compost at the rate of 3 tons to the acre at the Experiment Station, Pelwehera, on land opened 5 years earlier, yields of 22 bushels per acre were obtained. (1). In the chena the crop thrives without any manuring.

Weed control

Since Mineri is a short aged crop, only one intercultivation is necessary, when the crop is about a month old. Usually the crop is sufficiently quick growing to smother all weeds.

Control of pests and diseases

There are no serious pests or diseases. A smut disease attacks the earhead, but it can be controlled by treating the seed with a solution of Copper sulphate at the rate of 1 part in 100 parts of water, (both by weight) for 10 minutes, and drying the seed prior to sowing. (3).

Harvest and yields

The crop flowers in a month and is ready to be harvested in two months from sowing. Harvesting is done by hand using sickles. Earheads are allowed to dry in the sun before stacking. Threshing may be done by trampling with buffaloes. Yields amount to 20 bushels under intensive cultivation and 10 to 15 bushels under chena conditions.

Costs of cultivation and returns (4)

	Rs. cts.
Preparatory tillage (mechanical)	35.00
Cost of seed	2.40
Sowing (drilling), animal hire: 2 units	15.00
Intercultivations (two)	30.00
Fertilizers and application: ½ unit	17.50
Crop protection	20.00
Harvesting: 8 units	20.00
Threshing and cleaning	17.50
Drying and bagging: 4 units	12.00
Rs.	169.40

Yield—750 pounds	
Value of seed at 25 cts. per pound	Rs. 188.50
Expenditure	Rs. 169.40
Profit	Rs. 19.10

REFERENCES

1. White, J. S. L. *Panicum miliceeum* (Mineri). A promising short-aged food crop. Tropical Agriculturist. Vol. XCIX No. 4. p. 207-211. 1943.

2. Sithamparanathan, J. Improvement of highland crops in the dry zone. Part I. Cereals and Millets. Tropical Agriculturist. Vol. CXIV No. 1. 1958. p. 19-28.

3. Yegna Narayan Aiyer, A. K. *Field Crops of India*. p. 105-106.

4. Costs from Central Experiment Station, Peradeniya.

8. HEEN MINERI

Economic importance

Heen mineri or little mineri is another dry land grain of minor importance in the Yala chenas. It is capable of withstanding long periods of low moisture, and it is this drought resistant character that makes it a useful crop under poor conditions. Even under extreme conditions, it is capable of maturing a crop. As a food grain, it is rich in protein and fat, as shown by the following analysis. (1).

Moisture %	Protein %	Carbohydrate %	Ether extract (Fat) %	Fibre %
11.10	13.40	72.26	1.76	0.10

Mineral matter %	Calcium %	Phosphorus %	Calorific value per 100 gm.
1.07	0.022	0.257	359.7

BOTANY AND VARIETIES

Distinguished botanically as *Panicum miliare*, the plant is an annual grass. It has thin leafy stems, tillers profusely and depending on the variety attains a height of 2-4 feet. The panicles have drooping filiform branches. The grain is either white or greenish white in colour.

Varietal differences are based mainly on age. Early maturing varieties ripen in 3 months, medium varieties in 3½ months and late varieties in 4 months. (2).

Culture of the crop

The crop is suited to the dry zone chenas during the Yala season. Preparatory tillage is similar to other dry land grains. The seed may be sown in rows with seed drills and covered with the bladed harrow, or may be broadcast, and covered with the toothed harrow. Seed rate is about 8-10 pounds to the acre. Very little after-care is given, and the crop is allowed to mature.

Harvest and yields

Harvesting is done either with sickles, or by pulling the plants out whole. The sheaves may be stacked for a week, after which it is threshed by trampling under the feet of bullocks. Yields range from 300-500 pounds under average conditions. Under good cultural conditions yields of about 800 pounds can be obtained.

REFERENCES

1. Joachim, A. W.R. and Pandittesekera, D. G. The analysis of Ceylon Food Stuffs. Tropical Agricultirist. Vol. XCIX No. 1. p. 13-17. 1943.

2. Yegna Narayan Aiyer, A. K. *Field Crops of India*. Govt. Press, Bangalore. p. 101-2.

9. AMU

Economic importance

Amu, or Kodo millet, is a cereal crop of minor importance in Ceylon. It is cultivated only in very small extents, as a chena crop, in the dry zone and in the Jaffna peninsula. It produces a coarse grain, which is used for human consumption. It is recommended for diabetic patients, in the same way as kurakkan. Its food value is as follows: (1)

Moisture %	Protein %	Carbohydrate %	Ether extract (Fat) %	Fibre %
12.41	12.40	69.53	2.04	0.26

Mineral matter %	Calcium %	Phosphorus %	Calorific value per 100 gm.
3.36	0.043	0.328	346.1

BOTANY AND VARIETIES

Amu (*Paspalum scrobiculatum*) is a smooth annual grass, which tillers moderately, and attains a height of about 2 feet. Leaves are stiff and thick, and the plant is erect. Under dry conditions, the stems and leaves show a reddish discolouration. The inflorescence is a thin, long raceme. Spikelets are one flowered, and arranged on one side of a flattened rachis. There are no distinct varieties under cultivation.

Ecological Adaptation

Amu is remarkably drought resistant. It has the capacity to struggle on in spite of a lack of moisture and can be relegated to the poorer soils in the dry zone. The crop takes about 5-6 months to mature.

Culture of the crop

The soils may be prepared as for other minor millets. The seed may be either sown broadcast, or under better culture, drilled in rows. The seed rate amounts to about 20 pounds to the acre. After-care amounts to the control of weeds and fertilization. Both these items are limited by the poor economic returns obtainable from this crop. The crop is singularly free of pests and diseases.

Harvest and yields

The crop is ready for harvest about six months after sowing. The crop is harvested by hand and the grain is threshed by trampling under the feet of bullocks. The grains are similar to the grains of buckwheat, and have a hard horny coat, which has to be husked, before the edible part inside can be obtained. The out turn of flour is low and husking itself is cumbersome. Yields average 200-500 pounds to the acre. In certain parts of India, where the crop is grown under better cultural conditions, higher yields of between 600-800 pounds per acre have been obtained. (2).

REFERENCES

1. Joachim, A. W. R. and Pandittesekera D.G. The analysis of Ceylon Food Stuffs. Tropical Agriculturist Vol. XCIX. No. 1. 1943. p. 13-17.

2. Yegna Narayan Aiyer, A. K. *Field Crops of India*. p. 103-4.

10. CAMBU

Economic importance

Cambu, also called pearl millet, bulrush millet or spiked millet is a relatively new millet in Ceylon, having been introduced in 1938 from India. Its value lies in the grain, as well as the relatively large amounts of fodder, which amounts to as much as 2½ to 3 times the yield of grain. The grain is superior to kurakkan in nutritive value and contains 11.59 per cent protein, 4.99 % fat, 2.65 % mineral matter. (1). The crop used to be grown in small extents in Jaffna but has for sometime gone out of cultivation. The crop offers considerable promise as a Yala cereal for the dry zone, and the possibility of growing this crop in the dry zone, has been under investigation. (2).

BOTANICAL CHARACTERS

Cambu (*Pennisetum typhoideum*) is a tall growing grass which attains a height of 3-8 feet depending on the variety and the cultural conditions under which it is grown. The plant tillers profusely, giving rise to solid stems, and much leafy fodder. The leaves are long and lanceolate. The stalk of the inflorescence is hairy. The inflorescence is a rounded long cylindrical spike densely packed with spikelets. The spikelets are in groups of 1-8 on separate pedicels. The spike may be from 9-12 inches long, and 1-1½ inches in diameter. Colour of the spike ranges from greenish yellow to reddish brown, according to variety.

Varieties

Varietal differences are based on tillering habit, thickness of stems, awning habit, length of spike, and colour. In India several local varieties are recognized on the basis of these differences. These are distinguished mainly as fodder varieties and grain varieties (3).

In Ceylon the variety that was popularly grown was an introduction from Jamnagar in India. This well-known Jamnagar Giant variety has the following characteristic features: A large sized earhead, 1-3 feet in length, with large sized pearl like grain. It is profusely tillering, and is remarkably drought resistant. On the other hand, it can tolerate high rainfall conditions, and has given considerably high yields in Peradeniya. (1) A local variety of Cambu grown in the Jaffna peninsula, is characterized by a very small sized earhead, and small sized grain. It is also a very poor yielder.

CROP IMPROVEMENT

Crop improvement has been directed towards selection of varieties that could be successfully grown in the Yala season, in the dry zone, as an alternative to mineri, whose grain yields are lower. (2).

Ecological Adaptation

The crop performs well in moderately dry climates, which have intermittent light showers. Heavy early rain, results in stunted seedlings. Continuous rain, causes the plants to yellow, and washes away the pollen, during the flowering phase. As a result earheads do not get filled. Rain during ripening favours mouldiness discolouring the grain. The crop can be grown up to an elevation of 3,000 feet.

Light soils are the most suited to this crop. Chena soils are satisfactory. Heavy soils are not suitable.

Areas for cultivation

Over a large part of the dry zone, Cambu would be a suitable crop for the Yala season. If grown in the low and mid country wet zones, it should be cultivated during the Maha, so that the crop may ripen in the dry month of February.

CULTURE OF THE CROP

Seed bed preparation

Preparatory tillage is limited to light harrowing, which is most often sufficient. Deep cultivation is not necessary, as the roots are entirely surface feeders.

Seeds and sowing

Seeds may be either dibbled or drilled in rows. A seed drill may be used for drilling the seed. The seed rate amounts to between 4-6 pounds to the acre.

Spacing

Spacing for the Jamnagar Giant variety was found to be $1\frac{1}{2}$x 1 foot under local conditions. (1).

Nutrition

Commercial fertilizers applied as a top dressing are known to have given good results. A top dressing with Nitrate of soda at the rate of 20 pounds of nitrogen per acre, after about 3 weeks from sowing, was found to be satisfactory under Poona conditions. (1).

Weed control

At least two intercultivations, the first when the plants are about 6 inches high, and the 2nd when the plants are about 18 inches high would be necessary as a measure of weed control.

Control of pests and diseases

Birds are the main pests of this crop, and it has to be watched against bird attack for about 5 to 6 weeks from the time the earheads begin to fill up.

Caterpillars are sometimes found to attack the plants.

The most common disease of Cambu, is what is known as 'green ear' disease. The causative organism is a fungus *Sclerospora graminicola*. The disease appears in the form of a mass of twisted green leaves instead of the grain in the earhead, affecting a part or the entire earhead. No effective control measures are known.

Harvest. The crop is ready for harvest after 4 months from sowing. Earheads formed on later formed tillers do not mature at the same time as those formed earlier, and hence the harvest has to be staggered. It may be harvested in two or three instalments. The earheads are harvested separately, after which the stalks may be cut down for straw. The earheads are dried in the sun, and threshed either by trampling with bullocks or beating them with wooden flails. The seed is then cleaned by winnowing.

Yields. Under good cultural conditions, the yield from the variety Jamnagar Giant varied from 1,200-1,800 pounds per acre. Average yields amount to between 900-1,000 pounds.

REFERENCES

1. De Mel, C. N. E. J. and Gaywala, P. M. Recently introduced food crops at the Experimental Station, Peradeniya. 11. *Pennisetum* millet. Tropical Agriculturist Vol. XCVI. No. 4. 1941. p. 212-216.

2. Sithamparanathan, J. Improvement of highland crops in the dry zone. Part I. Cereals and Millets. Tropical Agriculturist Vol. CXIV No. 1. 1958. p. 19-28.

3. Yegna Narayan Aiyer, A. K. *Field Crops of India*. p. 84-90.

11. ADLAY

Economic importance

The importance of Adlay (*Coix Lachryma jobi* Linn) millet which was recognized around the 1930's has substantially diminished, and the cultivation of this crop is hardly undertaken even in small extents at the present time. During the war, adlay was given prominence as a substitute for rice which was difficult to get, and its virtues of being more wholesome than some of the other common cereals was stressed. Adlay flour can be used in the making of the usual articles of food.

Culture of the crop

Adlay has been grown in the past in abandoned owita land, chenas and highland. Preparatory tillage is minimal. Seeds are dibbled, at a spacing of 2 x 2 ft., about 1 inch deep. The seed rate is about 6-10 pounds to the acre. One intercultivation, before the plants tiller and shade the ground may be necessary. Adlay is relatively free from pests and diseases, but parrots cause considerable damage to the grain.

Harvest and yields

The crop can be harvested in 4 to 5 months. Harvesting is done by cutting the stalks. After threshing, the seeds are dried in the sun prior to milling. Yields range from 40-75 bushels per acre under average conditions.

REFERENCES

1. Pieris, H. A. Adlay, *Coix Lachryma jobi* (Linn.) Tropical Agriculturist Vol. LXXXIX No. 3. p. 160-162.

GROUP II—PULSES

12. COWPEA

Economic importance

Cowpea is an important leguminous crop which is grown chiefly for four distinct purposes. Firstly it is cultivated as a seed crop. As a pulse it can be used in a variety of ways. The seed has a protein content of 24.56 per cent and a mineral content of 3.23 per cent, which makes it as valuable a pulse as any of the standard ones consumed in Ceylon. Although the cultivation of cowpea for seed is traditional in India, in Ceylon, the cultivation of this crop for grain purposes is relatively recent, having been first introduced around 1938. (1). Secondly, cowpea is cultivated as a vegetable, and it is in this way that cowpea has been grown in this country, for a long time. The crop is raised to produce tender green pods which can be sold as a vegetable. Vegetable varieties are however, not as hardy as the grain varieties. Thirdly, cowpea is grown for fodder purposes. The crop forms excellent forage both for cutting and stall feeding, and can also be used for the making of hay or silage. When mixed with maize or Sorghum stalks, the crop makes excellent silage. Fourthly, cowpea is often used for green manurial purposes. Those varieties which possess a spreading habit of growth and which produce a luxuriant growth are used for this purpose.

The value of imports of pulses into Ceylon in 1961 stood at Rs. 42 million (2). In order to reduce the imports of lentils, which for instance, accounted for a major portion of this import value, guaranteed prices have been introduced for cowpea, toor dhal etc., but even so the progress achieved has been very little. The guaranteed price for cowpea which stood at Rs. 24/- per cwt. for 5 years from 1957/58, was increased to Rs. 33/60 per cwt. in 1962/63 because it was felt that increased prices would help to encourage wider cultivation. (3). It was also envisaged that the provision of effective credit and marketing facilities would go a long way in the extension of the cultivation of this crop. (2).

BOTANICAL DESCRIPTION

The Cowpea (*Vigna catiang*) belongs to the family Leguminoseae, and the sub-order Papilionaceae. It is an annual, somewhat erect plant, which in certain types requires stakes for support, while others generally spread on the ground as a low bush. The stems are thin and rounded, and glabrous except at the nodes. The leaves are pinnately trifoliate with a long petiole. The leaflets are large, dark green in colour, and ovate in shape. Inflorescence is a raceme with a long peduncle. The flowering part is nodose, and depending on the variety bears white, light pink, or light blue conspicuous flowers. The pods are rounded and thin and again depending on the varieties vary in length, from 4 to 5 inches on the one hand to 18-24 inches on the other. The seeds too vary in size and colour. In respect of size, large seeded varieties sometimes have seeds twice the size of small seeded varieties. In respect of colour, seeds may be cream coloured, brown, dull red, light purple, and in some cases even black, depending on the variety.

Varieties

Varietal differences are based not only on the characters described above, but also on the purposes for which the cowpea crop is grown. Thus it is possible to classify cowpea varieties into the following:

Grain varieties, vegetable varieties, fodder varieties and green manure varieties.

Grain varieties

The first grain variety, introduced into Ceylon was the Bombay cowpea (1). It has an erect and vigorous growth habit, short growing period, and fairly uniform maturity. The pods of this variety do not shatter on maturity. The variety is relatively resistant to the attack of aphids and bean fly. It is fairly drought resistant.

The 3½ month varieties of cowpea, namely Birmingham and Christavado with dry grain yields of 2,432 and 2,407 pounds per acre, proved best in repeated yield trials under rainfed conditions in the Maha. Under rainfed conditions on the Yala, the 80 day strain M. I. 1, selected from Bombay cowpea varieties for earliness and maturity, and the 80 day variety New Era, with yields of 1,440 pounds and 1,390 pounds dry grain per acre respectively, proved best. (4). Other varieties that have proved successful in yield trials are:

Negro and Victor II—for the Maha season (5)

Vegetable varieties

There are a large number of vegetable varieties under cultivation for their green pods, which are relished as a vegetable. The pods vary in size, and the plants themselves are either staked or supported in a number of varieties. Examples of these are the Digali-mé, Polon-mé, Sangu vellai, Paithangai and Vallaithoyan.

CROP IMPROVEMENT

One of the factors limiting the cultivation of pulse varieties of Cowpea, is the high cost of harvest. In this connection, crop improvement work has been directed towards selection of strains with a short flowering interval, and in which the pods are borne on erect stalks, well above the foliage, which would help in reducing harvesting costs (5). Crosses involving the parents Victor, Arlington, Bombay, New Era, C 521, Saigon, Negro are under investigation, and the current work is being directed towards the selection of high yielding strains in hybrid progenies from these crosses. (4).

ECOLOGICAL ADAPTATION

For a seed crop of cowpea, the essential climatic requirements are a reasonably warm growing season, with a fairly good distribution of rain, followed by bright weather during and after flowering. Continuous rain is unsuitable, and when this crop is grown in the wet zone under heavy rainfall, seed yields get reduced, due to excessive vegetative growth.

Cowpea grows well on well drained moderately light, or medium loam soils. Lime in the soil is essential. On rich soils, vegetative growth is excessive, and seed yields low. Soils of medium fertility are best suited for seed crops.

Areas for cultivation

Wet zone conditions are less suitable for the grain varieties of cowpea. (1). Dry zone conditions are definitely more favourable and the crop may be raised successfully anywhere in the dry zone during the Maha, and in those areas of the dry zone which receive about 20 inches of rainfall during the Yala. It can also be raised in paddy fields under village tanks in the dry zone, during the Yala, when the water is insufficient for a crop of paddy. Vegetable varieties may be grown either in the wet zone or dry zone areas.

CULTURE OF THE CROP

Land preparation

The land should be worked to a depth of about 6 to 8 inches, repeatedly, in order to attain a fine tilth.

Seeds and sowing

Cowpea seeds maintain their viability for a long time, up to six or seven years. When sown as a pure crop, the seed rate amount to about 15 to 20 pounds to the acre. Sometimes, cowpea is grown as a mixed crop with sorghum or gingelly. In that case the seed rate is considerably lower. Germination occurs in about 4-5 days.

Spacing

A spacing of 18 inches between rows, and 12 inches within the row is considered to be satisfactory for cowpea.

Nutrition

Heavy manuring is not practised in the case of cowpea for reasons stated earlier. However, a basal dressing of 1 cwt. of superphosphate and ½ cwt. of muriate of potash is usually given during preparatory tillage.

Intercultivation

One intercultivation when the crop is about 3 weeks old is usually adequate. The crop develops a heavy foliage, and weeds are controlled without difficulty.

CONTROL OF PESTS AND DISEASES

Pests

Cowpea is subject to the attacks of several insect pests such as leaf eating caterpillars, sap sucking bugs, plant lice etc. The most important insect pest is the Bean fly (*Agromyza phaseoli* C) which is more serious on the vegetable varieties than the pulse varieties. The bean fly lays its eggs on the leaves soon after the seedlings appear above ground, and the larva burrow through the petiole, into the stem, and eventually pupate at ground level, The plants often exhibit typical swellings and lesions near the collar where the stem gets ruptured by the crowding of larvae and pupae. Frequent spraying with endrin at the rate of 1 fluid oz. in 2 gallons of water gives effective control of the pest. Hilling up of infected plants above the collar region, promotes the development of adventitious roots at points above the lesions, leading to recovery. (6). Endrin sprays are also effective against most of the foliage pests mentioned earlier.

During storage, cowpeas are subject to attack by weevils, as is the case with most other pulses.

Diseases

Cowpeas are subject to attack by these diseases 1. Rust (*Euromyces appendiculatus*). 2. Powdery mildew (*Erysiphe polygmi*). 3. Root rot (*Rhizoctonia* sp.).

Of these the rust and root rot are the most serious. The use of resistant varieties is the only method of control in the case of the rust. The root rot can be controlled by adopting a suitable rotation of crops, as the fungus persists in the soil.

(4). **Stem rot disease.** This is a new disease observed on cowpea and found to be caused by a fungus (*Phytopthora* sp.) The disease appears in irregular patches, quiteoften in healthy plants. The disease appears on the stem, about an inch or two above ground level, in the form of a collar rot. Affected plants show symptoms similar to bacterial wilt, and finally die.

Diseased plants should be removed and burnt, and the land either left fallow for some time or not planted to leguminous crops.

'Black eye 5' and 'Havana' varieties of cowpea are believed to be resistant to the disease. (7).

Harvest

It is usual to harvest the first crop of pods in the tender stage, for the vegetable market. Bombay cowpea is ready for harvest in 3 months from sowing. Other varieties like Birmingham and Christavado are 3½ months varieties. Yala varieties are ready for harvest in 80 days.

When the crop matures uniformly, the crop could be harvested in one operation, by cutting the plants close to the ground, Uneven maturity increases the costs of harvesting, as several picks have to be taken. The harvested pods are dried, and threshed either by treading under the feet of bullocks or beating with wooden flails. The seed is then cleaned by winnowing.

Yields

Average yields of Bombay cowpea in India range from 900-1000 pounds dry seed per acre. Similar yields have been obtained in Ceylon, during the Yala. Maha varieties yield much higher, average yields ranging from 2,400 to 2,500 pounds of dry seed per acre.

Cowpea seed can be used whole in the same way as green gram, or as a split pulse.

Costs of cultivation and returns (8)

	Cost Rs. cts.
1st tillage	22.00
2nd tillage	22.00
Basal fertilizer and application: 2 men	25.00
Cost of seed and planting: 6 women	18.00
Intercultivation and thinning out: 10 women ...	20.00
Pest control	20.00
Harvesting and processing: 14 women	28.00
	155.00

G. P. S. price Rs. 33.60 per cwt.
Approximate yield 9 cwt.

Value of crop	Rs. 302.40
Expenditure	Rs. 155.00
Profit	Rs. 147.40

REFERENCES

1. De Mel, C. N. E. J. and Gaywala, P.M. Recently introduced food crops at the Experiment Station, Peradeniya. 111. Cowpea. Bombay variety. Tropical Agriculturist Vol. XCVI. No. 5. p. 265-73. 1941.

2. Short term implementation programme 1962.

3. Administration Report of the Commissioner of Agrarian Services 1963.

4. Administration Report of the Director of Agriculture for 1961/62.

5. Administration Report of the Director of Agriculture for 1960/61.

6. Fernando, M. The relative resistance of some cowpea varieties to *Agromzya phaseoli*. COQ. Tropical Agriculturist Vol. XCVI No. 4. p. 221-24. 1941.

7. Manikavasagar, P. New disease of cowpea. Circular No. PP/TI/61. 1961.

8. Costs from Dry Zone Research Station, Maha Illupalama.

13. DHAL

Economic importance

Pigeon pea or Tur dhal, also called Red gram, is one of the important pulses imported into Ceylon, although striking possibilities exist for its extended cultivation. Dhal constitutes one of the main protein ingredients in the local diet, containing as much as 22 % protein. The pulse is used chiefly in its split form as dhal, but the tender pods can be used as a vegetable in the same way as garden peas. The plant has several other uses as well. It matures for fodder comparatively quickly, and can be used as a perennial fodder crop. It can also be used as a green manure crop. It can also be grown as a shade crop, cover crop, and occasionally as a wind break hedge plant. The perennial varieties are not much in vogue at the present time, the interest centering mainly on annual dhals, which can be utilized for the production of the pulse.

A guaranteed price has been introduced for tur dhal, which in 1963 stood at Rs. 40.00 per cwt. as against Rs. 30.00 per cwt. paid in 1962. (1). In spite of these attractive incentives there has been little progress in the cultivation of dhal. The main limiting factor for the cultivation of pigeon pea, has been the high incidence of insect pests, particularly pod boring insects, when the crop is grown during the Maha season. Current investigations are therefore being directed towards securing varieties for Yala cultivation, during which time the pest damage is less severe. (2). It has been estimated that nearly 26,000 acres would be required to make Ceylon self-sufficient in dhal. (3).

BOTANICAL DESCRIPTION

The pigeon pea plant (*Cajanus indicus*: *C. Cajan*) belongs to the family Leguminoseae. It is classed under Phaseoleae, one of the divisions of the sub-order Papilionaceae, as a sub-tribe 'cajaneae'. It is a perennial woody shrub, although under cultivation it behaves as an annual. The stems are strong and woody, and freely branching. The plant may attain a height of six to eight feet. The root system is deep and extensive. The leaves are pinnately trifoliate, the leaflets being dotted with numerous minute glands on the lower surface. The inflorescence is a receme either terminal or arising from the axils in the upper branches of the bush. The flowers are yellow. The pods are 2-4 inches long, depending on the variety, about a ¼ inch in diameter. The seeds are 2 to 5 in number and are separated from each other by slight depressions on the pods.

Varieties

There are a large number of varieties, varietal differences being based on height, habit of growth, time of maturity, colour of flower, colour and shape of pods, size, colour and shape of seeds. (4). The varieties can however be classified into two main types:

1. Perennial types—which grow for more than an year, and assume a tree like appearance. Yields are good in the first year, but fall considerably in later years. This type is suitable for shade, fodder, or cover purposes, and can also be used as hedge plants.

Figure 10. Fruiting branch of *Cajanus indicus*

2. Annual types—small, field crops which can be cultivated for seed purposes. The white seeded varieties typified by the Gujerat variety produce a better quality dhal, than the red seeded varieties common to the areas south of Bombay. (4).

Several promising selections have been evaluated in yield trials at Maha Illupalama. Of these, Tur 5 has been found to be a satisfactory strain of dhal for the Maha season. The variety Tenkasi appears to be well adapted for Yala cultivation, during which time pest incidence is not so severe. (5).

CROP IMPROVEMENT

Crop improvement work in dhal has been directed mainly towards obtaining a dwarf type of plant, in which the lateral spread of branches is reduced, to give a small erect bush. This is important in view of the fact that insect damage is high during the Maha season, and when these varieties are carried over into the Yala, when incidence is low, they grow too tall. The present programme of hybridization involves these varieties and a dwarf variety introduced from Trinidad. The work is in progress. (5).

ECOLOGICAL ADAPTATION

The plant is remarkably drought resistant. Under dry zone conditions, it produces seed profusely. (6). Under dry conditions of climate, the crop matures early, and the incidence of pest damage is also low. (2). Under humid conditions on the other hand, the crop tends to produce luxuriant vegetative growth. Rain at the time of flowering, causes defective fertilization. Rainy weather also pre-disposes to attack by the pod-caterpillar. The plant cannot stand wet feet.

Dhal thrives in all types of soil, varying from sand to heavy clay loams. Well drained medium heavy loams are the most suited for its cultivation.

Areas for cultivation

All these factors make it a pulse crop decidedly suited to the dry zone of Ceylon, during the Yala season. For fodder purposes, or for shade, cover, and as hedge or wind breaks it can be grown in the Wet Zone successfully up to an elevation of about 3,500 feet where it could make very luxuriant vegetative growth.

Time of planting

For Maha planting, the seed should be sown as early as possible in October, with the commencement of the first rains. When planted in October, annual varieties would flower in January and yield a first crop in March. The second flowering starts in June and yields a second and final crop in August or September. For

Yala planting, the seed should be sown with the rains in April, but at the present time attempts to establish dhal as a Yala season crop are still in the experimental stage.

CULTURE OF THE CROP

Land preparation

Dhal is often grown in mixture with other crops, and hence the land preparation would depend on the associated crop. Generally the crops with which dhal is mixed are shorter duration crops like kurakkan and sorghum. The Department of Agriculture recommends the growing of sorghum in mixture with dhal. Sets of three rows of sorghum alternate with single rows, of Tur_5 in this case. (7). Here the land preparation undertaken will be as that for sorghum. In India dhal is either raised as a pure crop or grown as a subordinate mixture with other crops such as sorghum, maize, bulrush millet, other millets, gingelly, groundnuts etc. (4).

Spacing

As a pure crop, dhal should be planted in rows 3 feet by 2 feet. When sown as a mixture, the dhal is sown in widely spaced rows ranging from 4-8 feet, depending on the associated crop.

Seeds and sowing

For a pure crop the seed rate amounts to about 8 pounds per acre. The seed rate when grown as a mixture varies from 1½ to 3 pounds per acre. About 3 to 4 seeds may be planted in each hill, and later thinned down to 2 plants per hill.

Nutrition

Fertilizers applied to the associate crop benefit the dhal. For sorghum, a basal dressing of 3-5 tons of F. Y. M. per acre, together with the following fertilizer mixture at or after planting is recommended.

Sulphate of ammonia—1 cwt. per acre.
Superphosphate, ordinary—1 cwt. per acre.

Weed control

During the first month, the dhal crop shares the intercultivation given to the main crop. When grown with groundnut, as in India, the harvesting operations for groundnut involve digging the soil, and this helps as a final intercultivation without any extra cost. (4).

CONTROL OF PESTS AND DISEASES

Severe damage by insect pests, particularly during flower and pod formation, have been the main cause for declining yields observed at Maha Illupalama, since the first years after the introduction of the annual dhal varieties for cultivation. (8). This has also been the chief limiting factor to the extension of dhal cultivation. The annual dhal variety yields twice, once in Maha and again in Yala, and the pests of the two seasons are different. (8). They may be listed as follows:

Pests of Maha season

1. *Maruca testulalis.* The caterpillar of this moth causes the most serious damage in the early Maha, attacking as much as 50% of the flowers and pods. The egg is laid on the bud, and the young caterpillar on hatching bores into unopened buds and attacks these from inside. It also attacks young pods and eats up the seeds.

2. *Lampides boeticus.* Damage due to this pest is about 10-15%. The caterpillar attack decreases as the season progresses. The blue copper butterfly can be seen fritting about the crop right through the season. The eggs are laid on the bud, and the emerging caterpillar bores into the unopened buds, causing damage.

3. *Heliothes armigera.* The caterpillar of this pest, which is common in most leguminous crops, attacks buds and pods as above. The pest builds up towards the tail end of the Maha season. Damage may amount to 15-20%.

4. *Mylabris pustulata.* This is a flower eating beetle appearing around February and remaining till the flowering is over. This is not a very serious pest.

5. *Sphenarches caffer.* The caterpillar of this plume moth also causes bud and pod damage.

6. *Dolichothrips varipes.* Thrips are common, and found in large numbers on each bud. Severe attack results in drying and falling off of buds.

Control measures most effective for these Maha season pests are two or three sprayings with either Dieldrin at the rate of 1 fluid oz. in 1 gallon of water or Endrin at the rate of 1 fluid oz. in 2 gallons of water. Cost of spraying would work out to Rs. 22.50 per application with Dieldrin and Rs. 15.75 per application with Endrin, including the cost of labour. (8).

Pests of Yala season

The incidence of pest attack during the Yala season is markedly less than in the Maha. The following pests are common during Yala.

1. *Melanagromyza obtusa.* This is the only significant pest of the Yala. The fly lays its eggs through a hole inside the seed chamber of a developing pod. The emerging maggot lives on the seed. Each maggot eats only one seed. No

external damage is visible on the green pod, but the damage is usually serious amounting to 50-75% loss at times. Partly damaged seeds are also subject to bacterial and fungal attacks, and are rendered useless.

2. *Mylabris pustulata*, *Maruca testulalis*, *and Lampides boeticus*, which are serious pests in the Maha, do not reach significant proportions in the Yala.

Malathion spray at a concentration of 1 fluid oz. in 4 gallons of water gives the best results in the control of *M. obtusa* which may be considered to be the chief pest of the Yala.

DISEASES

Wilt disease (*Fusarium udum*)

This is the most serious disease of dhal. Attacked plants completely dry up, and may be seen here and there in the field. The wilt is due to the attack by the soil dwelling fungus, which gains entry into the plant through the root. Effective method of control is to grow resistant types, which are now available.

Harvest and yields

Harvesting is done by cutting the whole plant by means of a sickle. (In harvesting the first crop, it may be necessary to pick the beans by hand.) The cut plants are dried in the field for a couple of days, and then threshed on a threshing floor, either by beating with wooden flails, or by trampling under the feet of bullocks. The grains may now be cleaned by winnowing.

Yields of pure crops range from 800-1000 pounds per acre.

As a mixture the yields vary from 300-600 pounds per acre.

Maha Illupalama yields which ranged from 1200-1500 pounds per acre, have declined over the years to between 400-500 pounds per acre, due to insect damage.

Preparation of dhal

Good quality dhal, cooks soft on boiling, and retains this quality during long periods of storage. Two well defined methods are in vogue for the preparation of the commercial product.

1. **Dry method.** This involves preliminary sun-drying for 3 to 4 days, followed by partial splitting of the grains. The partial splitting is meant to crack the seed coat, and this is usually done on a stone mill, by feeding the grains rapidly into the mill. The partially split seeds are then treated with vegetable oil and stored. For long storage, castor oil is used. For short storage, of less than a month gingelly oil is used. The oil gets absorbed into the seed coat, and assists in the final splitting of the dhal. A modification of the dry method using coconut oil instead of gingelly oil was tried out and found

successful under Ceylon conditions. (9). In this method, the quantity of oil to be used during curing is greatly reduced, and is dispensed with entirely at the end of curing, thus preventing any rancidity developing during storage. A second sun drying of the treated grains for two to five days precedes the final splitting which is completed on the stone mill, by feeding the grains at a slower rate. The split dhal is now separated and cleaned from the seed coat by sieving and winnowing. The dhal is then treated finally with castor or gingelly oil at the rate of about 2½ pounds per 100 pounds of dhal, and is then ready for sale.

Dhal prepared by this method is of the perfect half-moon shape, cooks soft on boiling, and fetches a high price in the market. From 100 pounds of seed about 66 pounds of clean, good quality dhal can be obtained.

2. **Wet method**

The dhal is allowed to soak in water for about 6 hours, after which the water is drained away. At this stage, fine well sieved earth, at the rate of 5 pounds per 100 pounds of grain is added and well mixed. The mixture of soaked grain and earth is heaped during the night, and dried in the sun for a couple of days. The process is again repeated, the impurities then removed, and the seeds split into their halves on the stone mill.

About 80 pounds of dhal can be obtained from 100 pounds of seed by this method.

Costs of cultivation and returns (10)

	Cost Rs. cts.
1st tillage	22.00
2nd tillage	22.00
Basal fertilizer and application	25.00
Cost of seed and planting: (6 women)	18.00
Intercultivation	22.00
Top dressing ½ cwt. sulphate of ammonia: (3 women)	15.00
Pest control (Maha)	50.00
Bird scaring (1 woman, 1 month) Maha	60.00
Harvest (cutting) (3 men) Maha	7.75
Processing (8 women)	16.00
Pest control (Yala)	20.00
Bird scaring (1 woman, 1 month) Yala	60.00
Harvesting and processing (Yala)	22.75
	359.50

G. P. S. rate Rs. 40/- per cwt.
Approximate yield 10 cwt.

Value of crop		Rs. 400.00
Expenditure		Rs. 359.50
	Profit	Rs. 40.50

REFERENCES

1. Administration Report of the Commissioner of Agrarian Services.

2. Administration Report of the Director of Agriculture 1960/61.

3. Short term implementation programme 1962.

4. Gaywala, P.M. The cultivation of *cajanus cajan* and the methods of preparing marketable dhal. Tropical Agriculturist Vol. XC. No. 4. p. 212-221. 1938.

5. Administration Report of the Director of Agriculture. 1961/62.

6. Dhal (*Cajanus cajan*). Food production leaflet No. 7. Leaflet No. 176. Department of Agriculture.

7. Sorghum. Circular No. 8. Department of Agriculture.

8. Thevasagayam, E. D. and Canagasingham, L.S.C. Some observations on the insect pests of dhal (*Cajanus cajan*) and their control. Tropical Agriculturist Vol. CXVI No. 4. p. 287-298. 1960.

9. Gaywala, P. M. Recent progress in the cultivation of *Cajanus cajan* and the methods of preparing marketable dhal in Ceylon. Tropical Agriculturist Vol. XCIII No. 5. p. 257-70. 1939.

10. Costs from Dry Zone Research Station, Maha Illupalama.

14. SOYBEAN

Economic importance

The importance of soybean as a pulse crop, is due to its high food value, containing as it does 40% protein, 20% fat, and the vitamins, A, B and D. The yield of protein, weight for weight is said to be approximately twice that of meat, four times that of eggs, and twelve times that of milk. (1). Soybean protein contains in addition, all the essential amino acids for human food as well as animal feeds.

Soybean seed can be cooked in a variety of ways, the most convenient use however, is in the form of milk. In this way, soybean gained considerable importance during the war in Ceylon, as a substitute for milk foods which were in short supply, and also as a substitute for coffee. The cultivation of this crop, decreased after the end of the war, and today it is a pulse crop of minor importance, confined only to a few areas, in small extents.

Soybean, a native of Eastern Asia, is one of the oldest of cultivated crops. Its history is lost in antiquity. The most important soybean producing countries are China, Manchuria, U. S. A., Korea and Japan. In the U. S. A. the crop is cultivated for seed, hay and forage, and as a green manure. The seed is used for extraction of oil and also for flour.

BOTANICAL DESCRIPTION

The soybean plant (*Glycine max*) is an annual legume, usually erect, burly and leafy, and attaining a height of between 1½ to 3 feet. The soybean plant has a strictly determinate growth habit, that is the plant reaches a definite size, matures and dies. The plant has trifoliate leaves, the leaflets generally being ovate-lanceolate. With approaching maturity, the leaves turn yellow, and finally drop off before the pods mature. Leaves and stems are usually pubescent. The flowers which may be purple or white are borne in axillary racemes on peduncles arising at the nodes. Flowering is progressive from the base of the stem upwards. The pods are small, either straight or slightly curved and are covered with hairs. The colour of the pods varies from straw yellow to black. Each pod contains anything from 1 to 4 seeds. The seeds vary in shape from round to elliptical. Seeds too vary in colour from yellow to black, but are generally unicoloured. Sometimes the seed coats of certain varieties show mottling, under suitable environmental conditions, such as rich soils, liberal spacing between plants, and shading. (2). Mottling may also be due to hereditary factors.

Soybean is a self-fertilized plant. Natural crossing is less than 1 %, (3, 4) but this may account for many varietal mixtures.

Varieties

Soybean varieties differ widely in seed colour, flower colour, and colour of pubescence. (5). Varietal differences are also based on size of seed, and period of maturity. The large seeded varieties mature in 3-3½ months, and the small seeded varieties in 4-5½ months. The large seeded varieties are considered to be the most palatable. The small seeded varieties are more suited for use as green manures.

ECOLOGICAL ADAPTATION

The climatic requirements for soybean are somewhat similar to those of maize. (2). A wet season may not seriously limit growth, but soybeans are sensitive to over irrigation. (6). Excess moisture or prolonged drought, at the time of germination, is particularly injurious to the crop. (7). At elevations of over 5,000 feet, growth of the crop and the production of seed is generally not satisfactory.

Soybeans can be grown on a wide range of soils, but do best on fertile medium loams. Soybean soils must contain the proper nitrogen fixing bacteria. When grown on the same land for two or three successive seasons, increasing yields are obtained year by year.

Areas for cultivation

The crop is suited to the dry zone, although it is cultivated successfully in the low and mid country wet zone. In Jaffna, it can be raised successfully under irrigation from March to September.

Planting season

In the dry zone, the crop is sown in the Maha during October or November. In the wet zone, the crop can be grown either in the Maha or in the Yala. Yala planting should commence around April.

CULTURE OF THE CROP

Land preparation

The soybean crop requires very thorough cultivation, and land preparation should be done so as to provide a deep loose seed bed. Repeated working of the soil is necessary, and all weed competition must be controlled to prevent competition for soil moisture.

The soil for soybean culture should have the appropriate bacteria involved in nodulation. Otherwise, 100-150 pounds of soil inoculum from an area where the crop has been grown successfully is collected, allowed to dry, sieved and broadcast over the new area and harrowed in. (8).

SEEDS AND SOWING

Seed treatment

The seed should be inoculated with the nodule forming bacterium, if it is being grown for the first time on the land. Pure cultures of the Rhizobium may be obtained from agar cultures and used for inoculating the seed. The seed should be sown within a week of inoculation, as the bacterial numbers on the inoculated seed decline rather rapidly with storage.

Seed rate

Soybean seed is generally drilled in rows not more than 1 inch deep, and at the rate of one seed per hill. The following seed rates may be used. (9).

Large seed—90 pounds to the acre at a spacing of 1 foot by 3 inches.

Medium seed—20 pounds to the acre at a spacing of 2 feet by 3 inches.

Small seed—20 pounds to the acre at a spacing of 2 feet by 3 inches.

Nutrition

Nitrogen fertilizers are not considered necessary where the soil is inoculated with soybean nodule bacteria. (2). Lime applications, on very acid soils stimulate nodulation, and promote higher yields. An application of about 5 cwt. to 1 ton, per acre of air slaked lime, depending on the acidity of the soil about 2 to 3 weeks prior to sowing is recommended. (8). Applications of both potash and superphosphate to deficient soils gives beneficial results.

Weed control

At least two intercultivations should be given at monthly intervals to effectively control weeds. Later on the crop foliage effectively shades the soil and controls weeds.

Irrigation

Irrigation is practised, particularly in Jaffna when the crop is grown between March and September. It must be realized however, that irrigation practised soon after planting generally results in poor germination. If irrigation becomes necessary at planting time, the water should be laid on, and then free moisture allowed to evaporate or drain away before planting, and no further irrigation should be applied until after germination is complete. (1).

CONTROL OF PESTS AND DISEASES

Pests. The soybean is attacked in the field and in storage by certain insect pests.

1. Leaf eater moth (*Lamprosema indicta*). The caterpillar of this moth rolls the leaves into feeding shelters, and cannot be easily poisoned. Control measures adopted amount to dusting with lead arsenate and hydrated lime in the ratio of 1 : 6 respectively.

2. *Ceratoma denticolis*. Both immature and adult forms, feed on the foliage causing holes. Control measures are similar to above.

3. Stored grain moth (*Ephestia* sp.). The larvae attack stored seed.

4. Storage weevil (*Mulabris* sp.), also attacks stored seed. Fumigation with carbonbisulphide may be used to control the storage pests. Paradichlorobenzene when used for the control of storage pests lowers seed vitality. (1).

DISEASES

Virus disease

A virulent, virus disease, causing discolouration and distortion of leaves, occurs occasionally in the field. Being initially caused by seed, it later spreads from field to field, being transmitted by insect vectors. Infected plants should be rogued and destroyed, as otherwise the initial infection from seed, will be easily spread throughout the field by other agencies.

Harvest

Harvest is simple, and should be undertaken when the pods turn brown. The plants are snapped off at the soil surface, and sun dried. When fully dry, the seeds shatter. Light flailing extracts the rest of the seed.

Yields

Average yields amount to between 20-23 bushels per acre. Good yields may go up to 30 bushels.

Storage

The seed should be well dried in the sun for 2-3 hours a day, for several days prior to storing. Air tight bins should not be used, as this produces rancidity in the seed, spoiling them for either seed or consumption purposes. Storing in sacks or open bins is the recommended practice.

Costs of cultivation and returns (10)

		Costs Rs. cts.
Preparatory tillage: 5 machine hours: 2 units	...	62.00
Cost of seed: 12 pounds at 20 cts. per pound	...	2.40

Sowing (drilling): animal hire and 2 units ...	15.00
Cost of one intercultivation inclusive of any handweeding, animal hire: 8 units	30.00
Fertilizers and application: ½ unit	40.00
Harvesting: 8 units	20.00
Threshing and winnowing (mechanical)	15.00
Cleaning seed: 2 units	12.00
Measuring and bagging: 3 units	15.00
	211.40

Yield 1600 pounds		
Value at 20 cts. per pound	Rs.	320.00
Expenditure	Rs.	211.40
Profit	Rs.	108.60

REFERENCES

1. Hutchings, C. D. The Soybean—Glycine max. The Journal of the Jamaica Agric. Society. Vol. XLV No. 6, 7. 1941.

Also Tropical Agriculturist Vol XCVII. No. 5. p. 302-306. 1941.

2. Martin, J. H. and Leonard, W H. *Principles of Field Crop Production*. The MacMillan Co. N. Y. p. 735-754.

3. Garber, R. J. and Odland, T. E. Natural crossing in Soybeans. Jour. Amer. Soc. Agron, 18. 967-970. 1926.

4. Woodworth, C. M. The extent of natural cross-pollination in Soybeans. Jour. Amer. Soc. Agron. 14. p. 278-283. 1922.

5. Etheridge, W. C., Helm, C.A. and King, B.M. A classification of Soybeans, Mo. Agr. Exp. Stn. Res. Bull. 131. 1929.

6. Robertson, D.W., Kezer, A. and Deming G.W. Soybeans under irrigation in Colorado. Colo. Agri. Exp. St. Bull. 392. 1932.

7. Morse, W. J. and Cartter, J.L. Soybeans culture and varieties. U.S. Dept. Agr. Farmer's Bull. 1520. (revised) 1939.

8. The Soybean. Leaflet No. 175 (revised) Department of Agriculture, Ceylon.

9. The Soybean. Leaflet No. 175. Food production leaflet No. 6. Department of Agriculture, Ceylon.

10. Costs from Central Experiment Station, Peradeniya.

15. GREEN GRAM

Economic importance

Green gram is both an important and a wholesome pulse. It is also reputed to be free from the flatulence and heaviness produced by most other pulses. The split gram is consumed as food, and enters into a number of preparations. The whole gram can also be boiled or roasted and eaten. The husks can be soaked and used as cattle feed. Green gram can be used as a satisfactory substitute for lentils which up to now have not been grown in Ceylon, and on the imports of which nearly Rs. 15 million are expended each year. (1).

The guaranteed price for green gram is Rs. 49.92 per cwt. for Grade I, and Rs. 40.32 per cwt. for Grade II. This has been found to be lower than the cost of production and has stood in the way of an extension in the cultivation of green gram. (1). The amounts offered for sale under the guaranteed price scheme, amounted to only 82 cwt. in 1960, and only 10 cwt. in 1961. (2). An increase in the guaranteed price paid for green gram has been consequently proposed, the increase to be met by the imposition of an equivalent duty or cess on imports of this commodity. (1).

BOTANY AND VARIETIES

Green gram (*Phaseolus aureus*), belongs to the family Leguminoseae and the sub-family Papilionaceae. The plant is a small shrub, reaching about a foot in height. It is diffusely branched, and the leaves have a dark green appearance. Flowers arise in the axils of the leaves in elongated racemes, and are of a light tint in colour. The pods are small, the seeds green in colour and small in size. The split pulse is yellow in colour. The plant is closely allied to the black gram in appearance.

Recommended variety

The strain Mung (M. I. 1.) is recommended for cultivation, and has performed well for several seasons in trials conducted at Maha Illupalama. (3).

Crop improvement

Current work with green gram is directed towards securing varieties which could be gathered in one single harvest.

ECOLOGICAL ADAPTATION

Green gram is most suited to areas having a rainfall of less than 35 inches. In heavier rainfall areas, it can be grown after the cessation of the main heavy showers. It can be grown from sea-level up to an elevation of nearly 6,000 feet.

Green gram is most suited to soils that tend to be slightly clayey. As such good crops can be obtained on rice soils in the off season, or just before or after the crop of paddy. In India this is common practice, a couple of irrigations being given wherever necessary. (3). It can also be raised on red light loams, or on alluvial soils, provided they are sufficiently deep.

Areas for cultivation

The unirrigated high lands which would otherwise lie fallow during the Yala season offer possibilities for green gram cultivation. The main districts of cultivation are Jaffna, Polonnaruwa, Kurunegala, Badulla, Colombo, Ratnapura, Kegalle, and Kandy. Smaller extents are also cultivated in the following districts: Puttalam, Batticaloa, Hambantota, Kalutara and Matale.

Time of planting

Green gram is a short aged crop, the green pods being ready for picking in about 70 days from planting, and the ripe pods being ready for harvest in a further 3 weeks. As such green gram can be used as a catch crop, and planted mid season, in the Maha, after the heavy rains have ceased. Yala planting is usually around April, with the first light showers, in dry zone areas. In the low country wet zone, mid season planting is again the best.

CULTURE OF THE CROP

Land preparation

Land preparation for green gram is similar to that for cereals, except for the fact that most often, a very fine tilth is not attempted, and only a rough tilth secured. A shallow ploughing followed by a couple of diskings is usually sufficient. Clods should be broken down, and all trash removed.

Seeds and sowing

Green gram can be sown as a pure crop, or as a mixed crop. When sown as a mixed crop, it is usually subordinate to a taller, and longer aged crop. In India it is often sown as a mixed crop, subordinate to sorghum. (4.) It can further be sown for green manurial purposes particularly in paddy fields. The method of sowing, as well as the seed rate will therefore depend on the type of culture practised. As a green manure, the crop is usually sown broadcast. When grown for seed, it may be either sown broadcast or may be drilled in rows. The seed rate for a pure crop is about 15 pounds to the acre. Germination occurs in 3 to 5 days.

Spacing

When drilled in rows, a spacing of 10 inches between rows is common.

Intercultivation

About two cultivations are usually necessary, the first about 20 days after germination, and the second a fortnight later.

Nutrition

A basal dressing of 1 cwt. of superphosphate and ½ cwt. of muriate of potash gives good results.

CONTROL OF PESTS AND DISEASES

1. **Bean fly** *Agromyza phaseoli*

This is a common pest, and can be found on the leaves soon after the plants germinate. They lacerate the leaves. The larvae bore into the tissues, and finally traverse down the stem and cause a rot at the collar. Routine spraying with endrin at the rate of 1 oz. in 2 gallons of water gives effective control.

2. Other pests attacking this crop are similar to those found attacking cowpea. Control measures are similar to those described under cowpea.

Diseases

A virus disease, resulting in yellowing of the leaves has been observed at Maha Illupalama on both green gram and black gram. The disease is similar to that in Bandakka and is under study at the present time.

Harvest and yields

Green pods can be picked for vegetable in about 70 days from planting. In a month's time after that, the pods are dry, and the crop is ready for harvest. Plants may be harvested by pulling them out with their roots. They are then stacked for about a week on a threshing floor, after which they may be threshed either by beating with sticks, or trampling with the feet of oxen.

Good yields amount to about 800-900 pounds to the acre.

Costs of cultivation and returns (5)

	Cost Rs. cts.
1st tillage	22.00
2nd tillage	22.00
Basal fertilizer and application: 2 men	25.00
Cost of seed and planting: 6 women	18.00
Intercultivation and thinning out: 10 women ...	20.00

Pest control	20.00
Harvesting and processing: 14 women	28.00
	155.00

G. P. S. rate Rs. 45/- a cwt. (average of 2 grades)
Approximate yield 8 cwt.

Value of crop	Rs.	360.00
Expenditure	Rs.	155.00
Profit	Rs.	205.00

REFERENCES

1. Short Term Implementation Programme 1962.
2. Statistical Abstract of Ceylon 1962.
3. Administration Report of the Director of Agriculture 1960/61.
4. Yegna Narayan Aiyer, A. K. *Field Crops of India.* Govt. Press, Bangalore. p. 137-9.
5. Costs from Dry Zone Research Station, Maha Illupalama.

16. BLACK GRAM

Economic importance

Black gram, like glutens in wheat, possesses the property of 'raising' the various cakes made from it, and also has the capacity to give additional 'body' to the mass, when finely ground. It is a valued pulse which enters into several food preparations. As a cattle feed, when added to other materials like bran, black gram is believed to increase the flow of milk.

BOTANICAL DESCRIPTION

Black gram (*Phaseolus mungo*) belongs to the family Leguminoseae, and the sub-family Papilionaceae. The plant is a small shrub, attaining a height of about a foot, diffusely branched, and having both leaves and stems covered with rough reddish hairs, which impart to the plants a dark green colour. The plants have a strong tap root, and many lateral roots. The flowers are yellow in colour, and are borne in the axils in elongated racemes. The pods are long and cylindrical being about $1\frac{1}{2}$ to $2\frac{1}{2}$ inches in length, and septate between the seeds which may vary from 8-15 in each pod. The seeds are generally black, or very dark brown. The split seed of black gram is white in colour.

Varieties

Two varieties are generally distinguished in black gram, one being small seeded and the other large seeded. The large seeded variety is early maturing, has black seeds, and is generally considered to be the better of the two varieties. (1).

Of several strains evaluated at Maha Illupalama over several years, the strain M. Y. I. was found to be consistently superior to the control strain Tabbowa, yielding about 50% better than the control variety. (2). This strain is now recommended for cultivation.

Crop improvement

As in the case of green gram, current crop improvement work is directed towards securing varieties which can be gathered in one single harvest.

ECOLOGICAL ADAPTATION

The climatic requirements of black gram are similar to those of green gram. It is essentially a crop for dry areas, having a rainfall of less than 35 inches. It can be grown from sea-level up to an elevation of nearly 6,000 feet.

Black gram is quite suited to soils which are clayey. Red or light loams can also be put under this crop. It can be successfully raised on paddy soils just before or after the paddy crop.

Areas for cultivation

Black gram can be grown in the same areas that are considered suitable for green gram. The unirrigable highlands of the dry zone, offer possibilities for black gram cultivation during the Maha. In the low country and mid country wet zone, it should be possible to raise successful crops during the Yala.

Time of planting

Black gram is a three months crop, and should be planted immediately after the heavy monsoon rains in the Maha, around the middle of November. For Yala planting, sowing should commence around the middle of April.

CULTURE OF THE CROP

Land preparation

The land is prepared with one ploughing, followed by working with a blade harrow or cultivator. Only a rough tilth is attempted.

Seeds and sowing

The seeds are generally sown broadcast, and ploughed in or drilled in rows 10 inches apart. The seed rate is about 15 pounds to the acre. Germination occurs within a week.

Intercultivation

About two intercultivations are given the first 20 days after planting, and the second a fortnight later.

Nutrition

Very little fertilizer application is practised. The use of a mixed fertilizer (16: 8: 8) at the rate of 1 cwt. to the acre, initially at planting, and later at flowering gives good results. A basal application only of 1 cwt. of superphosphate and ½ cwt. of muriate of potash is also common practice.

Control of pests and diseases

The pests and diseases of this crop are similar to those on green gram. Control measures are similar to those described earlier.

Harvest

Flowering commences in about 7 weeks after planting, the pods being ready for gathering, in about 3 months from the planting date. The plants are pulled by the roots, stacked on a threshing floor for about a week and threshed by flailing or treading under the feet of oxen. The seeds are then dried, cleaned and stored.

Yields

Average yields amount to about 8 cwt. per acre. In yield trials at Maha Illupalama the strain M. Y. I. gave 849 pounds to the acre.

Costs of cultivation and returns (3)

	Cost Rs. cts.
1st tillage	22.00
2nd tillage	22.00
Basal fertilizer: 1 cwt. superphosphate, ¼ cwt. muriate of potash and application: 2 men	25.00
Cost of seed and planting: 6 women ...	18.00
Intercultivation and thinning out: 10 women ...	20.00
Pest control	20.00
Harvesting and processing: 14 women	28.00
	155.00

Price Rs. 45/- a cwt. Approximate yield 8 cwt.

Value of Crop	Rs. 360.00
Expenditure	Rs. 155.00
Profit	Rs. 205.00

REFERENCES

1. Yegna Narayan Aiyer, A. K. *Field Crops of India*. Govt. Press, Bangalore. p. 134-6.

2. Administration Report of the Director of Agriculture for 1960/61.

3. Costs from Dry Zone Research Station, Maha Illupalama.

17. BENGAL GRAM

Economic importance

Bengal gram is a popular pulse crop, which is eaten either boiled or fried. It is valued for its high protein content. Raw gram soaked in water is used as a feed for horses. Most of the Bengal gram consumed in Ceylon is imported. The imports of this pulse in 1964 amounted to 370,856 cwt. costing Rs. 9,630,088. (1). Very little is grown locally. It is however, the most important pulse crop of India. It is widely cultivated also in Southern Europe and Asia.

BOTANY AND VARIETIES

Bengal gram, also called chic pea or kadala, belongs to the family Leguminoseae. It is distinguished botanically as *Cicer arietinum.* The plant is a small, much branched, shrub attaining a height of about a foot. The leaflets of the pinnate leaves, are small, and have serrated edges. The leaves are covered with glandular hairs. The plants present a bluish green appearance. The flowers are solitary and are present in the axils of the leaves. Self fertilization is the rule, but cross pollination may occur to the extent of about 5-10%, due to the agency of insects. The pod is about an inch long and usually contains two seeds. The root system of the plant traverses down to about a foot.

Varietal differences in Cicer, are based on the colour and size of the flowers and their seeds. On the basis of seed colour, 4 main varieties can be distinguished, the varieties having brown, yellow, black and white seeds. The white seeded variety is the largest, and its beak is not as prominent as in the case of the other varieties, which also have a crinkled appearance. The white seeded variety is generally the better yielder, possessing in addition better quality.

ECOLOGICAL ADAPTATION

In India, Cicer is grown as a dry crop, but occasionally the crop is raised also under irrigation. It is generally a crop for the late season, after the heavy monsoonal showers have abated. In this way it can be grown as a late Maha crop, in the dry zone, during cooler weather, or in the Rahangala area in the up-country, where cooler conditions prevail.

In India the crop is grown on the black cotton soils which are highly retentive of moisture. Clayey loams are generally preferred for this crop. The crop can be raised also on lighter soils of the alluvial loam type. As a second crop after rice, it does well on soils having greater moisture retentive capacity. (2).

CULTURE OF THE CROP

Land preparation

Land preparation involves working of the soil, in order to achieve a rough tilth. The clods should be broken down, and the field levelled roughly prior to planting. Fine tilth is not essential to this crop.

Seeds and sowing

Seeds are generally sown in rows spaced about a foot apart. The seed rate amounts to 40-50 pounds per acre.

Intercultivation

A single intercultivation given about 3 weeks after planting is usually adequate. After that the crop develops sufficient foliage to cover the soil and smother the weeds. Cicer, is reputed to control weed growth effectively.

Nutrition

No direct manuring is practised in the case of Cicer, as luxuriant growth on rich soils results in poor seed set. On poor soils, a basal dressing of cattle manure or compost would be beneficial.

Topping

Sometimes, the plants are topped in order to induce vigorous branching, which results in a greater number of flowers and fruits. Topping may be undertaken about the time the plants begin to branch. In India and Pakistan, it is common practice to graze the crop with sheep or goats, when it is about 1 foot high.

Control of pests and diseases

The Cicer crop is subject to attack by a pod boring grub, which reduces the pods to empty shells. The damage is however not serious. The standing crop is also subject to a wilt disease, (*Fusarium orthoceros*) which results in the wilting of the plants at the flowering stage or slightly later. Resistant varieties are now available. (3).

Another common disease of Cicer is blight (*Ascochyta rabiei*). Brown spots of varying sizes appear on the leaves, stems, branches etc., and the diseased plants show partial or complete drying up. The disease is seed borne. Resistant varieties are now available. (2). Healthy seeds only should be planted as a measure of control.

Occasionally the flowers of Cicer remain sterile, without setting seed.

Harvest

A certain amount of the pods may be harvested when not fully ripe, and sold for cooking as a vegetable.

The crop reaches maturity in 3 months time, about which time the leaves turn brown, dry and shed on the field. The plants are harvested by pulling them with their roots. The harvested plants are stacked for about a week, after which the pods are threshed by trampling under the feet of bullocks, or beating them with wooden flails.

Yields. Average yields amount to about a 1,000 lbs. of seed to the acre. Good yieds may reach 1,800-2,000 lbs.

Harvest of acids from the leaves of Cicer

The leaves of the Cicer plant are coated with a thin film of a mixture of oxalic and malic acids, which impart to the leaves and the pods a sour taste. In India these acids are collected by spreading a thin muslin cloth over the crop in the night, so as to enable the dew dissolved acids to soak on the cloth. In the morning the cloth is wrung out, and the acids collected in bottles and sold, for their medicinal properties. The liquid is recommended for bowel complaints. (3).

REFERENCES

1. Customs Returns 1964.

2. Naqvi, R. H. and Aziz, M. A. Cultivation of Gram in West Pakistan. Agricultural series leaflet No. 9. Govt. Press, Karachi. 1963.

3. Yegna Narayan Aiyer, A.K. *Field Crops of India.* Govt. Press, Bangalore p. 126-31.

18. LENTILS

Economic importance

Lentils account for the major portion of the import value of pulses into Ceylon which in 1961 stood at Rs. 42 million (1). Guaranteed prices for cowpea, toor dhal, etc., were introduced with the intention of reducing the import bill on lentils. Because of its special ecological requirements, lentils have not been grown on any appreciable extents up to the present time. Trials being conducted at Rahangala indicate, however, that there is a potential for this crop in certain agro-climatic zones.

As a pulse crop, its importance cannot be overstated. As split pulse or dhal, it enters into everyday cooking, providing the necessary protein supplement to the common cereal foods.

BOTANICAL CHARACTERS

Lentils (*Lens esculenta*) belong to the family Leguminoseae. The plant is an erect bush, attaining a height of one to two feet. The leaves are compound and pinnate and terminate in a tendril. Small sessile leaflets occur in pairs of 4 to 6. The inflorescence is a raceme of 2 to 4 flowers. These may be white, purple, or pink in colour depending on the variety. The pods are small and two seeded.

Varieties

Varietal differences are based on the colour of the flowers, as well as the colour, shape, and mottling of the seeds.

Of 13 different varieties tested out at Rahangala the variety NP-11 from India showed the most promise. (2).

ECOLOGICAL ADAPTATION

Lentils are grown chiefly as a cold weather crop, and as such can be said to be suited to particular agro-climatic zones. The crop is under study at Rahangala at the present time. In North-West India lentils are cultivated even at elevations of 11,500 feet.

The soil requirements are not so exacting. Light loams, alluvial soils, and soils of moderate alkalinity are all suited to the crop.

CULTURE OF THE CROP

Under Rahangala conditions, planting is commenced towards the end of November. The crop is completely rainfed.

The land for planting is ploughed, harrowed, and brought to a fine tilth. The crop is row sown at 9-12 inches, using a seed rate of 25-30 pounds.

Two intercultivations are given for purposes of weed control, and to help the crop to establish itself.

A 2: 3: 1 NPK mixture is applied at planting. This is followed by a top dressing of ammonium sulphate at flowering.

Pests and diseases

No serious pests or diseases have been noticed in the test plots at Rahangala. (2).

Harvest and yields

The crop flowers in 6 to 7 weeks and is ready for harvest in 3½-4 months. When ready for harvest the plants are cut to ground level, dried, and later threshed under the feet of bullocks. Yields amount to 300-350 pounds per acre.

REFERENCES

1. Short term implementation programme 1962.

2. Vaz, C. R. de, Agricultural Research Officer, Rahangala. Private communication.

GROUP III—FIBRE CROPS

19. COTTON

Economic importance

The economic importance of cotton derives mainly from its harvestable fibres, which are products of its seed. Each of the fibres of cotton originates as a single cell of the epidermis of the seed coat and later elongates to become a short, medium or long length fibre. These fibres are used largely to supply one of the primary human needs, namely clothing. Besides fibres, many other important products are also obtained from cotton seeds, particularly oil and animal feed. After removal of the lint, further processing of the seed results in 7% of its weight as linters, 26% as hulls, 15% as oil, 45% as cake and 7% is waste. The oil can be put to several uses, chief among which are the manufacture of lard substitutes, soaps, salad and cooking oils. The cake contains as much as 45% protein, and makes valuable feed for livestock. When finely ground it is referred to as cotton seed meal.

Ceylon's annual requirements of cotton textiles was estimated at nearly 90 million yards in 1958. Production at the Wellawatte Spinning and Weaving Mills and other local handlooms was said to account for about 1/8 of this quantity. Even for this meagre production the country's output of raw cotton was considered insufficient. As a result these mills have had to depend on imported supplies of raw cotton, to keep them running economically. The Agricultural plan of 1958 (1) envisaged the development of 8,000 acres for the cotton project in the Hambantota District. Of this extent 2,400 acres were to be developed for cotton cultivation on a two course rotation, under which 1,200 acres were to be cultivated annually with cotton. The original scheme has now been revised to include the development of only 2,400 acres, of which 1,200 acres will carry cotton annually on a two course rotation. The short term implementation plan of 1962, estimated that by 1964, approximately 6,000 tons of raw seed cotton would be required to meet the full requirements of the Wellawatte and Veyangoda Weaving mills and also the local handloom industry. It estimated that 12,000 acres producing an average yield of 5 cwt. of seed cotton would be necessary to achieve this production and considered it necessary also to encourage the cultivation of cotton, on chena lands, by private farmers. The necessary incentives were to be provided to private farmers to cultivate nearly 10,000 acres on this basis. The most recent proposal envisages however a larger irrigated cotton project under the Walawe Basin development scheme.

BOTANY OF COTTON

The cotton plant belongs to the family Malvaceae and the genus *Gossypium*. It is believed to have had two centres of origin namely

Indo-China and Tropical Africa in the Old World and South and Central America in the New World. Examples of American cottons are *Gossypium hirsutum* which is the American upland cotton whose fibres range from $\frac{3}{4}$ to $1\frac{1}{4}$ inches or more in length, and *Gossypium barbadense* to which belong the sea island and American Egyptian cottons which have extra long, fine fibres $\frac{1}{2}$ to 2 inches long. The Asiatic cottons are *Gossypium arboreum* and *Gossypium herbaceum* whose fibres are short and coarse from $\frac{1}{2}$ to 7/8 inches. The chromosome number in the American cottons is 26 while that in the Asiatic cottons is 13. Crosses between the two have not produced consistently fertile hybrids.

Given below are some striking botanical differences between the Asiatic and the New World cottons:

Character	Asiatic cottons	New World cottons
1. Stem and leaves	Green, upright, narrow habit.	Reddish tinged leaves. Broader habit.
2. Flowers	Deep or Canary yellow. 'Eye' or large black dot present deep inside the flower at base of petals.	Cream coloured, large and red when closing. No dot present.
3. Bolls	Small, with 3 to 5 locks. Seed cotton is held firmly.	Large and roundish. Fibres held very firmly making ginning more difficult.
4. Colour	White, Khaki	Brilliantly white.
5. Staple length	Short, medium	Medium long.

The cotton plant is herbaceous, has a tap root, and attains a height of 2-5 feet. It has a main stem from which leaves arise in a regular spiral arrangement. It has two types of lateral branches—vegetative and fruiting, arising from an axillary and an extra-axillary bud respectively, in the axils of leaves. The vegetative branches are long and leafy and arise largely from the basal portion of the primary stem. Although they do not produce fruits themselves, they may give rise to several short fruiting branches. Similarly the upper portion of the primary stem carries a zone of fruiting branches. The fruit referred to as the boll is a 3 to 5 loculed capsule. Bolls are $\frac{1}{2}$ to 2 inches long and about 60 to 80 bolls are required to produce a pound of seed cotton. Flowering in cotton occurs about 8-11 weeks after planting and continues indefinitely. The fruit bud, also called a square is visible about 3-4 weeks prior to flowering. The time interval between flowering and the opening of the mature boll is about 6-8 weeks. At maturity the boll dehisces to expose the seed cotton. Cotton is self-fertilized to the extent of 87 to 95%, but cross pollination can occur freely. The plant produces bolls in excess of what it is able to finally mature. Generally about 50% of the bolls could be shed within a week of flowering.

Varieties

The hybrid HC 101, which has a staple length of 1 10/32 inches, a ginning out-turn of 33.8% and a standard warp count of 44, is considered to be eminently suited for local cultivation at the present time. Other selections which have been grown successfully in Ceylon are B P. 79, a five months American upland variety with a staple length of 1 1/8-1 1/4 inches and a warp count of 40. It must be borne in mind however that as in the case of sugar-cane, cotton varieties come and go, each variety produced by breeding and selection, being soon replaced by another, even better. During Maha 1960-61 yield trials conducted at the cotton research station, Hambantota showed that the strain CO 3—S6 significantly out yielded HC 101, the recommended variety for the district. The strain 5143C×5143-S-36 compared favourably with HC 101. In earlier trials these two strains had outyielded HC 101 in two consecutive seasons. (2).

ECOLOGICAL ADAPTATION

The ideal weather conditions for cotton culture are exacting. Very wet soil conditions at seeding time cause seed rot, and retard the growth of seedlings. Scant rains on the other hand though adequate for germination, subsequently result in poor seedling establishment. During the vegetative phase of growth, excessive rains cause surface rooting, with the result that with the onset of dry weather, the plants tend to shed their leaves as well as any of the early formed bolls. Excessive wet conditions promote rank vegetative growth and retard fruiting. Such conditions also predispose to attack by the cotton boll weevil. Weather conditions during the reproductive phase, are not only more important but decidedly critical. Flowering and fruiting in cotton is progressive, and flowers appear in an ascending series on successive fruiting branches with a time interval of 2½ days, and on each successive fruiting branch successive flowers appear every 6 to 7 days, so that this habit of progressive fruiting exposes the crop to the vagaries of the weather for a considerable length of time. Consequently, in each zone of fruiting, the relative abundance of fruit, degree of boll shedding, size of bolls, length of staple, and fibre quality are all considerably influenced by the weather conditions prevailing at the time of development of the bolls.

The influence of seasonal rainfall on cotton yields can be seen from results obtained at Maha Illupalama, over an eight year period. (4). In each year cotton was grown in the Maha, without any supplementary irrigation. Variations in the number of wet days and in total seasonal rainfall, caused wide differences in yield.

Yield of seed cotton lbs./acre

Maha season	50/51	51/52	52/53	53/54	54/55	55/56	56/57	58/59
Yield ..	1,092	690	492	3C6	353	220	1,118	885
Rainfall (season) in. ..	23.19	33.72	15.00	40.58	40.60	18.50	20.11	25.20
No. of wet days	57	38	30	52	42	27	44	43

(B. P. 79 was used from 1950-57, and in 1958/59 HC 101 was used)

In India, cotton is grown largely on what are called the 'Black cotton soils', which are highly retentive of moisture. These soils have a high content of clay, organic matter and iron in organic combination, and their black colour is attributed to titaniferous particles as well as their high content of organic matter. Cotton can be grown in other soils as well. The advantage of loamy soils is that they are usually well drained and not likely to become too wet. Incorporation of organic matter improves their water holding capacity. Gravelly, stony or sandy soils are not suited to cotton culture and should generally be avoided, particularly under unirrigated conditions.

Areas for Cotton cultivation

Cotton grows well within 37°N and 32°S latitude. The climatic essentials and general requirements for cotton are 1. A mean annual temperature of over 70°F. Temperature is a critical factor also for flower initiation, a minimum of 70°F being essential. 2. A minimum of 20 inches of rainfall. 3. Sunny weather during the ripening of the bolls.

Rainy weather during the time the bolls begin to open retards maturity, interrupts the picking, and damages the exposed fibres. Thus the areas selected for cotton culture should not have late Maha rains, as it will ruin the tail end cotton. These requirements are met with primarily in the Hambantota district, which area may be considered the most suitable for cotton culture. Anuradhapura and possibly Mannar may be considered possible areas for extension.

CROP PHYSIOLOGY

(a). **Boll shedding.** The cotton plant produces more bolls than it can mature, and at times sheds as much as 50% of the bolls produced. Boll shedding is therefore of considerable economic importance, and it is good to consider some of the factors influencing boll shedding. The most important factors causing this effect are weather factors. High temperature, a heavy and continuous rain, abrupt changes in the weather from dry to wet or hot to cold, all result in boll shedding. Continuous rain may also cause imperfect pollination, and give the same result. Boll shedding is primarily associated with the water requirements of the crop. Water requirement is highest during the setting and formation of fruit. Moisture stress at this time results in boll shedding. Such stress at this time can be minimized either by providing supplementary irrigation, or by effective weed control, to eliminate competition for moisture. Finally, impeded drainage conditions in the soil, or strongly alkaline conditions, also result in both leaf and boll shedding.

(b). **Nutrition.** Potent factors in increasing cotton yields are the cultivation of the crop in the most suitable areas, and the nutrition of the crop. In the United States, the results of over 150 experiments showed that the yield of lint was increased by about 40 pounds for each 100 pounds of mixed fertilizer applied. (5). In cotton as in many other crops, the uptake of nutrients is governed by the physiological stage of development of the plant. The total seasonal intake of nutrients is distributed as follows:

Seedling emergence to square formation 12%
Square formation to boll formation 58%
Boll formation to maturity 30%

Martin and Leonard (5) give the following quantities of mineral nutrients, as that absorbed from the soil by a cotton crop producing 700 lbs. of seed cotton per acre.

Nutrient	Total absorbed in pounds	In seed cotton in pounds
Nitrogen (N)	77	15
Phosphoric acid (P_2O_5)	23	7
Potash (K_2O)	67	7
Lime (CaO)	79	1½
Magnesia (Mgo)	26	2
Total	272	33½

These figures give a general indication of the needs of the crop that have to be met from fertilizers and from the soil. Since cotton is a row crop, fertilizer is best applied in bands on either side of the row.

Rotations

In most countries where cotton is grown, rotations are practised to overcome the problems encountered by continuous culture.

Further, rotations are also used as a means of reducing the fertilizer needs of the crop. Continuous culture with a row crop like cotton, particularly on erodible soil can cause considerable loss of top soil. In the past cotton in Ceylon has been for the most part a chena crop. The cotton project at Ridiyagama envisaged the following rotation to be grown in a two course rotation as follows:

	Maha	**Yala**
1st Year	Cotton	Sunn hemp
2nd Year	Sorghum and Pigeon pea	Pigeon pea continued

Experience in other countries has demonstrated the value of rotations in increasing cotton yields. The yield of seed cotton in six southern states of the United States were increased by 200 pounds per acre by crop rotation as compared with continuous culture. (6).

Planting season

Rainfed cotton should be planted with the first Maha rains in late September or early October. Figures 11 and 12 show histograms of the mean monthly rainfall in Hambantota and Anuradhapura over a ten year period. Assuming that sowing is begun with the first Maha rains, the figures illustrate the likely dates of square formation, boll formation and harvest. Irrigated cotton can be grown in the Yala, if facilities for irrigation are available.

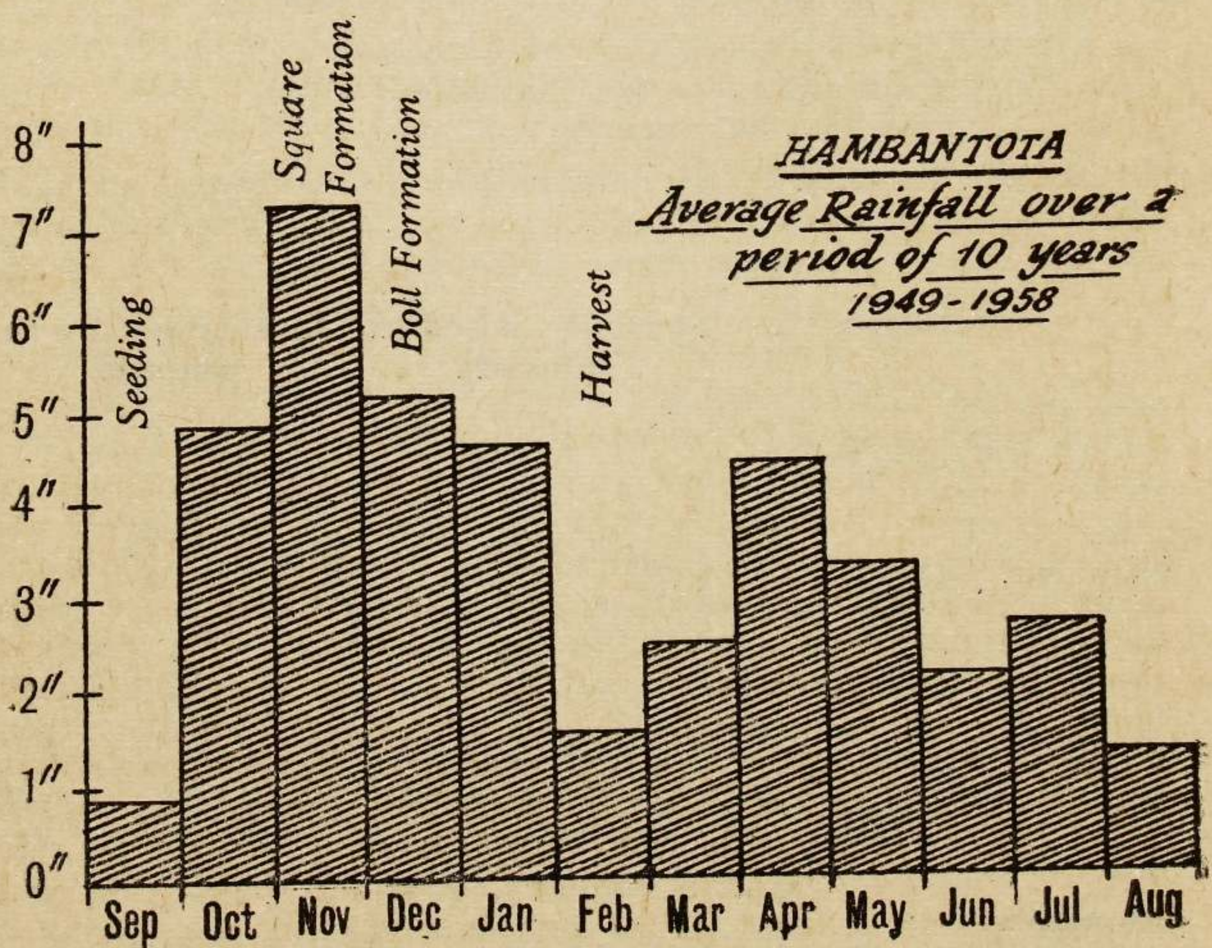


Figure 11. Growth phases of the cotton plant in relation to rainfall pattern

CULTURE OF THE CROP

Seed bed preparation

The land is usually ploughed up to a depth of 6-8 inches. In the dry zone where inversion tillage is not advocated, disking with a heavy disk harrow could be expected to give satisfactory results. The main purpose of preparatory tillage in this case is weed control. A very fine seed bed is not essential.

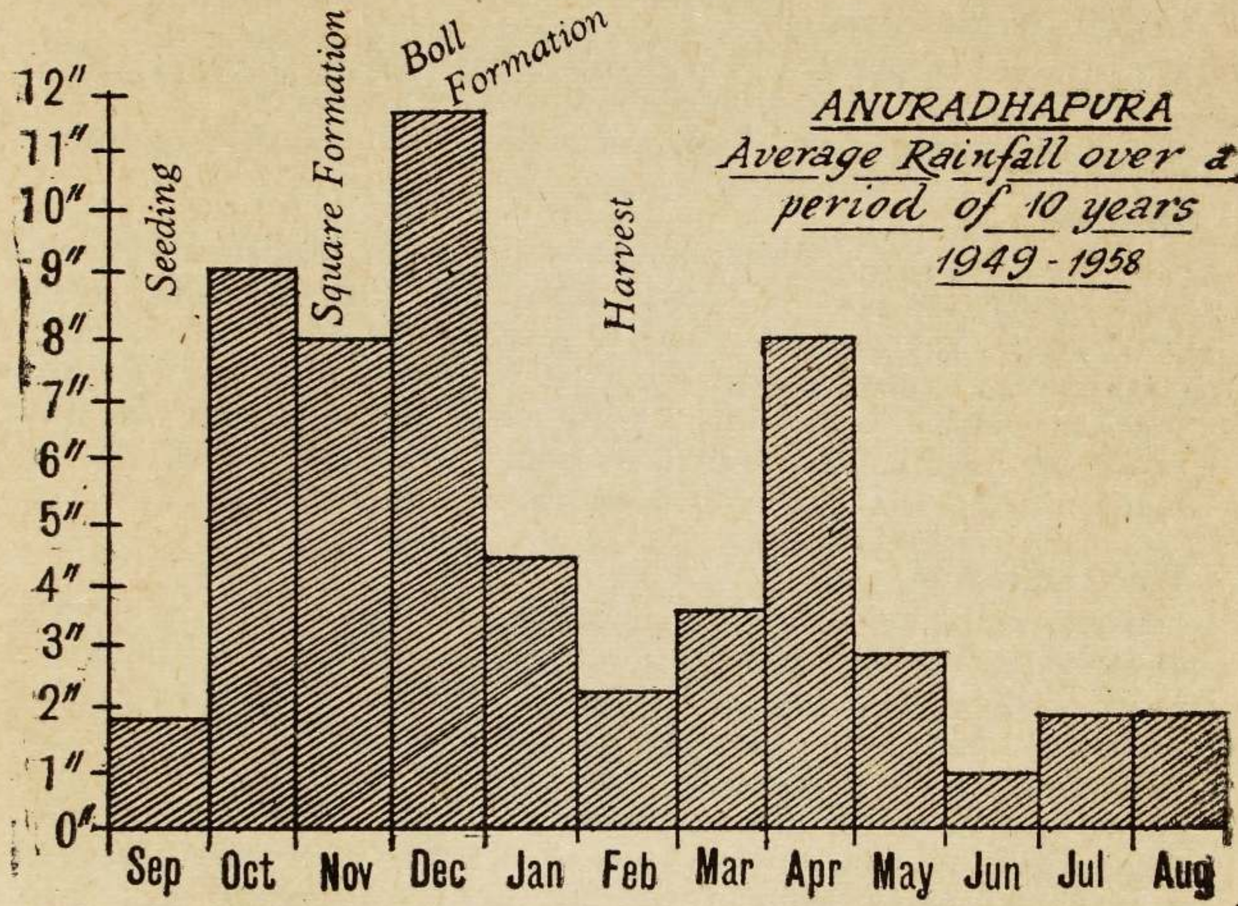


Figure 12. Growth phases of the cotton plant in relation to rainfall pattern

Treatment of seed for sowing

It is essential either to defuzz cotton seed or make the fuzz, paste on to the seed, in order to prevent seeds clinging together. Such seeds cannot be easily discharged from a seed drill. In India the common practice is to rub the seeds with a paste of moist earth and cow dung which pastes the fuzz on to the seed. The seeds are then dried in the shade and sown. Similar pastes can also be made out of rice or maize starch, and the effect would be the same. Sometimes the seeds are treated chemically with commercially strong sulphuric acid for two minutes and then washed free of the acid. This treatment chars the fuzz. Soaking in zinc chloride solution for 10-15 minutes achieves the same results. Chemical treatment is advocated only for roller ginned seeds, as saw ginned seeds usually are damaged and chemical treatment reduces germination capacity.

After defuzzing, cotton seeds are usually soaked overnight in water prior to sowing. This improves the percentage germination.

Method of planting

Cotton seed may be either dibbled or drilled in rows. Dibbling is done by hand. Drilling is usually done with a seed drill. Plants could be thinned down to the required stand after germination. The seed rate is about 10 pounds to the acre.

Depth of planting

Usually seed is planted to a depth of 1¼ inches. Deep planting is not desirable, since it interferes with germination. A certain amount of compaction of the soil is desirable soon after planting.

Spacing

Although cotton is quite adapted to producing satisfactory yields over a wide range of field stands, moderately close spacing gives the best results. Spacing, however, is governed by the type of inter-cultivation envisaged, and the type of implements used for this purpose. Rows 3 feet apart with 12-16 inches within the row facilitates mechanical intercultivation. In India a spacing of 2′ between rows and 3″-9″ within the row is common.

Weed control

Competition by weeds for moisture seriously affects the growth of the cotton crop. In addition, *Cynodon dactylon* (daub grass) is particularly undesirable in a cotton field since it secretes a toxic material which suppresses the growth of cotton. Weed control in cotton can be achieved in one of many ways. If the crop is grown to a desirable spacing mechanical tillage gives good results. Chemical weed control could consist of a pre-emergence treatment with diuron at the rate of 1-1½ lbs. active ingredient per acre applied in 40 gallons of water (cost of diuron Rs. 15.00 per lb.) or a later application of a contact herbicide, after providing shields for the crop plants.

Irrigation

Most cotton growing countries use irrigation for growing their cotton. The water requirements of the cotton crop are critical. Highest requirement for water is at the time of flowering and boll formation. Provided irrigation facilities are available, it should be possible to grow cotton in most areas of the dry zone in the Yala season.

CONTROL OF PESTS AND DISEASES

1. Cotton leaf roller *Sylepta derogata*.

The small butterfly lays its eggs on the underside of the leaf, from where the caterpillar perforates the leaf to the midrib. The leaf rolls up, is pasted together by thin threads, and serves to protect the chrysalis. Control is to spray 20% D. D. T. at the rate of 1 fluid oz. in 20 gallons of water. Endrin at the rate of 1 fluid oz. in 4 gallons of water can also be applied once a fortnight for the 1st 6 weeks.

2. Cotton aphid *Aphis gossypii.*

Common in all cotton growing countries. Parasite sucks parts of the plant causing stunted shoot and leaf growth. Routine spraying with endrin can be adopted as a measure of control. Severe infestation can lead to boll shedding.

Boll parasites

3. Pink Boll worm *Pectinophora gossypiella.*

This is transferred by seed. It is a very destructive cotton pest. The larvae feed on the seed and the fibre is rendered useless. The butterfly lays its eggs on the flowers or young bolls, and the caterpillars bore into the young capsules and feed on the seed. Seed disinfection by heating is an effective method of control. Attacked plants should be removed and burnt.

4 Spotted boll worm *Earias fabia*

This is a common pest in S. E. Asia and the Philippines. Adult is a small moth with brownish white forewing striped with a broad green band. It lays its eggs on shoots, leaves, and flower buds. These hatch in 5 days and larvae bore into the shoots, flower buds, and young capsules. More mature larvae attack mature bolls and feed on seeds. Life cycle is completed in 4-5 weeks. Endrin at the rate of 1 fluid oz. in 4 gallons of water is very effective when sprayed at regular intervals.

5. Cotton stainer *Dysdercus similis*

This is a dull orange red coloured bug. Adult is 6-9 mm. in size. The age of the adult is 6 weeks. Feeds on young bolls, causing boll shedding or poor development. It also stains the fibre due to deposition of saliva. The most effective control is a malathion spray at the rate of 1 fluid oz. of 50% malathion in 5 gallons of water.

6. Dusky Cotton bug *Oxycarenus latus*

A small reddish bug 3-4 mm. in size. Both the nymphs as well as the adults feed by sucking on the seeds of open bolls. The damage is caused not so much by feeding, as by their moving around the boll, where their excreta discolours the lint. They get caught up during picking and ginning, and in the process of being crushed discolour the lint. Malathion at the rate of 1 fluid oz. in 5 gallons of water is an effective method of control. A certain amount of control can be achieved by dusting with B. H. C. at the rate of 20 pounds per acre. About 2 to 3 dustings, about 2 to 3 weeks before harvest is generally advisable.

7. Cotton boll worm *Heliothis armigera*, is a cotton pest common in the United States, but is rare in Ceylon and India.

Preliminary studies on the control of these cotton pests, conducted at Maha Illupalama, showed that of several insecticides tried, viz. B.H.C., D.D.T., Diptrex, Endrin, E.P.N., and Gusathion at two concentrations each applied at fortnightly intervals and according to pest incidence, Endrin gave the best control of all the pests.(7).

Fungus diseases

8. Seedling rot *Rhizoctonia* sp. *Pythium debarianum*, occurs under unfavourable growth conditions, particularly in moist weather. No special control methods are known, although damage can be limited by improved cultivation conditions.

9. Angular leaf spot, black arm disease, bacterial blight

Bacterium malvacearum
Pseudomonas ,,
Xanthomonas ,,

The only bacterial disease yet known. Attack begins on leaves, causing waterspots which later dry out. The infection later spreads to the stalks and buds, finally resulting in boll rot. Considerable damage can be caused by a severe shedding of both leaves and bolls. Rainy weather favours its spread, and the infection is carried from plant to plant by seed. Disinfection of the seed is the most effective method of control. Since the infection is also spread through the soil, crop rotation wherein leguminous plants are avoided should also serve as a measure of control. Infected plant residues should be burnt. Resistant varieties of cotton have been bred at the Gezira cotton scheme, in Sudan.

Physiological diseases

A complex of physiological diseases resulting in severe leaf and boll shedding, and retarded growth occur under certain conditions. This can result from unfavourable soil conditions, insufficient drainage and nutrient deficiencies in the soil.

Harvesting

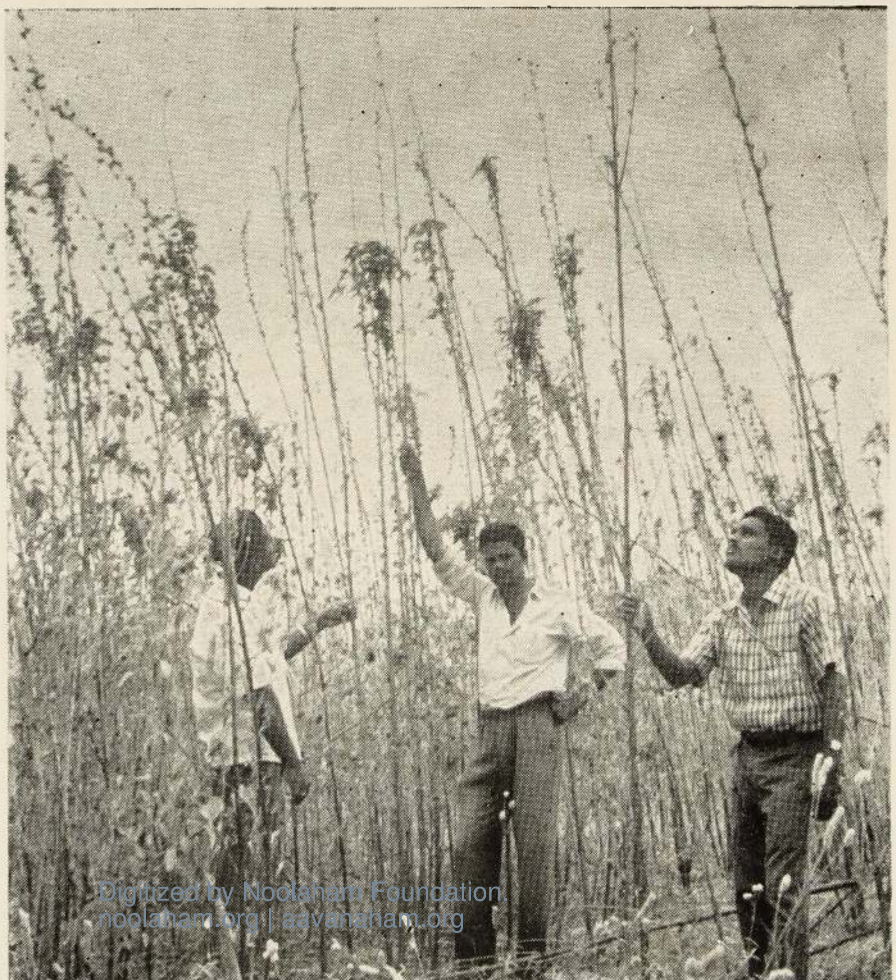
Harvesting in Ceylon is done by hand. The picking should be clean without admixture with bits of leaves. Clean white cotton should be picked separately from lumpy discoloured cotton. Mixed cotton fetches a lower price. Generally 2 to 3 picks may be taken. Mechanical harvesting is practised in some parts of the United States. In these areas the crop is defoliated by the use of chemicals prior to mechanical harvesting.

Yields

Yields under local conditions amount to between 4 to 5 cwt. of seed cotton per acre. Considerable variation in yields has been caused by fluctuations in weather conditions.

Plate 9. Picking Cotton.

Plate 10. A field stand of Kenaf.



QUALITY IN COTTON

Staple length

The value of the cotton crop depends on a large number of characters that determine the quality of the fibre. Staple length is the main consideration in the classification and grading of cotton. Long staple cotton is used in the making of better grade yarns. The higher the staple length, the better is the fibre for spinning and such fibres have a higher warp count, which is the number of windings on a special frame which a specified weight of the yarn will give. The higher the count the longer will be the yarn for the specified weight and therefore the finer will be the yarn.

e.g.

Short staple cotton with a staple length of less than 0.75 inches will have less than 30 counts.

Medium or medium long cotton having a staple length of between 0.75 to 1.25 inches will give up to 50 counts.

Long staple cotton having a staple length of more than 1.25 inches will give more than 50 counts.

Fineness

Fineness is related to the weight per unit length of the fibre. The fineness of the spun yarn depends on the fineness of the fibre. Soil and weather factors strongly influence fineness.

Staple strength

Staple strength is also an important factor in rating cotton. Strength is measured in terms of pounds of pull per square inch.

$>$ 96 lbs. pull/sq. inch—very good
86-96 lbs. pull/sq. inch—strong
76-85 lbs. pull/sq. inch—average
$<$76 lbs. pull/sq. inch—fair.

Colour

The most favoured colour is white. Natural tints are valuable when the colours are fast colours. The most common natural tint in cotton is khaki. Recent work in Russia has produced fast coloured cottons.

Ginning percentage

Ginning percentage refers to the proportion of the lint by weight in 100 parts of seed cotton. This is an important index of yield, since the larger the proportion of lint per pound of seed cotton, the larger will be the yield of lint per acre.

All these characters are of considerable economic importance, and although they are also varietal characters and form part of the genetic make up of particular varieties, they are at the same time largely and overwhelmingly influenced by ecological factors.

COSTS OF CULTIVATION AND RETURNS

Costs of cultivation of cotton at Cotton Plantation, Ambalantota. (9)

		Cost per acre	No. of Units
1.	Preparatory tillage (including tractor hire and labour to collect roost and cheddying bunds Rs. 54/- for ploughing and harrowing) ...	Rs. 79.16	7½ W'm
2.	Seeding (150 acs. with drills and 50 acs. by hand)	13.07	4 ,,
3.	Weed control	33.22	7½ ,,
4.	Pest control	5.53	1½ ,,
5.	Intercultivation with spring type cultivator	13.06	3 ,,
6.	Fertilization	4.44	1 M
7.	Watching	13.50	2½ M
8.	Harvesting	78.75	22 W'm
9.	Processing	17.95	5 ,,
10.	Weighing & transporting plus Rly. Wrts.	6.96	1½ ,,
11.	Fertilizers	19.42	5½ ,,
12.	Karmex (Diuron)	17.98	4 M
13.	Insecticides	9.57	2 M
14.	Uprooting and burning ...	17.50	5 W'm
		Rs. 330.11	
	Overheads 10%	33.10	
	Total cost per acre	Rs. 363.22	
	Yield of seed cotton per acre 7.18 cwt.		
	Valued at Rs. 55/- per cwt.	394.90	

Costs of cultivation of 4 acres Cotton (multiplication) '56-57

Distribution	Women	Men	Boys & Girls	Cost
Planting	25½	—	—	Rs. 67.32
Weeding	24	—	—	63 36
Earthing up	52	—	—	137 28
Spraying	—	4	—	12.64
Harvesting	118	15½	38	442.79
Clearing	9	6½	—	44.70
Bagging	—	18	—	56.88
Ploughing 4 acres @ Rs. 21/- per ac.				84.00
Harrowing 4 acres @ Rs. 18/- per ac.				72.00
Spray Endrin 3 bottles at Rs. 10/- per bottle				30.00
				Rs. 1010.97
Total yield 37 cwt. 64 lbs. valued at Rs. 55/- per cwt.				Rs. 2066.36

Profit and Loss

Income	Rs. 2066.36
Expenditure	1010.97
Profit	1055.39 on four acres.

Summary of labour units

Description		Women	Men	Boys & Girls	Total units
Planting	..	25½	—	—	25½
Weeding	..	24	—	—	24
Earthing	..	52	—	—	52
Spraying	..	—	4	—	4
Harrowing	..	118	15½	38	171½
Cleaning cotton	..	9	6½	—	15½
Bagging cotton	..	—	18	—	18
Total units		228½	44	38	310½

Cost of unit—	Man	Rs. 3.16
	Woman	2.04
	Boy & Girl	2.45

Cotton Extents Cultivated

				Y[illegible]	[illegible]
1959/60		..	13 acres	12,433 lbs.	956
1960/61	..	..	17 ,,	14,372 ,,	845
1961/62	..	..	6 ,,	3,103 ,,	517
1962/63	..	..	22 ,,	13,376 ,,	608
1963/64	..	..	12 ,,	3,868 ,,	322½

REFERENCES

1. Agricultural Plan—First report of the Ministry Planning Committee. Ministry of Agriculture and Food. 1958. p. 69-73.

2. Short Term Implementation Programme 1962.

3. Administration Report of the Director of Agriculture for 1960-61. Nov. 1962.

4. Panabokke, C. R. Water consumption pattern of crops in the dry zone environment. Tropical Agriculturist. Vol. CXV. p. 187-94. 1959.

5. *Principles of Field Crop Production*—Martin and Leonard. The Macmillan Company, N.Y. 1955.

6. Skinner, J. J. Use of Commercial fertilizers in cotton production. U. S. D.A. Circular 726. p. 1-26. 1945.

7. Thevasagayam, E. S. and Mohinudeen, S. S. Preliminary studies on the control of insect pests of Cotton. Tropical Agriculturist Vol. CXVI No. 4. Dec. 1960. p. 299.

8. Profit from Cotton. Folder No. 5. Department of Agriculture 1954.

9. Dias, I. P. S. Private communication.

20. KENAF

Economic importance

Kenaf is not a new crop in Ceylon. Known locally as embulpala, it has grown in the dry zone jungles of Ceylon for a long time, and has been used by the peasants for making twine and rope. Its potential value, as a commercial crop for the dry zone, has only recently been demonstrated.

Kenaf is an important fibre crop, and is a satisfactory substitute for Jute. Kenaf fibre is rough and strong, and has a breaking strength of between 115 to 190 lbs. The fibres are from 5 to 10 feet long, bright, glossy and of considerable commercial value. It is used largely for the making of rough sack cloth, gunnies, and canvas. It is also used for making fishing nets, on account of its ability to stand extensive under-water usage. The leaves and tender portions of the plant are reputed to be excellent cattle feed, particularly for cows in milk. The seed is sometimes used as cattle food.

The imports into Ceylon of Jute products in 1962 were as follows (1)

	Quantity	Value (Rupees)
Jute fabric	4,398,250 yards	3,094,384
Jute hessian gunny bags, new or used	36,053 cwt.	161,459
Jute including cuttings and waste	111 cwt.	6,725

In view of these imports the cultivation of Kenaf on an organized scale cannot be overemphasized.

Kenaf is an important export crop of India. The acreage in Madras is estimated at around 50,000 acres. A long ton of Kenaf can fetch as much as £80 sterling in the fibre market; Cuban varieties fetch the highest prices in the world market at the present time.

BOTANICAL CHARACTERS

Kenaf (*Hibiscus cannabinus*) belongs to the family Malvaceae. It is sometimes referred to as Deccan hemp, on account of the fibre it produces. The plants may be tall stemmed, medium or even short stemmed. Leaves may be cordate and entire or deeply lobed and palmate. Flowers arise in the axils of the leaves along the main stem, the sepals are bristly and lanceolate, the petals are light yellow to cream in colour, with a dark eye in the centre. The capsules are round, pointed and bristly at the tip.

Varieties

There are a number of varieties under cultivation, which fall mainly into two categories. One group is green leaved, the other is reddish leaved. Colour of the stems correspond to the colour of the leaves in both cases. Varieties differ also in the shape of leaves, some being cordate and entire, others being palmate and lobed. Sometimes on the same plant, the lower leaves may be entire, the upper ones palmate. There are several local varieties in Ceylon. Of these varieties Periyakulama and Hurigaswewa are reputed to be high yielders, giving yields of 1,600-1,800 pounds of fibre per acre. (2). There are also a number of introduced varieties, now being evaluated in yield trials, from Cuba, Gautemala, India and Africa. Cuba 2032 has performed best out of the introduced varieties in trials conducted at Maha Illupalama. Cuba 2032 has a better fibre quality than the local varieties, although the latter are the better yielders. Most of the introduced varieties are short day varieties. On the other hand the local varieties are photoperiod insensitive, and are better suited for Maha cultivation in the dry zone of Ceylon. Photoperiod insensitive varieties have been introduced in recent years from Gautemala and are being evaluated under local conditions. (2). The local varieties though taller than the Cuban varieties, and better yielders, yet produce a weaker fibre. Current research at Maha Illupalama is aimed at producing a hybrid that will combine the high yield potential of the local variety with the better fibre quality of the Cuban varieties.

ECOLOGICAL ADAPTATION

Kenaf is generally grown purely as a rainfed crop and is suited to areas of good rainfall. A rainfall of 20-25 inches during the growing season is enough to raise a successful crop of Kenaf. Rich soils, produce luxuriant growth. Red loams or alluvial soils are most suitable for Kenaf cultivation. In India, Kenaf is grown mainly on the deep black cotton soils, as a purely rainfed crop. (3). It is also grown successfully as a semi-irrigated crop on sugar cane fields.

Areas for cultivation

The Kenaf crop is suited for cultivation in any part of the dry zone.

Planting season

Planting should commence with the first Maha rains in late September to mid-October. The crop could be raised between October and February.

CULTURE OF THE CROP

Land preparation

Land preparation should be thorough so as to provide a good seed bed. All clods should be broken down, and soil prepared to a fine tilth by repeated working with a disc harrow, since the seed size is very small.

Seeds and sowing

Eight to ten pounds of seed are required to plant an acre. The seed may be either dibbled or drilled in the row. The spacing between rows should be 1 foot, and the seeds should be drilled at a spacing of 4 inches in the row.

Nutrition

Experience gained at Maha Illupalama indicates that a basal dressing of commercial fertilizers at the rate of 1 cwt. of concentrated superphosphate, $\frac{1}{2}$ cwt. of ammonium sulphate, and $\frac{1}{2}$ cwt. of muriate of potash should be applied at the time of land preparation. A second dressing of $1\frac{1}{2}$ cwt. of ammonium sulphate could be given six weeks later. The fertilizer may be applied in bands 3 to 4 inches away from the rows at a depth of 2-3 inches. Heavy applications of fertilizer stimulates vigorous growth, and should be practised extensively in order to obtain high fibre yields. Under such conditions plants may attain a height of 12-15 feet.

Weed control

The growth of the plants is so rapid under good cultural conditions that weed control presents no serious problem. The plants are spaced close enough, for them to rapidly shade the entire area with their foliage, and thus control the growth of weeds.

Control of pests and diseases

There are no pests or diseases of any importance in this crop.

Harvest and Yields

In about 130-140 days after planting, the crop will be ready for harvest. At this time the seed pods at the bottom of the stem are mature and ready to burst. The crop may be harvested at this stage by cutting the plants at the base. The leaves and tender portions are lopped, and the stems tied into bundles for retting.

Retting of the fibre

Retting is carried out by soaking the bundles in water for about 10 days, after which the stalks are separated and cleaned. The bark is peeled off by hand. The fibre extracted is now hung out to dry. Yields of fibre amount to about 1,200-1,500 pounds per acre. When large extents of land are brought under the cultivation of this crop, it may be necessary to undertake the extraction of the fibre by the use of decorticating machines.

Seed production

When the crop is required for seed production purposes, harvesting is undertaken at a later stage, when about 1/3 of the capsules are dry. The method of harvest is similar, but the stalks are tied up in bundles and stacked upright in 'stooks' to dry. When fully dry, they are threshed to extract the seed. Seed yields range from about 400 to 600 pounds to the acre.

Costs of cultivation and returns (4)

	Rs. cts.
Tillage (Disc or tyne tiller) two operations @ Rs. 15/- per operation	30.00
Drilling seed by mechanical drill	15.00
Cost of seed, 15 lb. @ Rs. 1/- per lb.	15.00
Fertilizer applications (2) @ 2 men units per application	10.00
Intercultivation once with Tractor ...	15.00
Cost of Fertilizers:	
1 cwt. sulphate of ammonia	15.00
1 cwt. conc. superphosphate	18.00
¼ cwt. muriate of potash	5.00
Harvesting 12 men units	30.00
Bundling: 3 men units	7.50
Transport and stacking for retting:	
*Transport charges	15.00
Labour 5 men units	12.50
Peeling and drying: 15 women units	30.00
	Rs. 218.00

*Varies with distance from water source

Man unit Rs. 2/50 per day
Woman unit Rs. 2/00 per day

Yield of Fibre—1500 lbs./acre	
Cost @ 25 cts. per lb. of fibre	Rs. 375.00
Cost of production	Rs. 218.00
Profit	Rs. 157.00 per acre

REFERENCES

1. Customs Returns 1962.
2. Administration Report of the Director of Agriculture 1961-62.
3. Yegna Narayan Aiyer, A. K. *Field Crops of India*, 1947. p. 424-6.
4. Sivanayagam, T. Private Communication.

21. SUNN HEMP

Economic importance

Sunn hemp is a long established fibre crop of some importance, while its other uses are mainly as a green manure and fodder crop. The fibre obtained from sunn hemp is coarser than jute fibre, and is used in the making of cordage, rough cloth, grain bags, and ropes. Ropes made of sunn hemp fibre are strong and resist the action of water. Sunn hemp has been a fibre crop of considerable importance in the Jaffna peninsula, where the fibre is utilized in making the nets of the local fishermen.

Sunn hemp finds an important place also as a green manure crop, particularly in areas of tobacco cultivation. Green manuring with sunn hemp for tobacco is considered to be better from the point of view of earliness of crop and yield than the addition of heavy doses of farm yard manure. (1).

It is also of minor importance as a fodder crop. The seeds and pods make valuable feed, during the lean months, when no fodder of value is easily available. In the young tender stage, the leaves provide a satisfactory early bite. With the introduction and extension of kenaf, which is a better substitute for jute, and which gives much higher yields of fibre than sunn hemp, its relative importance as a fibre crop is bound to diminish. Its value as a green manure crop however cannot be overstated.

BOTANICAL CHARACTERS

Sunn hemp (*Crotolaria juncea*) belongs to the family Leguminoseae and the sub-family Papilionaceae. The plant can grow to a height of about 6 feet under good cultural conditions. The stem is about a ½ inch thick, and its outer skin contains the long bast fibres. The inner stem is woody, hollow and filled with pith. The plant is deep rooted, and the roots carry the characteristic nodules. Leaves are small, and lanceolate. Close spacing of the plants, inhibits free branching. Flowers are yellow, and are borne in clusters at the terminal ends of the main stems and branches. The flowers are self sterile and cross pollination is the rule. The pods are cylindrical about 2 inches long, and ½ inch thick. When dry the seeds rattle in the pods.

Varieties

Varietal differences in sunn hemp are based on the period of maturity, branching habit, and the yield capacity. The sowing to flowering interval is about 80 days in the early varieties, 100 days in the medium varieties and 120 days in the late varieties. (2).

ECOLOGICAL ADAPTATION

The crop requires light rains during its growing season, for rapid and vigorous growth. It can withstand long periods of dry weather but during such time. is very susceptible to attacks by insect pests.

On heavy clay, or light sandy soils, the quality of the fibre produced is poor. Moderately deep, well drained, loams are the most suitable for the fibre crop. (3). When grown as a green manure crop, it can be cultivated on almost any type of soil. Red loams, light alluvial soils are particularly suitable for such crops.

Areas for cultivation

Sunn hemp has been traditionally grown in Jaffna, on paddy lands, following the Maha rice crop during February and March for fibre purposes. On tobacco lands, and vegetable gardens it is grown also for its green manurial value. For this purpose it can be expected to produce a good crop with the light showers during the Yala season.

CULTURE OF THE CROP FOR FIBRE

Land preparation

Land preparation is not so thorough as in the case of other crops. The soil is worked a couple of times prior to sowing.

Seeds and sowing

The seed can be either drilled in rows, or sown broadcast. The latter is the more common practice, the land being cross ploughed soon after broadcasting the seed. In India about 60 pounds to the acre is the usual seed rate used. (4) though much higher rates even amounting to about 245 pounds per acre is sometimes sown in certain parts of South India. (5). Germination is quick, and in about a week the crop forms a thick cover on the land.

Nutrition

Very little fertilizer practice is adopted with this crop. On observation plots at Peradeniya the addition of a 16—8—8 mixture at the rate of 1 cwt. per acre gave excellent results.

Irrigation

Wherever irrigation facilities are available, the crop may be irrigated but this is not usual practice. In Jaffna where irrigation from wells is possible, furrows are constructed in the fields, separating them into small plots. Furrow irrigation is practised once a fortnight, but the amount of irrigation is generally small.

Weed control

Since thick sowing is practised with this crop, the plants are able to grow quickly and smother the weeds. In row sown crops, which is not the usual practice, one or two intercultivations at the early stages would be beneficial.

CONTROL OF PESTS AND DISEASES

Pests

The sunn hemp crop is subject to attack by a number of pests and diseases which can be very destructive to the crop. The main pests are:

1. The caterpillars of three moths.

   (*a*) The sunn hemp moth (*Utetheisa pulchella* L.)
   (*b*) *A gina caribraria* C.
   (*c*) *Argina syringa* C.

All three are day fliers and can be seen in sunn hemp fields. The caterpillars feed on the leaves and cause much damage. Spraying the crop with stomach poisons, is advocated as a measure of control.

2. A pod-boring caterpillar, a green sap-sucking bug, and a flea beetle, are also occasional pests.

Diseases

Sunn hemp is subject to two serious diseases.

1. Sunn hemp wilt. 2. Sunn hemp rust.

The wilt is serious, causing young and old plants alike to dry up. The rust attacks leaves, stems and pods causing great damage. The use of resistant varieties is the only effective method of control.

Harvest

The crop takes about 4½ months to mature, and is harvested between June and July when the pods have matured. Best fibre is produced when the pods are fairly mature. At this stage,the stems are cut close to the ground and left on the field to wither for a few days. Leaves are then removed, and the stems are bundled and stored for further drying. The seeds can be removed by threshing, and the stems got ready for retting.

Yields

Yields of fibre average around 400 pounds to the acre. Indian yields average around 500-800 pounds to the acre.

Retting of the fibre

In Jaffna the retting of the fibre is done by fishermen who purchase the stems from the farmers. The bundles of stems are weighted down into the sea or the lagoon, and kept submerged for 5-10 days. When the retting is complete, as indicated by a softening of the tissues, the bundle is beaten on the surface of the water, each end separately. The separation of the fibre is also done in water, by moving the stems quickly in the water, when the fibre separates. The bundles with the fibre still attached are then left in stooks to dry for about ½ day. The fibre is removed and sun-dried for a couple of days.

Plate 11. Retted Kenaf fibre being hung out to dry.

Plate 12. Threshing Sunn Hemp with the tractor.

CULTURE OF THE CROP FOR GREEN MANURE

Land preparation

When the crop is grown for green manure purposes on paddy lands as in Jaffna, little land preparation is necessary. The crop is sown soon after the harvest of the paddy crop. On garden lands preparatory tillage amounts to working the soil a couple of times to get an even, though not necessarily fine seed bed.

Seeds and sowing

For green manure purposes on garden lands, about 112 pounds per acre is sown in order to get a heavy yield of green manure.

Turning in the crop

The crop is turned into the soil when about seven weeks old, just about the time of flowering. In Jaffna the crop is turned in around the end of November or December, and provides good manurial value to the succeeding crop of tobacco that is planted around December or January.

Yields

Yields of green manure amount to about 3 to 5 tons per acre.

REFERENCES

1. Howard A. and Howard, G.C. Studies in Indian Fibre plants. I. On two varieties of Sann (*Crotolaria juncea*) Memoirs. Dept. Agric. Ind. Bot. series Vol. III. No. 3. 1910.

2. Yegna Narayan Aiyer, A. K. *Field Crops of India*. p. 418-424.

3. Paul, W.R. C. and Chelvanayagam, A.V. Sunn hemp in the Jaffna Peninsula. Tropical Agriculturist Vol. LXXXVI. No. 1. 1936.

4. India (Sunn or Sann) hemp. Empire Marketing Board. No. 35. 1930.

5. Subha Rao, C. K. Sunn hemp (*Crotolaria juncea*) Dept. of Agric. Madras Bull. No. 59. 1908.

GROUP IV—SUGAR CROPS

22. SUGAR-CANE

Economic importance

The economic importance of sugar-cane derives from its capacity to accumulate in its stalks, crystallizable cane sugar (sucrose). Bi-products of economic importance include molasses which consists of dissolved salts, albuminoids, and the non-crystallizable sugar fraction. Molasses could either be fermented to make alcohol, or used in the making of silage. Occasionally the green tops of the cane could be fed to cattle either directly or in the form of silage. The more important sugar-cane growing countries in the world are India, Cuba, Java, Brazil, Philippines and the U. S. A.

Sugar-cane is not a new crop in Ceylon. Its cultivation probably dates back to very early times, and the available evidence suggests that as early as 1842, there were about a dozen sugar factories in operation and that the Island was independent of sugar imports at that time. (1). The sugar industry collapsed however with the turn of the century and till very recently spasmodic efforts to revive it, proved unsuccessful. The cultivation of chewing cane however, survived right through this period and it is still cultivated on a sizeable scale in the low country wet zone.

The Agricultural plan of 1958, (2). estimated the annual requirements of sugar to be 140,000 tons. On results obtained by the Department of Agriculture, yield estimates of plant cane and ratoon crops was put at 30 tons of millable cane per acre. Assuming a recovery of 10% the estimates showed that 47,000 acres would be adequate to attain self-sufficiency. These estimates have subsequently been revised. The short term implementation programme of 1962, estimated the island's annual requirements of sugar to reach 230,000 tons by 1964. (3). Up to now all attempts to embark on sugar-cane cultivation on a large scale have been beset with several difficulties. Progress on a 16,000 acre plantation at Gal Oya, and a 6,000 acre plantation at Kantalai has also been slow. In 1962, only a total of 8,200 acres had been planted under the Kantalai and Gal Oya schemes. A further acreage of 12,500 acres were to be planted by the end of 1964. The yield of cane has also been considerably below the original estimate, average yields obtained amounting to only 22 tons per acre. The shortfalls in output, have materially affected the economic functioning of the two factories at Gal Oya and Kantalai. In 1961, only 8% of the cane required by the factories was produced, resulting in a high cost of production of sugar. Some of the difficulties associated with this shortfall in output may be attributed to damage caused to standing crops by elephants and fire, while the major difficulty has been the shortage of labour for harvest, and the low output per labourer. Due to all these difficulties local production in 1964 was expected to be only 7.5% of the island's requirements. (3).

BOTANY OF SUGAR-CANE

Sugar-cane belongs to the family Gramineae and to the genus *saccharum*. There are three species: *Saccharum officinarum* comprising the thick or noble, canes, *Saccharum sinense* which includes the Uba Cane, which is sometimes considered to be a good fodder grass, and *Saccharum barberi* which is composed of the thin reed like canes. On a percentage dry weight basis the individual organs of the sugar-cane plant constitute approximately the following proportions: (4).

Roots	12.7%
Stubble	4.5%
Trash	24.6%
Stalks	49.2%
Tops	9.0%

Vegetative morphology

The unit of a sugar-cane stem is an internode or joint. (Fig 13). These joints are short at the base of the stem, gradually increase in length till a maximum is reached, and then decrease in size. The top and base sections are thus characterized by the presence of many short joints, which fact has a bearing of some practical importance. Since each joint has a bud a large number of tillers arise from the base. The tops too carry a relatively large number of buds, and are used for planting purposes, as the sucrose content in these is also low. The bud is located at the base of each leaf and is fully covered by the leaf-sheath. Depending on the variety, the bud may be round, triangular or oval and flat or plump. Under suitable conditions, the buds sprout and give rise to shoots. Around the nodes are small pits, which are the embryonic roots. When the cane is planted, or in the presence of moisture, roots grow from these points.

Composition of the Cane

Sugar-cane may be considered to consist of two fractions, the sugar-cane juice and the fibrous framework of carbonaceous material referred to as the fibre or 'mark' of the cane. The higher the mark, the more difficult it will be to mill the cane. The juice itself is composed of water with dissolved or suspended solids. These solids are mainly sugars, both sucrose and glucose. The non-sugar fraction contains dissolved salts, albuminoids, colouring matter, gums and waxes. The juice from the central pith of the cane is the purest and consists mainly of sucrose. The sucrose content in the juice varies from 13-14% in the poor canes to 23-24% in the rich canes; and it is this sugar that gives the value to the cane. Pure sugar is 100% sucrose. It is a crystallizable solid, and the higher the percentage of sucrose in the cane, the higher will be the out-turn of sugar. Glucose in the juice retards crystallization, and makes manufactured sugar hygroscopic. The percentage

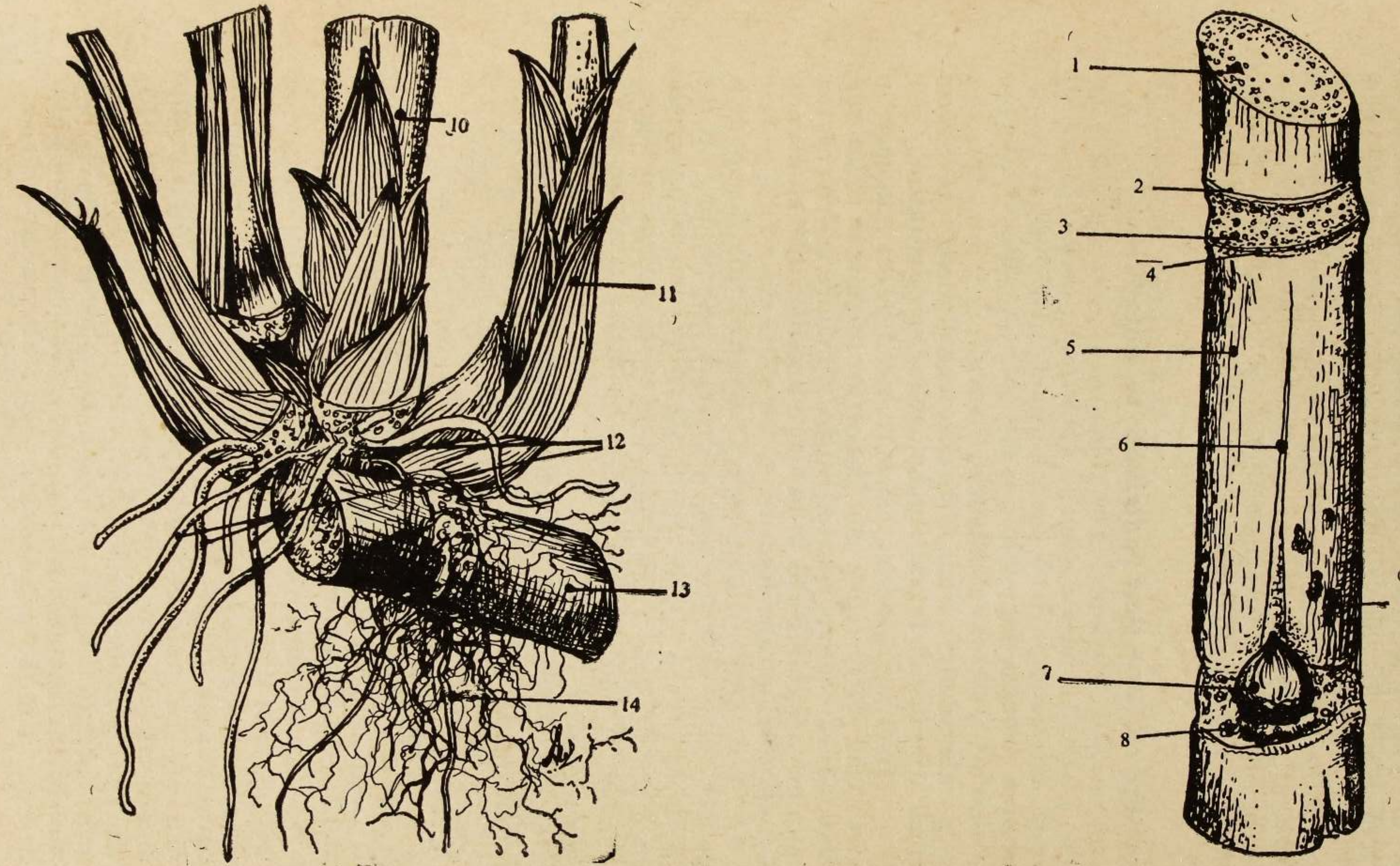


Figure 13. Vegetative Unit in Sugar cane

1. Vascular Bundles 2. Growth Ring 3. Root Ring 4. Leaf Scar 5. Corky Cracks
6. Bud Furrow 7. Bud 8. Root Primordia 9. Corky Patch 10. Primary Shoot
11. Secondary Shoot 12. New Roots Arising from Developing Shoots 13. Planted Cutting
14. Original Roots of Cutting.

of sucrose in the cane varies with the age and ripeness of the cane. It also varies within the same cane, depending on the portion of the cane from which the juice is taken. Usually the top of the stem is poor in sucrose and rich in melassigenic substances and is of little use in the factory. A ripe cane should not contain more than 0.5% glucose. Further, the enzyme invertase promotes the conversion of sucrose into invert sugar and care should be taken to ensure quick milling after harvest to prevent this inversion taking place.

Characters of Cane that contribute to suitability

1. Colour of Cane: The colour of cane is dependent on two pigments, Anthocyanin in epidermal and sub-epidermal cells and chlorophyll of deeper tissues. Too deep a purple or pink colour is undesirable as this imparts a colour to the sap and tends to discolour the sugar.

2. Hardness of rind: Generally varieties with very hard rinds are difficult to mill, and therefore not desirable.

3. Tillering: Tillering capacity has a direct influence on yield and is therefore an important economic character. Varieties with a high tillering capacity produce more canes per hill, and are considered to be more suitable than those with a poor tillering capacity.

4. Length of internode: Canes with longer internodes are easier to mill, and also have a higher purity of sugar. Internodes vary from about 3-9 inches. Those sections of the stem which have a pre-ponderance of nodes have a larger number of buds, which account for the bulk of the non-sugar fractions in the juice.

5. Thickness of Cane: Thicker canes are generally larger yielders. Thickness of cane is related to the sugar yields per acre. Thickness round the middle can range from 3-6 inches or more.

6. Shape of the internode: Internodes may be cylindrical, tumescent, bobbin shaped, conoidal, obconoidal or curved. If it is too round and bulging in the middle, it is liable to split and pre-dispose to fungal attack.

7. Age: In areas with limited water resources, it would be well to select short aged varieties of cane. Some varieties are longer aged and are suitable for ratooning. Sugar-cane varieties usually take from 8 months to 24 months to reach maturity. Rapid growth takes place during the first 8 months, and during this period environmental conditions, particularly temperature, moisture and light must be optimum for rapid vegetative growth. This is followed by a period of low growth activity and increased sugar storage. The cane is assumed to be ripe when the sugar content is at a maximum.

8. Ripeness for harvest: Cane varieties vary in the length of time they can be left standing in the field after they are ripe enough for milling. Some varieties can be left for as long as 3 months while others deteriorate rapidly and are of no use.

9. Yield capacity, fertilizer response, resistance to pests and diseases, are the other important characters that contribute to suitability. Some of these are varietal characters, but can be suitably modified by proper field management.

Tillering in Sugar-Cane

The mode of tillering in sugar-cane is so intricate that its study requires a careful digging up and dissection of the underground parts of the plant. Barber described the mode of tillering in cane by means of formulae, the simplest of which describes tillering in tropical thick canes, as a+3b+3c, where a refers to the primary shoot, b refers to the secondaries and c the tertaries. More complicated formulae are described by Barber for both the thin indigenous Indian canes, as well as the wild canes. (5).

They are:

a+9b+7c (*S. barberi*)
a+8b+23c+31d+3e (*S. spontaneum*).

Varieties however differ in the trend of tillering and the ultimate number of tillers at harvest. Again unlike in most grasses where tillering and elongation occur as two distinct and consecutive phases of growth, in cane whenever ample space is given, each shoot will grow steadily upward as soon as it is formed. Then again tillering in sugar-cane is almost a continuous process resulting in a large number of stalks.

A number of factors influence tillering in sugar-cane. Some of the more important environmental factors are:

1. Light—This includes both the intensity and duration of light. Under high light intensities, the downward flow of hormones diminishes, and hence their inhibitory effect on tiller formation is removed. Accordingly tillering is markedly reduced in cloudy and shaded areas. Day lengths have similar effects. Short days depress tillering.

2. Temperature—Optimum temperature for maximum tillering is around 30°C.

3. Fertilizers—Fertilizer nitrogen promotes tillering up to a point. Beyond the optimum, there is no further effect.

4. Moisture—Irrigation influences tillering favourably.

5. Spacing—Spacing between rows and within the rows has a direct effect on the trend of tillering and the ultimate number of millable stalks. A wider spacing promotes greater tillering.

6. Earthing up: This forms an important tool in the hands of the sugar-cane grower, since both the number and the quality of tillers is affected by the extent to which the plants are earthed up. Early tillering can be encouraged, by a light earthing up, thus exposing the young primaries to the beneficial effects of heat and light. Subsequent tillering can be controlled by a heavy earthing up which cuts off both heat and light. Consequently only very strong shoots will be able to push through the soil.

Depending on all the above factors tillering can occur quickly or be spread over several months after planting. At harvest time therefore there will be fully ripe mother canes, and a number of other canes varying in ripeness and younger in age from the mother cane. Since it will almost be impossible to harvest each age class separately, the next best thing would be to aim at nearly equal maturity in all the stalks. This is necessary because the immature canes reduce the quality of the juice on account of their high content of glucose. In practice this is achieved by encouraging rapid tillering during the first three months, and then removing all subsequent tillers. A number of cultural techniques can be used to achieve the same result.

Varieties

Just as in cotton, selection and breeding work, throws up new and better varieties all the time, and each good variety is soon replaced by another which is considered to be even better. Several imported varieties of sugar-cane have been introduced and evaluated in Ceylon, mainly from the East Java Experiment Station, the Coimbatore Sugar-cane Breeding Station and other places. Out of several imported varieties three promising varieties have been isolated at Gal Oya. They are CO 419, CO 875, and CO 775. Of these CO 775 shows the most promise. The results of a variety trial conducted in 1963, showed that of six imported varieties tested, CO 775, and CP 44/155 appeared to be the most promising. (6). (Table 1)

ECOLOGICAL ADAPTATION

Sugar-cane thrives best in areas of moderate rainfall, around 30-40 inches. This of course has to be supplemented by timely irrigation, during rainless months particularly in view of the fact that the crop is on the land for a long time, nearly 10 months in the case of the early maturing canes, and 18 months in the late maturing ones. Ratoon crops will also need further irrigation. Ideal conditions exist in the dry zone of Ceylon for sugar-cane cultivation, provided irrigation facilities are available for supplementary irrigation. Gal Oya gets an abundant rainfall with about 80 inches during the Maha and 20 inches during the Yala. There

TABLE I

Results of varietal trial analysis of Juice and Cane on a crop eleven months old—Gal Oya (Amaratunga 1964)

Variety	Date	Weight per cane in lbs.	Tons / acre (estimated yield)	Juice and Cane Analysis				
				Brix value	Polarity	Purity	Reducing sugars	Sugar %
CO 527 ..	28.4.64	2.92	57.29	15.91	13.39	84.16	1.76	10.69
CO 419 ..	28.4.64	4.34	67.77	14.13	11.00	77.85	1.89	9.67
CO 775 ..	28.4.64	3.43	65.22	16.76	13.95	83.23	1.53	11.43
CP 44/144..	29.4.64	3.67	48.55	18.35	16.02	87.30	0.59	12.77
CO 1111 ..	29,4,64	2.18	40.24	15.30	12.82	83.79	1.81	9.82
CO 875 ..	29.4.64	2.61	33.45	13.31	10.00	75.13	2.22	8.56

is also the added advantage of a semi-dry period from about March to May, which is suitable for planting and a dry period from June to September for the maturing and harvest of cane. Similar conditions exist also at Kantalai. Both locations have also the facilities for supplementary irrigation.

Irrigation requirements both in respect of quantity and frequency of irrigation have been the subject of several experiments in India. Mollison (7) experimenting in the sugar-cane tract around Poona found that frequent light irrigations was preferable to few heavy irrigations.

The best soils for sugar-cane are light coloured brown or reddish loams. Deep soils with good drainage are ideal. Stony and gravelly soils, are not suitable. Clay soils retard maturity. Soils in the Gal Oya valley vary from heavy loams to sandy soils with pH values ranging from 5.5 to 6.4.

Ample drainage is essential in sugar-cane fields. Whenever sugar-cane plantations are in close proximity to tanks, there is a possibility of the subsoil becoming too moist. A wet sub-soil retards the growth of the cane. Such a soil predisposes to the attack by red rot disease, and tends to increase the salt content in the root zone which has an adverse effect on the quality of the juice. In such instances either open drains on the sides of a field or ditches in the field itself must be constructed to drain out seepage water, and to prevent the sub-soil from getting too moist. Poor drainage can cause striking differences in yield. Yield differences amounting to nearly 25 tons of millable cane per acre, have been observed on the Hebbal farm near Bangalore, due to poor drainage conditions. (7).

Yields Obtained on Hebbal Farm, Mysore

Under Good drainage	31.5 tons/acre
Under Intermediate drainage	22.5 tons/acre
Under Poor drainage	6.5 tons/acre

Rotations

Sugar-cane lands generally have a high level of soil fertility, due to the fact that the roots, stubble and trash of the cane add considerable quantities of organic matter to the soil. For a crop of 40 tons millable cane per acre, this amounts to nearly 8 tons of dry matter per acre. The increased fertility may also be attributed to the systems of culture, regular irrigation, and the residual effects of large quantities of fertilizers added to the crop. Accordingly, sugar-cane lands could be utilized to get very successful crops of paddy in a rotation. At Gal Oya, lands where a sugar-cane crop had been taken, and the discarded ratoons ploughed in, gave bumper yields of rice in the Maha season of 1962/63 compared to newly cleared jungle land. The following rotation is recommended, on the basis of research carried out by F. A. O. experts, at Gal Oya.

1st year—Plant Cane
2nd year—First ratoon
3rd year—Second ratoon
4th year—Maha—Paddy
Yala—green manure
5th year—Plant Cane

Planting season

The best time for planting cane in Ceylon is between March to May. Too early a planting, results in arrowing (flowering) of the cane in September, this being true particularly of some of the Indian varieties of cane. Too late a planting on the other hand retards the growth of the cane during its grand period of growth due to the cloudy weather during the Maha. Accordingly yield decreases with later planting. Time of planting trials, conducted at Gal Oya show that the quality of the cane, planted after May is extremely poor. (Table 2).

CULTURE OF THE CROP

Land preparation

Heavy machinery is used in land preparation in Gal Oya and Kantalai. Deep tillage is practised. The land is then ridged to a depth of 12-13 inches. The spacing between furrows is 43 inches.

Planting material

The planting material used in sugar-cane cultivation is a cutting of the stalk containing one or more buds. A top cutting is the most

TABLE 2

Time of Planting Trial—Gal Oya (Amaratunga 1964)

Date of planting		Age Month	Days	Brix value	Pola-ri y	Purity	Juice and Cane Analysis Pola-rity % Cane	Fibre % Cane	Reducc-ing Sugars
12.2.63	..	15	28	17.52	14.46	82.53	10.12	22.72	0.98
19.2.63	..	15	21	17.25	14.26	82.72	10.09	22.87	0.96
26.2.63	..	15	14	17.92	15.07	84.12	11.96	19.18	0.95
4.3.63	..	15	7	18.07	15.16	84.23	11.96	19.02	0.93
11.3.63	..	15	0	18.27	15.73	86.09	12.02	17.68	0.65
20.3.63	..	14	23	19.17	16.69	87.06	12.98	17.02	0.55
7.4.63	..	14	16	19.41	17.15	88.35	13.08	15.26	0.43
14 4 63	..	14	9	19.96	17.71	88.72	13.27	14.98	0 41

desirable because it constitutes the non-millable portion of the stem. The limiting factor is that it is available only at the time of harvest. But its usefulness for planting, stems from the concentration of nodes in the upper end of the stalk, with its consequent high number of buds. Stalk cuttings from the lower portion, are costly because they are millable. Either sections of the stem, or the entire length can however be used as planting material. Cuttings from the top section in any case germinate more rapidly than those from the lower sections. The occurrence of such a germination gradient from top to bottom has been explained on the basis of the moisture content of the buds whch decreases towards the base of the stem. Younger buds contain more moisture, because they have been less exposed to drying. The position of the buds at planting makes some difference to the time of emergence of the shoot. Buds facing upwards, emerge twice as fast as the buds facing downwards. When cuttings containing more than one bud are planted an additional factor of apical dominance is noticed. In most sugar-cane countries, the practice is to plant the cutting in such a way that the buds remain to a side.

Rapid propagation methods

Owing to the difficulty of having to wait till harvest time, in order to obtain planting material several methods are now in vogue for the rapid propagation of planting material.

Seblang or sprouting method

In this method planting is done in light fertile soil, and adequate care is taken to ensure wide spacing, shallow planting, heavy fertilization and even watering. As soon as new tillers are formed, and have established their own root system, they are separated from the mother plant and planted out on their own. Successive generations of tillers are established in this way, and this method gives the highest rate of propagation.

Single-eye method

In this method, shoots are allowed to develop four or more aerial internodes. These are then cut to ground level, segmented into single eye cuttings and germinated in special containers.

Rayungan method

This method is similar to the single-eye method, but differs from it in that the development of the buds into shoots takes place on the plants themselves. To promote such shoot development, decapitation is resorted to, in order to eliminate apical dominance. At two to four week intervals, developing shoots are harvested and planted out. Successive harvests, promote further shoot development along the stalk. Ample fertilization promotes maximum rayungan development.

Planting

Seed setts having 3 eye buds are placed end to end in a furrow and covered lightly with soil. (Plate 13). In furrows 3 feet apart this would require about 10,000 setts per acre. Germination is complete after 3 weeks, and tillering commences about six weeks after planting.

Plant nutrition

Sugar-cane is a heavy feeder, and fertilizer application would depend on the fertility level of the soil. Results of Indian experiments show that a cane crop yielding 25 tons of millable cane to the acre removes 55 pounds of CaO, 56 pounds of N, 68 pounds of P_2O_5 and 190 pounds of K_2O from each acre of land. (7). South Indian practice is to apply 200 pounds of N, 50 pounds of P_2O_5 and 100 pounds of K_2O per acre to plant cane. For irrigated cane in Jamaica 400 pounds of ammonium sulphate, 200-400 pounds of superphosphate and 100-300 pounds of muriate of potash is applied. Table 3 gives a summary of fertilizer practice at Gal Oya. (6).

The phosphate and the potash mixture is applied prior to planting while the nitrogen is applied at intervals of 3-4 weeks after planting.

Plate 13. Furrow planting of Sugar-cane. Cuttings being placed end to end.

Plate 14. Harvesting Sugar-cane at Kantalai.

TABLE 3

Fertilizer practice at Gal Oya

Plant crop	Cwt/acre		
	Heavy soils	Medium soils	Light soils
P & K Mixture	1½	2	2
Ammonium sulphate nitrate	1	1	1
Ammonium sulphate 3rd dose ..	1	1½	2
Ammonium sulphate 4th dose.. ..	1	2	2½
	4½	6½	7½

Ratoon crop	Cwt/acre		
	Heavy soils	Medium soils	Light soils
P & K mixture	1½	2	2
Ammonium sulphate nitrate	1	1	1
Ammonium sulphate 3rd dose ..	1¼	1½	1½
Ammonium sulphate 4th dose ..	1¾	2½	2½
	5½	7	7

Intercultivation

Several intercultivation operations are carried out to promote the development of a good stand. They are:

1. Hilling up—3 to 4 weeks after planting when a small quantity of soil is used to cover the roots of the plants, together with the first dose of fertilizer nitrogen.

2. Stirring up—Superficial stirring of the soil to control weed growth, and promote root growth.

3. Partial earthing up—4 weeks after hilling up.

4. Final earthing up—3 to 4 weeks after partial earthing up. The original ridge is now converted to a furrow.

Weed control

Weed control during the first few months is essential. After that the cane would close in sufficiently to control weeds automatically. Manual weeding can be expensive. Pre-emergence weedicides have been tried out and are proving successful. Simazine at the rate of 4 pounds active ingredient/acre in 40 gallons of water has shown promise. 2—4—D controls weeds for about 5 weeks.

PESTS AND DISEASES

Pests. The more important pests in sugar-cane fields appear to be wild elephants, wild boar, porcupines and stray cattle. Considerable damage is caused to the cane crop by these animals, both at Gal Oya and at Kantalai. In Gal Oya damage to the crop by wild elephants has been reduced to a certain extent by the use of electric fences along the perimeter. The control of wild boar presents greater problems, and so far shooting is the only mode of control. Stray cattle can be controlled by the use of barbed wire fences.

Diseases. The more important diseases of sugar-cane in Ceylon are ratoon stunting disease, and smut. The R. S. D. disease which is caused by a virus causes serious economic losses, by stunting and retarding growth, particularly in the ratoon crops. Within a few years, the disease spreads rapidly into an area, and soon existing varieties become useless. The losses may amount to 15% of the crop. The disease can be controlled by prolonged heat treatment of the nursery seed material. The other disease of significance is smut (*Ustilage scitaminea*). The characteristic symptoms of smut is the production of a black whip from the terminal bud. Here again infected varieties will have to be replaced. CO 453, is very susceptible to smut. Resistant varieties have to be used, in order to control this disease. Other diseases which are noticed, but which are not of any major significance at the present time are brown spot, pineapple disease, red rot, red rot of the leaf sheath, rind disease, ring spot, schizophyllum rot, sheath rot, yellow spot, which are all fungal in origin, grassy shoot mosaic and ring mosaic which are virus diseases, and also leaf scald, mottled stripe, and red stripe which are bacterial in origin. Yet another unidentified disease is a kind of leaf striping, which again is only of minor importance.

Harvesting

When the cane crop is mature it should be harvested and once harvested the cane should be milled quickly. Harvest time should coincide with the dry season, to enable a long period for crushing. There are two general methods for ascertaining the right time (ripeness) of cane for harvest.

1. The first method is to harvest a sample of stalks at 14 day intervals, around harvest time, crush, and analyse the juice for sucrose content. The percentage of recoverable sucrose steadies when the cane is mature.

2. The second method involves the withdrawal of a sample of juice by a juice sampler and using a hand refractometer to determine the brix value. Brix refers to the percentage total solids in the juice. Due to the high positive correlation existing between brix and sucrose concentration, the curves for brix and sucrose are similar.

In Ceylon harvesting is done by hand. The cane is cut down to ground level, trimmed and loaded for transport to the factory.

Yields

With better varieties of cane it should be possible to get an average yield of 40 tons millable cane to the acre. Yields of CO 527 at Gal Oya were only 21.3 tons in 1963. Variety trials show an estimated yield of nearly 65 tons per acre for CO 775 the new variety. (6)

Ratooning of Cane

Sugar-cane is normally ratooned, and 2 ratoon crops generally obtained. Ratooning involves a saving in labour, fertilizers, and other factors of production. The ratoon crop also is available for crushing earlier in the season. The yield of ratoon cane is however generally lower than that of plant cane.

Manufacture of Sugar

Cane produced for the factory is normally used in the manufacture of consumption sugar called 'plantation white'. The process includes the following steps:

1. The juice is extracted by crushing.
2. The juice is then strained and treated with lime to help in the formation of scum, which is removed and used as molasses.
3. The clear juice is treated with sulphur dioxide and bleached.
4. The juice is evaporated and concentrated in a series of vacuum pans, by steam heating under reduced pressure.
5. The syrup is then concentrated into masscuite of the proper consistency, also by steam heating under reduced pressure.
6. The masscuite is later passed into cooling tanks to promote crystallization.
7. The sugar is now centrifuged and later dyed with blue.
8. The sugar so produced is finally dried with hot air.

Costs and Returns

The figures available at Gal Oya indicate very clearly some of the factors that have contributed to the losses incurred by the infant sugar industry in Ceylon, every year.

The growing cost per ton of cane at Gal Oya for 1962/63 was Rs. 72.85, including the cost of discarded and damaged cane.

The growing cost per ton included the cost of land preparation fertilizers, irrigation, land rent, administrative costs, labour and field overheads, and the cost of direct labour. The cost per ton of cane delivered at the factory was Rs. 119.75 made up of

Average cost of growing cane	Rs.	72.85	per ton
Average cost of harvesting		28.12	per ton
Average cost of transport		18.78	
		119.75	
Manufacturing cost		48.20	per ton of cane
Overheads		22.05	
		190.00	
Cost per ton of sugar		2,787.80	

On account of the high cost of production per ton of sugar, proposals have been made to reduce some of these costs. These include the use of canes of improved quality, and reducing the growing, harvesting and crop protection costs by various methods of land alienation to colonists for cultivation. On the basis of these proposals it is estimated that the reduced cost of production per ton of sugar would be Rs. 1745.84, which would represent a reduction in the present cost of production by Rs. 1041.96. Since the Government paid around Rs. 850.00 per ton of sugar, the net loss per ton of sugar at Gal Oya in 1962-63 was Rs. 1947/80.

At Kantalai, even with the use of Army Labour, the costs of cultivation are slightly less. The figures given below show the cost of production of both planted cane, as well as ratoon cane, with and without the use of Army Labour. (8).

PLANTED CROPS

		Cost Per Acre Rs. cts.
1.	Land preparation	150.00
2.	Fertilizers	58.00
3.	Planting without C.A.P.C. (army)	20.00
	Planting with C.A.P.C.	52.00
4.	Irrigation without C.A.P.C. ...	40.00
	Irrigation with C.A.P.C....	104.00
5.	Weedicides	95.00
6.	Cost of spraying	4.00
7.	Crop protection	15.00
8.	Management	27.00
9.	Harvesting without C.A.P.C.	300.00
	Harvesting with C A.P.C.	520.00

10.	Miscellaneous work such as maintaining irrigation canals, bunds, etc. without C.A.P.C. ...	10.00
	with C.A.P.C.	26.00
11.	Cost of seed material	90.00
12.	Transport costs	38.00
	Total costs without C.A.P.C.	847.00
	Total cost with C.A.P.C. ...	1,179.00
	Average yield per acre—20 tons.	
	Cost per ton of cane with C.A.P.C. ...	58.95
	Cost per ton of cane without C.A.P.C. ...	42.35

RATOON CROPS

		Cost per Acre Rs. cts.
1.	Fertilizers	75.00
2.	Cost of application	5.00
3.	Weedicides (4 lbs. Karmex only)	46.74
4.	Cost of spraying	4.00
5.	Intercultivation	10.00
6.	Irrigation without C.A.P.C.	40.00
	Irrigation with C.A.P.C.	104.00
7.	Crop protection per season	15.00
8.	Management costs per season	27.00
9.	Miscellaneous work:	
	without C.A.P.C.	10.00
	with C.A.P.C.	26.00
10.	Cost of transport—Average yield of ratoons--17 tons	38.00
11.	Harvesting costs:	
	with C.A.P.C.	442.00
	without C.A.P.C.	225.00
	Total costs with C.A.P.C.	802.74
	Total costs without C.A.P.C.	490.74
	Cost per ton with C.A.P.C.	47.22
	Cost per ton without C.A.P.C.	28.87

REFERENCES

1. Sugar-Cane in Ceylon. Editorial. Tropical Agriculturist, Vol. CVII. No. 4. p. 205-6.
2. Agricultural plan. First report of the Ministry Planning Committee. Ministry of Agriculture and Food. 1958. p. 65-66.
3. Short term implementation programme 1962.
4. Van Dellewijn, C. Botany of Sugar-Cane. Waltham. Mass. U. S. A. The Chronica Botanica Co. 1952.
5. Barber, C. A. Studies in Indian Sugar-Canes. No. 4. Tillering or underground branching. Mem. Dept. Agric. India. Bot. Ser. 10 (2) 39-153. 1919.
6. Amaratunga, J. L. Agricultural practices and the progress of Sugar-Cane cultivation in the Gal Oya Valley. C. A. A. S. sessions. 1964.
7. Yegna Narayan Aiyer A. K. *Field Crops of India.* Govt. Press, Bangalore.
8. Dahanayake, A. Agricultural Research Officer, Kantalai. Private Communication.

GROUP V—NARCOTICS

23. TOBACCO

Economic importance

Tobacco cultivation was introduced into Ceylon in 1610, during the Portuguese era (1). Its importance derives from the narcotic properties of tobacco leaves. Tobacco leaves are used primarily in the manufacture of cigarettes, cigars and pipe tobacco. They are also used for the making of snuff. Tobacco leaves can further be used for chewing, and such tobacco is referred to as chewing tobacco.

Ceylon's annual requirements of tobacco were estimated in 1958 to be nearly 3½ million pounds of cured leaf of cigarette tobacco, and nearly 2 million pounds of cured leaf of bidi tobacco. (2).

The cultivation of cigarette tobacco and the curing of the leaves in Ceylon, has been largely under the aegis of private tobacco companies which issue selected seed to the cultivators and also purchase the produce from them. The acreage under cigarette tobacco cultivation in 1960-61 was 10,000 acres, with a production of over 4 million pounds of cured leaf. (3). Of this amount the major part was grown on high land, under rainfed conditions in the Kandy, Nuwara Eliya, Matale, Kurunegala and Puttalam districts, The remaining acreage was grown on well drained paddy lands in the Yala season with supplementary irrigation. These areas are located in Hingurakgoda, Polonnaruwa, Elahera, Kantalai and Gal Oya. As far as cigarette tobacco production is concerned, the country is more or less self-sufficient. However, a million rupees worth of cigarette tobacco is still imported for blending purposes.

As far as bidi tobacco is concerned it is estimated that 4,000 acres would be sufficient to produce the country's requirements. Two distinct zones, namely the zone between Matale and Jaffna and the zone between Minipe and Tangalle are considered to be eminently suited for bidi tobacco. Till very recently, bidi tobacco was not cultivated on a commercial scale. In 1961-62, nearly 115,000 pounds of bidi tobacco leaf was produced from 300 acres in the bidi tobacco extension schemes. (4). In 1962 imports of bidi tobacco amounted to 3,000,000 pounds, costing nearly Rs. 4 million. In addition Rs. 666,990 was expended on the import of manufactured bidis. (5).

Cigar tobacco is cultivated mainly in Jaffna and the Kandyan hilly regions. Three component parts constitute a cigar, namely the filler, binder and the wrapper tobacco. Filler is the inner part of the cigar which constitutes the cigar proper and gives to it, its special smoking quality. Binder is the leaf which is wrapped over the filler keeping it in shape and binding it together. The wrapper is the leaf which forms the outer cover over the cigar which gives to it, its distinctive colour, texture and smoothness of feel. All three types of leaf must possess high burning quality to be of economic value. Each type of leaf has its own distinctive features which determine the use to which it is put. In Ceylon all these three types of leaf are produced on the same plant commonly referred to as the Dumbara tobacco. The wrapper is made from the lower leaves, the binder from the leaves immediately above, and the filler from the upper most leaves. In other countries, each leaf class is represented by distinct varieties. For the Jaffna cigar, the top leaf or 'theruvi' is used for the wrapper. The "oddusal" or centre leaf along with the good leaf and scrap are used for the binder and filler (6).

BOTANY OF TOBACCO

The tobacco plant belongs to the family Solanaceae, and to the genus *Nicotiana*. The species *N. tabacum*, is the most widely cultivated throughout the world. *N. rustica* is a hardy species found growing wild in Mexico. In the United States, it is cultivated for the sake of its high content of nicotine which is used in the making of insecticides.

N. persica, is a white flowered variety grown in Persia. The leaves on curing have a yellowish colour and a mild flavour. The cultivated species of *tabacum*, are plants that usually attain a height of 4-6 feet. The tap root is strong and goes down to a depth of about 2-2½ feet. Lateral roots spread radially to about 3 feet. The upper leaves of the tobacco plant are generally smaller than the lower leaves. The leaves arise from the stem alternately and spirally, so that the ninth leaf is directly above the first leaf. The leaves themselves have either a crowded or loose appearance depending on the variety. Similarly differences arise also in the shapes and sizes of leaves. Both the stem and leaves are pubescent, and sticky to the touch, due to the exudation of resin. The tobacco plant produces a terminal cluster of flowers. The flowers are funnel shaped and the terminal ones open first. They may be light red, white, or light pink in colour. The fruit is a capsule, containing about 4000-8000 seeds. A single tobacco plant may produce a million seeds. Tobacco is a self fertilized plant.

Varieties

There are a large number of varieties of tobacco under cultivation, the differences being based on the size and shape of the leaves, period of maturity and particularly the quality of the cured leaf on which alone is dependent its use.

Cigarette tobacco

The main variety of cigarette tobacco under cultivation in Ceylon is Harrison's special, a virginia tobacco. Of 11 imported varieties of cigarette tobacco studied in 1960-61 by the Tobacco Division of the Department of Agriculture, Virginia Gold, Vesta 30 and Golden Special were found to be better than the standard Harrison's special variety (3).

Bidi tobacco

A number of selections of bidi tobacco are under cultivation. Of these K49 and G6 are particularly suited for irrigated areas and S20 and S12 are more suited under rainfed conditions.

Pipe tobacco

The main pipe tobacco varieties are Island Pride and Turret which are country varieties.

Other varieties

A number of other varieties have also been grown or are being evaluated at the present time.

Flue curing varieties

Delcrest, White Gold, Hicks

Air curing varieties

Dumbara, Canadian Aromatic, White Burley, Canadian Burley.

Sun curing varieties

Dark Western.

Rack curing varieties

Turkish Tobacco

Selection of Mother Plants for Seed Production in cigarette tobacco

Since tobacco is a largely self-fertilized plant, it lends itself to effective selective propagation. Selection of course is primarily based on the quality of the leaf which must conform to certain physical and chemical requirements. The colour, texture, and aroma of the leaves become important physical criteria for selection. A thin textured leaf with bright colour is considered more suitable for cigarette tobacco. High quality cigarette tobacco should also be high in soluble carbohydrates and potash and relatively low in crude fibre, nicotine, nitrogen, calcium, ash and acids. A high content of potash and low chlorine is beneficial to the maintenance of good burning quality. Good burning quality is evidenced by a good fire holding capacity which imparts to a cigarette a slowness and eveness of burn. It also results in the production of a residual ash which is white in colour. When selecting plants for seed, the following attributes should therefore be normally taken into account.

1. The size, shape, thickness, number and spacing of the leaves.

2. Venation of the leaves. A pronounced venation is not conducive to uniform drying. Also the angle of venation in relation to the midrib should be wide.

3. Colour of leaf, and earliness of maturity. A bright coloured leaf is preferable.

4. Silky leaves, which do not crinkle easily and having a fair degree of hairyness, and resin development, on the upper surface.

5. Plants that do not sucker freely.

Bagging flowers for seed

Flowers on selected plants should be bagged when the first flowers open. The opened flowers can be removed, and the rest of the raceme bagged. Bags are usually dusted with DDT before use, in order to prevent any insect attack. The seed is harvested when the capsules turn brown and mature. Tobacco seed usually contains a small quantity of low quality seed, which can be separated by means of a tobacco seed separator. Tobacco seeds should be stored in a cool place, generally in coloured bottles.

ECOLOGICAL ADAPTATION

Although tobacco can be grown under a wide range of climatic and soil conditions, the quality and commercial value of the leaf is conditioned by the environment under which it is grown. Tobacco can be grown between 60°N latitude and 40°S latitude. The optimum temperature for seed germination is about 88°F, for seedling growth in the nursery is around 75 to 80°F, and in the field around 80°F. A minimum of 50°F is required for tobacco areas. In areas where the field temperature is around 80°F, 70 to 80 days is enough to mature the crop. With a lower temperature, nearly 100-120 days is required to mature the crop.

An annual rainfall of 40-45 inches, which is well distributed is ideal for tobacco culture. A low rainfall results in tobacco that is high in nitrogen, nicotine, either extract, acids, and calcium and low in potash and soluble carbohydrates. On the other hand the crop is not suited to high rainfall areas as the heavy rainfall at maturity washes away the resins which form on the leaf surface and thereby reduces the quality of the leaf.

Humidity is also an important factor in tobacco culture. A high humidity at harvest, which permits the harvested leaves to cure at the proper rate is important.

Hence the optimum conditions would be a moderate rainfall during the growing season to permit uninterrupted growth followed by a dry season at harvest time during which the humidity does not fall below 80%. Windy areas are not suitable for tobacco culture, since wind tends to tear and damage the leaves. Cultivation of tobacco in close proximity to the sea is also not recommended since it leads to the excess deposition of sodium chloride on the leaves, which reduces their fire holding capacity.

Tobacco can be grown on a wide variety of soils ranging from red, light or ash coloured loams to rich heavy soils. Tobacco is in fact cultivated also on alluvial soils in river valleys, as well as on very sandy areas. Different varieties of tobacco are cultivated, each suited to a different kind of product, and hence it is possible to adjust varieties to suit various soil types. For example, a light soil is most suited to growing a thin high quality leaf, and hence in these areas, cigarette tobacco, cigar wrapper tobacco, and the better type pipe tobacco could be cultivated. Similarly a heavy soil rich in nitrogen is more suited to the growing of large heavy bodied leaves, and could be profitably cultivated to pipe, cigar and chewing tobacco. In all tobacco soils however, good drainage is of paramount importance. Tobacco roots are very sensitive to heavy rainfall or irrigation without adequate drainage. Since tobacco is fairly deep rooted, soil depth also becomes a factor of importance. In general, tobacco soils should be slightly acidic, with a pH around 5.5 to 6.5. Excess acidity is undesirable, since it affects quality by interfering with the absorption of calcium, magnesium and phosphorus and increasing the absorption of aluminium and manganese.

FERTILIZERS

Since tobacco is a money crop, and gives reasonably high returns per acre, expenses incurred in heavy applications of fertilizers would be justified. Proper relative proportions of calcium, magnesium and potassium are essential for good burning quality in tobacco, especially of the cigar types, and can usually be achieved by correct fertilizer practice. It has been estimated that a 1000 pound crop of flue cured tobacco leaves contains the following quantities of nutrients: 16 pounds of elemental nitrogen, 4 pounds of phosphoric acid, 20 pounds of potash, 25 pounds of calcium, 31 pounds of magnesia and 6 pounds of sulphur. (7).

For cigarette tobacco the Department of Agriculture recommends the application of fertilizers in two doses, the first, seven to 10 days after transplanting and the second, 2 weeks after transplanting. For light sandy loams deficient in nitrogen the recommended mixture consists of 100 pounds of ammonium sulphate, 200 pounds of concentrated superphosphate and 125 pounds of sulphate of potash. For medium loams, such as well drained paddy lands, the recommended mixture consists of 50-60 pounds of ammonium sulphate, 200 pounds of concentrated superphosphate, and 125 pounds of sulphate of potash. For bidi tobacco which responds to heavy nitrogenous manuring, the addition of 5 tons of compost or cattle manure per acre is recommended. In the alternative the application of 2 hundred weight of ammonium sulphate in two doses, the first one week after planting, and the second 3 weeks later is suggested as a suitable fertilizer practice. When using potassic fertilizers, it is important to avoid the use of chlorides, such as muriate of potash, as they impair the burning quality.

Table 1

Fertilizer trial on Cultivators Fields

On Sandy Loam Soil—Gal Oya

(Kandiah and Ratnasingham 1962)

	Fertilizer mixtures					
	Quantities			Ratios		
	N	P	K	N/P	N/K	P/K
B_1	25	80	80	3.1	3.1	10.0
B_2	25	90	80	2.8	3.1	11.2
B_3	25	100	80	2.5	3.1	12.5

Unit Allotment No.	Fertilizer mixture	Green wt. per plant in lbs.	Green wt. per acre in lbs.	Price per lb. green leaf cts.	Percentage dry matter	Price per lb. cured leaf Rs. cts.
3/1 ..	B1	0.976	6.050	13.2	19.2	2.26
	B2	0.977	6.057	13.5	18.7	2.17
	B3	0.922	6.152	13.4	15.2	2.39
4/119 ..	B1	1.32	8.185	12.3	11.20	2.80
	B2	1.42	8.804	14.6	10.10	3.05
	B3	1.32	8.185	13.6	10.80	2.81
15/97 ..	B1	0.317	1.965	16.9	21.6	2.85
	B2	0.371	2.300	16.0	18.8	2.84
	B3	0.448	2.777	17.2	16.2	2.99
5/84 ..	B1	0.378	2.343	14.9	8.5	2.59
	B2	0.683	4.235	13.8	10.4	2.67
	B3	0.473	2,933	15.5	25.0	2.87
6/70 ..	B1	1.28	7.936	14.7	14.4	2.39
	B2	1.14	7.068	13.8	14.1	2,45
	B3	1.32	8,185	15.5	17.0	2.17
11/20 ..	B1	0.523	3.243	16.7	13.4	2.43
	B2	0.541	3.355	16.7	14.1	2.86
	B3	0.567	3.576	16.3	13.6	2.46

The Ceylon Tobacco Company recommends the application of a 5—18—15 fertilizer mixture at the rate of 700 pounds to the acre, in two doses, the first application 7 days after planting, and the second application 14 days after planting. In actual practice the fertilizer is applied in a half circle around the plant, the first application being given at a depth of 3″ and the second at a depth of 6″. When tobacco is cultivated on hilly land it is important to apply the fertilizer on the upper side of the plant. Fertilizer trials conducted in the Gal Oya valley showed that a mixture containing N/P: N/K: P/K in the ratio of 2.5: 3.1: 12.5 was suitable for sandy loams and sandy soils, while a mixture containing these nutrient elements in the ratio 2.0: 2.5: 12.5 was suitable for loams and heavier soil types. (8). (Tables 1 and 2).

TABLE 2

Fertilizer trial on Model Farm—Unit 4
On Loamy Soil at Gal Oya
(Kandiah and Ratnasingham 1962)

Fertilizer mixtures

	Quantities			Ratios		
	N	P	K	N/P	N/K	P/K
1.	20	80	70	2.5	2.9	11.4
2.	20	90	70	2.2	2.9	12.8
2.	20	100	70	2.0	2.9	14.3
4.	20	100	80	2.0	2.5	12.5
5.	20	100	90	2.0	2.2	11.1
6.	20	100	100	2.0	2.2	10.0

Fertilizer mixture	Green wt per plant in lbs.	Price per lb. green leaf cts.	Percentage dry matter	Price per lb. cured leaf Rs. cts.	Price of green leaf per acre Rs.
1.	1.85	13.1	10.96	1.56	1,500
2.	1.33	12.4	7.80	1.36	1,023
3.	1.54	13.0	12.96	1.26	1,241
4.	1.88	13.4	8.67	1.51	1,562
5.	1.50	13.7	9.10	1.40	1,274
6.	1.81	13.4	11.41	0.95	1,054

ROTATIONS

Since tobacco is a money crop, conditions suitable primarily for tobacco should govern any scheme of rotation on tobacco lands. Experience in other countries has shown that tobacco following a legume sequence is not so desirable on account of the excess of nitrogen in the soil which tends to produce a heavy type of leaf.

This may not hold true under Ceylon conditions, but even if it were so, the quality would not be affected, if the nitrogen fertilization in such a sequence is reduced, or if the deleterious effects of excess nitrogen is counterbalanced by a heavy application of a potassic fertilizer.

Tobacco should not follow other solanaceous crops in a rotation, on account of their susceptibility to disease, particularly bacterial wilt.

The inclusion of a grass or weed fallow in a rotation has been found to be most suitable for tobacco. For rainfed highlands in Ceylon, where tobacco is grown in the Maha, a suitable rotation would be to grow tobacco once in 3 years. (9) During the 2nd and 3rd years the land could be put under a cereal or a cereal and mustard. During the Yala season, the land could be put under short aged legumes like cowpeas, green gram and beans or left fallow. For tobacco grown in the Yala in the rainfed highlands, a recommended rotation is to grow tobacco once in 2 years. During the second year the land is cultivated with some short aged legume. During the Maha of the same two years, some cereal or cereal and mustard may be cultivated. For irrigated paddy lands, again a two year rotation is recommended. Tobacco is grown in the Yala, followed by paddy in the Maha. During the 2nd year a short aged legume is grown in the Yala, followed by Paddy again in the Maha. The rotation recommended for tobacco in the Jaffna Peninsula where lift irrigation from wells is available is a two year rotation, with tobacco in the Maha followed by onions, yams and vegetables in the Yala. During the second year vegetables or yams in the Maha is followed by a cereal in the Yala.

Planting season

As indicated earlier, tobacco is cultivated in the rainfed highlands mainly in the Maha. In these areas, nursery preparation and sowing commences around mid October. Field planting is between December and January. Time of planting trials conducted by the Tobacco Division of the Department of Agriculture carried out at Tinneveli, Maha Illupalama and Polonnaruwa, show that early December planting is best for these areas. (3). Yala cultivation is usually undertaken only where irrigation is available. Planting in these areas commences around early May. Trials conducted at Polonnaruwa confirm this time of planting.

CULTURE OF THE CROP

Nursery preparation

Nursery preparation is important in tobacco culture, because the seed is so small, and it is important to get uniform seedlings. A site once used should not be used for another two years, otherwise there is a danger of the plants being attacked by bacterial wilt.

Plate 15. Tobacco nursery beds, covered with cheesecloth in the background, and open in the foreground.

Plate 16. Cigarette Tobacco nurseries at Hanguranketa. Note. Cheesecloth covering has been removed to harden the plants.

The area selected should have a friable sandy loam soil, should be free from any solanaceous crops, and should have a good water supply for irrigation. The nursery bed has to be free of any weeds and has to be worked down to a fine tilth. The standard size nursery bed is 15 feet long and 3 feet wide. This is a convenient size of bed for weeding purposes and also to effect proper measures for weed control. The soil should be sterilized either by burning trash over it, or by using some soil fumigant. This is particularly necessary against eel worm which attacks seedlings. Shell DD soil fumigant at the rate of 1 gallon to 1650 square feet is generally used for this purpose. The fumigant is discharged using a gun, about 35 injections being sufficient for a bed, given 1 inch apart. Such treated beds should not be sown immediately, and it is desirable to rest the bed for 21 days before sowing the seed. Some farmers camber the nursery beds, making the middle crest about 2 inches higher than the sides. Prior to sowing, the nursery bed should be raked, and about 1 pound of a fertilizer mixture added generally in a granular form, per bed. It is also usual practice to spray a solution of aldrex at the rate of 5 fluid oz. in 2 gallons of water, which amount is sufficient for about 35 beds, against seed picking ants.

Seed Treatment and Sowing

About ½ gram of seed, i.e. about 12,000 seeds are used to sow a nursery bed of the standard size. The seed is immersed in water, stirred well, and sown, using a watering can with a special rubber rose, to ensure even sowing. If sown evenly, it would be possible to raise about 60 seedlings per square foot, giving about 2,000-2,200 seedlings per bed.

After-care of Nursery beds

Nursery beds should be watered daily and kept moist till well after germination of the seedlings. Germination takes place in about 7 days and is completed by 14 days. Nursery beds are also covered with cheese cloth or coarse muslin to keep insects out, and also to provide shade to the young seedlings in the early stages. When the plants are about 3 weeks old they can be thinned down. From about the 10th day the covers are gradually removed for greater periods during the day, in order to harden the plants, and these can be finally removed around the 28th day. Tobacco seedlings are subject to a number of diseases, and nursery care should be directed towards controlling these seedling diseases. Regular spraying with fungicides and insecticides, should be commenced a week after germination, and continued right through the nursery stage. In practice after 10 days, weekly spraying with peronox at the rate of 2 oz. in 2 gallons of water is commenced for the control of damping off. This amount is sufficient for 70 beds. Rogor 40 at the rate of 16 fluid oz. in 40 gallons of water is applied at the rate of 1 gallon per bed for the control of whitefly, which causes leaf curl,

(Plate 17) and endrex 20 at the rate of 1 oz. in 2 gallons of water applied every 3rd day is used for the control of leaf eating insects. When the plants are about 5-8 weeks old, they are usually ready for transplanting in the field.

Land preparation in the field

Land preparation consists of ploughing to a depth of about 9 inches, harrowing and levelling, to break down clods, and obtain a weed free seed bed. The field is generally irrigated to moisten the soil prior to transplanting.

Transplanting

A dull day is chosen for transplanting. All woody, leggy, dwarf and bench rooted plants are discarded at transplanting. Ideal plants for transplanting should possess leaves which start from the base of the plant. They should be about 5 inches tall. Good healthy seedlings are selected and planted out.

Spacing

Spacing varies in various parts of the country. In the hilly areas in the up country the field spacing adopted is 2½ feet between rows, and 2½ feet within the row. In the low country areas the spacing is generally 3 feet between rows, and 2½ feet within the row. Sometimes two plants are planted to a hill and later thinned out.

Intercultivation

Once the plants are well established, intercultivation is carried out between the rows, and sometimes round the base of the plants, in order to eliminate any competition from weeds, and also to effect moisture conservation by the creation of a mulch.

Irrigation may be given as flood irrigation or as furrow irrigation which is the normal practice with irrigated tobacco. When well irrigation is used as in Jaffna, the presence of dissolved salts such as chlorides, nitrates, sulphates and carbonates may exert a deleterious effect on the quality of the leaf, irrespective of the type of soil on which the tobacco is grown.

SPECIAL OPERATIONS

Topping: Topping involves the breaking off of the top or crown of the plant at about the third leaf below the flower head. This is done with a view to preventing the plants from producing seed, and thus forcing the maximum development of the leaves. Topping results in larger, thicker and darker leaves that mature earlier. It may be necessary to go over a field 2 or 3 times in order to top all plants at about the same stage of growth.

Desuckering: After the plants are topped, shoots called suckers begin to grow vigorously from the axils of the leaves, and have to be removed. Desuckering is done a week or 10 days after topping and may have to be repeated at weekly intervals if necessary. The purpose of desuckering is similar to topping, that is to prevent photosynthates being diverted to parts other than the leaves.

Priming: The removal of sand leaves in tobacco (the lowest leaves) in order to remove dead and diseased leaves, and to promote a greater circulation of air is referred to as priming. Priming helps to check the spread of frog-eye disease within the crop.

The tobacco plant takes about 3 months after transplanting to mature. As the leaves ripen they become sticky to the touch. When ready for harvest the leaves develop yellow spots here and there on the surface, which later spreads over the entire leaves, which also have a limp appearance at this time.

PESTS AND DISEASES

Tobacco is subject to attack by several pests and diseases.

Insect pests

1. The tobacco aphid. *Myzus persicoe.* This pest weakens the plant, by attacking the leaves of the growing plant. Affected leaves twist and curl, and become poorly developed. The underside of the leaves is covered with myriads of these insects. Control is to remove and burn infected leaves.

2. Stem borer. *Phinorimoea heliopa.* This attacks seedlings in the nursery or young plants in the field. When transplanted these seedlings carry the pest with them, attacked plants give rise to bunched leaves which form a rosette. The damage is caused by the grub of a thin brown moth which lays its eggs on the leaf stalks. The grubs, bore into the stem, and damage the tissue. At this spot, a swelling is usually visible and can be used to detect the attack and the presence of the grub. A small slit made at this point reveals the grub which can be removed and destroyed. Nursery care is important in the control of this pest. Covering the nursery with a cheese cloth, prevents the moth from laying its eggs on the leaves at night. In the field a fortnightly spray using 15-25% DDT emulsifiable concentrate at the rate of 1 fluid oz. in 2 gallons of water gives a measure of control.

3. Leaf eating Caterpillar. *Prodenia litura.* Considerable damage resulting finally in serious defoliation of the plants can occur, due to attacks by the leaf eating caterpillar. The adult insect is a moth that lays its eggs on the young leaves. The grubs emerge in large numbers and feed on the leaves. Spraying with lead arsenate, is effective in the early stages.

Diseases

1. Damping off. One of the commonest diseases of tobacco nurseries is damping off. This occurs chiefly under high moisture conditions. Control measures adopted consist of a weekly spray commencing 7 days after germination and continuing for about 35 days. A copper fungicide such as peronox at the rate of 2 fluid oz. in 2 gallons of water is used to control the disease.

2. Frog eye disease. *Cercospora nicotianeae.* This is a serious fungus disease, particularly on cigarette tobacco. The disease appears at first as spots, which later coalesce, turn brown and dry up, producing holes on the leaf. In the process of flue curing affected spots appear as blemishes, even if in the early stages. Unsuitable weather conditions, such as rain at the wrong time predispose to the disease. Control measures usually adopted consist of spraying with a copper fungicide, about the time of topping.

3. Bacterial wilt. *Pseudomonas solanacearum.* This is another serious disease in tobacco, as well as in all other solanaceous crops in Ceylon. The bacteria are soil borne, and affected plants wilt and die rapidly. No effective control methods are yet known, but one method of checking the disease would be to rotate crops on the land, taking care to see that solanaceous crops like brinjals, tomatoes, potatoes do not follow each other. Thus it is equally important not to repeat tobacco on the same land more than once in 3 years. Whenever the attack occurs in the field, it is advisable to remove and burn all diseased plants.

4. Tobacco mosaic virus. This is another important disease of tobacco. Plants infected with mosaic may be reduced by 30 to 35% in yield and 50 to 60% in value. Infected leaves have light and dark green or yellow areas in a mosaic pattern. There are several strains of the virus, some causing mottling, others causing distortion of the leaves. The disease is very infectious and can be easily transmitted to healthy plants by direct or indirect contact. The virus remains active for several years even on dead material. No effective methods of control are known. Sterilization of tobacco beds, destruction of all refuse, and the removal and burning of all infected seedlings are some of the control methods adopted. Since plants vary in the degree of susceptibility, it should be possible to breed resistant varieties.

5. Yellow net virus. This disease occurs only in the field. Leaves show a network of light and dark green, hence called Chinese brocade. A systemic pesticide such as Rogor 40 is sprayed regularly to nursery beds, in order to afford protection to the plants later in the field. Recent trials conducted to measure the varietal resistance to this disease showed that of 49 varieties artificially inoculated with the yellow net virus, none were immune to the disease. The two commercial varieties Harrison's special and Vesta 30, were found to be highly susceptible. (4).

Physiological Diseases

Sand drown. This disease is common in areas where there is a marked magnesium deficiency. The lower leaves turn yellow, and appear limp and lifeless.

Harvest

Two general methods of harvesting tobacco are priming and stalk cutting. Priming involves the successive harvesting of lower leaves and this results in gains in weight of the upper leaves. In practice the highest mature leaf on a plant is located and all leaves up to that point are picked. On this basis about 5 to 6 picks are taken. In stalk cutting, the stalks are cut off near the base and allowed to wilt on the ground. Heavy bodied cigar tobacco leaves are generally harvested by stalk cutting in Jaffna.

For flue curing it is desirable to use uniform leaves, and these should be harvested in stages. Harvested leaves should be left in the shade till ready for the barn. Leaves should preferably be strung together to prevent sweating.

Harvest of bidi tobacco

Unlike in cigarette tobacco, top leaves mature first. Maturity in bidi tobacco can be judged by the appearance of the leaves which pucker and turn slightly yellow. Spangling or the formation of reddish brown spots on the leaves is a sign of good quality. Since in bidi tobacco, the top leaves are of a higher quality, they are cured and marketed separately.

Yields

Under good conditions an average yield of 400 pounds of cured leaf per acre can be obtained.

CURING

The purpose of curing is to dry the leaves, promote the decomposition of chlorophyll, hydrolysis of starch into sugars and control the respiration or fermentation of the sugars. Mineral salts also crystallize during the process, producing the grain of the leaf. Losses of nicotine during curing range from 10-33%. During curing there is a decrease in total weight of 84-88%. When the curing is completed the leaves are allowed to regain moisture to the extent of about 24 to 32%, to facilitate handling of the leaves without breakage. The curing itself is done in barns which are large enough to hold 5 to 7 tiers of suspended leaves or stalks.

Air curing

In air curing the leaves are cured in barns with ventilating doors which are opened or closed to regulate the temperature and humidity. At the commencement of the curing the relative humidity should be around 85 % but when the leaves begin to brown a lower humidity is desirable. Sometimes artificial heating is provided to lower the humidity and increase the rapidity of drying. It takes about 4 to 8 weeks by this method.

Flue curing

This is by far the most efficient method of curing. In principle the early curing stages are hastened and then while the leaves are still of a light yellow colour the drying is completed. The yellow colour of the leaf is fixed during the later part of the yellowing stage. The heat is provided through aluminium pipes inside the barn. Heat is generated generally by wood fire. Flue curing can be completed in 130 hours. Moss and Teeter (10) of the North Carolina Experiment Station illustrated the requirements for flue cured tobacco during curing, which may be summarized as follows:

Temperature and Humidity levels	Time	Stage of curing
1. Temperature raised from 85°F to 110°F gradually. Relative humidity 65-85 %	40 hours	Yellowing
2. Temperature raised gradually to 135°F Relative humidity reduced to 25 %	30 hours	Drying
3. Temperature raised to 165°F Relative humidity dropped to 10 % or less	25 hours	Killing

The heating is then stopped and the tobacco allowed to take up moisture. The floors are wetted to raise the humidity.

Tobacco barns, constructed under the aegis of the Ceylon Tobacco Company for flue curing, are of the standard size, 16×16 feet. Each barn has a capacity of about 4,500 pounds of leaf, which is the normal expected yield from 8 acres. In the Jaffna area the capacity of tobacco barns is about 3,000 pounds of leaf, since the leaves are larger. A barn in Jaffna caters for yields from 4 acres. The barn has ventilations both at the top and bottom. Each barn has accommodation for 7 tiers, each tier being 2½ feet apart. The leaves of tobacco are strung on sticks. Normally 22 bunches, each containing 3 leaves are tied alternately on each stick, eleven on each side. 70 sticks occupy one tier and about 500 sticks can be put into one barn.

Prior to being loaded into the barn, the leaves are graded into ripe, under-ripe and over-ripe leaves. The ripe leaves are again graded into light green and dark green leaves. The dark green leaves are loaded on to the upper tiers. The flue pipes are then clayed to prevent any smoke from escaping. Similarly the bottom ventilations are also closed and sealed with clay. During the curing process, once the colour is fixed these are cracked to get rid of any moisture in the barn. Ventilations should normally be

Plate 17. Leaf Curl caused by White Fly attack on Cigarette Tobacco.

Plate 18. Potato varietal trial at Sita Eliya.

opened only after raising the temperature to the required amount for the particular stage in curing, otherwise cool air enters the barn, causing sponging of the leaves.

Fire curing

In fire curing the tobacco is allowed to wilt in the barn for 3 to 5 days and is then fired slowly to maintain the temperature at 90° to 95°F until yellowing is completed. The temperature is then raised to 125-130°F until the leaves are dry. The firing process takes 3 to 5 days.

GRADING OF TOBACCO

Grading is done on the basis of colour. The leaves of tobacco are then made into hands of 25 leaves and heaped together in platforms and covered over with mats in a dark room. This gives the tobacco added flavour and aroma. The process is sometimes referred to as shingling.

There are several recognized grades in the local market. The Ceylon Tobacco Company purchases leaves, which conform to the following nine grade specifications. (11). Current prices are also shown.

1/V Bright lemon yellow leaf free from blemish. A ripe leaf with no green.

Price Rs. 3/60 per pound.

2/V Orange coloured full bodied leaf of good texture free from blemish. Ripe leaf with no green.

Price Rs. 3/70 per pound.

3/V Lemon or orange coloured leaf similar to grades 1 and 2, but carrying up to 10% blemish. Leaf must be of good body with no green.

Price Rs. 3/45 per pound.

4/V As grades 1 and 2 but with green tinge. Free from blemish.

Price Rs. 2/55 per pound.

5/V Semi-bright leaf orange to yellowish brown. Can carry blemish but must be of good body and texture. No green or perished leaf acceptable.

Price Rs. 2/70 per pound.

6/V Green leaf running to yellow or orange. Can carry blemish. No perished leaf.

Price Rs. 1/55 per pound.

7/V Dried scraps in grades 1, 2 and 3. Pieces that will pass through a ½ inch mesh not acceptable. Sucker leaf also not acceptable.

Price Rs. 2/00 per pound.

8/V Scrap from grades 4 and 5. Perished leaf and pieces passing through ½ inch mesh not acceptable. Sucker leaf also not acceptable.

Price Rs. 1/45 per pound.

9/V Leaf of good body from light chocolate to dark mahogany. No air cured or perished leaf can be accepted.

Price Rs. 1/40 per pound.

Bidi tobacco

In bidi tobacco the leaf is crushed into small flakes and sieved. The sieved flakes are graded according to size. Each bidi is made by rolling about ½ a gram of such sieved flakes in a wrapper made from the leaves of the tree *Diospyres melanoxylon* (S. Kadumbaria). This tree is abundant in the jungles of Ekiriyankumbura in the Uva province.

COSTS AND RETURNS

Tobacco is a money crop, and considerable profits can be obtained by its cultivation.

Cigarette tobacco

At the present time the costs of cultivation, in the Hanguranketa area, of an acre of tobacco amounts to Rs. 600/-. The crop can be sold readily to the private companies, at Rs. 2.50 per pound. With an average yield of 400 pounds per acre, the net income amounts to Rs. 1000/- per acre. This works out to a profit of Rs. 400/- per acre. Each cultivator cultivates approximately 8 acres, enough to supply the requirements of a barn. This should bring him a profit of about Rs. 3,200/- in a period of approximately 4½ months.

Bidi tobacco

Returns obtained from bidi tobacco compare favourably with those obtained from cigarette tobacco. In 1961-62 yields of bidi tobacco amounted to about 400 pounds per acre, and the average prices obtained varied from Rs. 2.00 to Rs. 2.46 per pound. This brings in an income of Rs. 800.00-1000.00 per acre.

REFERENCES

1. George Watt. *The Commercial Products of India.*

2. Agricultural Plan 1958. First report of the Ministry Planning Committee. Ministry of Agriculture and Food.

3. Administration Report of the Director of Agriculture, 1960-61.

4. Administration Report of the Director of Agriculture, 1961-62.

5. Customs Returns (1962).

6. Wijeratne, W. H. The mild cigar tobacco industry of Ceylon. Tropical Agriculturist Vol. CIX No. 1. 1953. p. 41-45.

7. Martin, J. H. and Leonard W. H. *Principles of Field Crop Production.* 1949.

8. Kandiah, S. and Ratnasingham, K. Tobacco investigations in the Gal Oya Valley. Tropical Agriculturist Vol. CXVIII. No. 2. April-June 1962. p. 55.

9. Cigarette tobacco pays. Departmental circular 32. 1956.

10. Moss, E. G. and Teeter, N. C. Bright leaf tobacco curing. N. C. Agric. Expt. St. Bull. 346. p. 1-125. 1944.

11. Ceylon Tobacco Company. Private Communication.

GROUP VI—ROOT CROPS

24. POTATO

Economic importance

Next to cereals, potatoes form the most important food crop in most parts of the world. Germany, U.S.S.R., Poland, France, U.S.A., and Czechoslovakia are the leading producers. In Ceylon, the potato is a relatively new crop, although an acclamatized variety (*Solanum andigenum*), commonly called the Nuwara Eliya potato, has been grown on a small scale in the higher elevations for several decades. The cultivation of potato on a large scale, attempted originally in 1951-52, failed due to poor organization, and the incidence of diseases. (1). The cultivation was resuscitated in 1957, at Rahangala. In spite of the early promise, of self-sufficiency, imports of this commodity have shown a steady increase over the years. (Table 1). (2).

TABLE I

Import of Potatoes

	1957	1958	1959	1960	1961	1962
Quantity (cwt.) .. (in thousands ..	722	865	944	1,115	1,189	1,098
Value .. (in rupees thousands)	15,382	16,629	17,816	19,169	20,497	22,233

This increase was attributed among other things to increased *per capita* consumption and the failure of production to keep pace both with population and demand, resulting in an increase in *per capita* imports. (3). See also Fig. 14 showing *per capita* annual consumption of imported potatoes. A guaranteed price for potatoes was introduced in 1960/61 and stood at Rs. 28.00 per cwt. in 1962/63. (4). In spite of such incentives self-sufficiency in this commodity is far from being achieved, and in fact may never be achieved, due to the complex of problems associated with the cultivation of this crop on a commercial scale. The 1962 short term implementation programme stated that until the technical problems relating to varietal selection, high susceptibility to virus and bacterial diseases, fertilizer application and storage are resolved in a manner that would permit wider application of techniques at the cultivator level, production plans for the

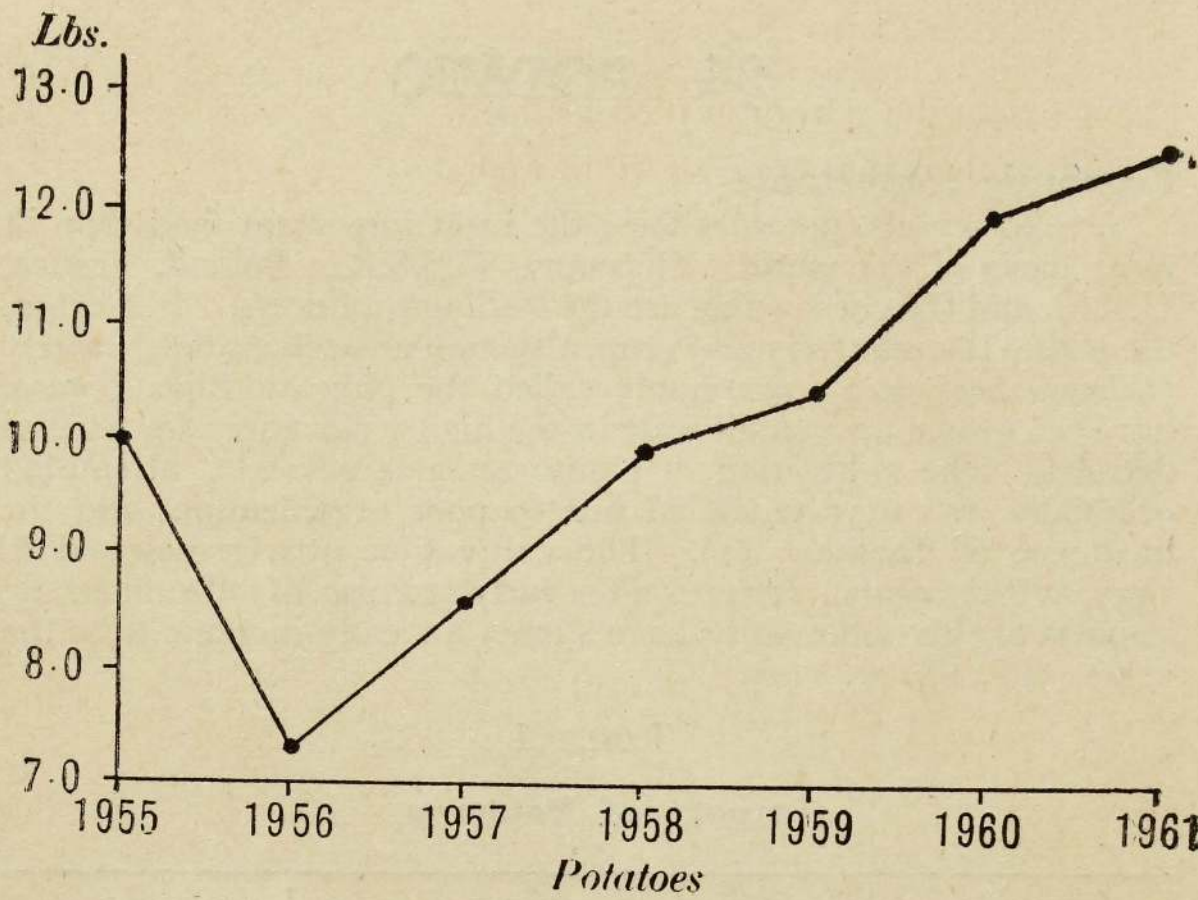


Figure 14. *Per Capita* Annual Consumption of Imported Potatoes.

attainment of self-sufficiency would be highly speculative. (3). The plan further stated that on the basis of the 1961 imports, an additional acreage of 14,800 acres in the wet zone would be required to make the country self-sufficient in potatoes. (3).

BOTANICAL DESCRIPTION

The cultivated potato (*Solanum tuberosum*) belongs to the family Solanaceae. The potato plant is an annual, attaining a height of 1 to 1½ feet. The stem is stout, erect, branched, and slightly hairy. The leaves are made up of one terminal leaflet, 2 to 4 pairs of oblong acute leaflets, and two or more short leaflets. The potato tuber is formed at the outer end of a stolon, which may vary in length. The tuber is a modified stem with lateral branches forming the so called 'eyes' (5). The eyes are arranged around each tuber in the form of a spiral. Each eye contains at least 3 buds protected by scales. The plant produces flowers which arise as compound, terminal cymes, with long peduncles. The fruit, also referred to as the potato ball is a smooth, rounded, green or brown berry, less than an inch in diameter.

The structure of the Potato tuber

The potato tuber has a pithy central core. Parenchymatous tissue surrounds the pith. Most of the starch is deposited in the parenchyma. The vascular ring containing the cambium occurs towards the outer part. Next to it is the cortex that contains the pigments, characteristic of coloured skinned varieties. The potato skin is largely cork. Scales form on the outer surface of the skin. Openings on the skin are called lenticels.

Potato tubers that are exposed to sunlight for several days, either before or after digging, acquire a greenish colour, due to the development of chlorophyll in the skin. This change is accompanied by the development of increased quantities of solanin (an alkaloid glucoside) in the cortex. This imparts a bitter taste to the tuber, and can be poisonous when present in excessive quantities.

Varieties

Several potato varieties, from a number of different countries, have been introduced and evaluated in Ceylon in recent years. Many of the older varieties are now being replaced with newer ones, which are not only heavy yielders, but are relatively resistant to disease. The Department of Agriculture recommended the following varieties for the various agro-climatic zones for 1964-65. (6).

Up Country Wet Zone

Arka. This is a 3-3½ months variety. It is characterized by tubers with a light yellow coloured flesh, and red skin. The tubers are well shaped and shallow-eyed. On good soils the variety is capable of producing heavy crops, with big sized tubers. It is not susceptible to late blight.

Condea. This is 3-3½ months variety. It is characterized by tubers with a deep yellow coloured flesh, and white skin. The tubers are oval and shallow eyed. On good soils heavy crops can be obtained. The foliage is dark green and covers the soil quickly. It is not susceptible to late blight.

Cosima. This is a 3-3½ months variety. It is characterized by tubers with a yellow coloured flesh and white skin. The tubers are well shaped and shallow eyed. On good soils, it performs well. The foliage is dark green and covers the soil quickly. It is only slightly susceptible to late blight.

Extase. This is a 3-3½ months variety, characterized by tubers with light yellow coloured flesh and white skin. The tubers are well shaped and shallow eyed. Produces a good crop on good soils. The foliage is light green, slowly developing and covers the soil only moderately. Responds to a heavy application of nitrogen. It is only slightly susceptible to late blight.

Spartaan. This is an early variety (2½-3 months), characterized by tubers with light yellow coloured flesh and white skin. The tubers are well shaped and shallow eyed. Foliage is light green, but quick developing, and covers the soil well. It responds to a heavy dose of nitrogen. Only slightly susceptible to late blight.

Up Country Dry Zone

Arka (as above)

Ginike. This is a 3 months variety. The tubers have a light yellow flesh, and red skin. The tubers are well shaped, and medium deep eyed. Produces a good crop on all fertile soils. The foliage is quick developing, and covers the soil well.

Low Country Dry Zone

Arka, Condea, Extase, Ginike, Spartaan (as above).

Alpha. This is a 3-3½ months variety, characterized by tubers with light yellow coloured flesh and white skin. The tubers are well shaped and fairly shallow eyed. Initial growth of foliage is slow. It covers the soil well at the later stages of growth.

Up to date. This is a 3-3½ months variety characterized by tubers with white flesh and white skin. The tubers are oval and shallow eyed. The variety is fairly drought resistant. and produces a heavy crop on all fertile soils. Foliage is quick growing and covers the soil well.

CROP IMPROVEMENT

The desirable characteristics of good quality eating potatoes, depend on the characteristics of the starch, size and shape of tubers, depth of eyes, and colour of flesh, among other factors. Most of the desirable characteristics are found in the varieties listed above. It appears that Ceylon would always have to depend on foreign varieties of potatoes, as a local crop improvement programme is stifled by the fact that potatoes do not flower and set seed freely under local conditions.

ECOLOGICAL ADAPTATION

Temperature may be said to be the most critical ecological factor governing the choice of a particular area for potato cultiv- ation. Tuber production, in the potato crop is retarded at soil temperatures above 68°F. and completely inhibited at 84°F. above which point the respiratory loss of carbohydrates exceeds that produced by photosynthesis. (7). Hence potatoes do best either at elevations of over 3,000 feet in Ceylon, where the temper- atures are lower, (6), or in areas elsewhere during the time of the year, when the nights are cool. (6). A combination of long days, high temperature and high nitrogen favour a heavy growth of plants in the potato crop. (8). Maximum tuberization occurs, with cool temperatures, abundant nitrogen, and days of intermediate length. (9). Long days and cool temperatures also favour flowering and seed formation. Thus potatoes do not generally flower and set seed under Ceylon conditions. Rainfall is not limiting in potato production, but high rainfall combined with high humidity pre-disposes the crop to attack by fungus diseases.

Potatoes tolerate a wide range of soils ranging from sandy loams silt loams, loams and peat. (10). Best soils are deep, well drained light loams. Slightly acidic soils that are rich in organic matter are most conducive to the production of high yields. The patna soils, including both the dry and the wet patnas are quite suitable for potato cultivation. Sticky clay soils interfere with harvest and necessitate cleaning of the tubers to which they adhere prior to marketing.

Areas for cultivation

Early attempts at commercial production of potatoes, were confined purely to the up country areas. With the resuscitation of interest in the crop in 1957, the Department of Agriculture opened nine potato stations in the up country of Ceylon, which were classified into seed stations and production farms. (11). Horton Plains, Pedro, and Uda Radella, together with Kandapola, were classified as seed stations. Sita Eliya, Meepilimana, Galpalama, Ragala and Bopatalawa were placed in the category of production farms. Elevations of these stations, together with final acreages envisaged are given below. (11).

Station	Elevation	Final acreage of station
Pedro	7200-7400′	400
Horton Plains	7200′	528
Uda Radella	7300′	175
Kandapola	6600′	60
Sita Eliya	6200′	450
Meepilimana	6200′	225
Galpalama	6400′	80
Ragala	5700′	120
Bopatalawa	5200′	350

Recent policy has however changed, and production is no longer considered a function of government farms. Accordingly all the nine stations are likely to function as seed stations in the future. Commercial production of potatoes is likely to pass into the hands of private farmers, and for this purpose the Department of Agriculture recommends the following areas as being suitable for potato cultivation. (6).

Up Country (Wet and dry patnas over 3000′).

Nuwara Eliya district, Udukinde, Medakinde, and the higher ranges of Kandy and Matale districts.

Dry Zone. Only from October-December after the heavy rains are over.

Planting season. The following planting seasons are recommended. (6).

Up Country. Nuwara Eliya district—Late September to February.

Higher ranges of Matale and Kandy districts—December-January. Paddy lands—June-July.

Dry Zone. October-December.

Rotations

Recent experience has shown, that the early expectation of the feasibility of raising two or even three crops a year simply by adjusting the dates of sowing and the dates of harvesting (12) have been largely speculative, and that on account of the many diseases to which the crop is subject, it is best not to grow a crop of potatoes more frequently than once in two years on the same land. On account of the nature of the cultivation, associated with the crop, potatoes are an ideal rotation crop. The land receives several intercultivations, and is in a good condition for most of the following crops. Caesar (13) after conducting several trials with beans, peas, leeks, carrots, and mustard as possible rotation crops for potatoes, came to the conclusion that the best rotation for potatoes was to grow potatoes in one season and put the land under pasture for the following 1½ years. The inclusion of a herbage break in such a rotation, in addition to improving the fertility of the soil, enables the maintenance of animals on the pasture, which would go a long way in providing the much needed organic matter to potato lands. However suitable this rotation would appear to be from an agronomic point of view, it has still to be proved that it is an economic proposition to follow every crop of potatoes with 18 months of pasture.

CULTURE OF THE CROP

Land preparation

Land preparation for potatoes involves working of the soil to a depth of about 9 inches, in order to attain a fine tilth. Furrows are then opened 6 inches deep at a spacing of 1½ to 2 feet. Organic manures, and fertilizers may be applied to the furrows and worked into the soil at the time of land preparation. Wherever there is a danger of waterlogging, raised beds should be prepared. This is of considerable importance, particularly in the low country dry zone.

Seed potatoes

Only certified seed potatoes should be used for planting. These are reasonably free from diseases that are transmitted in the tuber.

The seed potatoes should be sprouted prior to planting. Large vigorous sprouts are an indication of quick emergence and earliness of maturity. Seed potatoes can be sprouted by keeping them in trays, in subdued light till the eyes develop short, sturdy, coloured sprouts. Sprouting occurs at temperatures of 40°F or higher, but only after completion of a period of dormancy, which is caused by restricted oxidation. (14). The rest period may range from 4-16 weeks when stored at 70°F or longer at cooler temperatures.

Seed rate required to plant an acre amounts to about 15-24 cwt. of seed tubers.

Cut tubers, or seed pieces which are commonly used for planting in temperate areas, should not be used under local conditions on account of the risk of wilt infection, which is not encountered in temperate areas.

Large sized seed potatoes, tend to give a higher yield, than smaller sized ones, but the initial seed rate is higher.

Planting

Seed potatoes should be planted in the furrows, except, where planting is done on raised beds as in the dry zone areas. The tubers are placed about 12-14 inches apart and covered with about 2 inches of soil, so that the land is more or less flat.

Spacing

Results of spacing trials indicate that closer spacing results in greater yields than wider spacing. Of 3 planting distances used in a cultural trial at Rahangala, involving planting at 8 inches, 12 inches and 16 inches in the rows spaced 2 feet apart, the spacing of 8 inches within the row gave a significantly higher yield than the spacing of 16 inches. There were no significant differences either between the 8 and 12 inch spacings, or the 12 and 16 inch spacings. (1).

Nutrition

The potato crop is one of the most heavily fertilized crops in the world. This is so because of the fact that the nutrient requirements of the crop are heavy, and the income per acre is high. Nearly as much as 2,500 pounds per acre of high analysis fertilizer are used in certain parts of the United States for this crop . (15). Ponnamperuma (16) reported that on the basis of experiments conducted in the hill country of Ceylon, striking increases in yield could be obtained by the use of fertilizers, manure and lime. He reported responses as high as 2.8 tons per acre to 100 lbs. N, 5.2 tons per acre to 200 lbs. P_2O_5, 1.8 tons per acre to 10 tons cattle manure [and 1.9 tons per acre to 10 cwt. dolomitic limestone with the variety 'Up to date,' at Rahangala, on deep, strongly acid, well drained lateritic soils of medium texture and good structure. Response to potassium was noticed only during one season. There were no significant responses to the trace elements copper, boron, zinc and molybdenum. Ceylon soils are reasonably rich in potassium, and hence the response to applied potassium is not marked. European soils that are normally rich in phosphrous show similar responses to applied phosphorus. A 1—0.8—1.5 fertilizer mixture is common in certain parts of Europe for potatoes. Under local conditions a 1—2.5—0.5 fertilizer mixture is sometimes recommended.

In a more recent recommendation the Department of Agriculture suggests the following fertilizer usage for the various potato growing areas. (6). Cattle manure or well rotted compost is recommended at the rate of 5 tons per acre. Dolomitic limestone which is recommended for liming certain areas should be worked into the soil at least 2 weeks before planting to avoid loss of nitrogen and the fixation of phosphorus. (Table 2).

TABLE 2

Recommended Fertilizer rates in cwt. per acre

Type of Soil	Ammonium Sulphate	Conc. Super-phosphate	Muriate of potash	Dolomitic Lime
Wet patna black soils of the Nuwara Eliya district ..	2½	4½	1	15
Jungle soils (Nuwara Eliya district) ..	3½	5	1	15
Paddy fields at high elevations ..	3	4½	1	—
Dry patna soils at Udukinda ..	4½	6	1	10
Low country dry zone soils ..	4	4	1	—

The fertilizers should be added well before planting and worked into the soil for optimum results. On account of the fact that the soils are acidic, and the rainfall in certain areas is high, the nitrogen fertilizer could be added in the form of urea. Sulphate of potash may be substituted for muriate of potash

Intercultivation

In Europe the potato is referred to as a hoeing crop. The soil is constantly worked in order to maintain it in a loose condition, and to control the weeds. Under European conditions, this kind of repeated intercultivation may be undertaken up to even 5 times during the season.

Repeated working, and earthing up is necessary not only to control weeds, but also to maintain the tubers well below the surface, so as to avoid greening of the tubers, which occurs on exposure to light. The earthing up operation is usually done twice, the 1st earthing up being given 4 weeks after planting and the 2nd about 2 weeks later.

CONTROL OF POTATO DISEASES

The potato crop succumbs to a diversity of diseases, and the disease problem is possibly the greatest limiting factor to the large scale cultivation of potatoes in Ceylon. The disease aspect is handled in the following three ways:

1. The breeding of disease resistant varieties. This is not done locally, and the varieties grown in Ceylon are imported from other potato growing countries.

2. The multiplication of disease free planting material. This is one of the main activities of the Department of Agriculture seed stations. All phyto-sanitary precautions are adopted at these stations, in the production of certified seed.

3. The control of disease in the field.

The more important diseases are listed below:

Late blight (*Phytophtora infestans*)

This is a disease which is common during wet weather in the up country. It is a fungus disease that develops particularly under conditions of high humidity and high temperature. Abeygunawardene and Balasooriya (17) suggested that in the up country areas receiving predominantly the Yala rains, October and January sowings could fully or partly escape the blight, which could reach serious proportions during the Yala season from May to September. In areas receiving the Maha rains, January, April and July sowings would give crops which could fully or partly escape the blight. The disease may be recognized by the black watery patches that appear on the leaves. The disease can spread to the tubers later on, causing dry rot. Control measures adopted are the spraying of the crop 4 weeks after planting with a fungicide containing disdithiocarbamate such as dithane, lonacol or mangancurit. In experiments designed to screen a range of fungicides for their efficacy against late blight of potato, organic fungicides were found to be superior to inorganic fungicides. Dithiocarbamates proved to be superior to other organic fungicides, and of the dithiocarbamates, dithane Z-78 was reported to be the most effective. (18). The spray solution is prepared at the rate of 1 lb. of fungicide in 30 gallons of water per acre. The spraying is repeated 2 weeks later. Late blight is not severe in the Udukinda area. (6). Here cupravit can be used effectively. In cloudy weather, a weekly spraying of the fungicide is recommended.

The best method of combating the disease, however, is to plant resistant varieties. Resistant varieties are available, but the resistance is not permanent. In Europe the resistance lasts only for about 7-8 years. In Ceylon the breakdown is even quicker (about 3-4 years). Hence, it is important to always continue the breeding and selection of resistant varieties, in order to successfully replace varieties that break down after some time.

Bacterial wilt. (*Pseudomonas solanacearum*)

This disease is caused by a soil borne bacterium, and is a serious disease at elevations below 5,000 feet. (19). Plants wilt and die as though suffering from a lack of water, within 3 days of the attack. The cut tuber shows a ringed appearance which on pressing exudes a whitish bacterial ooze. No control measures are known. Visser and Caesar (20) studied the tolerance to bacterial wilt of a number of commercial potato varieties, and reported that immunity or even resistance did not exist, but there was a certain tolerance among varieties indicated by the spread of infection. Varieties infected late produced profitable tubers, though not entirely free from the disease.

These workers also suggested that Tea lands in the up country could be used during the replanting period, for commercial potato growing, by shortening the period under Gautemala grass, as these lands appeared to be free of wilt.

In Europe, the disease presents no problem on account of the cool winters, as the bacteria are killed by prolonged cold weather. In Ceylon, the sandy soils of the dry zone have been found to be relatively free of the bacterium, during the times of the year when the temperatures are high enough to heat up the soil, and kill the bacterium. This information is however relatively recent (13). Soil temperatures above 50°C, are injurious to the bacterium.

The bacterium is also destroyed by anaerobic conditions in the soil. Hence paddy lands, which carry paddy during one season under flooded culture, become suitable areas for potato culture during the fallow season.

This has been demonstrated quite conclusively wherever potatoes have been raised in rotation with paddy. (19). The growing of solanaceous crops on the same land, should be strictly avoided as a measure of control of the disease.

Black leg. (*Bacterium phytophtorum*)

This is also a disease caused by a soil borne bacterium. The stems of the affected plants turn black, the foliage become yellow and then wilt. When pulled the foliage detaches easily, and at the point of breakage the stem is black. Hence the name black leg. This is found occasionally in water logged areas. It is predominant in Patna lands. The disease can be transferred by seed potatoes, hence seed potatoes have to be certified free of black leg. The disease is not very important in Ceylon.

Virus diseases

Virus diseases though serious in temperate countries, have still not been reported in Ceylon.

Pests

Cut worm (*Agrotis ypsilon*)

This is the most troublesome pest in the up country. The worms come out only in the night, and feed on the leaves and stems. The stem is cut about 1 cm. above the soil surface. The attack occurs suddenly and effective control measures should be taken immediately. As a routine measure the crop may be treated when 4 weeks old, or earlier if necessary, with endrin at the rate of 1 fluid oz. of endrin 20% emulsifiable concentrate in 2 gallons of water. A cigarette tinful is poured around the base of each of the plants.

Root eating ant (*Dorylos orientalis*)

Root eating ants cause considerable damage at the lower elevations. Termites do similar damage in the dry zone. Ants cause damage by eating up the roots and riddling the tubers. Tubers are destroyed completely. Wherever the pest can be troublesome, the furrows for planting should be treated a couple of days prior to planting with aldrin 20% emulsifiable concentrate at the rate of 1½ fluid oz. in 1 gallon of water.

Potato tuber moth. (*Gnorimoschema opercullella*)

The tuber moth lays its eggs on the leaves. The larvae attack the leaves and bore into the stem and tubers. The leaves carry brownish blotches. Control measures include a foliage spray with DDT 25% emulsifiable concentrate, at the rate of 1 fluid oz. of the insecticide in 1 gallon of water. Approximately 60 gallons of the spray solution will be required to spray an acre. The pest can occur either in the field or in storage. In storage the tubers may be dusted with 5%-10% DDT dust, as a measure of control.

Epilachna beetles

These pests are troublesome in the dry zone. The larvae eat the leaves, leaving only the veins. Control measures adopted include spraying with a solution of malathion 50% emulsifiable concentrate at the rate of 1 fluid oz. in 5 gallons of water. About 60 gallons of the spray solution are required to spray an acre. Occasionally follidol is used in the control of this pest.

Harvesting

Potato tubers may be considered to be ready for harvest, when the skin of the tuber does not peel off easily. This can be tested by rubbing the skin of the tubers with the thumb. Harvesting is usually done by hand, by digging the tubers out. Mechanical harvesters are used in certain parts of the world.

Grading

The tubers may be graded on the basis of size. Standard grades for potatoes are

Ware—big sized potatoes—Consumption potatoes.
Seed—medium sized potatoes—Seed potatoes.
Chat—small sized potatoes—Pig feed.

In Ceylon the tubers are graded into:

1. Tubers that are over 1 inch in diameter.
2. Tubers that are less than 1 inch in diameter.

Yields

Average yields amount to between 3-6 tons per acre.

Losses in storage

Losses in storage go up to about 30% under Nuwara Eliya conditions in 32 weeks. At Rahangala the losses amount to 50% in 32 weeks. Under warmer conditions the losses are even greater.

COSTS OF CULTIVATION OF AN ACRE OF POTATOES (21)

Labour costs

1. Preparation of land	Labour	10	Rate	Rs. 2.75	Rs.	27.50
2. Preparation of bunds	,,	3	,,	,,	Rs.	8.25
3. Ridging	,,	14	,,	,,	Rs.	38.50
4 Planting	,,	12	,,	,,	Rs	33.00
5 Weeding	,,	8	,,	,,	Rs.	22.00
6. Earthing up (once)	,,	11	,,	,,	Rs.	30.25
7. Application of Fertilizer etc.	,,	4	,,	,,	Rs.	11.00
8. Harvesting	,,	26	,,	,,	Rs.	71.50
9. Sorting and grading	,,	4	,,	,,	Rs.	11.00
10. Pest and disease control	,,	7	,,	,,	Rs.	19.25
Labour Units		99	,,	,,	Rs.	272.25

Other costs

11. Cost of 2040 lbs. of Imported seed potatoes @-/35 cts. per lb.	Rs.	714.00
12. Cost of mixed fertilizer 1100 lbs. @ -/20 cts per lb	Rs	220.00
13. Cost of 15 cwt. of dolomitic lime @ 4.40 per cwt	Rs.	67.50
14. Cost of 1 bt. of endrex	Rs.	6.00
15. Cost of diethene 8 lbs. @ 5/- per lb. (4 times spraying)	Rs.	40.00
16. Tractor hours @ 20/- per hour, Ploughing and transporting 4 hours	Rs.	80.00
17. Overhead charges etc	Rs	36.61
Total	Rs.	1,436.36

Yield 7376 lbs @ -/30 cts	Rs	2,212.80
Cost of cultivation	Rs	1,436.36
Profit	Rs	776.44

REFERENCES

1. Richards, A. V. The cultivation of potatoes in Ceylon. Tropical Agriculturist Vol. CXIV. No. 1. p. 83-88. 1958.

2. Customs Returns.

3. Short Term Implementation Programme 1962.

4. Administration Report of the Commissioner of Agrarian Services. 1962/63.

5. Artschwager, E. Studies on the potato tuber. Jour. Agr. Res. 27. (11). p. 809-835. 1924.

6. Potato. Department of Agriculture. Leaflet. 1964.

7. Bushnell, J. The relation of temperature to the growth and respiration of the potato plant. Minn. Agri. Exp. Sta. Tech. Bull. 34. p. 1-29. 1925.

8. Boswell, V. R. and Jones H. A. Climate and vegetable crops. U. S. Dept. Agr. Yr. Bk. p. 373-399. 1941.

9. Martin, J. H. and Lenard, W. H. *Principles of Field Crop Production.* Macmillan Co. New York. 1955.

10. Morgan, M. F., Gourley, J. H., and Ableiter, J. K. The soil requirements of economic plants. Soils and Men. U. S. Dept. Agr. Yr. Bk. p. 753-776. 1938.

11. Administration Report of the Director of Agriculture for 1961/62.

12. Report of Dr. Pushkarnath, Director, Central Potato Research Institute. Tropical Agriculturist. Vol. CXIV. No. 2. p. 75-82. 1958.

13. Caesar. K. Private Communication.

14. Appleman, C.O. Study of rest period in potato tubers. Md. Agr. Exp. Sta. Bull. 183. p. 181-226. 1914.

15. Smith Ora. Advances in Agronomy. 1. p. 352-390. 1940.

16. Ponnamperuma, F.N. Response of potato to fertilizers, manure, lime, and trace elements. Tropical Agriculturist Vol. CXIV. No. 2. p. 99-114. 1958.

17. Abeygunawardene, D. V. W. and Balasooriya I. Disease hazards in potato cultivation. I. Late blight caused by *Phytophthora infestans*. (Mont) de Bary. Tropical Agriculturist. Vol. CXVII. No. 4. p. 211-220. 1961.

18. Abeygunawardene D. V. W. and Peiris, J. W. L. Experiments on the fungicidal control of late blight of potato. 1. Screening of fungicides. Tropical Agriculturist Vol. CXIV. No. 2. p. 89-98. 1958.

19. Abeygunawardene, D. V. W. and Wijesooriya, R. A. Methods of potato seed production in Ceylon. Tropical Agriculturist Vol. CXVI. p. 131. 1960.

20. Visser, T. and Caesar, K. Tolerance to bacterial wilt (*Pseudomonas solanacearum* E. F. S.) and yield of potato varieties in the up-country of Ceylon. Journal of the Nat. Agric. Soc. of Ceylon. Vol. 2. No. 1. 1965.

21. Costs from Potato Research Station, Sita Eliya.

25. MANIOC

Economic importance

Manioc may be considered to be the most useful of all the root crops grown in Ceylon. Although the tubers are poor in minerals and vitamins, and may under certain circumstances develop toxic concentrations of hydrocyanic acid, the crop has continued to increase in popularity. As a poor man's food, manioc has few rivals. But besides this, there are several reasons for the popularity of this crop. Firstly, it is a crop that yields an abundant quantity of edible roots, for the comparatively little money and labour expended on its cultivation. Secondly, it is a crop that can be grown with relative ease and harvested whenever necessary, harvest operations themselves being quite simple. Thirdly, it is a crop that is suited both to the wet zone as well as the dry zone, although its drought resistant character is often overemphasized.

In recent years, increasing attention has been paid to the possibilities of using dehydrated manioc, as a substitute for cereals in the ration of poultry, owing to rising costs of cereal components. Considerable quantities of manioc are also used for feeding livestock, particularly pigs.

When grown for the sake of flour, the crop can assume industrial importance.

Manioc was first introduced into Ceylon during the Dutch period (1). In spite of its many striking virtues, the crop has remained as a small holdings crop, being mainly cultivated by peasants to meet their household needs, or for small trade. Apart from these small extents a few large scale cultivations have been established for purposes of producing manioc meal for animal feed. Striking results have been obtained with this feed as one of the main energy sources in rations for pigs. (2). The crop offers considerable scope for extended cultivation, and a careful evaluation of all its potential uses, with a view to encouraging organized cultivation is long overdue.

BOTANICAL DESCRIPTION

Manoic belongs to the family Euphorbiaceae, and the genus *Manihot*. Several species of the genus, are well-known sources of rubber. For example the ceara rubber is *M. glaziovii* Mull. Arg. The manioc plant, also called tapioca plant or cassava, is distinguished botanically as *Manihot utilissima*. Pohl. The manioc plants have tall thin stems which show along their length leaf scars. The stem displays a range of colours varying from green, greenish white light red or deep red, depending on the variety. The colour of the petioles, as well as the veins of the leaves, correspond to the colour of the stems in each case. The leaves are either 5 or 7 lobed depending on the variety. All Ceylon races of manioc, except some, flower. (3). The plants do not flower freely however under cultivation. The family is characterized by the possession of unisexual flowers, which may occasionally undergo abortion. Either the corolla or the whole perianth may be absent. The ovary is three celled, and matures into a capsule with three seeds.

The plants possess large edible roots rich in starch, and it is for these tubers the plants are cultivated. Depending on the variety, the tubers may take anything from 3 months to 3 years.

Varieties

Manioc varieties can be broadly distinguished on the basis of a striking difference of economic importance, which is the content of a bitter principle, a cyanogenetic glucoside in the roots, into 'bitter' and 'sweet' varieties. The bitter varieties cannot be eaten raw on account of the poison, and can be eaten with safety only after boiling. The separation of cultivated varieties, however, into two species viz. 'bitter' cassava *M. utilissima* Pohl and 'sweet' cassava *M. aipi* Pohl. appears to have little justification. (1).

Varietal differences in general are based on a number of characters such as growth and branching, colour of stems, colour and shape of leaves, tuber quality, and age of maturity. Roots of certain varieties can be harvested in 3 months after planting, while others take about 3 years. There are other varieties that mature in 4, 5, 6, 8, 12 and 18 months. The availability of so many varieties with varying periods of maturity, permits the production of manioc right through the year. (4).

Manioc varieties are largely designated by a diversity of local names. All the races of cassava occurring in Ceylon were bulked into 75 races, on the basis of detailed studies of the morphology, and the performance of a total of 143 accessions made in 1939 (1). Two common types were recognized namely the Sinyokka type, characterized by the presence of a red pigment in various parts of the plant, and the possession of a zig-zag, unbranched stem, and the Manyokka type, an unpigmented type possessed of a straight, early branching stem. It was postulated that the intergrades between these two types, occurred through natural crossing between these two parents. (1).

For planting, the following varieties tested out by the Department of Agriculture are recommended. (4).

Philippine varieties

Mu-6 (Sudu-beli mannoyakka)
Mu-22 (Kalu-ala sinnoyakka)
Mu-41 (Sinnoyakka)
Mu-51 (Kos mannoyakka)
Mu-73 (Maha mannoyakka)

These are all $4\frac{1}{2}$ month varieties. The Department of Agriculture also recommends the following hybrid varieties for planting:

Hybrid varieties
MUh-4
MUh-8
MUh-21

These hybrid varieties are 4 to $4\frac{1}{2}$ month varieties.

Programme of hybridization in manioc

A breeding programme aimed at combining the high yield of roots with a low content in hydrocyanic acid was commenced by the Department of Agriculture in 1939. (3).

The presence of a cyanogenetic glucoside, linamarin, from which in injured or old tissue, hydrocyanic acid may be liberated due to the action of enzymes, is one of the factors, that limit the usefulness of this crop. Stored roots, develop lethal concentrations of this poison. When such roots are consumed, the hydrocyanic acid present acts as a poison, affecting both the respiratory functions of the cell, as well as the oxidation—reduction activities of vitamins and hormones. (5).

For the hybridization programme, the race Mu 41 was chosen as the yield parent, on account of the fact that tuber yields of Mu 41 have been among the highest of the Ceylon races. The HCN content of Mu 41 however is high. Crosses involved Mu 51 and Mu 59, two parents possessing a low HCN figure and Mu 41. Sixteen hybrids were produced namely MUh 3, MUh 4, MUh 5, MUh 7, MUh 8, MUh 9, MUh 10, MUh 11, MUh 12, MUh 14, MUh 16, MUh 17, MUh 18, MUh 19, MUh 20 and MUh 21.

The hydrocyanic acid content of the tuber flesh of the parents and of the hybrids at the age of 12 months was reported as follows. (3). (Table 1).

HCN figures for hybrids MUh 5, MUh 12 and MUh 14 were comparatively low, while most of the hybrids gave HCN figures similar to the HCN rich parent MU 41. The hybrids recommended for cultivation were evaluated in later yield trials.

ECOLOGICAL ADAPTATION

Manioc is predominantly a crop confined to the equatorial latitudes of the tropics. The crop is not suited to the colder areas. It can be cultivated from sea-level to about 3,500 feet. Above this elevation the low temperatures, prevailing during the colder months, makes the cultivation of this crop uneconomic. In cold weather the plant is said to shed its leaves. The crop is suited however to heavy rainfall areas, even up to over 100 inches. It can also be grown satisfactorily as a rainfed crop in areas of much lesser

TABLE I

Hydrocyanic acid content of parents and hybrids (Chandraratna and Nanayakkara 1948)

Hybrid	Parents			HCN content in milligrams per 100 grm tissue		
	Female		Male	Female Parent	Male Parent	Hybrid
MUh 3	MU 41	×	MU 51	10.3	3.4	9.2
MUh 4	MU 41	×	MU 59	10.3	4.6	8.0
MUh 5	MU 51	×	MU 41	3.4	10.3	7.6
MUh 7	MU 51	×	MU 41	3.4	10.3	11.1
MUh 8	MU 51	×	MU 41	3.4	10.3	13.3
MUh 9	MU 51	×	MU 41	3.4	10.3	13.3
MUh 10	MU 41	×	MU 59	10.3	4.6	8.4
MUh 11	MU 41	×	MU 59	10.3	4.6	10.0
MUh 12	MU 41	×	MU 59	10.3	4.6	7.0
MUh 14	MU 59	×	MU 41	4.6	10.3	7.5
MUh 16	MU 59	×	MU 41	4.6	10.3	10.3
MUh 17	MU 41	×	MU 51	10.3	3.4	9.5
MUh 18	MU 41	×	MU 51	3.4	10.3	8.5
MUh 19	MU 51	×	MU 41	3.4	10.3	8.5
MUh 20	MU 41	×	MU 51	3.4	10.3	8.5
MUh 21	MU 59	×	MU 41	4.6	10.3	10.3

rainfall. The crop does well in open sunny situations, and should not generally be grown under shade.

Manioc does best on well drained soils of the sandy loam type. Stiff clays are not suitable for this crop. Drainage is of considerable importance. For this reason the crop is often cultivated on hill sides, but the practice however, is not recommended as it favours soil erosion.

Areas for cultivation

The crop can be grown successfully in the low country and mid country wet zone and in drier areas.

Planting season

In the drier areas the crop is planted generally during the Maha. In the low country and mid country wet zone, it can be planted both during the Maha and Yala seasons.

CULTURE OF THE CROP

Land preparation

Land preparation involves the loosening of the soil to a depth of about 12 inches, as the roots of manioc go deep into the soil.

The land should be ploughed and the soil well prepared by breaking down the clods, removing stubble and roots etc., and bringing the soil to a loose condition.

Planting material

The planting material for manioc consists of stem cuttings, which are obtained when harvesting a previous crop. The woody bottom portion and the tender top portion is not generally suitable, for obtaining stem cuttings for planting purposes. A cutting of about 9 inches and having 4 to 6 nodes from the middle portion of the stem constitutes the best planting material. The cuttings should be prepared for planting by making the lower end slightly sharp by means of a slanting cut, to enable the cuttings to be pushed into the soil, during planting.

Planting

The cuttings should normally be planted erect, into the moist soil, so that about 3 nodes show above ground. Other methods of planting that have been tried out are horizontal planting, where cuttings are laid flat and pushed into the soft mud, and slanted planting. The cuttings sprout from the nodes within a week. In an experiment designed to evaluate the type and size of cuttings and the method of planting, the following results were reported. (6) (Table 2).

TABLE 2

Yield in relation to size and type of set (Jeyaseelan 1951)

Treatments	Yields in pounds per acre	No. of tubers/acre
Basal cuttings ..	28,689	59,650
Apical cuttings ..	26,003	48,686
Vertical planting ..	29,524	51,681
Horizontal planting ..	25,168	56,655
Twelve inch cuttings ..	28,604	59,199
Six inch cuttings ..	26,038	49,137

Better yields were obtained by the use of longer cuttings as against shorter ones, basal cuttings as against apical cuttings and the adoption of vertical planting as against horizontal planting. The higher yields were also attributed to the larger number of tubers produced by the basal cuttings, and twelve inch cuttings and the larger sized tubers produced by vertical planting.

In another experiment conducted in the Philippines it was reported that old cuttings (basal cuttings) gave significantly higher yields of roots, as well as starch per hectare than young cuttings (apical cuttings) (7).

Spacing

Manioc cuttings are best spaced 3 feet each way.

Nutrition

Manioc responds to heavy manuring. The following fertilizer rates are recommended by the Department of Agriculture at planting: (4).

On new clearings—1 cwt. concentrated superphosphate per acre.

On cultivated land—1 cwt. ammophos (20/35) and 1 cwt. muriate of potash per acre. A top dressing with either ammonium sulphate or ammonium nitrate at the rate of 1 cwt. per acre is recommended about 2 months after planting.

Intercultivation

Intercultivation for weed control purposes should commence about 3-4 weeks after planting. The weeding may be repeated at intervals of about 3 weeks depending on the density of weed growth. During the 2nd intercultivation the soil should be loosened round the plants. A certain amount of earthing up is desirable at the last intercultivation.

Pests and diseases

Manioc is relatively free from the attack of any serious pests and diseases. Bandicoots do a certain amount of damage in certain areas.

Harvest

Manoic is harvested by carefully digging round the plants, so as to avoid damaging the roots. It is not advisable to store harvested manioc for more than 24 hours. As such the harvest should be so staggered, as to lift only such quantities as are immediately required at any one time. Maturity of the roots can be determined by doing a few test harvests. In general the yellowing of the leaves, and the development of brown layers of cork on the stems are signs of maturity of the roots. Manioc roots may be about 3 inches in diameter, 12-18 inches in length and weigh about 2 to 5 pounds each. A plant generally carries 4 to 5 roots.

Yield

Yield from well grown crops approximate 10 tons to the acre. Higher yields approximating 15 tons to the acre have been reported from the West Indies (8). The roots loose 75% of their weight on drying, and the out-turn of flour is about 50% of this dry weight.

The poisonous principle in Manioc

The presence of a cyanogenetic glucoside linamarin, particularly in the roots of the bitter varieties, from which hydrocyanic acid can be liberated by enzymic action has already been referred to. This can happen during storage after harvest, or when the roots are damaged during harvest. The poison is present more near the cortical layers than in the interior of the roots. Firm and yellow fleshed varieties usually contain more of the poison than the white, soft kinds. Boiling destroys the enzyme, and the HCN is dissolved out by the water. Frying the root slices, destroys the poison completely.

TAPIOCA FLOUR

To the pure starchy flour prepared from the roots of Manioc is given the name tapioca. Tapioca flour can be manufactured on a commercial scale, in factories equipped with suitable machinery. The 'pearl' and 'flake' tapioca of commerce are prepared in this way. On a smaller scale, the tapioca flour may be prepared in the following manner

1. The roots are cleaned, by peeling off the skin and washing.
2. The roots are now grated into a fine meal.
3. The meal is tied up in a muslin cloth, and kneaded in water. The starch passes into the water, while the impurities remain in the bag during the process. The process is repeated till all the starch comes through into the water.
4. The starch that settles down as a layer is then separated by decanting the water off.
5. The wet starch is then sun-dried and later dried thoroughly on a hot plate.

Sweet Cassava flour mixed with rice starch is used in the making of vermicelli. (9).

MANUFACTURE OF 'SAGO' FROM MANIOC

The manufacture of 'sago' from manioc starch, has been undertaken with success in Ceylon. The cost of production is however high, in relation to the import price, which during 1962 was Rs. 29.80 per cwt. It has been suggested that the high cost of production could be substantially brought down, if the manufacturer also grew his own manioc. If the producer grew his manioc on a plantation scale, the cost of the raw material would be Rs. 2.50 per cwt. and the cost of production of sago in the region of Rs. 16.00 per cwt. (10). Approximately 2,700 acres of manioc, per year would be required to meet the country's requirements of sago.

The simplest manufacturing process is as follows:

Washing tuber——Washing tuber
|
Rasping
Secondary grinding
Slurrying
Sedimentation
Decantation
Partial dehydration
Granulation
Gelatinisation
Drying
Grading
Packing

Costs of cultivation and returns (11)

	Rs. cts.
Preparatory tillage	55.00
Organic manures	125.00
Lining and planting: 8 units	30.00
Cost of planting material, 5000 cuttings per acre at -/01 cts.	50.00
Intercultivations (two)	30.00
Earthing up and cost of artificial fertilizers: 10 units ...	45.00
Harvesting and transport: 20 units	125.00
	460.00

Average yield 24,200 pounds	
Value of crop at -/03 cts. per pound	Rs. 762.00
Expenditure	Rs. 460.00
Profit	Rs. 302.00

1. Chandraratna, M. F. and Nanayakkara, K. D. S. S. Studies in Cassava. A classification of races occurring in Ceylon. Tropical Agriculturist Vol. C. p. 219-230. 1944.

2. De Mel, R. H. Private communication.

3. Chandraratna, M. F. and Nanayakkara, K. D. S. S. Studies in Cassava. II. The production of hybrids. Tropical Agriculturist Vol. CIV. No. 2. p. 59-74. 1948.

4. Manioc. Food Crops Bulletin. No. 12. Department of Agriculture.

5. Clark, A. Effects arising from respiratory inhibition and from anoxaemia. Jour. Trop. Med. and Hyg. XLIII. p. 91-96. 1940.

6. Jeyaseelan, K. N. Studies in growth and yield of Cassava. 1. Yield in relation to size and type of set. Tropical Agriculturist Vol. C II. No. 3. p. 168-171. 1951.

7. Huertas, A. S. A study of the yield of cassava as affected by age of cuttings The Philippine Agriculturist. Vol. XXVIII No. 9. 1940. Also Tropical Agriculturist Vol. XCIV. No. 6. p. 316-321. 1940.

8. Yegna Narayan Aiyer, A. K. *Field Crops of India.* Govt. Press, Bangalore. p. 305-310.

9. Will Perera, J. A. Cassava in Ceylon. Tropical Agriculturist Vol. XCIV. No. 1. p. 24-26. 1940.

10. Fernando, L. J. Some notes on the economic potential for the organized exploitation of manioc in Ceylon. Ceylon Institute of Scientific and Industrial Research.

11. Costs from Central Experiment Station, Peradeniya.

26. SWEET POTATO

Economic importance

The sweet potato constitutes an important and popular root crop which is grown primarily for food that can be prepared from the fresh tubers. In food value the sweet potato is similar to the ordinary potato, except for a slightly lower crude protein content. (Table 1).

TABLE 1

Food value of sweet potato and the common potato

	Sweet potato per cent	Potato per cent
Moisture ..	72.2	72.2
Crude protein ..	1.2	2.3
Crude fat ..	0.5	0.3
Nitrogen free extract (by difference) ..	24.3	22.9
Crude fibre ..	0.8	1.2
Ash ..	1.0	1.1
	100.00	100.00

The sweet potato also contains about 100 micrograms per gram of carotene, and fair amounts of ascorbic acid and B vitamins.

Sweet potato vines can be used for roughage feeding or for the making of silage. The crop is sometimes grown as a cover crop on estates. In the Southern United States, the crop was extensively used for the extraction of starch, from 1934 to 1948 (2,3) the starch being used in laundering.

Sweet potato is grown in most tropical and sub-tropical countries of the world. In the U. S. A. sweet potato ranks next in importance to the potato as a field crop.

BOTANY AND VARIETIES

The sweet potato (*Ipomoea batatas*) belongs to the family Convolvulaceae or morning glory family. The plant is a perennial, that is grown as an annual under cultivation. The vines are either green or red to purple in colour and about 4-16 feet long. The vines may be hairy, especially at the nodes. The leaves of most varieties are heart shaped, with the margins either toothed or entire, or deeply lobed. In some varieties the leaves may be tinged with a slight purple. The flowers are funnel shaped, and either bluish or purple.

The roots vary in the colour of the outer skin, as well as the colour of the inner flesh, depending on the varieties. The roots do not have eyebuds, as in the ordinary potato tuber, but shoots arise from adventitious buds. (4).

Varietal differences are based mainly on the colour of the skin as well as the flesh of the tubers. Skin colour varies from light brown to pinkish red. The red skin varieties have a greater consumer preference. The colour of the flesh is white, yellow or golden yellow.

Recommended varieties for cultivation are FA 17, and IB 15, both of which are 4 month varieties. (5). In recent trials at Peradeniya, the varieties N 47 and B 44 out-yielded the selection IB 15, by 20 and 40% respectively. (6).

ECOLOGICAL ADAPTATION

Sweet potatoes can be grown from sea-level up to an elevation of about 3,000 feet. It is well suited to high rainfall areas, although it does satisfactorily even in areas of lower rainfall. Warm sunny weather, with adequate moisture aids in tuberization.

The sweet potato is rather lenient in its soil requirements. A sandy soil, with a clay subsoil is quite suited to the crop, but good yields are obtainable in very sandy soil types that are heavily fertilized. (7). Very fertile soils promote heavy vine growth, but are detrimental to the production of roots. (7). Drainage is important, and the usual practice of growing sweet potatoes, on ridges, helps to overcome the difficulties encountered with inadequate surface drainage.

Areas for cultivation

Sweet potatoes can be cultivated successfully in the low country and mid country wet zone.

Planting season

Sweet potatoes can be grown during both the Maha and the Yala seasons. Planting is usually commenced with the early rains.

CULTURE OF THE CROP

Land preparation

Land preparation for sweet potatoes involves ploughing and disking the soil to break down the clods and remove all trash and stubble. The land is then ridged with a ridger. The ridge is usually 1-1½ feet wide and about 9 inches high, and spaced 3 feet apart.

Planting material

Planting material consists of stem cuttings, about 6-10 inches long. Cuttings may be taken when the vines begin to run, from

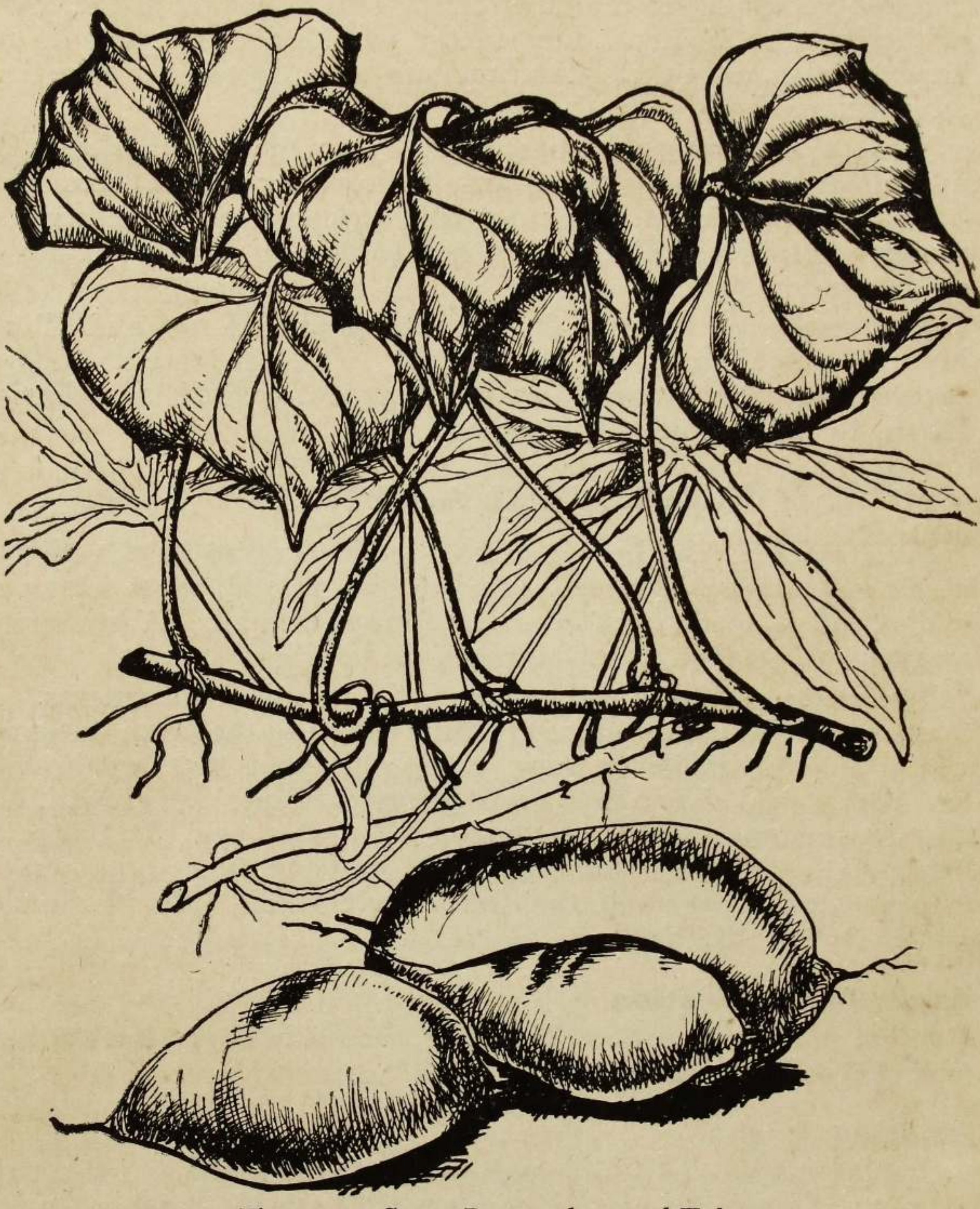


Figure 15. Sweet Potato plant and Tubers

a newly established field, or at harvest time. Cuttings from which all the leaves have been removed are used for planting.

Planting method

Planting is best done when there is adequate moisture in the soil. The cuttings are planted in such a way as to bury about 2-3 nodes. The planting is done about 18 inches apart on the ridge.

Nutrition

Experiments conducted in some of the Southern States of the United States, where sweet potatoes are grown on a large scale, indicate that sweet potatoes respond to potash fertilizers in excess of 50 pounds to the acre. (8). There is also evidence that ample potash sometimes produces thick roots (9), but has little influence on root shape. (8). Moderate liming is also recommended for areas where the pH of the soil is below 5. (7). The Department of Agriculture recommends the application of the following fertilizer mixture per acre 2 weeks after planting. (5).

1 cwt. of sulphate of ammonia
1½ cwt. of concentrated superphosphate
1½ cwt. of muriate of potash

Intercultivation

A single intercultivation about 3 weeks after planting for the purpose of weed control is adequate in most instances. Thereafter the growth of the vines is rapid and the foliage covers the soil, smothering all weeds.

Control of pests and diseases

There are no serious pests or diseases of significance in Ceylon. The crop is subject to the attack by several diseases both in the field and in storage, in other sweet potato growing countries. Some of these diseases are stem rot or wilt, black rot, foot rot or die off, scurf and soft rot. A common storage disease in the U.S.A. is dry rot. The sweet potato weevil, and the adult sweet potato leaf beetle are also troublesome insect pests. When the crop is left too long in the field in Ceylon the roots are subject to attack by termites and rodents.

Harvest

Depending on the variety under cultivation, the crop can be harvested between 3½ to 5 months from planting. Harvesting involves the lifting of the tubers, which is usually done manually with the mamoty. The harvested tubers should be stored in a cool dry place.

Yields

Average yields vary between 4-8 tons per acre.

Costs of cultivation and returns (10)

	Cost Rs. cts.
Preparatory tillage (mechanical) ...	75.00
Cost of organic manure, fertilizers and application ...	165.00
Cost of planting material	40.00
Planting: 8 units	20.00
Two intercultivations: 12 units	30.00
Harvesting and transport: 20 units	150.00
	480.00

Yield 8,000 pounds			
Value at 10 cts. per pound	...	Rs.	800.00
	Profit	Rs.	320.00

REFERENCES

1. Sweet Potato. (*Ipomoea batatas*). Malayan Agricultural Journal. Vol. XXVIII No. 5. 1940. Also Tropical Agriculturist Vol. XCIV No. 6 p. 378-382. 1940.

2. Boswell, V. R. and Jones, H. A. Climate and vegetable crops. U. S. Dept. Agr. Yr. Bk. p. 373-99. 1941.

3. Paine, H. S., Thurber, F.H. and Balch, R.T. Manufacture of sweet potato starch in the United States. Jour. Indust. & Eng. Chem. 30: 1331-1343. 1938.

4. Artschwager, E. On the anatomy of the sweet potato root, with notes on internodal breakdown. Journ. Agr. Res. 27 (3). p. 157-166. 1924.

5. Sweet potato. Food Crops Bulletin No. 10. Department of Agriculture.

6. Administration Report of the Director of Agriculture for 1960-61.

7. Miller, F. E., Beattie, J. H. and Zimmerly, H. H. Sweet potato growing. U. S. Dept. Agr. Farmers Bull. 999. p. 1-26. 1938.

8. Boswell, V.R., Beattie, J.H. and McCown, J.D. Effect of potash on grade, shape and yield of certain varieties of sweet potatoes grown in South California. U. S. Dept. Agr. Circ. 498. p. 1-23. 1938.

9. Schermerhorn, L. G. Sweet potato studies in New Jersey. N.J. Ag. Exp. St. Bull. 398. p. 1-19. 1924.

10. Costs from Central Experiment Station, Peradeniya.

27. DIOSCOREA YAM

Economic importance

Dioscorea Yams are wholesome and nutritious. In food value, most of the cultivated varieties of dioscorea are superior to potatoes, as well as the more important locally grown root crops. Table 1 gives a comparative analysis of locally grown root crops. (1).

TABLE 1

Analysis of locally grown root crops

Root Crop	Moisture	Protein	Carbohydrate	Ether Extract	Fibre	Mineral matter	Calorific value per 100 grms.
Dioscorea	71.23	1.73	25.43	0.03	0.62	0.96	108.9
Manioc	67.83	0.81	29.63	0.58	0.71	0.44	127.06
Sweet Potato	81.01	1.40	15.99	0.22	0.17	1.21	71.50
Desi Ala	70.00	2.00	26.63	0.20	0.60	1.20	112.06

Dioscorea yams lend themselves to the preparation of a number of tasty dishes, both as breakfast food as well as sweetmeats. The yams have been known in Ceylon for a long time.

BOTANY AND VARIETIES

The true yam, that produces tubers instead of fleshy roots, belongs to the genus *Dioscorea* and to the family Dioscoreaceae. The plant is native to the eastern tropics. Most of the cultivated yams fall into the two species *Dioscorea alata* Linn. distinguished as the Greater Yam and *Dioscorea esculenta* Burkill, distinguished as the Lesser Yam. (2). *Dioscorea alata* is characterized by the presence of winged stems which twine to the right. The leaves may be subsagittate or subhastately ovate. *Dioscorea esculenta* is characterized by the presence of thorns, and twines to the left. The stems are cylindrical and the leaves are cordate.

Nearly 40 varieties are grown in Ceylon. The varieties differ in the colour of the flesh and the size of the yams. Certain varieties also bear aerial tubers, which are small, smooth skinned and hard.

Red or purple fleshed varieties (3)

The following are popular yams of this group:

Name of variety	Description
King Yam	Medium sized, regular yam. Soft and mealy, when boiled. Stores well.
Jaffna purple	Larger yam, irregular in shape. Similar to king yam in quality.
Mauritius red	Branched irregular yam, somewhat hard. Stores well.
Lenadandilla	Indigenous variety with purplish flesh. Hard yam, becomes slimy on boiling.
Rakthavalli	Medium sized digitate yam. Slimy when boiled. Does not store well, and has to be eaten fresh.
White or cream fleshed varieties	
Kirikondol	Soft, starchy, longish yams. Stores well Tasty yam.
Ulakai-vali	Longish yam, similar to above. Not as popular as kirikondol. Less tasty. Stores well.
Vel-ala	Longish branched yams. Tends to be watery on boiling. Storage qualities poor.
Baeton	Longish yam, soft and mealy when boiled. Storage qualities good.
Mauritius white	Hard yam, similar to Mauritius red. Tends to be watery on boiling. Storage qualities good. Flesh has a purplish tinge.
Kombu-valli	Medium sized, branched yams. Breaks easily on lifting and possesses poor keeping quality.
Ini-ala	Elongated medium sized yam, which produces digitate yams from the stem end. Eating quality poor.

Other popular varieties

Other popular varieties of Dioscorea are Hingurala, Rata-kondol, Angili-ala, Kukul-ala, Udala and Siri-kilangu.

Poisonous varieties

Poisonous varieties of Dioscorea occur in the wet zone jungles. Uyala and Panukondol, are examples of such types.

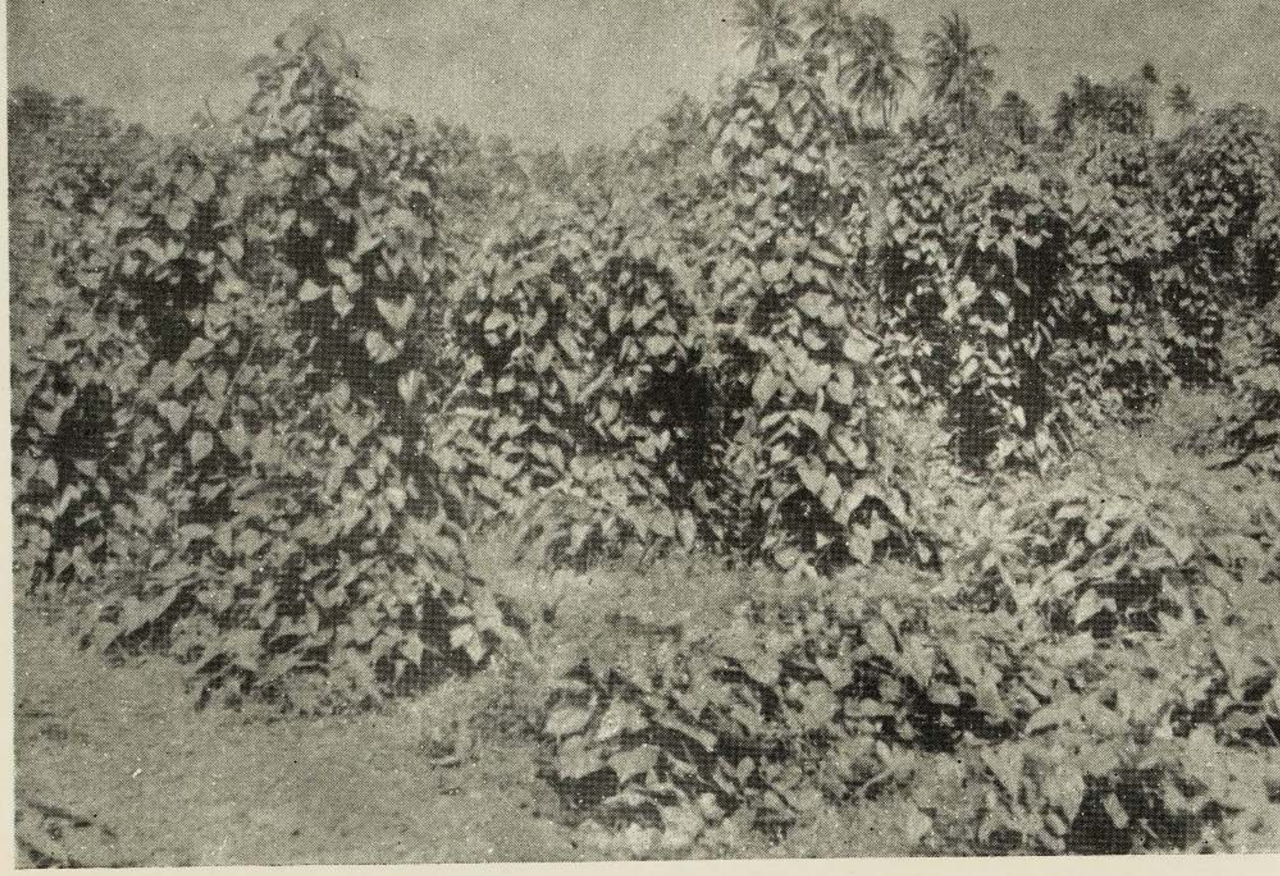


Plate 19. Field of Dioscorea yams.

Plate 20. Innala being grown on raised beds. Note. Ridge planting is the common practice.

Botanically the following include the principal Ceylon varieties (4).

D. alata. Stem 3 to 5 winged or angled, tuberiferous without prickles. Leaves opposite, entire. e.g. Angili-ala, Kiri-kondol, Kiri-vel-ala, Raja-ala or Rata-kondol.

D. bulbifera. Stem round, leaves alternate. e.g. Uda-ala.

D. obcuneata. Stem round or slightly grooved, tuberiferous with prickles, leaves alternate or opposite, entire. e.g. Hiri-tala.

D. pentaphylla. Leaves 3 to 5 digitate. e.g. Katu-ala.

D. spicata. Stem round without prickles or tubers, leaves opposite. e.g. Gon-ala.

D. fasciculata. e.g. Katukukul-ala and Kukul-ala.

D. aculeata. e.g. Kaha-ala.

D. tomentosa. e.g. Uyala *D. sativa.* e.g. Panu-kondol	} inedible Ceylon yams

ECOLOGICAL ADAPTATION

Dioscorea yams can be cultivated from sea-level up to an elevation of 3,000 feet. The crop is quite suited to high rainfall areas, but can be expected to perform satisfactorily, even in the dry zone, due to its ability to withstand drought conditions for long periods. The crop does particularly well in the low country and mid country wet zone.

The crop can be raised in well prepared planting holes, on practically any type of soil, provided adequate drainage is available. Since the crop is planted in individual planting holes, the addition of liberal amounts of organic matter or leaf mould, to the planting holes, improves the physical condition of the soil in these holes, and provides suitable conditions for the crop.

Areas for cultivation

The crop can be raised successfully anywhere in the low country and mid country. The crop can also be planted as a catch crop in new clearings of rubber and coconut in between the rows of young plants. Dioscorea yams are also cultivated extensively in the Jaffna peninsula with irrigation in the off season.

Planting season and growth habit

Dioscorea yams are normally planted in the Yala season with first rains in April. The crop remains on the land for two seasons, namely through the Yala and the following Maha. During the 1st season, vegetative growth takes place at the expense of the stored reserves in the seed yam. Elaboration and storage of material occurs during the 2nd season after the photosynthetic system is fully developed.

CULTURE OF THE CROP

Land preparation

Land preparation involves the preparation of either individual pits or long trenches for the planting of the setts. When individual pits are used for planting, planting holes may be prepared 2′×2′×2′ and spaced 3 feet apart. Closer spacings between hills, gave significantly higher yields under Peradeniya conditions. (2). When trenches are used for planting, they should be 2 feet wide, 2 feet deep and spaced 3 feet from centre to centre. The pits or trenches, are filled to ground level with a mixture of top soil and well rotted compost or leaf mould. This is best done at least 3 weeks prior to planting to allow the soil to settle down in the pits and trenches.

Planting material

Planting material consists of seed yams, the ideal size of which should be around 10 ounces in weight. Larger yams could be cut into 10 oz. setts. Uncut yams generally give the higher yields. Cut yams should be prepared for planting by smearing the cut surface with wood ash to prevent rotting. In small scale planting, as in home gardens, tops (stem ends) of yams could be used as planting material.

Dioscorea yams go through a period of dormancy, and begin to sprout only about 2 months after harvest. In practice the yams are sprouted before planting. This is done by placing the setts close together in shallow trenches and slightly covering them over with soil or in sand beds. Sprouting occurs in about 3-4 weeks. Normally however, the yams can be sprouted by leaving them in a dark room for sometime.

Planting out

The usual practice is to plant one sprouted seed sett or yam, per pit, at a depth of about 6 inches. In trenches, sprouted seed yams or setts are planted at a spacing of 3 feet, to a depth of 6 inches. The surface of the pits or trenches is then covered with a layer of straw or leaves, to provide a mulch for purposes of weed control, and the conservation of soil moisture. After emergence the vines are staked. Bamboo poles 12 feet tall can be used for staking. Staking enables the better orientation of leaves to the incident light, and thereby helps to increase yields. The ideal number of setts that should be used for planting per hill, the spacing between hills, and the desirability or otherwise of staking, are some of the cultural factors that have been investigated in dioscorea yams.

In an experiment designed to test the effect of the number of setts per hill, spacing of hills, depth of planting hole, and staking on the yield of two varieties of yams, the following results were reported. (2). (Table 2.)

TABLE 2

Yield of tubers in tons per acre (Chandraratna and Nanayakkara 1944)

		Number of setts		Spacing		Staking		Variety		Mean Yield (—0.229)
		One per hill	Two per hill	3 × 3′	3 × 1½′	Unstaked	Staked	Jamani	No. 288	
Number of setts	one/hill	—	—	1.93	2.54	1.67	2.80	1.32	3.14	2.23
	Two/hill	—	—	2.21	3.93	2.59	3.55	2.11	4.03	3.07
Spacing	3 × 3′	1.93	2.21	—	—	1.64	2.49	1.14	2.99	2.07
	3 × 1½′	2.54	3.93	—	—	2.61	3.86	2.29	4.18	3.24
Staking	Unstaked	1.67	2.59	1.64	2.61	—	—	1.10	3.15	2.13
	Staked	2.80	3.55	2.49	3.86	—	—	2.33	4.02	3.18
Variety	Jamani	1.32	2.11	1.14	2.29	1.10	2.33	—	—	1.72
	No. 288	3.14	4.03	2.99	4.18	2.15	4.02	—	—	3.59

Significantly higher yields were obtained with two setts per hill than one. Each sett weighed 4 oz. Spacing of $3' \times 1\frac{1}{2}'$ was significantly better than the $3' \times 2'$ spacing. Staked plants gave significantly higher yields than unstaked ones. Strain No. 288 (*Dioscorea esculenta* var. *spinosa*), significantly outyielded Strain Jamani (*Dioscorea alata*).

After-care of the crop

Since the crop stays on the land for a long time, it is essential to see that weeds are controlled effectively. Regular weeding should be routine practice.

Control of pests and diseases

There are no serious insect pests on this crop.

Among the diseases, cercospora leaf spot, (caused by *Cercospora dioscoreae*) can be serious often resulting in a reduction of yields. Staking of the plants helps to reduce the incidence of attack. Unstaked plants, suffer probably due to the higher humidity near the plants which promotes the attack.

Harvest

The crop is usually ready for harvest around December-January. About this time the leaves begin to wither and finally drop. The yams are lifted by digging them out.

Yields

Yields vary with the varieties. For example, the variety Kukulala yields on the average 3-4 pounds of yams per plant. On the other hand the variety Kahata-ala yields about 30 pounds or more. Average yields range from about 4-6 tons per acre.

Storage

One of the limiting factors to the cultivation of dioscorea yams on a large scale is that the yams cannot be stored for long periods. They can, however, be kept in a reasonably good condition for sometime provided they are carefully cleaned of all the adhering earth, and stored in a cool dry place. Injured tissue is susceptible to quick rotting.

Costs of cultivation and returns (5)

	Cost Rs. cts.
Preparatory tillage (mechanical) ...	52.00
Cost of organic manures and application	250.00
Lining and holing: 160 units	800.00
Filling pits: 40 units	150.00
Cost of planting material	480.00

Planting	...	...	...	...	27.50
Two hand weedings		...	...	...	87.50
Trellising	...	...	...		200.00
Earthing up and cost of fertilizers			...	...	48.00
Harvest and transport: 40 units			...	...	200.00
					2,295.00

Yield 20,000 pounds		
Value at 15 cts. per pound		Rs. 3000.00
	Profit	Rs 705.00

REFERENCES

1. Dioscorea yams. Circular No. 11. Department of Agriculture, Ceylon.

2. Chandraratna, M.F. and Nanayakkara, K. D. S. S. An investigation of cultural factors affecting the yield of yams. Tropical Agriculturist Vol. C. p. 82-87. 1944.

3. Dioscorea yams. Food Crops Bulletin. No. 17. Department of Agriculture, Ceylon.

4. Macmillan, H. F. *Tropical Planting and Gardening.* MacMillan & Co. Ltd. 1943. p. 289-90.

5. Costs From Central Experiment Station, Peradeniya.

28. INNALA

Economic importance

Innala, also called the country potato is one of the most paying amongst the root crops, and is a popular food, especially when cooked as a curry and eaten with rice. It can be boiled and eaten in the same way as manioc. When fried as chips it is as palatable as potato chips. Its food value is given by the following analysis (1).

Moisture	Proteins	Carbohydrates	Fat	Fibre	Mineral matter
%	%	%	%	%	%
77.6	1.3	19.7	0.1	0.4	0.9

Compared to other yams, innala is relatively low in starch, and moderately high in proteins and minerals. The crop is also singularly free of pests and diseases, and as such offers considerable scope for expanded cultivation. The plant is a native of Tropical Africa, from where it was introduced into Asia.

BOTANY AND VARIETIES

Innala (*Plectranthus tuberosus*; also *Coleus rotundifolius* Poir Chev. et. Perrot) is a herbaceous annual. The leaves of the plant are somewhat thickish, and have an aromatic smell resembling that of mint. The tuber resembles the common potato, but is smaller in size, and darker in colour. The tuber too has a distinct aromatic flavour.

There are two main varieties, a small tubered variety, also referred to as 'sinhala innala' and a large tubered variety also called 'rata innala'. The small tubers are noted for their delicate flavour. The larger variety yields more and is also easier to harvest on account of the size.

ECOLOGICAL ADAPTATION

Innala is a crop that is suited to high rainfall areas. The crop remains on the land for a period of nearly six months and during this period environmental conditions should be such as to promote early vegetative growth followed by maximum tuberization. Evenly distributed rains and relatively low night temperatures favour tuberization.

Sandy loam soils are the most suitable for innala cultivation. Fair yields can be obtained from loamy soils but heavy clayey soils are unsuitable. Innala does not stand waterlogging and the usual practice is to grow innala on ridges, except in the drier areas. Trials carried out on the University experimental plots, showed that successive crops of innala, could not be grown on the same land, without seriously affecting yields.

Areas for cultivation

Innala is grown largely in the low and mid country wet zone. It is a common crop on the river banks in the Kandy district. In the Colombo district, innala is a common crop in vegetable tracts.

Planting season

Innala is grown in the Yala season. Tubers commence germinating about the end of March. Cuttings for planting are raised in nurseries from these tubers and later planted out in the field during the Yala season about the end of June or early July.

Figure 16. An Innala plant with Tubers

CULTURE OF THE CROP

Nursery practice

The plump, healthy tubers obtained from the December-January harvests, are selected and stored for planting in a nursery, about the end of March. The storing may be done in a cool, well ventilated room, and the tubers may be covered with a layer of sand to prevent drying. Nursery beds are constructed as raised beds about 3-4 feet broad, and of any convenient length. The beds are manured heavily with cattle manure at the rate of about 20 tons per acre. The tubers are planted in rows $2'' \times 6''$, one tuber per hill. The tuber may be planted about $1\frac{1}{2}$ inches deep. Irrigation is necessary, at the early stages, and should be continued if no rain is available. Two to three cultivations may be given for purposes of weed control, and the cuttings will normally be ready for planting in late June or early July.

Land preparation for field planting

Innala is usually planted on ridges. The land is ploughed about two weeks prior to planting and harrowed to break up the clods. The soil is then thrown into ridges, either by the use of a ridger or by the plough itself, the ridges being spaced three feet from centre to centre. In small holdings, these operations may be done with the mamoty, or with bullock drawn implements. On sloping land, the ridges should be laid on the contour.

Planting methods

There are three general methods of planting innala, which are in use. All three methods use cuttings for planting, but the amount of tubers necessary for raising the cuttings used in each method, depends on the particular method used. The methods are 1. Ordinary planting. 2. Planting of coiled cuttings. 3. Planting of cuttings horizontally. About 8,000 tubers planted in an area of 2,000 square feet, gives enough cuttings for an acre, by the first method of planting. Double and treble the quantities are required for the 2nd and 3rd methods of planting respectively. (2).

The common practice adopted in the Galle district is to plant 6 inch cuttings from the first nursery into a second nursery by about May or early June. Cuttings from the second nursery are planted out in the field by August. Only 1/8 the quantity of seed tubers, is required for this method. (2).

Ordinary planting

In this method, cuttings about 6 inches long, and having 3 or 4 leaves at the top end, are used. These are planted in rows down the ridges, 9″ from each other. Planting depth is usually about 3″.

Coiled planting

In this method cuttings about 9 inches long are used. A length of about 5 inches of the more mature portion is coiled and planted in holes made along the ridges, about 3 inches wide and two inches deep. Spacing used is same as above.

Horizontal planting

In this method cuttings about 12 inches long are used. The cuttings are placed horizontally across the ridge, two at a time, in opposite direction and almost touching each other. About 9 inches of the cuttings remain on the ridge and 3 inches outside. The spacing between such pairs is about 3″.

Of the three methods in vogue, coiled planting has shown the best results. (2).

Nutrition

Fertilizers may be applied at the rate of 1 cwt. per acre of a 16: 8: 8 mixture. Cattle manure, if available can be forked in at planting at the rate of about 10 tons per acre.

Weed control

About 2 intercultivations are normally necessary, one about 3 weeks after planting, and the other about a month later, for purposes of weed control A slight earthing up given at this time promotes better root development. Usually no intercultivation is necessary after this, as the foliage covers the soil effectively and controls the weeds.

CONTROL OF PESTS AND DISEASES

The crop is relatively free of any pests or diseases. A caterpillar pest, occasionaly attacks the leaves during the nursery stage. This can be easily controlled by spraying with lead arsenate.

Harvest

Harvest is commenced by the end of December or early January, when the plants begin to die. Harvesting presents no problems The tubers can be easily lifted from the soil, using hand forks or other simple implements as they are formed very near the surface.

Yields. Yields of innala vary between 3 to 6 tons per acre Average yields amount to about 4 tons.

Costs of cultivation and returns (3)

			Cost Rs cts
Ploughing Harrowing Spiking Construction of ridges with plough	Preparatory tillage (mechanical)	...	75 00

{Manuring ridges Cost of manure (organic)	250 00
Planting cuttings (including cost of cuttings): 8 units ...	120 00
Weeding twice: 16 units	40 00
Earthing up	45.00
Harvesting with hand forks	250.00
	780.00

Approximate yield 10,000 pounds
Cost of innala per pound 15 cts. Value Rs. 1500.00
Profit Rs. 720.00

REFERENCES

1. Jo chim, A.W.R. *et al.* The an lysis of Ceylon Food Stuffs, II, III,. T opic l Ag iculturist Vol. XCIII No. 1. 1938, and p rt VI, XCIII. No. 6. 1936.

2. White J.S. . The cultivation of *Coleus rotundifolius* (Poir) A. Chev et. Perrot. (Country pot to) in Ceylon. Tropic l Agriculturist Vol. CIV. No. 3. p. 151 54. 1948.

3. Costs From Centr l Experiment Station, Peradeniya.

29. TANNIAS

(Alocasias and Colocasias)

Economic importance

Tannias or Coco yams have long been a common food of the people. The yams, and in some varieties the leaves and stalks as well can be cooked in several ways. In ease of cultivation, tannias have few rivals. They are adapted to a diversity of environmental conditions. The yams are wholesome and nutritious. Tannias are a popular food crop in the West Indies, Egypt, Hawaii and Tropical America.

BOTANY AND VARIETIES

Tannias or Coco yams belong to the family Aroideae. The plants are herbaceous tuberous perennials, with large leaves, cultivated as annuals, and occurring under numerous names. The names vary in different countries. In Ceylon, they are designated by several names such as Kiri-ala, Desi-ala, Kand-ala, Sevel-ala, Gahala etc. There are two distinct forms, one having peltate leaves, and the other having hastate leaves. (Fig. 17.) The latter group is usually placed under the genus *Xanthosoma*. (1).

Examples of the two forms are

1. *Alocasia* (*Xanthosoma*) *indica* which is characterized by hastate leaves: e.g. 'Habarala'.
2. *Colocasia antiquroum* which is characterized by peltate leaves e.g. 'Kiri-ala'.

The commonly cultivated varieties of tannias are:

Thummas-ala	— 3 month variety
Dehi-ala or Desi-ala	— 4 month variety
Kiri-ala Kandala	— 6 - 9 month variety

The leaves and stalks of most varieties are green, while that of the variety Kandala is purplish.

ECOLOGICAL ADAPTATION

Tannias can be grown successfully up to an elevation of about 4,000 feet. They are quite suited to high rainfall areas, and can be expected to do well in the low country and mid country wet zone. Some of the relatively short aged varieties can be also be grown successfully in the dry zone, without irrigation. Soil requirements are not exacting. They can be grown on a wide range of soil types, except hard clays, and pure sands. Certain varieties such as Habarala, Sevel-ala, and varieties with edible leaves can be grown in low-lying moist situations. (2). Other varieties do well when grown on dry land, under irrigation, or in areas of high rainfall.

Planting season

Tannias can be planted almost throughout the year except during the very dry months. There can be thus an year round supply of yams, as different varieties can be planted and lifted at different times of the year. Further, lifting can be staggered depending on the ages of the varieties concerned.

CULTURE OF THE CROP

Planting material

Planting material consists of either crowns, or tubers. Crowns have to be planted almost immediately after harvest. Tubers can be stored, prior to planting. Small sized tubers could be planted whole. Large ones should be cut into two or three pieces, each containing two or three 'eyes' It is usual to smear the cut surface with wood ash to prevent rotting.

Land preparation and planting

The land should be worked to a depth of about 9-12 inches. The application of a well rotted compost or cattle manure at this time gives beneficial results.

Planting is usually done in individual planting holes. The tubers are buried 3 to 4 inches deep. When crowns are used they should be planted deep enough so as to bury the old yam.

Spacing

The following spacings are recommended. (3).

Thummas-ala $2' \times 2'$
Gahala, Dehiala and Kandala $3' \times 3''$
Kiri-ala $4' \times 4'$

Nutrition

Tannias respond well to manuring. Heavy applications of well rotted cattle manure or compost, at planting, can double the yield of tubers. (2).

After-care of the crop

Preliminary weeding may be necessary till the plants grow up and shade the soil. Mulching the soil with straw, leaves, or cadjan, controls weeds, and conserves soil moisture. An earthing up of the soil to prevent exposure of the tubers is also beneficial.

Control of pests and diseases

There are no serious pests or diseases.

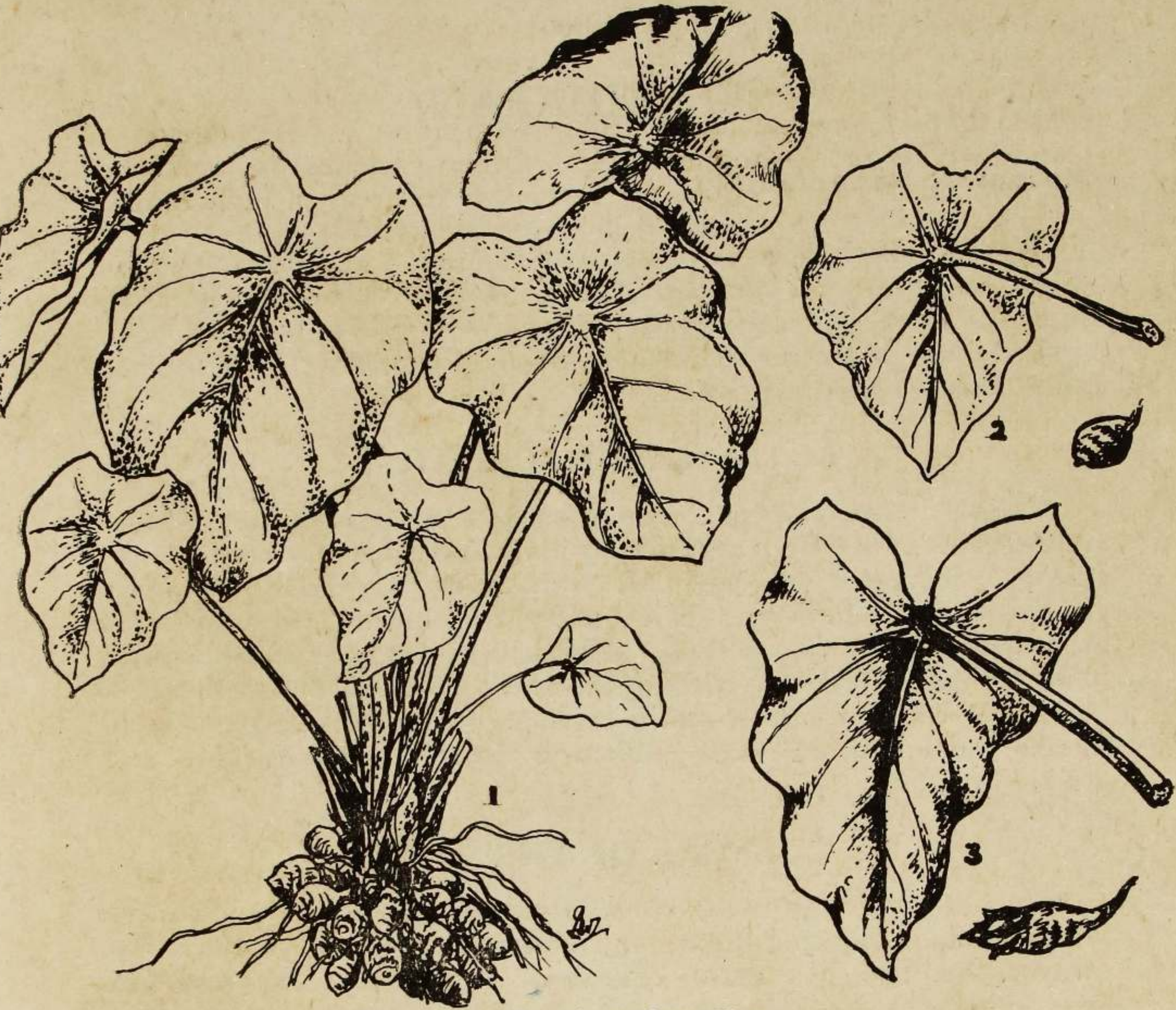


Figure 17. Tannia or Coco Yam
1. Plant showing tubers
2. Peltate leaf (Colocasia)
3. Hastate leaf (Xanthosoma)

Harvest

Depending on the variety, the crop may be lifted from 3 months onwards. The tubers are lifted by carefully digging the whole plant out, without injuring the tubers. Uninjured tubers store relatively well.

Yields

Average yields range from 3-5 tons per acre. Higher yields can be obtained under good cultural conditions. The tubers vary in size, and usually possess a fibrous skin.

REFERENCES

1. MacMillan H. F. *Tropical Planting and Gardening*. MacMillan & Co. Ltd. 1943. p. 288-9.
2. Tannia or the Coco-yam. Leaflet No. 178. Department of Agriculture, Ceylon.
Also Mollegode W. Tropical Agriculturist Vol. No. 5. p. 278-80 1939.
3. Tannias. Food Crops Bulletin No. 18. Department of Agriculture, Ceylon

30. KIDARAN

Economic importance

The underground corms of these plants are rich in food value, being particularly high in proteins and minerals and low in starch. The yield of starch is less than 5 % (1). In Jaffna as well as in other locations in the low country wet zone, the crop is raised on a field scale though only in small extents, and yields a heavy crop of tubers, that fetch reasonable prices.

BOTANICAL DESCRIPTION

Kidaran (*Amorphophallus campanulatus*) belongs to the family Aroideae. It is a stout herbaceous plant, and gives rise to a hemispherical, depressed, underground corm which may be 8-10 inches in diameter. The corm is of a dull brown colour. It bears a large mottled leaf on a long petiole. The flower is large, purplish brown and foetid. There are many wild and cultivated varieties. The corms of wild varieties contain crystals of calcium oxalate, which make them irritant. The cultivated varieties are relatively free of the irritant.

CULTURE OF THE CROP

The tuberous outgrowths of the fully developed corms are planted in individual planting holes, which may be prepared in the same way as for dioscorea yams. Planting is generally done with the rains either in the Maha or the Yala. The corms can be dug out for use about 12 months later.

Yields. Average corms weigh from 4-8 pounds each. Corms weighing 15-20 pounds can be produced under good cultural conditions.

The corms can be stored for long periods if stored dry in a well ventilated room.

REFERENCES

1. Reantaso, C.G. Pungapung as a source of starch and alcohol, Phill. Agrist. Vol. XXIV. p. 239-48 1935.

GROUP VII—SPICES AND CONDIMENTS

31. CHILLIES

Economic importance

Chillies are vital ingredients in the local diet. Dried chilli, ground into powder is used in everyday cooking. Green chillies are equally popular for flavouring, and other varieties such as grossum are used as vegetables. Imports of dried chillies have steadily risen over the years and stands at nearly Rs. 40 million per year, resulting in considerable loss of foreign exchange. Table 1 gives the quantity of dried chillies imported into Ceylon and their value from 1958-1962. (1).

TABLE 1

Imports of dried chillies

	1958	1959	1960	1961	1962
Quantity (1000 cwt.)	285	316	345	340	380
Value (Rs. '000) ..	21,773	24,619	36,537	32,902	36,241

This increase in imports is due to the increase in population, increase in *per capita* consumption, and insufficient production to meet the demand. (2).

Although a guaranteed price has existed for dried chillies it has failed to stimulate production as even this price was low in relation to the actual cost of production. This combined with the fact that there is an attractive market price for green chillies, has encouraged the farmer to divert large acreages to the cultivation of green chillies. In 1962, therefore a further increase in the guaranteed price by 20 cts. per pound was recommended. (2). The guaranteed price paid for dried chillies stood at Rs. 145.60 per cwt. for Grade I, Rs. 131.04 for Grade II and Rs. 110.88 for Grade III during 1962/63. (3).

It was envisaged that in order to cut down imports, it was necessary to set aside a sufficient acreage of irrigated land in the dry zone for this crop, in addition to promoting its cultivation on chenas, home gardens and highland allotments. In order to effect maximum import substitution, it was estimated that a total of 19,400 additional acres under rainfed conditions, and 38,900 additional acres under irrigation would be necessary. It was also considered necessary that a further acreage should be devoted to the cultivation of green chillies. (2).

BOTANICAL DESCRIPTION

The chilli plant belongs to the family Solanaceae, and the genus *Capsicum*. The home of the genus *Capsicum* is held to be Tropical America. (4). Under cultivation numerous forms have arisen and are classified under the species annuum. The only wild chilli, which is commonly found in most tropical countries is the Bird chilli. (*C. frutescens.* L.). *C. annuum* and *C. frutescens*, were distinguished in Linnaues' original classification as being annuals and perennials respectively. Prain (5) considered the chief distinguishing character to be the number of pedicels, which in the case of *C. annuum* is one compared to two or three in the case of *C. frutescens.* Paul (4) considered *C. frutescens* to be a closely related but ecologically distinct species having interspecific sterility with the varieties of *C. annuum.*

The chilli plant is characterized by the presence of a strong tap root, and many branching lateral roots and rootlets, which penetrate the soil to a depth of about 18 inches, and have also a similar lateral range. The leaves are lanceolate, broad across the middle, and alternate. The stem is thin, cylindrical and much branched. The pattern of branching is continuous till plants attain their full size. The flower is terminal and below the flower the stem divides into two branches, each branch develops and gives rise to a flower at its extremity, and below each flower the stem divides again into two branches, which again repeat the process. The plant is a low bush, attaining a height of about 2-3 feet. Flowers are bisexual. The fruit is a berry, the shape of which varies according to variety. The seeds are packed round a central septum.

Varieties

The classification of the cultivated varieties of chillies which vary in size, shape and pungency of the fruit, has been the subject of intensive study. More recently Paul (4) suggested that the shape of the calyx and the shape of the fruit may be considered useful for separating varieties, and suggested the following classification.

C. frutescens L. Plants growing wild, shrubby and perennial.

I. Calyx cup shaped and embracing the base of the fruit.

A. Base of fruit compressed.

(*a*) Fruits elongate............var. minimum—Bird chilli

(*b*) Fruits conical or ovate.........var. baccatum—Chilipiquin.

C. annuum L. Plants under cultivation, herbaceous or suffrutescent, annual, biennial or weakly perennial.

I. Calyx cup shaped and embracing the base of the fruit.

A. Base of fruit compressed.
Fruits elongate.........var. conoides—Tabasco.

B. Base of fruit not compressed.
Fruits elongate.........var. acuminatum—Dry chilli.

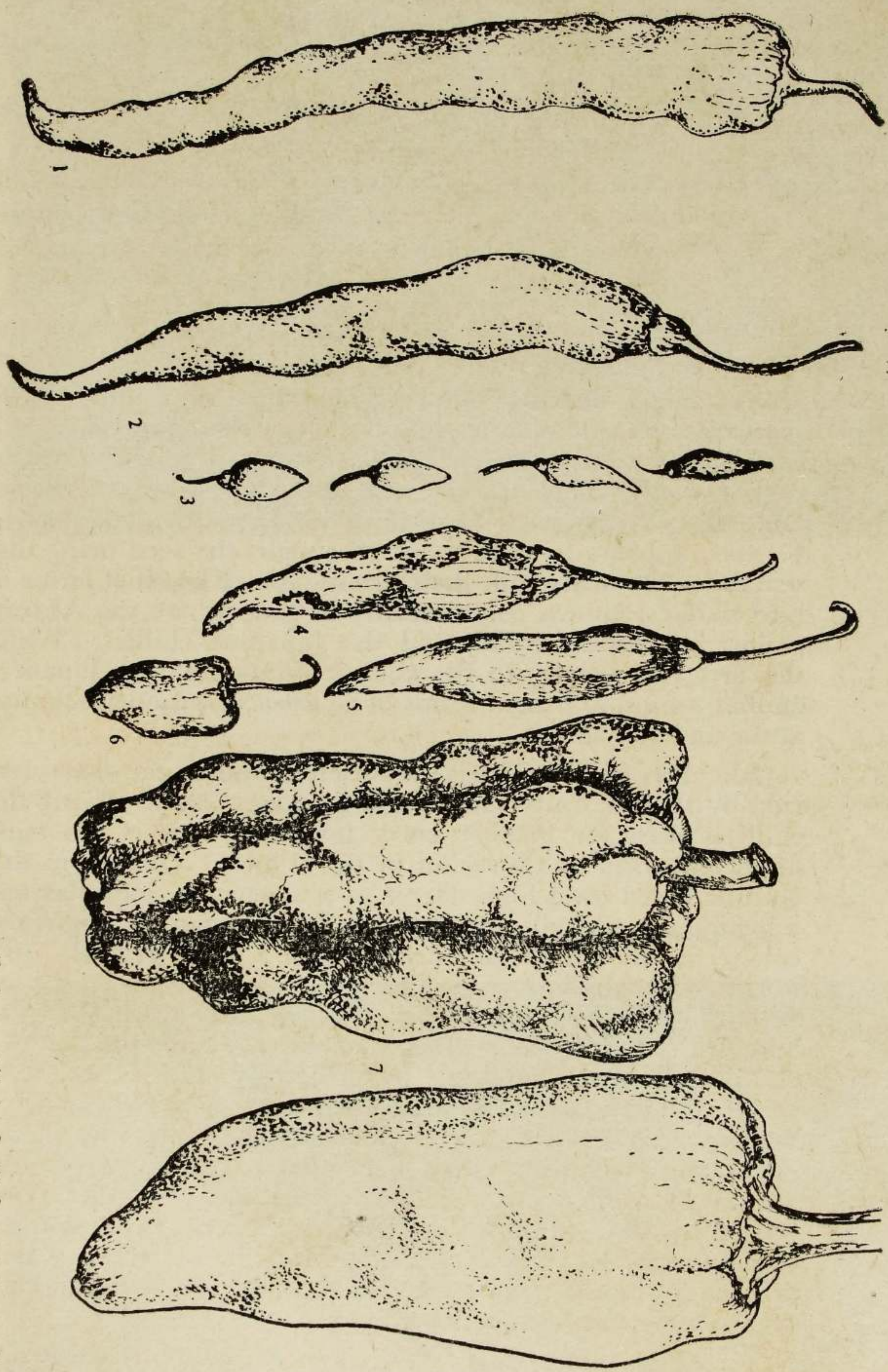


Figure 18. Chilli Varieties

1 & 2 Capsicum annuum var. longum
3 Capsicum frutescens var. minimum
4, 5, & 6, Capsicum annuum var. acuminatum (4, 5 Tuticorin, 6 Wanni)
7. Capsicum annuum var. grossum

II. Calyx pateriform and not generally embracing the base of the fruit.

(*a*) Fruits globose......... var. Cerasiforme—Cherry pepper
(*b*) Fruits conical.........var. Cuneatum—Pimento.
(*c*) Fruits elongate.........var. Longum—Green chilli.
(*d*) Fruits oblate.........var. Oblatum—Squash pepper.
(*e*) Fruits squarish or sub truncate.........var. Grossum—Bell pepper.

For commercial purposes, the varieties of Capsicum of economic importance are classified into the following. (6). (Fig. 18).

(**a**). **Bird chilli.** This includes the small but highly pungent fruits of oblong-conical shape, belonging mostly to *C. frutescens*. These are used commercially for pharmaceutical preparations. They are also used in the preparation of sauces and cayenne pepper. This chilli is not cultivated, and in Ceylon, appears in newly cleared jungle, the seed being disseminated by birds with their droppings. The chief forms of bird chillies, known commercially in Europe are the African chillies, Zanzibar chillies and the Japanese chillies. While the first two belong to the variety minimum, the Japanese chillies are small fruited forms of *C. annuum*, varieties acuminatum and longum.

(**b**). **Dry chilli.** This is the variety acuminatum, characterized by slender fruits with a thin pericarp. After drying the chilli is used for making curry powder. This is the most important form of Capsicum in the tropics. Quality in dry chilli is based on a high degree of pungency, a good flavour, a medium sized fruit, a moderately thin pericarp, a bright red colour, a smooth glossy surface, and a firm pedicel. (6). Forms of dry chilli grown in Ceylon, include the *Wanni*, grown without irrigation in the chenas, characterized by small degenerate fruits and *Tuticorin* which is considered to be the best dry chilli in Ceylon. (Table 2) In Jaffna, dry chillies are grown under well irrigation, and some forms have acquired the place names where they are grown. The important forms are Chankanai and Atchuvely—both belonging to the var. acuminatum and Point Pedro belonging to the var. Longum. Imported dry chillies known by their trade names in Ceylon include Patna, Gujerat, Nalchatty, Muladi, Tuticorin, which are mainly Indian varieties. There are also a number of others imported from other countries.

(**c**). **The green chilli.** This is the variety longum. Fruits are medium sized, pungent, and have thick pericarps. Used in the fully developed but green stage for seasoning. Sometimes var. acuminatum can also be used similarly by picking the pods green. This is grown generally in the wet zone areas,

Plate 21. A plot of Kidaran and a harvested tuber.

Plate 22. A crop of Dry Chillies (var. *acuminatum*) in Jaffna.

TABLE 2

Pod measurements of the Bird, Wanni and Tuticorin chillies (Paul 1940)

		Minimum cm.	Mean cm.	Maximum cm.
Bird	Length	0.9	1.056 $\pm$ 0.126	1.2
	Breadth	0.3	0.37 $\pm$ 0.04	0.4
Wanni	Length	1.5	2.14 $\pm$ 0.416	2.9
	Breadth	0.9	1.204 $\pm$ 0.196	1.8
Tuticorin	Length	5.2	6.324 $\pm$ 0.765	7.7
	Breadth	0.9	1.12 $\pm$ 0.199	1.3

and its cultivation particularly in areas close to the markets, gives handsome returns. Yields are higher than red chillies, but these cannot be stored.

(d). **Pimento.** Fruits have a thick pericarp. They are non-pungent. In the U. S. A. this name is used for canning peppers. They belong to the variety cuneatum.

(e). **Paprika.** This is an elongated medium sized fruit of the variety longum. Has a thick pericarp, again non-pungent. When ground, forms the paprika of commerce.

(f). **Bell pepper.** Includes the large non-pungent fruits with thick pericarps belonging to the variety grossum. They are used in salads, and for stuffing. It is commonly referred to as the vegetable chilli.

CROP IMPROVEMENT

The crop improvement work with dried chillies has been directed largely towards the selection of strains which are resistant to the complex of diseases, to which the chilli plant is subject. Yields of dried chillies which in earlier years amounted to nearly 15 cwt. per acre have declined steadily over the years to about 8 cwt. per acre, due to the ravages caused by chilli leaf curl disease. Of nearly 90 varieties both local and introduced, screened for leaf curl, mottle and tobacco mosaic viruses, none showed any high degree of tolerance to the leaf curl virus. In a cross between Tuticorin and Myliddy varieties the F3 progenies showed some indications of tolerance to the leaf curl and mottle viruses. Some introduced varieties showed tolerance to the tobacco mosaic virus. Hybridization between these and local varieties is being continued. (7). Interspecific crosses between *C. annuum* and *C. frutescens*, are also under investigation, with a view to arriving at disease resistant varieties.

ECOLOGICAL ADAPTATION

Chillies are cultivated under a wide range of environmental conditions, being grown under both tropical and sub-tropical conditions. The plants grow successfully from sea-level up to elevations of 5,000 feet. When grown as a rainfed crop, chillies can be grown successfully in areas with an annual rainfall of between 25-100 inches. The crop can also be raised as an irrigated crop. The moisture content of the soil has an important effect on the growth and yield of chillies. In Ceylon, dried chillies are raised under irrigation in Jaffna, but is grown under rainfed conditions elsewhere in the dry zone. The yields obtained in Jaffna are almost double that obtained from a rainfed crop. (8). Temperature has an equally important effect on the growth and productivity of chillies. Cochran (9) found with one variety, that maximum growth occurred at the 70-80°F temperature range. He also found that early blossoming and maturity of fruit was favoured by high temperatures, but higher temperatures lowered the setting of fruit. At blossoming time therefore, a lowering of the temperature results in greater fruit set.

Chillies require a well drained fertile soil of the somewhat heavy loam type. Good deep soils are preferred. Ordinary red loams, produce good crops with sufficient manuring. Badly drained soils cause the plants to shed their leaves, and to sicken in many ways, resulting in poor yields.

Areas for cultivation

Dry chillies are grown mainly in areas of comparatively low rainfall where the ripening and drying of the fruits can take place successfully. In heavier rainfall areas, green chillies are grown along with the vegetable chilli (var. grossum). The extents cultivated with chillies on a district basis in Yala 1960, Maha 1960-61 and Yala 1961 are shown in Table 3. (10).

Rotations

On chena lands in the dry zone, chillies continue to be grown in mixture with kurakkan, maize, mustard and amaranthus sp., during the Maha. The Wanni chilli (var. cuneatum) is sown mixed with these crops, and harvested in 2 to 3 picks by June and July, well after the harvest of the other crops. Poor yields are obtained as a

TABLE 3

Extents cultivated with Chillies (Acres)

District	Yala 1960	Maha 1960-61	Yala 1961
Colombo	119	273	339
Kalutara	155	336	215
Kandy	1,309	1,038	560
Matale	1,539	1,925	1,668
Nuwara Eliya	51	503	269
Badulla	423	1,404	1,183
Ratnapura	334	1,384	588
Kegalla	263	314	623
Galle	213	301	296
Matara	114	157	224
Hambantota	676	5,101	2,002
Kurunegala	1,871	1,471	2,635
Puttalam	1,635	2,316	1,590
Anuradhapura	298	3,854	386
Polonnaruwa	125	675	125
Trincomalee	60	288	110
Batticaloa	720	1,560	650
Vavuniya	401	70	611
Mannar	15	210	17
Jaffna	605	1,200	690
Total ..	10,935	24,380	14,781

rule. In Jaffna the cultivation of both green as well as dry chillies is carried out on a more intensive scale. The crop is grown both in paddy fields in rotation with paddy, tobacco and millets and on high land with tobacco, millets and manioc. Transplants are used, and good yields are obtained with irrigation.

Planting season

Dry chillies are grown as a rainfed crop in the Maha. Planting should commence in the last week of September or 1st week of October. In the Weraketiya area of the Southern province where the Yala rains are distributed over a period of 3 months dry chillies can also be cultivated during Yala (11). Planting in this area should commence around the third week of April. As an irrigated crop, dry chillies should be planted in December-January, after the heavy Maha rains, or in May if planted in paddy fields, where only one crop of rice is grown. (1.1). Green chillies may be planted around April during the Yala or around early October in the Maha.

CULTURE OF THE CROP

Chillies are raised from seed only in the chenas, when grown as a mixed crop. The improved practice is to raise the crop from transplants whether the crop is dry chillies, green chillies or vegetable chillies.

NURSERY PRACTICE

Seed bed preparation

Good nursery beds are essential for the raising of a supply of vigorous seedlings. The soil should be worked a number of times, to secure a fine tilth, after which cattle manure at the rate of 2 to 3 pounds per sq. ft. should be incorporated and the beds levelled. Raised beds, which provide for adequate drainage, are essential for the prevention of attacks of the damping-off disease, so common in nursery beds. 3 foot wide beds raised to 6 to 9 inches high with 1 foot drains are usually adequate for the purpose.

Sterilization of nursery beds

Seed beds should be sterilized by any of the following methods, in order to control soil borne chilli diseases.

1. Burning heaps of trash.
2. Watering with a disinfectant solution prepared either by mixing 1 oz. of ceresan wet in 5 gallons of water or 1 fluid oz. of tillex in 5 gallons of water.
3. By applying Shell DD soil fumigant at the rate of 4 c.c per sq. ft. two weeks prior to seeding.

Seeds and seed rate

For dry chillies particularly, the seed should be obtained from the pods of the first two pickings. In every case however, it is best to remove the seeds from the pods just prior to sowing, as the seeds lose their viability rapidly after extraction. ½ pound of seed sown in 360 sq. ft. of nursery beds is adequate to provide sufficient seedlings to plant an acre.

Seed disinfection

Seed may also be disinfected against seed borne diseases by dusting with ceresan dry dust or tillex dry dust or agrosan at the rate of 1½ teaspoonfuls to a pound of seed, or by immersing the seed for 30 minutes in a solution of ceresan wet (1 oz. in 5 gallons of water) or tillex (1 fluid oz. in 5 gallons of water).

Sowing

The seed may be sown in lines, to a depth of a ¼ inch, and the surface of the soil lightly pressed down with a plank. The beds should then be watered and covered over with straw or cadjan. Watering should be done daily, even twice a day. The covering may be removed after a week. Seedlings will be ready for transplanting in 4 weeks time. The use of sulphate of ammonia solutions to water the nursery results in weak seedlings that do not stand transplanting well.

If seedlings die in patches, due to damping off disease, the affected areas should be watered with a solution of tillex. The nurseries should be sprayed weekly against virus diseases, with a solution prepared by mixing 1 oz. of DDT 50% water wettable powder and 1 oz. sulphur wettable powder in 4 gallons of water.

Topping

The usual practice is to top the chilli plants prior to transplanting. This is considered to be a necessary practice because in the process of transplanting many of the finer roots and root hairs get damaged, and until fresh rootlets are developed, the leaf surface has to be reduced in proportion to the absorptive surface (12).

FIELD PLANTING

Land preparation

Thorough land preparation is essential for chilli cultivation. Prior to planting the land should be ploughed and harrowed in order to bring about a good tilth.

Spacing

Spacing of the crop differs for the different systems of cultivation. For a rainfed crop a spacing of 3 feet between rows, and 18 inches within the rows may be given. For an irrigated crop, a spacing of 3×3 feet is considered to be the best. (11). The number of seedlings per hill can vary between 2 and 4. When more than four seedlings are planted to a hill, overcrowding results and the fruits per plant decrease in number and size. The wide spacing of 3′ between rows facilitates mechanical intercultivation. If other methods of weed control are adopted the crop could be planted closer and expected to give better yields.

Planting out

Planting should be undertaken in the presence of adequate soil moisture. The transplants should be planted at the desired spacings. Transplanting is believed to ensure earlier as well as more profuse branching towards the base of the plant than seeds sown at stake. (13).

Nutrition

A number of workers have demonstrated the importance of nitrogen in the nutrition of the chilli plant. Stuckey and McClinton (14) found that nitrogen increased plant growth and fruit production although the susceptibility to blossom end rot also increased. Cochran (9) on the basis of pot experiments, showed that high nitrogen significantly increased the number of blossoms formed and the number that set fruit. Joachim and Paul (15) examined the effect of fertilizers in increasing the yield of Tuticorin chillies at two places in the dry zone of Ceylon, under field conditions. They reported that nitrogenous fertilizers at the rate of 20 lbs. and 40 lbs. N per acre gave significant fresh weight increases, over the unmanured plots. Sulphate of ammonia in particular showed a tendency to induce early bearing. Phosphorus and potash, however, when included in a mixture with nitrogen had no effect in increasing yield.

More recent trials conducted in the Yala of 1962 to determine the effect of continued top dressings of nitrogen (10 lbs. N—ammonium sulphate applied every two weeks commencing 2 weeks after planting) on the yield of pods of Tuticorin chilli grown under irrigation, gave the following results. (Table 4) (7). 5 tons of compost, 80 pounds P_2O_5 (superphosphate) and 40 pounds K_2O (muriate of potash) were applied to all plots prior to transplanting.

TABLE 4

Effect of Nitrogen on Pod yields in Tuticorin Chillies

Treatment	Mean yields (pounds of dry pods/acre)
Control (No nitrogen)	1,138
2 applications (20 lbs. N)	1,658
4 applications (40 lbs. N)	1,812
6 applications (60 lbs. N)	1,876
8 applications (80 lbs. N)	1,913

In another trial designed to determine the effect of phosphate on the yields of pods of Tuticorin chilli, 5 tons of Compost, 20 lbs. K_2O were applied before transplanting and 60 lbs. N (ammonium sulphate), 20 lbs. K_2O (muriate of potash) in split doses to all plots. Phosphate was applied as superphosphate along with the compost. The results obtained are shown in Table 5. There was thus a marked response to phosphate applications. (7).

TABLE 5

Phosphate applications and Pod yields

Treatment	Mean plot yields (pounds of dry chillies/acre)
20 lbs. P_2O_5 ..	1120
40 lbs. P_2O_5 ..	1328
80 lbs. P_2O_5	1480

Intercultivation and Weed control

The first intercultivation for weed control which may be fairly deep is given 7-10 days after planting out, about the time the vacancies are filled. The second intercultivation may be given about 2 weeks later, at the time fertilizers are applied. The third intercultivation is generally given about 3 weeks later, and is usually very shallow. The first two intercultivations may be undertaken with a toothed cultivator or blade harrow. The third is best done with a shallow working implement.

With frequent intercultivations, weed control is usually effective. The chemical control of weeds in a chilli crop is still not a feasible proposition. A large number of herbicides tried out with the Tuticorin chilli, have not proved successful. The chilli plants were damaged by all the herbicides tried out. (7). The further benefit obtained by frequent intercultivation is the creation of a surface soil mulch which helps to conserve soil moisture.

Irrigation

With irrigated chillies as in Jaffna, the seedlings are planted in furrows, and furrow irrigation is given for the first three weeks. Thereafter basin irrigation is adopted.

CONTROL OF PESTS AND DISEASES

Common pests and diseases of Capsicum are as follows:

Chilli leaf curl complex

Occurs wherever chilli is grown in Ceylon. It is of particular importance in the Jaffna peninsula and the dry zone areas where chilli is extensively grown, and has been the one single factor which has caused considerable lowering of yields, compared to the yields obtained in earlier years. The chilli leaf curl complex could be resolved into 5 components, each of which is caused by a separate causal agent. (16). These are:

1. Leaf curl caused by mites.
2. Leaf curl caused by thrips.
3. Leaf curl caused by vein clearing virus.
4. Mottle leaf caused by chilli mottle virus.
5. Mottle leaf caused by tobacco mosaic virus.

In the field the disease presents a complex picture, on account of infection by more than one causal agent at a time, making accurate diagnosis difficult. When the symptoms are not complicated by more than one factor or modified by environment, each infection manifests itself in the following manner.

Leaf curl caused by mites This is the commonest type of leaf curl in Ceylon. Infected plants appear stunted, leaves being generally curved downwards (adaxially). The earlier infected leaves in particular give an 'inverted spoon' appearance. Occasionally there is a partial suppression of lamina at the petiolar end. Affected leaves, become brittle, and appear narrow and thick. In cases of acute infection, the apical meristem is killed and the apex dries up. The development of the axillary bud is interfered with, often resulting in clusters of minute, thickened leaves. On recently attacked leaves, mites crawling about, can be seen on examination under a lens. Control measures adopted amount to routine spraying with a Lime sulphur spray (sulfinette at the rate of 1oz./1 gallon). The chemical treatment should be undertaken early enough, in order to be effective.

Leaf curl caused by thrips

Here too, the infected plants appear stunted. but the leaves are curved upwards (addaxially) presenting a 'boat shaped' appearance. Leaves also show a certain amount of interveinal buckling. The upper epidermis is without the normal gloss, due to the scraping of the surface by the insect, irregularly. Control measures adopted amount to routine spraying with nicotine sulphate solutions at the rate of 1 oz. in 1 gallon.

In both cases the leaf curl is caused as a result of the mechanical damage caused to the leaves, by the insects feeding on them. As such once the insects are eliminated normal growth can be resumed. In recent years DDT and toxaphene have proved effective in spraying trials in the control of mites and thrips.

Leaf curl caused by vein clearing virus

Affected plants appear stunted and bushy. The internodes get shortened, and the leaves show a pale appearance. There is also an upward rolling of the leaves, producing a boat shaped effect, similar to that caused by thrips. The main symptom is the clearing of the veins, particularly the minor ones.

Mottle leaf caused by chilli mottle virus

The plants are only slightly stunted. Leaves show a light green and dark green mottling, and there is a tendency to distortion particularly at the leaf tips. Certain sections of the lamina occasionally get buckled.

Mottle leaf caused by tobacco mosaic virus

Compared to other types, this produces the least malformation. The most important symptom is a diffused mottle of light and dark areas which appear scattered on the leaf.

Two additional virus diseases of chilli have also been recognized in recent years. (17). These are:

Little leaf of chilli

This is particularly prevalent in the Jaffna, Puttalam and Vavuniya districts. The disease appears towards the end of the crop, the leaves getting progressively reduced in size, until the lamina is almost virtually suppressed. The leaves get considerably reduced in size, and in acute cases, only the branches of the plants are apparent from a short distance. The causal factors of this disease are not yet clearly understood.

Mosaic of Capsicum annuum

This new disease presents symptoms strongly suggestive of a virus attack. In seedlings the symptoms consist of a mosaic of yellow white and green areas on the leaves. There is no distortion of the leaves, and the symptoms disappear with maturity. The damage to the crop is inconsiderable.

The viruses, once transmitted by a vector then become systemic, and spread easily causing considerable damage. This could happen even if the vector is eliminated subsequent to the infection. General spraying could control the vector population, but this measure alone is ineffective as a method of control, since the vectors are usually found to harbour on alternate hosts, which may be weeds or some other solanaceous crops. Control in such cases has to include, the early detection and elimination of virus infected plants in the field, and also the vigorous suppression of weeds within or near the crop. A further precaution is necessary in the case of the tobacco mosaic virus, which is easily transmitted by sap. Here the handling of plants has to be done only after the preliminary precautions, such as washing of hands are completed.

Considering the problems as a whole it is clear from what has been achieved so far as regards the control of the disease, that modern organic systemic contact insecticides even at very high doses are effective against thrips and mite induced leaf curls, but not the virus caused leaf curls of chilli. The most fruitful line of attack, lies therefore in the breeding of virus resistant varieties

Diseases of parasitic origin

Damping off: (*Pythium* sp.)

Seedlings are attacked by this disease in the nursery, about a week to a fortnight after germination, particularly in the presence of excess moisture and insufficient light. The presence of shade accentuates the attack, by increasing the humidity. Spraying the nursery bed with bonisol at the rate of 1 oz. per gallon of water is effective in controlling damping off. Ceresan or tillex liquid can also be used effectively.

Collar rot: (*Sclerotium rolfsii* Sacc.)

Very common disease in Capsicum in Ceylon The fungus attacks the plant at the collar producing a brown decay, and then a wilt. The mycelia can be seen on this region. The disease occurs in all soil and climatic conditions in Ceylon.

Bacterial wilt: (*Bacillus solanacearum* E. F. Sm.)

Attacked plants wilt and die. No effective control measures are yet available. Rotation with other non-solanaceous crops is a recommended practice.

Leaf spot: (*Cercospora capsici*, H & W).

Can be quite a serious disease in the nursery. The attacked plants show circular water soaked spots, which later become grey brown and dry on the leaves. On older plants in the field, the attack takes the form of a decay at the calyx end of the fruit. Seed sterilization, weekly spraying with bonisol at the rate of 1 oz. in 1 gallon of water is effective in controlling the disease.

Fruit diseases: *Gloesporium piperatum* E and E
Colletotrichum nigrum. E and H
Vermicularia capsici Syd.

These fungi cause fruit diseases, particularly in wet weather. *Gloesporium* attacks the ripe or ripening fruits. *Colletotricum* causes a pre-mature reddening. *Vermicularia* attacks both young shoots and ripe pods. Young shoots show a die back. Each of the fungi, produces a characteristic spotting on the fruits. Control is either seed disinfection, or spraying in the field with bonisol.

PHYSIOLOGICAL DISEASES

Blossom end rot

Common in the vegetable chillies. Early symptoms are similar to sun scald (another disease common to this type, resulting in exposed sunken areas, being invaded by soft rotting bacteria). The symptoms appear at the end of half grown fruits.

Disease occurs during periods of deficient soil moisture; irrigation during dry periods reduces the extent of damage.

Flowering and picking of chillies

Flowering occurs about 6 weeks after planting out and continues for a period of about 3 months. In the case of the Tuticorin chilli, picking of green but fully developed fruits can commence about 2½ months after transplanting while picking of the red ripe fruit can be done about 2 to 3 weeks later.

Picking of chillies in the green, but fully developed condition has for a long time been reported to give greater yields, than picking of red ripe fruits. Paul (18) held that when the fruits are picked green, that acts as a stimulus to the plant to produce more flowers and therefore more fruit. Joachim, Harboard and Thuraisingham (19) reported that harvesting chillies 'green' with the first picking, and 'red' at subsequent pickings resulted in a fresh weight of 7.5

cwt. per acre over picking 'red' throughout. In a more recent trial however, there was no indication even at high fertilizer levels, of a stimulation in yields by continued picking of only green chillies throughout the season as against picking only ripe chillies, one green pick followed by ripe picks and 3 green picks followed by ripe picks (7). Generally about 5-8 pickings may be taken of the dry or green chilli during a period of 3 to 4 months. The second and third pickings are generally the heaviest.

Curing

For dry chilli production only red ripe fruits should be picked. Picking when there is dew on the pods or immediately after a shower should generally be avoided as the presence of moisture on the pods produces discolouration. The harvested crop is then heaped indoors for about 2 days, to enable all the pods to ripen fully and develop a uniform deep red colour. The pods are then sun dried, for a week, by spreading out evenly on a drying floor or mat. On the morning of the third day, when the pods are still semi-dry and pliable, they are flattened out by pressing down with a wooden plank or rolling to facilitate packing of the chillies. The average out-turn by weight of fresh to dry chillies by the process of sun-drying is about 33%. (18).

Yields

The yields of dry chillies in Ceylon varies from 4-6 cwt. for a rainfed crop, and about 15-20 cwt. for an irrigated crop. In a varietal trial conducted at Rahangala the following yields were obtained. (Table 6). (7).

TABLE 6

Yields of chilli varieties

Variety	Yields in cwt/acre
NP 46 A ..	6.65
Jaffna Karuppan ..	6.60
Myladdy 1 ..	6.39
NP 51 ..	5.68
Iran ..	5.17
NP 41 ..	5 12

After drying, chillies are generally sorted out into two grades, according to size and colour. All the good sized, bright red coloured pods are classed as Grade I. The poorer pods are classed as Grade II. The G. P. S. recognizes three grades.

Costs of cultivation and returns (20)

		Rs. cts.
Preparatory tillage: 5 machine hours: 2 units		62.00
Organic manures	... ...	100.00
Cost of seed and nursery preparation	... ...	25.00
Lining out and holing	... ...	30.00
Planting	... ...	20.00
Intercultivation: 3 weedings	... ...	140.00
Irrigation	... ...	45.00
Crop protection	... ...	12.00
Fertilizers and application	... ...	40.00
Harvesting: 1 green pick, 3 red picks	50 units	150.00
Preparation for market	... ...	70.00
		694.00
Yield:		
800 pounds green chillies at 50 cts. per pound	...	400.00
$4\frac{1}{2}$ cwt. dry chillies at Rs. 140/- per cwt.		630.00
		1,030.00
	Profit Rs.	336.00

REFERENCES

1. Customs Returns.

2. Short Term Implementation Programme 1962.

3. Administration Report of the Commissioner of Agrarian Services 1962/63.

4. Paul, W. R.C. A study of the genus *Capsicum*, with special reference to the dry chilli—I. Tropical Agriculturist Vol. XCIV. No. 1. p. 10-21. 1940

5. Prain, D. Bengal plants, 2, 747-749. 1903.

6. Paul, W. R.C. A study of the genus *Capsicum*, with special reference to the dry chilli—II. Tropical Agriculturist Vol. XCIV. No. 2. p. 63-78. 1940.

7. Administration Report of the Director of Agriculture 1961/62.

8. Paul, W. R.C. A study of the genus *Capsicum* with special reference to the dry chilli—IV. Tropical Agriculturist Vol. XCIV. No. 4. p. 198-213. 1940.

9. Cochran, W. L. Some factors influencing growth and fruit setting in the pepper (*Capsicum frutescens* L). Mem. 190. Corn. Agric. Exp. St. p. 1-39. 1936.

10. Administration Report of the Director of Agriculture 1960/61.

11. Dry chillies. Leaflet No. 177. Department of Agriculture.

12. Paul, W. R.C. A study of the genus *Capsicum* with special reference to the dry chilli—V. Tropical Agriculturist Vol. XCIV No. 5. p. 271-281. 1940.

13. Garcia, F. Improved variety No. 9. of native chili. New Mexico Ag. Exp. St. Bull. 124. p. 1-16. 1921.

14. Stuckey, H. P. and McClinton, J. A. Pimento and Bell peppers. Ga. Ag. Exp. Stn. Bull. 140. 1921.

15. Joachim, A. W. R. and Paul, W.R.C. Manurial experiments with chillies. Tropical Agriculturist 91. p. 217-230. 1938.

16. Peiris, J. W. L. Chilli leaf curl complex. Tropical Agriculturist Vol. CIX No. 3. p. 201-204. 1953.

17. Fernando, H. E. and Peiris, J. W. L. Investigations on the chilli leaf curl complex and its control. Tropical Agriculturist Vol CXIII. No. 4. p. 305-323 1957.

18. Paul, W. R. C. A study of the genus *Capsicum* with special reference to the dry chilli. VI. Tropical Agriculturist Vol. XCIV No. 6. p. 332-353. 1940.

19. Joachim, Harboard G. and Thuraisingham, S. K. Further manurial and cultural experiments on chillies. Tropical Agriculturist 92. p. 339-347. 1939.

20. Costs from Central Experiment Station, Peradeniya.

32. ONIONS

Economic importance

Onions are a vital ingredient in the daily diet of the people of Ceylon. In recent years, substantial advances have been made in the production of red onions. This is reflected in the relatively low imports of red onions, compared to other types particularly Bombay, Bellary and other varieties where imports have steadily risen over the years. In 1962 the foreign exchange expended on the import of these onions reached 17.2 million rupees. (1). Table I shows the import of both types of onions into Ceylon, for the period 1955-62 in terms of both quantity and value.

TABLE I

Import of Onions 1955-62

		1955	1956	1957	1958	1959	1960	1961	1962
Red onions	Quantity	8	50	2	13	46	203	212	166
	Value	112	764	15	214	575	3285	2861	2516
Other onions	Quantity	731	679	748	991	1196	1116	1135	1405
	Value	9173	12181	15306	17470	17108	15259	18484	17231

Value in Rupees thousands
Weight in cwt. thousands
Source: Customs Returns

The rate of increase in the imports of onions has been greater than the rate of population increase, as is indicated by the rise in *per capita* consumption of imports of this commodity. (2). (Fig. 19). On the basis of these imports, the additional acreage required for self-sufficiency in onions has been estimated as follows:

Red onions—2,350 acres under irrigation in the dry zone.

Other varieties of onions—3,950 acres under rainfed conditions in the dry zone, and 11,350 acres under irrigation in the dry zone.

The proposed increase in acreage of red onions, may not in itself, meet the shortages experienced annually during the months of November, December and January, without the provision of

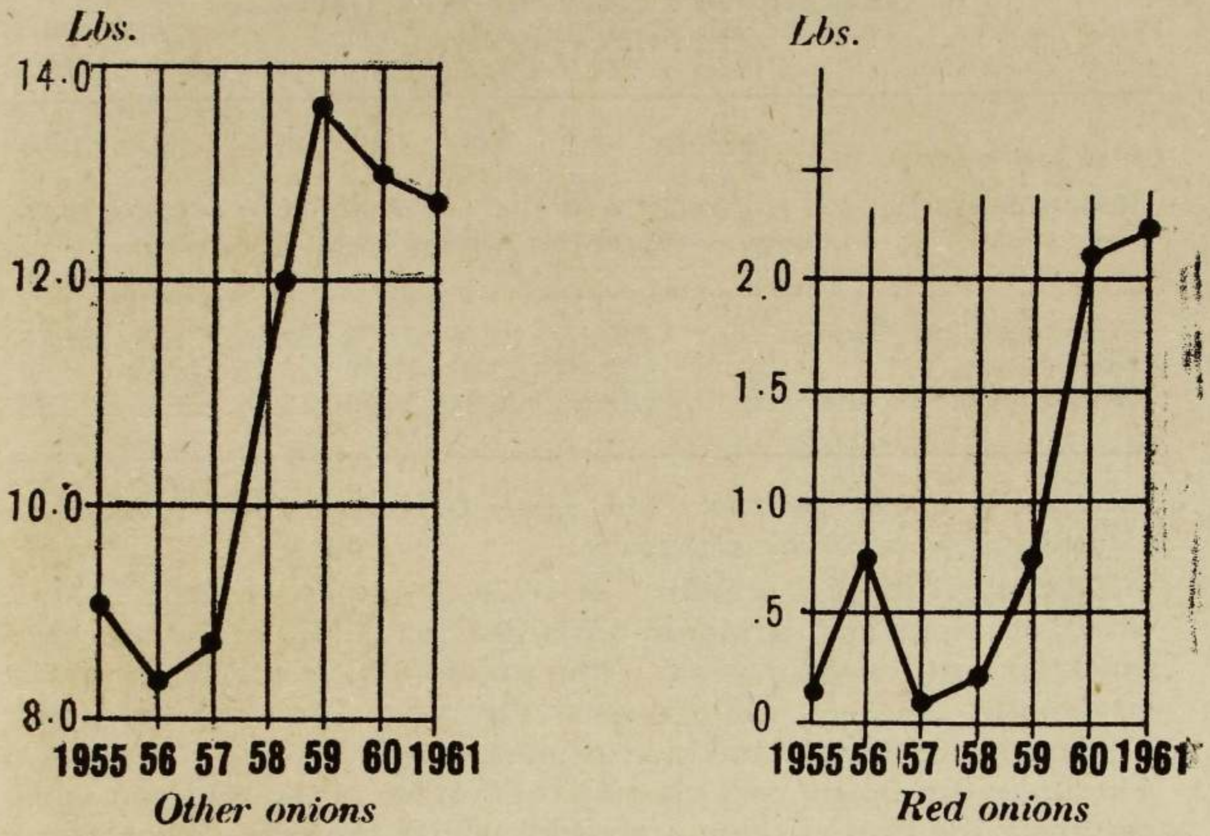


Figure 19. *Per Capita* Annual Consumption of Imported Onions (2)

organized storage facilities. On the basis of the present consumption rate of 10,000 cwt. per week, storage capacity for 120,000 cwt. of onions would be required to tide over the period of onion shortage during this period.

A guaranteed price scheme exists for onions. This has been introduced in order to encourage the cultivation of onions on a larger scale.

Guaranteed price scheme for red onions

On account of the shrinkage and driage losses incurred during the storage of red onions, most farmers sell their produce soon after harvest. This results in gluts immediately after harvest and scarcities during the off season. In order to provide suitable incentives to store some of their produce to meet off season demands the Government introduced a sliding scale of guaranteed prices. (Table 2.) (3).

Guaranteed price scheme for Bombay onions

A guaranteed price scheme for Bombay onions was introduced in 1964, and stood at Rs. 28/- per cwt. (3).

BOTANICAL CHARACTERS

The onion plant belongs to the family Liliaceae. The large onion, of which the common Bombay onion is typical, is distinguished

Guaranteed Prices for Red Onions
(In rupees per cwt.)

	1958	1959	1960	1961	1962	1963	1964
Red onions Grade I ..	22.84	26.88	—	28.00	28.00	28.00	28.00
Grade II ..						21.28	21.28
First month after harvest		20.16	20.16	21.28	21.28	21.28	21.28
Next 6 weeks ..		22.40	22.40	23.52	23.52	23.52	23.52
10 weeks after harvest ..		26.64	26.64	25.76	25.76	25.76	25.76

botanically as *Allium cepa*. The small red onion, also referred to as the shallot is *Allium ascalonium*.

The onion itself is a bulb. It consists mainly of fleshy leaves, which envelope and surmount a flat disc shaped stem. Roots arise from the bottom of the stem. The small shoot in the centre of the disc finally emerges and grows as the green leaves of the plant. The leaves are tubular and have the characteristic smell of the onion. The bulbs are borne very close to the surface of the soil, and when maturing the tops of these are visible above ground. The mature onion produces a flowering stalk, which is hollow and which bears at its tapering top, an umbel. Onion is a cross fertilized plant. Self-fed flowers do not set seed. The fruit is a three celled capsule. The seeds are black in colour and somewhat triangular in shape.

Viability of onion seed

The viability of onion seed is generally very low, and usually lasts for only one season.

ECOLOGICAL ADAPTATION

The onion is a relatively short aged crop that is widely adapted to and in fact extensively grown in the tropics and sub-tropics. It can be grown in areas where a three month period of warm weather obtains, and where the rainfall during the cultivating season is around 30 inches. It is not a crop that is suitable for heavy rainfall areas.

The onion crop requires a well drained soil of the garden loam type. The soil must be free of stones, gravel and grit. Red loams or black rich garden soils rich in organic matter are eminently suited for onion cultivation. Poorer soils have to be well worked and heavily manured.

RED ONIONS

Areas for cultivation

Red onions have been traditionally grown in the Northern province under irrigation. It can be grown successfully in the dry zone areas where irrigation facilities are available. The total acreage that was under onions during Maha 1960-61 and Yala 1961 is shown in Table 3 (4).

TABLE 3

Red onion acreage 1960-61

District	Maha 1960-61	Yala 1961
Colombo	157	214
Kalutara	9	35
Kandy	224	861
Matale	309	333
Nuwara Eliya	334	188
Badulla	275	393
Ratnapura	341	274
Kegalle	121	193
Galle	51	51
Matara	65	23
Hambantota	261	65
Kurunegala	370	255
Puttalam	462	656
Anuradhapura	165	76
Polonnaruwa	65	321
Trincomalee	105	47
Batticaloa	100	105
Vavuniya	15	1136
Mannar	30	9
Jaffna	2500	3068
Total ..	5959	8303

Most of the onions produced in the wet zone were sold as spring onions. Besides these areas, a certain amount of off season production could be undertaken in the islands off Jaffna during October-January.

Rotations

The main crop of onions generally follows tobacco in the Jaffna district, and hence it does well on the residual effect of the organic matter applied to the tobacco. The direct effect of applying cattle manure to the onion crop was only 7.9% superior to the residual effects of cattle manure applied to the preceding tobacco crop (4). Red onions are also rotated with paddy.

Planting season

In Jaffna it is not uncommon to grow red onions three times a year. The main planting times are January, April and July. April-May planting gives the highest yields, and hence the largest area is planted during this time (5).

CULTURE OF THE CROP

Land preparation

The land for onion cultivation should be prepared so as to provide a loose and fine seed bed. In areas subject to heavy rainfall during the growing period, the land could be prepared into ridges and furrows and planting could be done on the ridge. For irrigation $3' \times 3'$ beds are satisfactory.

Planting material

Planting material used for raising red onions is generally seed bulbs. Onions stored for about 8 to 10 weeks after harvest are suitable for planting. When seed bulbs are used about 750-800 pounds would be required for an acre. Intensive planting is practised in Jaffna where a higher seed rate, about 15-16 cwt. per acre is used. When seed is used, 8-10 pounds would be adequate to plant an acre.

Method of planting

When seed bulbs are used for planting the usual practice is to cut off the apex of the bulb, to promote even shoot growth, prior to planting. The bulbs are planted in rows 6 inches apart, at a spacing of 4 inches within the row.

When seeds are used, they may be sown in lines 6 inches apart on the beds. Plants could be thinned down to 4 inches apart when about 3-4 inches high.

Irrigation

For irrigated onions, square basins about $4' \times 4'$ are common in Jaffna. Prior to planting, water is impounded into the basins, just enough to wet the soil for planting of the bulbs. Subsequent to planting water is withheld from the basins for about 4 days or so, to facilitate sprouting and to prevent rotting of the bulbs due to excess of moisture. Soon after sprouting, irrigation is commenced and continued at a frequency of once, every 3 days, till about a fortnight before harvest.

Nutrition

Red onions respond well to manuring (6). Prior to planting 10 tons of cattle manure is forked into the soil.

Commercial fertilizers could be added at the rate of 1 cwt. of super phosphate and 1 cwt. of muriate of potash per acre at planting, with a top dressing of 1 cwt. of ammonium sulphate when the crop is 3 weeks old, followed by a second dose at the same rate 2 weeks later.

A $3 \times 3 \times 3$ factorial trial laid down at Rahangala in Yala 1962, to evaluate the fertilizer requirements of red onions, in which the

Plate 23. Irrigated Red Onions in Jaffna.

Plate 24. Harvest of Red Onions.

following were the levels of fertilizers, showed that there was no significant response only to N. None of the two factor interactions were significant (7).

Levels of fertilizers

No	N30	N60 lbs. N/acre
Po	P40	P80 lbs. P_2O_5/acre
Ko	K60	K120 lbs. K_2O/acre

Dolomitic limestone was added at the rate of 10 cwt./acre as a basal dressing at 2 weeks before planting and cattle manure at the rate of 5 tons/acre was also given as a basal dressing. Nitrogen was applied in split doses 1/3 at planting and 2/3, 4 weeks later. In trials conducted at Vavuniya 20 pounds of N per acre was found to be optimum. (4).

Intercultivation

Intercultivation in the case of red onions is aimed at the control of weeds, and in the case of basin irrigated onions, at loosening the soil, which tends to form a crust at the surface.

Preliminary screening trials conducted at Maha Illupalama in the chemical control of weeds in red onions, have shown that the herbicides Lorox and Prometryne are the most effective (7).

Harvest and yields

The onion crop matures in about 2½ to 3 months from planting. Yellowing of the leaves is an indication of maturity of the crop. Harvesting should be done in dry weather, and harvested onions left to dry in the shade, before storing. Average yields amount to 5 tons per acre. Irrigated crops with good attention yield about 12 tons to the acre.

Storage

Red onions should not be stored in heaps, as this results in sweating. They should be stored in well ventilated store houses in thin layers, or in onion baskets.

BOMBAY ONIONS

Bombay onions are a relatively new crop in Ceylon. Its cultivation has been confined mainly to the Department of Agriculture Experiment Stations, and to small extents on cultivators' fields. The crop has given promising yields, under these conditions, and the future of the crop appears to be bright.

Areas for cultivation

The prospects for the extension of the acreage under the cultivation of Bombay onions lie mainly in the dry zone. The crop is sufficiently remunerative for it to be cultivated on a commercial scale, wherever irrigation facilities are available in the Yala season. The rainfall during the Maha can be both intensive and excessive, so as to make conditions unsuitable for cultivation in certain years.

Varieties

Varietal differences in onions are based on the size, colour and pungency of the bulbs. In California nearly 18 varieties are cultivated. In South India too several varieties are grown, notable among which are the large Bellary onions which are flesh coloured and attain a size of 3 to 4 inches across, and the large sized white Bombay onions. Medium sized kinds of this variety are both flesh coloured and white. The flesh coloured Bombay onion is the one largely imported and consumed in Ceylon. Trials conducted at Maha Illupalama show that of the Bombay onion varieties, Poona Red is the variety most suited for cultivation in Ceylon. The Bombay White is not so suited to Ceylon conditions. (4).

Rotations

Bombay onions take between 3½ to 4 months from planting to harvest, depending on whether they are direct sown or transplanted. Good crops can be raised in the Yala season (April to July) under irrigation in the dry zone. More than one crop could be taken during the year, but generally onions could be fitted into a cropping sequence with other crops. In certain parts of India, Bombay onions are taken as a catch crop in the midst of long duration crops like sugar-cane or turmeric. (8). Onions are grown in the interspaces between the young sugar-cane crop during the first three or four months, so that they can be harvested by the time the rows begin to close up and before the main manuring and earthing up operations commence.

Planting season

For irrigated onions Yala planting from April to July gives the best results. Results of a time of planting trial conducted at Rahangala, with the variety Poona Red, in which plantings were done at monthly intervals for one year commencing from the 10th of April 1961, indicate that plantings on 10th April, 10th May and 10th June were significantly superior to all other plantings with a large percentage of marketable bulbs. (Table 4) (7).

Planting material

Bombay onions have to be grown from seed, and the cultivation may be undertaken in one of three ways:

1. Sowing the seed in nurseries, and transplanting the seedlings in the field.
2. Direct sowing of the seed in the field.
3. Planting of seed bulbs obtained from true seed.

TABLE 4

Time of planting trial with Bombay onions

Date of Planting	Yield in cwt./acre
10th April 1961 ..	22.11
10th May 1961.. ..	23.63
10th June 1961.. ..	24.62

CULTURE OF BOMBAY ONIONS USING TRANSPLANTS

Land preparation

When transplants are used for the cultivation of onions, the seed should be sown in nursery beds. These have to be prepared after repeatedly working the soil, in order to obtain seed beds of fine tilth. 3 feet by 20 feet would be a convenient size for these beds which should be slightly raised. Cattle manure at the rate of 25 pounds for every 60 square feet should be forked into the soil. (9).

The field for planting Bombay onions should also be prepared by working the soil thoroughly after which beds 3 feet wide separated by 1 foot shallow drains could be constructed.

Nursery technique

Seeds are sown in the nursery beds, in rows 6 inches apart. Sowing should be superficial, the seeds being buried not more than ¼ inch. Seed rate required to raise enough seedlings to plant an acre is about 8 pounds. Soon after planting the soil may be mulched with straw.

Germination occurs in about 8 days, by which time the mulch may be removed. The seedlings will be ready for transplanting in 4 to 5 weeks.

Time of planting nurseries

Investigations into the time of planting Maha nurseries were carried out commencing from the 21st August to the 16th of October, sowing being done at fortnightly intervals. Early sowings were found to perform best, yields dropping sharply after early September. (4).

Field Transplanting

When ready for transplanting, the seedlings are carefully pulled out of the nursery beds. In the field, they are transplanted at a spacing of 6″ in the row, in rows spaced 6 inches apart.

Transplants of onions respond favourably to treatment with starter solutions. Janhari and Singh (10) showed that treated plants obtained a superior growth and final yield than untreated ones. (Table 5). Treatments included a dung starter (A), chemical starters like ammonium sulphate and potassium dihydrogen phosphate (B), Sodium nitrate (C) and growth regulator substances (indole acetic acid) at two concentrations (D) and (E). These were compared with control plants (F).

TABLE 5

Average fresh weight per bulb in grams at successive periods of growth (Average of 20 plants) (Janhari and Singh 1960)

Age in days after transplanting	Treatment					
	A	B	C	D	E	F
30	2.675	5.250	3.305	2.760	2.805	2.125
45	6.875	23.835	10.775	7.585	9.805	5.600
60	19.880	48.575	20.125	23.575	28.470	16.725
75	40.845	76.000	38.520	43.350	36.285	26.670
90	49.530	90.250	58.550	52.940	45.480	35.800
105	67.610	128.045	84.175	72.685	78.965	49.775
120	98.345	186.540	128.650	95.484	108.880	76.685
135	137.470	204.270	169.800	156.170	160.470	107.930

Nutrition

Prior to transplanting the field should be manured with well rotted cattle manure at the rate of 3 tons to the acre. Commercial fertilizers could be added at the following rates to the acre. (9).

$\frac{3}{4}$ cwt. concentrated superphosphate
$\frac{1}{2}$ cwt. muriate of potash
$\frac{1}{2}$ cwt. ammonium sulphate

Intercultivation

Intercultivation is aimed primarily at controlling weeds, but should also be used to loosen the soil, particularly in irrigated areas. This could be done twice, two weeks and five weeks after transplanting.

Irrigation

Light irrigation should commence immediately after transplanting and should be continued at a frequency of once in 3 days till about a fortnight before harvest.

Culture of onions by direct sowing of true seed

When direct field sowing is practised in the cultivation of Bombay onions, the seed may be either sown broadcast or sown in lines 4 to 5 inches apart at distances of 2 inches within the row. The seeds are gently pushed into the soil not more than a $\frac{1}{4}$ inch deep. The seed rate when true seed is used for direct sowing in the field amounts to 30 pounds to the acre. When the seedlings are 4 to 5 weeks old, they should be thinned out to 4 inches apart.

Culture of onions by planting seed bulbs

The term 'seed bulb' is applied to a small onion bulb, usually less than an inch in diameter used for propagation purposes only.

Such seed bulbs are raised from true seed which is sown in special nurseries to a thick stand. The purpose of this heavy seeding is to force the plants to grow in a crowded condition to reduce the normal size of the bulbs. These thick stands result in competition for soil moisture and nutrients and give seed bulbs of desirable size. Thin or uneven stands result in oversized seed bulbs. (11).

Land preparation

This involves a thorough working of the soil, and the preparation of beds, similar to the ones described earlier.

Spacing and seed rate

Seed bulbs are planted on the beds 4 to 5 inches apart each way. The seed rate amounts to about 1,500 pounds to the acre. Young shoots appear in 10 days, and grow rapidly.

Intercultivation

This is directed mainly towards controlling weeds. First inter-cultivation could be given 3 weeks after planting, followed by a second cultivation a fortnight later.

Nutrition

The amounts of fertilizer and organic matter added, would be similar to that described for transplanted onions.

CONTROL OF PESTS AND DISEASES IN ONIONS

Pests

THRIPS

These are minute insects that feed on the leaves, sucking the sap, and causing white blotches. They can be noticed among the scaly leaves at the collar of the bulbs, and should be controlled by a soaking spray of dieldrin as soon as blotches are noticed. The spray solution may be prepared by mixing 1 fluid ounce of dieldrin 20% emulsifiable concentrate in 2 gallons of water.

LEAF-EATING CATERPILLARS

Caterpillar damage can be considerable. Spraying with Malathion (malathion E. C. 1 fluid oz. in 5 gallons of water) gives good protection.

Diseases

DAMPING OFF

Damping off is a wilting of plants due to fungal rot at the base of the plant, and is commonly noticed in nurseries. Sterilized nursery beds show very little disease. If however, the disease occurs, it could be controlled by spraying the area with a copper fungicide mixed at the rate of 1 oz. in 5 gallons of water.

Onion Bulb rot (*Fusarium solani*)

This is mainly a storage disease. Bulbs rot and fail to germinate. When it occurs in the field the leaf tips of affected plants become yellow progressing downwards. Methods of control are the use of clean bulbs for planting, and storage of bulbs under dry, well ventilated conditions. Field sanitation may be achieved by adopting suitable rotations.

Harvesting and yields

Transplanted crops of onions take a little longer (4 months) to harvest than direct seeded ones (3½ months). When ready for harvest irrigation should be stopped, and the leaves flattened with a plank in order to harden the bulbs for harvest. Harvesting involves digging the bulbs out, or pulling them out, when grown on loose and friable soil. Harvested bulbs should be left in the field for a couple of days, to dry the leaves. The bulbs may then be cleaned and stored in a cool, well ventilated place. Yields of up to 6 tons per acre could be obtained. When seed bulbs are planted, good harvests may yield up to 15,000 pounds to the acre.

Raising of true seed

This is a specialized operation, and is not done at present in Ceylon due to the fact that no satisfactory seeding strain is yet available. Preliminary trials conducted at Maha Illupalama in Maha 1961-62 and Yala 1962, indicate that with the variety Poona Red, it may be possible to raise good quality seed in the dry zone. The late Maha season appears to be the most suitable for seed production. (7).

For the raising of true seeds, large, thoroughly matured bulbs are planted on specially prepared beds. The mature bulbs send up a flowering stalk, usually one sometimes two, after about 2 months growth, at the tip of which is borne an umbel of flowers. These set and ripen seed in about 6 weeks when they could be harvesed. The seeds should be dried in the sun, before storing. About

800-1000 pounds of seed could be obtained per acre. Usually seed production is undertaken on small extents of land, the average size being either 1/10 or 1/20 of an acre.

Storage of onions

Freshly harvested onions lose weight in storage and storage losses may go up to 20 or 25%.

Losses due to rotting, while in storage can also be serious and may go up to 40%. Frequent inspection and removal of rotting bulbs is necessary. Another cause of loss is sprouting. This could be reduced by providing cold storage conditions. Very low temperatures are not necessary. Cold storage experiments carried out in Poona, showed that when bulbs were stored at 90-95°F, the bulbs remained healthy after six months of storage, did not sprout at all, formed no roots, and lost weight by driage only to about 21% (8). The general method of storing onions is to spread them out on floors, racks or shelves in well ventilated rooms. Since storage of onions is very necessary in order to meet scarcities during the off season, cold storage facilities should be made available either at Government institutions or Co-operative societies to meet this problem.

Costs of cultivation and returns per acre of Red onions in Jaffna (12).

	Rs. cts.
Land rent	170 00
Preparatory tillage	170 00
Manure	480 00
Seed: 16 cwt.	560.00
Planting	90.00
Irrigation	300.00
Weeding	100.00
Harvesting and cleaning	300.00
Control of pests and diseases	40.00
	2,210.00

Average yield—90 cwt.

G. P. S. price—Rs. 28/- per cwt.

Value of Crop	Rs.	2,520.00
Expenditure	Rs.	2,210.00
Profit ...	Rs.	310.00

REFERENCES

1. Customs Returns.

2. Short Term Implementation Programme 1962.

3. Administration Report of the Commissioner of Agrarian Services.

4. Administration Report of the Director of Agriculture 1960-61.

5. Food Crops Bulletin No. 6. Department of Agriculture—Red onions.

6. Molegoda, W. Red onions or Shallot, Onions and Garlic. Tropical Agriculturist Vol. XCIX No. 4. 1943.

7. Administration Report of the Director of Agriculture 1961-62.

8. Yegan Narayan Aiyer, A. K. *Field Crops of India* 1947. p. 371-79.

9. Food Crops Bulletin No. 20 Department of Agriculture—Bombay onions.

10. Janhari, O.S. and Singh, R.S. Preliminary studies on influence of starter solution and Beta-indole acetic acid on further growth and development of onion (*Allium cepa*. Linn.) transplants. Tropical Agriculturist Vol. CXVI. No. 3. p. 191-203 1960.

11. Onion-set production. Farmer's Bulletin No. 1955. U. S. D. A.

12. Kanagaratnam, S., D. A. E. O. Jaffna. Private communication.

33. GARLIC

Economic importance

Garlic has a unique pungency, which makes it a valuable spice for seasoning. Occasionally however, it is used for the treatment of flatulence, in native medicine.

Ceylon produces only a negligible fraction of her requirements. The imports of garlic in respect of quantity and value for the years 1955-62 are shown in Table 1.

TABLE 1

Imports of garlic

Year	1955	1956	1957	1958	1959	1960	1961	1962
Quantity ..	41	35	41	55	41	45	46	45
Value ..	1628	1955	2098	2660	2215	2117	3155	3171

Value in rupees thousands.
Weight in thousands cwt.
Source: Customs Returns.

On the basis of these imports, it has been estimated that an additional acreage of 1,320 acres would be required to make Ceylon self-sufficient in garlic. (2). Since garlic can be cultivated only in a limited agro-climatic zone, availability of suitable land and competition from upcountry vegetables have stood in the way of an expansion in the cultivation of garlic.

BOTANY OF THE CROP

The garlic, (*Allium sativum*) like the onion to which it is closely allied, belongs to the family Liliaceae. The garlic bulb is composed of a number of little bulbs or cloves which arise in the axils of the scale like leaves, which emerge from the flattish disc like stem. Hence the garlic bulb is really a compound bulb. The leaves are long, linear and flat, and bluish green in colour, and are easily distinguished from the leaves of onions and shallots which are hollow. Fibrous roots arise from the base of the stem, and may traverse down to a foot in depth. A flowering stem bears at the top an umbel of flowers and small bulbs also called 'bulbils'. The seeds are small and black and have flattish compressed sides.

Varieties

There are no distinct varieties cultivated. Differences exist however in size between varieties of bulbs, cultivated in different areas, some being larger than others. An Indian variety successfully grown in Ceylon is Mallaipoodu. A local variety of garlic is commonly grown in the Welimada district. Variety trials conducted at Palugama and Boralanda with two strains of the variety Mallaipoodu and the local Welimada variety showed that the Welimada variety and the Mallaipoodu-1945 strain overwhelmingly out-yielded Mallaipoodu-1944 at both places. (3).

ECOLOGICAL ADAPTATION

Garlic requires a cool moist period during growth and a relatively dry period during the maturing of the crop. The soil requirements for garlic are similar to those of onions. Adequate moisture in the soil is essential during the development of the bulbs. The crop does not tolerate waterlogged conditions.

Areas for cultivation

The most suitable areas for garlic cultvation are the higher cooler elevations in Ceylon, like Welimada, Palugama, Haputale, Ohiya, parts of Walapane and Udahewaheta. (4). Elevation is important. Garlic does well at elevations between 3000-4000 feet. It can be grown also in the mid-country areas, but here the environmental conditions are not so suited to the cultivation of garlic and generally poor yields are obtained.

Planting season

Planting of garlic in the areas mentioned above usually commence around the middle of May, during the intermediate phase of the Southwest monsoon. At this time the winds are severe in this area, and the cultivation of exotic vegetables for which this area is noted, is not undertaken. Accordingly during this time only crops like carrots, garlic, onions are grown.

CULTURE OF THE CROP

Land preparation

Since garlic is a deep rooted crop, it needs a certain amount of deep tillage. The usual practice being to work the soil to a depth of at least 8 inches. The soil is worked to a fine tilth, and laid into beds 3 feet broad, and of any convenient length depending on the extent and lay of the land.

Planting material

Planting material in garlic consists of the little bulbs or cloves which can be separated from the compound bulbs. Slender elongated bulbils in the middle of a bulb should not be used for planting.

Garlic does not produce any viable seed. About 450 to 500 pounds of cloves are required to plant an acre.

Method of planting

Cultivators in the Palugama area spread the bulbils on a mat and sprinkle water overnight prior to planting the next day. Cloves sorted according to size, are planted separately to ensure uniformity in maturing. The cloves are planted in an upright position and lightly pushed into the soil, with the apex flush with the surface of the soil. (5).

Spacing and nutrition

Spacing and manurial trials conducted at Palugama and Boralanda with the three varieties Mallaipoodu 1944, Malaipoodu 1945, and the local Welimada variety showed that at both centres, yields increased with closer spacing. (Tables 2 and 3). At Boralanda application of cattle dung at the rate of 20 and 35 tons per acre gave higher yields than dung applied at the rate of 5 tons per acre. At Palugama the 35 tons per acre application gave a significantly higher yield than lighter applications. (3).

TABLE 2

Yield of bulbs at Palugama (in cwt. per acre)
(Pieris and Chandraratna 1946)

Varieties	Spacings		
	6″×6″	6″×4″	4″×4″
Welimada	16.74	22.50	25.92
Mallaipoodu-1944	7.74	14.58	11.34
Mallaipoodu-1945	27.72	33.12	38.70

Varieties	Manurings		
	5 tons/acre	20 tons/acre	35 tons/acre
Welimada	14.58	22.68	27.90
Mallaipoodu-1944	10.26	7.56	15.84
Mallaipoodu-1945	32.58	29.34	37.62

Spacings	Manurin		
	5 tons/acre	20 tons/acre	35 tons/acre
6″ × 6″	14.04	16.74	21.42
6″ × 4″	20.16	22.50	27.54
4″ × 4″	23.22	20.34	32.40

TABLE 3

Yield of bulbs at Boralanda (in cwt. per acre)
(Pieris and Chandraratna 1946)

Varieties	Spacings		
	6″ × 6″	6″ × 4″	4″ × 4″
Welimada	7.20	11.52	17.28
Mallaipoodu-1944	5.76	6.48	8.64
Mallaipoodu-1945	15.84	15.84	17.28

Varieties	Manurings		
	5 tons/acre	20 tons/acre	35 tons/acre
Welimada	10.80	16.56	8.64
Mallaipoodu-1944	7.20	8.64	5.04
Mallaipoodu-1945	12.96	15.84	20.16

Spacings	Manurings		
	5 tons/acre	20 tons/acre	35 tons/acre
6″ × 6″	8.64	10.80	9.36
6″ × 4″	7.92	15.84	10.08
4″ × 4″	14.40	14.40	14.40

Irrigation

Irrigation should be commenced immediately after the leaves emerge, and must be continued till shortly before harvest. Copious amounts of water during the formation of bulbs is an essential requirement.

CONTROL OF PESTS AND DISEASES

Very few pests attack garlic. Thrips (*Thrips tabaci* L.) attack garlic, and cause similar damage as to that of onions. Nicotinic acid spray can be used to control this pest.

Two common diseases of garlic are:

1. Mildew *Oidiopsis taurica.* (Liv) which also attacks chillies and brinjals. The attack comes on during dry weather. Attacked leaves dry up and weaken the plants. Bordeaux mixture could be used to control the fungus.

2. Another fungus disease which attacks garlic, is *Alternaria palundi.* Effective control is bordeaux mixture.

Harvest and yields

When planted in May, garlic can be harvested around September. The crop takes about 5 months from planting to harvest. Harvesting usually involves digging the bulbs out, or pulling the plants out by hand when the soil is loose and friable, after which the plants are tied together by the leaves and left out to dry. Later the roots may be washed, the leaves trimmed and the bulbs dried before marketing. The bulbs should be placed in single layers in a dry place in strong sunlight till the bulbs dry, and the white membranes covering the bulb become crisp and flaky. Yields averaging 15 to 20 cwt. per acre could be obtained under intensive cultivation.

Storage

When required for planting, leaves of the bulbs should not be trimmed. Bundles of about a hundred can be tied together and hung till required.

REFERENCES

1. Customs Returns.

2. Short Term Implementation Programme 1962.

3. Pieris, H. A. and Chandraratna, M. F. Cultural studies with garlic (*Allium sativum* L.)

   1. Variety, Spacing and Manurial trials at Palugama and Boralanda. Tropical Agriculturist, Vol. CII. No. 4. 1946. p. 202-205.

4. Molegode, W. Red onions or shallot, onions and garlic. Tropical Agriculturist Vol. XCIX No. 4. 1943. p. 218-220.

5. Pieris, H. A. The cultivation of garlic (*Allium sarivum* L) in Udukinda Division—Uva province. Tropical Agriculturist Vcl. C. p. 248. 1944.

34. GINGER

Economic importance

Ginger is a daily requirement in most households. It is used in local medicine, and as a spice for flavouring and seasoning. The ginger of commerce is the dried rhizome of the plant. It is used to a small extent in the raw or fresh state. Ginger is cultivated mainly in small holdings, and the country is self-sufficient in its ginger requirements. The chief cultivators of ginger are India, China, North and West Africa and Jamaica. Malabar ginger from South India is famous in world markets.

BOTANICAL CHARACTERS

The ginger plant (*Zingiber officinale*) belongs to the Order Scitaminales, and the family Zingiberaceae, to which turmeric too belongs. The plant is a perennial, and even though aerial parts die out annually the plant can perennate by means of the underground portions. The underground rhizomes, are much branched giving rise to primaries, secondaries and tertiaries, the last formed ones having young buds at the tip. Propagation is by the rhizomes which have 'eye buds', which send up shoots above ground. A clump of rhizomes consists of hands and fingers. Roots arise from the base of the rhizomes, and go down to a foot in depth. The above ground stem is unbranched, and thin, formed by the sheathing petioles of the leaves. The leaf blades, are narrow and lanceolate, and are borne about right angles to the stem. Flowers generally do not arise. The plant attains a height of 1 to 2 feet.

Varieties

There are several varieties under cultivation. The local Ceylon ginger, is inferior to the Indian varieties in size and thickness of hand, fracture and internal colour. Its fibre content is higher, and it is reputed to dry badly. (1). The common variety cultivated in the Central province is Calicut ginger, which has large thick hands, but this too like the local ginger is fibrous. Another Indian variety, quite common in the Western province is Cochin ginger, which though not as plump as Calicut ginger has a very good fracture and low fibre content. The hands of the Cochin ginger in cross section are yellowish in colour and opaque. The local ginger is much less yellowish and translucent. Calicut ginger is intermediate between the two. There is in addition, another variety called China ginger which is only suitable for preserves or for use as green ginger. (2). The local ginger has hands of small thickness, and numerous fingers which necessitate breaking the ginger into pieces prior to curing. This makes peeling prior to curing difficult and expensive. The typical Cochin ginger has fewer fingers, is less fibrous, and when peeled is of a bright canary yellow.

ECOLOGICAL ADAPTATION

Ginger can be cultivated from about sea-level up to elevations of about 5,000 feet. The crop requires ample rainfall, and considerable shade. It is well suited to areas with a rainfall of about 100 inches. The shade requirements for ginger are normally met with in the type of mixed cultivation practised in small holdings.

Ginger and turmeric are well suited for mixed cultivation. Turmeric leaves are held upright above the ginger and receive adequate light. At the same time, they impart beneficial shade to the ginger crop. (3).

Ginger can be cultivated on a wide variety of soils ranging from sandy soils to clayey loams. Good drainage is essential. Acidic soils are more suited for the cultivation of ginger.

Areas for cultivation

The main areas for ginger cultivation in the 1930's were in the Central province and the Western province. In the Kandy district, particularly in villages between Kadugannawa and Peradeniya, ginger is one of the most paying minor crops. In 1930-31 owing to the need to encourage the cultivation and curing of ginger on a larger scale in this area, the Yatinuwara ginger growers union was formed. (4). Another area where ginger has been traditionally grown in the Western province is Nugegoda. The Cochin variety of ginger is sometimes referred to as Nugegoda ginger owing to the fact that it was widely cultivated in this area in the past. In recent years, the cultivation of ginger has spread into other areas as well, and in 1960-61 the following extents were cultivated with ginger in the respective districts. (Table 1.) (5).

Planting season

Ginger is normally planted in March or April. The crop remains in the land, normally till December-January.

CULTURE OF THE CROP

Land preparation

A loose friable soil in which the rhizomes can develop successfully is essential for ginger cultivation. Accordingly the soil should be worked to a fine tilth up to depth of about 5 inches. On level lands, this could be achieved with the plough or disc harrow. On sloping lands, contour drains should be cut in addition, the distance between drains depending on the slope. Preparatory tillage should commence about 2 months prior to planting, and the soil turned over atleast 3 times.

TABLE I

Extents cultivated with Ginger 1960-61

District	Acres
Anuradhapura	5
Puttalam	67
Kurunegala	111
Badulla	17
Hambantota	2
Matara	68
Galle	74
Kalutara	40
Colombo	389
Ratnapura	95
Kegalle	358
Kandy	511
Matale	97
Nuwara Eliya	39
Total ..	1,873

On flat lands in particular, drainage is essential, and in such cases the land may be prepared in 3 different ways. (3).

1. Beds of 12×6 feet.
2. Ridges and furrows, in which the ridges are 24 inches apart.
3. Broad ridges, with flat tops 3 to 4 feet wide, with an 18 inch furrow between ridges.

Planting material

Planting is done on the beds or the ridges 12 to 15 inches apart. Small sets, should be used for planting. The use of whole hands as planting material results in small sets, in which the fingers are bunched together. 1,200 to 1,500 pounds of seed ginger are required to plant an acre.

Mulching

Soon after planting, the ginger crop is mulched with dried leaves, paddy husk or straw. A mulch of straw at the rate of 4,500-5,000 pounds per acre has been found to be effective. (3). Mulching is done with a view to conserving soil moisture and effecting weed control.

Nutrition

The application of artificial fertilizers, cattle manure, or the practice of mulching, all help to increase yields in the ginger crop.

Plate 25. Ginger growing in association with other crops under coconut at Piliyandala.

Plate 26. A field of Turmeric.

In manurial and cultural trials conducted at Giragama, the centre of the ginger growing area in the Kandy district, it was observed that manured ginger gave significantly higher yields than un-manured ginger. Manuring with artificials at the rate of 5 cwt. per acre was equivalent to manuring with cattle manure at the rate of 9.2 tons per acre. The use of straw mulch had a beneficial effect on yield, but lime was not advantageous. The treatment used and the results obtained are shown in Table 2. (6).

Treatment

N—Nugegoda ginger
G—Local or Giragama ginger
S—Straw mulch (35 cwt. per acre)
L—Lime (15 cwt. per acre, 3 weeks before planting).
C—Cattle manure (9.3 tons per acre, day before planting)
A—Artificial fertilizers. (Mixture of equal parts of a mixed fertilizer at 5 cwt. per acre a day before planting).

TABLE 2

Yield per plot (450 sq. ft.) in pounds of raw ginger (Joachim and Pieris 1934)

Treatment		Blocks			
		A	B	C	Mean
1.	N	150.5	120	83	117.8
2.	NS	151	123	118	130.7
3.	NL	142.5	100	111	117.8
4.	NLS	191.5	121	97.5	136.7
5.	G	142	166	106	138.0
6.	GS	167	170	132	156.3
7.	GL	142.5	142.5	106	130.3
8.	GLS	130.5	149.5	128	136.0
9.	NC	166.5	149	103	139.5
10.	NSC	195	144.5	117.5	152.3
11.	NLC	180	171	81.5	144.2
12.	NLSC	237.5	184.5	121	181.0
13.	GC	236	150.5	148	178.2
14.	GSC	182	163.5	154	166.5
15.	GLC	150.5	175.5	100	142.0
16.	GLSC	152.5	202.5	156.5	170.5
17.	NA	169	162.5	102.5	144.7
18.	NSA	182.5	163	121	155.5
19.	NLA	153.5	140	107	133.5
20.	NLSA	201	189.5	111	167.2
21.	GA	155	153.5	118	142.2
22.	GSA	178.5	206	170	184.8
23.	GLA	155.5	158	147.5	158.6
24.	GLSA	183	195	170	182.7

Weed control

Two weedings are essential but a third weeding may become necessary. The problem is considerably reduced, however, due to the mulching.

CONTROL OF PESTS AND DISEASES

Pests. There are no serious pests. The grub of the shoot boring insect (*Dichocrosis punctiferalis.* G.) attacks the shoots of the ginger plant, causing the shoots to wilt and die. The pest is not extensive.

Diseases

1. A serious disease of ginger is soft rot, caused by *Pythium gracile* schenk. Leaves of the affected plants turn yellow and pale, and wilt and dry. The fungus descends to the base of the shoot which becomes soft and watery. Rhizomes get affected next, and all the inside tissue becomes a putrefying mass. The plant becomes useless beyond that stage, and does not produce any further rhizomes. Badly drained and damp conditions, pre-dispose to the disease. (7). The disease is both seed borne and soil borne. Control depends on the use of healthy seed, and care should be taken to avoid planting ginger in the same soil for several years.

2. Vermicularia disease. Sometimes this disease is seen on a ginger crop. Leaves get covered with many yellowish and brownish spots, which develop and cause drying of the leaves and shoots. The plants should be either dusted with quick lime or sprayed with bordeaux mixture.

Harvest and yields

The ginger crop is lifted around December-January, during the dry weather. Leaves begin to dry up, when the crop is ready for harvest. Small holders lift the crop in stages, and not all at once, depending on market conditions. Ginger can be stored for long periods, if kept in a cool, well ventilated room. In practice, the ginger is sorted, to reject any decaying portions, and then heaped up, and covered with ginger or turmeric leaves sprinkled with water. The heap is examined once a fortnight to remove any rotten pieces. Ginger can be stored in this manner for 7 to 8 months. Storage losses amount to 20% under good storage.

Average yields amount to four fold. Under good culture, yields may rise to six fold.

Ratooning of ginger

A ratoon crop may be obtained, by leaving in the soil a portion of the rhizome containing an eye. This gives rise to a subsequent crop. Ratoon ginger is smaller and more fibrous.

Curing of ginger

The curing of ginger is a skilled operation. Dry weather during curing is essential, as wet conditions cause mould formation, and impart to the ginger a musty odour and bad flavour. Conditions during February and March are usually satisfactory for curing. Harvesting should be done in stages, just enough to handle each day. Immediately after lifting, the rhizomes are cleaned of the adhering earth, and roots, and immersed in a tank of water and thoroughly washed. The water is constantly changed, and finally the ginger is soaked in fresh clean water to facilitate peeling of the skin. Peeling is a delicate operation, and special peeling knives are used for this purpose. Peeling involves the scraping of the outer skin, without damaging the cells below, which contain much of the oil on which the aroma of good quality ginger depends. (3, 8). Peeling and washing the rhizomes should go on simultaneously. The more efficient the washing the whiter will be the product. The peeled ginger is then allowed to remain in clean water overnight, and washed again the next day, in lime water. Good quality lime should be used, as it influences the finished product. 1 bushel of lime is required for 3 cwt. of raw ginger. Lime treated ginger has better keeping qualities. The treated ginger is then sun-dried for 5 to 6 days, and frequently turned to ensure evenness of drying. If not sufficiently white, the process should be repeated. Bagging should not be undertaken till the cured product is fully dry. When thoroughly dry, the cured ginger should be rubbed on rough sacking to remove any skin left behind during peeling. The finished product may now be graded on the basis of the colour and size. A number of modified processes for ginger curing are also in vogue. Six pounds of green ginger is required to produce 1 pound of cured ginger

Costs of cultivation and returns (9)

	Cost Rs. cts.
Preparatory tillage:	
Machine	52.00
Animals	30.00
16 units	80.00
Cost of organic manure and application: 12 units ...	155.00
Cost of seed: 1200 pounds at 50 cts. per pound ...	600.00
Sprouting	95.00
Transport and planting	45.00
Weeding and mulching	225.00
Fertilizers and application	75.00
Harvesting: 10 units at Rs. 5/-, 20 units at Rs. 2/50 ...	100.00
Cleaning	75.00
Transport and storage	75.00
	1,607.00

Yield—10,000 pounds			
Value at 40 cts. per pound	...	Rs.	4.000.00
	Profit	Rs.	2,393.00

REFERENCES

1. Joachim, A. W. R. Experiences in ginger curing. Tropical Agriculturist Vol. LXXX No. 5. p. 268-275. 1933.

2. Joachim, A. W. R. The curing of ginger. Tropical Agriculturist Vol. LXXXIII No. 4. p. 212-216. 1934.

3. Karunaratne, C. R. Cultivation and preparation of ginger. Tropical Agriculturist Vol. LXXXIX No. 6. p. 350-358. 1937.

4. Molegode, W. Ginger cultivation in the Kandy district. Tropical Agriculturist Vol. LXXVII. No. 6. p. 336-9. 1931.

5. Administration Report of the Director of Agriculture. 1960-61.

6. Joachim, A. W. R. and Pieris H. A. Ginger manurial and cultural experiments. Tropical Agriculturist Vol. LXXXII. No. 6. p. 340-353. 1934.

7. Yegna Narayan Aiyer, A. K. *Field Crops of India*. Govt. Press. Bangalore p. 567-573.

8. Home and Garden Bulletin No. 2. Turmeric, Ginger. Department of Agriculture.

9. Costs from Central Experiment Station, Peradeniya.

35. TURMERIC

Economic importance

The turmeric plant is the source of an important spice, which is used in cooking, besides being also the source of a dye of some value. The commercial product for which it is cultivated is the underground swollen stem. In India the commercial product is obtained both from cultivated turmeric as well as wild turmeric. The plant is grown widely in India and China. In certain parts of India, particularly in the moist shady hill sides and valleys of Peninsular India, large tracts of wild turmeric, form an important minor product.

In Ceylon, although the cultivation of turmeric presents no serious difficulty in certain agro-climatic zones, imports of turmeric have steadily increased from 1955. Curing difficulties, particularly when small quantities are produced, appear to have accentuated the problem. (1). The imports of turmeric from 1957-62, in respect of both quantity and value are given in Table 1. (2).

TABLE 1

Imports of Turmeric (cwt.)

	Quantity	Value
1957	20	440
1958	21	539
1959	23	897
1960	25	1,087
1961	24	1,166
1962	27	1,764

Value in rupees thousands
Weight in thousands cwt.
Source: Customs Returns

On the basis of these imports it has been estimated that an additional extent of 1,000 acres in the wet zone, will have to be brought under turmeric cultivation in order to make Ceylon self-sufficient in this product. The provision of curing facilities by some central organization that is well equipped, will go a long way towards encouraging small holders to take to this crop in larger numbers.

BOTANICAL CHARACTERS

The turmeric plant belongs to the order Scitaminales and the family Zingiberaceae. Botanically it is distinguished as *Cucurma* *domestica* val. The family to which it belongs includes two other important spices, Ginger and Cardamoms. The underground stem of turmeric, is referred to as the corm. The corms are marked along their length by means of circular scaly rings which are the nodes. Leaf buds arise from these nodes. When planted, a shoot arises from these buds, and it later emerges out of the ground and opens its leaves in about a fortnight to a month from planting. The leaves are small at first, but can become quite big later as the plant grows. In well grown plants, leaves may be about 2 feet in length and 6 to 8 inches broad in the middle.

The stem which is composed of the expanded lower portion of the petioles has a flattish appearance Plants attain a height of about 4 feet when well grown. The root stock develops at the base of the plant which becomes swollen into a rounded corm. The 'rounds' of commerce are formed from these. 'Fingers' arise as primary corms from these root stocks. These may again give rise to secondary corms. Fingers are thus much branched and may be about 4 to 6 inches long and ¾ to 1 inch in diameter. Secondary corms are much smaller. Roots of the turmeric plant, reach down to almost a foot. Flowering occurs only occasionally.

Varieties

Varietal differences in turmeric are based chiefly on their usefulness as a spice on the one hand and as a dye on the other.

Spice Varieties

Generally varieties used as spices are soft, and do not have excellent dyeing properties. Guntur and Poona are two of the Indian varieties that have been grown in Ceylon. There is also a local variety commonly grown in the mid-country wet zone. The South Indian variety Madras manjal is reputed for its superior flavour.

Varieties used as Dyes

The Cochin variety, which forms large bulbs of a greyish brown hue externally, and is brownish orange within, is chiefly used as colouring material and is not very aromatic. There are numerous other Indian varieties named after the provinces or localities where they grow best, which have not been systematically evaluated under Ceylon conditions.

ECOLOGICAL ADAPTATION

Turmeric is a relatively long aged crop. It is normally a crop for high moisture areas, and does well in areas where the rainfall during the year averages between 90-100 inches. Another factor on which divergent opinions exist is its requirements for shade. In small holdings in the wet zone of Ceylon turmeric is grown as a mixed crop, and is subjected to heavy shade. But available experimental evidence suggests that shade has a depressing effect on the yield of turmeric. (Table 2). (3).

TABLE 2

Yield of uncured rhizomes (in pounds)

(Paul and Fernando 1944)

	Shaded	Unshaded	Total
Fingers	78	517	595
Mother setts	64	436	500
	142	953	1095

The yield results obtained in this experiment should be interpreted with caution, as the shade used was artificial shade provided by cadjans.

The soils that are best suited for turmeric are either sandy loams or fertile lateritic loams which are well drained. Slightly acidic soils are preferred since turmeric does not thrive on alkaline soils.

Areas for cultivation

The mid and low country wet zone of Ceylon is the area most suited for the cultivation of turmeric. In these areas, turmeric is grown largely in small holdings in mixture with a variety of crops. In 1960-61 the acreages under turmeric were as follows: (Table 3). (4).

TABLE 3

Extents under Turmeric 1960-61

District	Acres
Puttalam	.. 7
Kurunegala	.. 69
Badulla	.. 26
Matara	.. 57
Galle	.. 49
Kalutara	.. 27
Colombo	.. 153
Ratnapura	.. 97
Kegalle	.. 340
Kandy	.. 419
Matale	.. 110
Nuwara Eliya	.. 46
Total	.. 1400

Planting season

Turmeric is usually planted around the middle of April. It remains on the land for nearly 10 months.

CULTURE OF THE CROP

Land preparation

Turmeric requires good cultivation and manuring. In small holdings, land preparation consists of working the soil with mamoties. The seed bed preparation may be said to be as intensive as in garden cultivation. In very heavy rainfall areas, the land may be prepared into a system of ridges and furrows, and planting may be done on the ridge.

Planting material

Fingers constitute the best planting material for turmeric. In experiments carried out to evaluate the influence of type of seed turmeric used on yield, in which fingers were compared with quadrisected mother setts, plants derived from fingers gave significantly higher yields than plants derived from mother setts. (3). A higher seed rate has to be used when fingers are used for planting. The seed rate for fingers amounts to 1,500 pounds per acre. These should be quite ripe and have a good bud at the growing end.

Depth of planting

The fingers should be planted at a depth of 2 to 4 inches. Shallow planting is not inferior to deep planting. (3).

Spacing

The common planting distance for turmeric is 1 foot between the rows and 9 inches within the row. Field practices vary however, and wider spacings than this are also used. Results of spacing experiments point to the desirability of close spacings. In trials carried out at Nugawela with three types of seed turmeric, plants spaced $\frac{1}{2} \times \frac{1}{2}$ ft. yielded a significantly greater weight of uncured rhizomes than plants spaced either 1×1 ft. or $1\frac{1}{2} \times 1\frac{1}{2}$ ft. (Table 4). (5).

Nutrition

Cattle manure at the rate of about 10 tons to the acre is added at planting. Most often cattle manure is not available for such heavy application. Since the soils on which turmeric is generally grown are relatively rich in organic matter, a basal dressing of artificial fertilizers is not necessary. Two top dressings of a mixed fertilizer could be applied about 6 weeks and 3 months after planting.

Shade

As has been pointed out earlier, the shade requirements for turmeric are controversial. However, the general practice adopted

TABLE 4

Yield of uncured rhizomes (in pounds)
(Paul and Fernando 1941)

Spacings		Types of seed		
	Fingers of local variety	Whole mother setts of local variety	Fingers of the variety Poona	Total
$1\frac{1}{2} \times 1\frac{1}{2}$ft. ..	21.25	40.25	34.00	95.50
1×1 ft. ..	32.25	41.00	56.75	130.00
$\frac{1}{2} \times \frac{1}{2}$ ft. ..	72.25	73.75	57.75	203.75
Total ..	125.75	155.00	148.50	429.25

in turmeric growing areas is to provide shade. This shade is most often provided by the cultivation of turmeric in association with other crops. It is often grown under young coconut, bananas, or along with crops like bandakka.

Weed control

In small holdings, a heavy mulch formed by the fallen leaves, helps to control weeds, which would otherwise compete with the plants for nutrients and moisture. Mulching experiments have shown increased yields with mulching when compared to no mulching. In an experiment conducted at Nugawela, turmeric plots were mulched with 12 tons of rice straw per acre on the date of planting, and a further mulching with 12 tons of rice straw was given to one set of plots. While yields increased with mulching, as compared to no mulching, the second application failed to show any response. (Table 5.) (5).

TABLE 5

Yield of uncured rhizomes (in pounds)
(Paul and Fernando 1941)

Spacings	No mulchings	Mulchings 12 tons of rice straw at planting	Further 12 tons of rice straw later	Total
$1\frac{1}{2} \times 1\frac{1}{2}$ ft. ..	22.00	43.25	30.25	95.50
1×1 ft. ..	28.75	46.00	55.25	130.00
$\frac{1}{2} \times \frac{1}{2}$ ft. ..	66.50	94.00	43.25	203.75
Total ..	117.25	183.25	128.75	429.25

CONTROL OF PESTS AND DISEASES

Turmeric is a crop that is relatively free from pests and diseases. Thrips and other scale insects are occasionally found on turmeric, but are only of minor importance.

Shoot boring Caterpillar *Dichocrosis punctiferalis* G.

The caterpillar bores into and cuts the central shoot of the plant, which dries up. As soon as shoots begin to wilt, they should be removed, and the pest destroyed.

Leaf spot *Taphrina maculans.* Butt. This appears as brownish yellow spots on the upper surface of the leaves, which later coalesce into larger spots. Due to a weakening of the plants, yields get reduced. Spraying the leaves with bordeaux mixture, gives good control.

Harvest and yields

When the corms ripen and are ready for harvest, the leaves of the plants begin to yellow and dry up one by one. At this stage the corms may be dug out, but they can be left in the ground for longer periods if necessary. Yields of up to 17,500 pounds of fresh turmeric can be obtained from pure crops under good culture. An average yield is around 12,500 to 15,000 pounds.

Curing of turmeric

When lifting the crop care should be exercised so as not to damage the corms. The soil should be removed from the harvested crop, along with any roots that may be present. The fingers should then be separated from the rounds. A small quantity may be sold as raw fingers, depending on the demand. The balance is processed for the manufacture of the dried product, which is the turmeric of commerce.

The mother setts are now split length wise into four, and along with the finger setts that have been further cleaned are boiled in order to kill the cells prior to drying. For boiling the turmeric is placed inside an earthen or metal pot, and sufficient water is added to cover the turmeric. Dried turmeric leaves are packed into the remaining space in the pot. The mouth of the pot is then covered with gunny, and secured firmly with a string, and sealed with clay. The pot is now heated over a slow fire for about 3 hours, after which it is allowed to cool. The boiled turmeric is now taken out of the pot and spread out to dry in the sun. In 5 to 7 days the turmeric gets fully dried. Prior to sale the cured turmeric has to be polished, and this can be done either by rubbing the dried turmeric in a serrated earthen vessel, or by rotating in a special drum for about 10 minutes to produce the desired abrasive effect. About 5 pounds of fresh rhizomes produce about 1 pound of the cured

Plate 27. Curing of Turmeric. Washing and potting of Turmeric prior to boiling.

Plate 28. A crop of Ground-nuts growing on the flat at Vavuniya.

product. Cured turmeric fetches a guaranteed price of Rs. 84/- per cwt. (6).

Costs of cultivation and returns (7)

	Rs. cts.
Preparatory tillage : machine ...	52.00
animals	30.00
16 units	80.00
Cost of organic manure and application: 42 units ...	155.00
Cost of seed: 1200 pounds at 10 cts. per pound ...	120.00
Sprouting	95.00
Transport and planting	45.00
Weeding and mulching	225.00
Fertilizers and application	75.00
Harvesting: 10 units at Rs. 5/-; 20 units at Rs. 2/50 ...	100 00
Cleaning	75.00
Curing: 25 units at Rs. 3.00	75.00
Cost of firewood for curing	25.00
Transport and storage	75.00
	1,227.00

Yield 12,500 pounds		
Value at Rs. 84/- per cwt. ...	Rs.	4,947.60
Expenditure	Rs.	1,227.00
Profit	Rs.	3,720.60

REFERENCES

1. Short Term Implementation Programme 1962.

2. Customs Returns.

3. Paul, W.R.C. and Fernando, M. 1944. Cultural experiments with Turmeric (*Cucurma domestica* val.)

(111). The influence of type of seed, mulching, planting depth and shade on yield. Tropical Agriculturist Vol. C. No. 1. p. 9-13.

4. Administration Report of the Director of Agriculture for 1960-61.

5. Paul, W. R. C. and Fernando, M. 1941. Cultural experiment with Turmeric (*Cucurma domestica* val.)

(11). The influence of spacing, mulching, and kind of seed on yield. Tropical Agriculturist Vol. XCVII. No. 1. p. 10-13.

6. Turmeric curing. Home and Garden Bulletin No. 7. Department of Agriculture.

7. Costs from Central Experiment Station, Peradeniya.

36. CORIANDER

Economic importance

Coriander seeds are an important condiment in cookery. Coriander seeds are equally valued for their use as household remedies in the treatment of simple ailments, on account of their medicinal properties. Industrially, the seeds are the source of coriander oil. Coriander is a crop of considerable importance in South India, where it is grown on the black cotton soils of Madras and Mysore. In Ceylon the crop is confined to a few home gardens. Almost the entirety of the country's requirements of coriander seeds, is imported. The crop is under study at the present time.

BOTANY AND VARIETIES

The Coriander plant belongs to the family Umbellifereae, and is distinguished botanically as *Coriandrum sativum*. The plant is a small herb, attaining a height of about 2 feet. The stem is thin, rounded and hollow, and is either light green or purplish. The plant is much branched and has a tendency to lodge on account of the weakness of the stems. The leaves are alternate and compound, and become highly segmented and linear towards the top. The inflorescence is a compound umbel and comprises usually some five smaller umbels. The flowers are either white or tinged with purple, and are both bisexual and unisexual. Unisexual flowers are mostly staminate. The fruit is small and rounded, and is ribbed on the surface. On pressing the fruit breaks into two semi-circular locules, each being convex on the outside and concave on the inside, and containing one seed. The fruits contain a volatile oil, which varies in amounts ranging from 0.2 % to 1.0 % according to variety (1). The plant as well as the seeds have a strong, characteristic aroma.

Varietal differences are based on the colour of the stem and flowers, on which basis two distinct varieties are distinguished. One variety has light green stems, and white flowers, the other variety has purple stems and slightly purplish flowers. In preliminary observational trials conducted at Rahangala, with 3 varieties of coriander, *C. sativum* from Lebanon showed promise. (2).

ECOLOGICAL ADAPTATION

Coriander is quite suited to the cooler tracts, with low or moderate rainfall. Suitable soils are the typical black cotton soils as are found in South India, and the heavy black clayey soils, usually planted with rice, under irrigation. In South India large areas of rice lands under several tanks are often cultivated with coriander, during years when there is not sufficient water for rice, the crop being grown with the help of the moisture retained in the soil. The crop can also be grown on red or light loamy soils.

Areas for cultivation

Coriander as a condiment crop is being evaluated at Rahangala at the present time. The present studies indicate that the cultiv-ation could be extended to the dry patnas of Upper Uva, where conditions similar to those of Rahangala obtain. (3).

Planting season

Under Rahangala conditions the crop is grown during the Yala season with the commencement of the first rains.

CULTURE OF THE CROP

Land preparation

Land preparation for coriander involves ploughing with the first rains. The land is then repeatedly worked with a blade harrow in order to secure a fine tilth. A basal dressing of 5 tons of cattle manure may be incorporated and worked into the soil at this stage.

Seeds and sowing

The coriander seed has to be prepared for sowing, by breaking it into two halves. As stated earlier, the coriander seed is really the fruit consisting of two semi-circular locules, closely adhering to each other. The small round seed is located inside these locules one in each. A plant can arise from each seed, as such splitting the fruit into the two halves, effects a saving on the seed, at the same time preventing too thick a stand. Sowing is done either in rows or by broadcasting. When row sown, the rows are spaced, 9 inches apart. Germination occurs in 10-12 days. The period may be prolonged if whole fruits are used for planting. Seed rate amounts to 10-15 pounds per acre.

Intercultivation

Soon after sprouting, an intercultivation with a toothed hoe is given, followed by a second intercultivation just before the rows close up. In about 8-10 weeks the plants are full grown and in flower. The fruits ripen in another 6-8 weeks.

CONTROL OF PESTS AND DISEASES

Coriander is not generally subject to any serious pests. The fruits are sometimes attacked by a boring grub, which eats the contents of the fruit and leaves it empty.

The more serious diseases are 1. wilt, which can kill many plants, and 2. mildew, which appears when there is moisture and dampness at flowering, and which can cause a total loss of the crop.

Sulphur dusting, or spraying with bordeaux mixture effectively controls the mildew. There are no known remedies for wilt.

Harvest

Under the climatic conditions of Rahangala, the crop takes 4½ to 5 months for harvest. Under South Indian conditions however, the crop matures in 3 to 3½ months. Harvesting is done by pulling out the plants. The plants are then stacked on a drying floor for a few days. The seed is separated by beating with wooden flails or trampling under the feet of bullocks. The produce is cleaned, winnowed and dried before storing.

Yields

Good crops yield around 1,800-2,000 pounds per acre. Average yields amount to about 800 pounds per acre.

REFERENCES

1. Yegna Narayan Aiyer, A. K. *Field Crops of India*. Govt. Press, Bangalore. p. 359-63.

2. Administration Report of the Director of Agriculture for 1961/62.

3. De Vaz, C. R. Private Communication.

37. FENUGREEK

Economic importance

Fenugreek is an important condiment crop, the seeds being used in cookery in much the same way as coriander or cumin seed. The seeds are also valued for their medicinal properties. The green plants can be used as pot herbs and gathered long before they flower, for seasoning food. In certain parts of India the crop is grown for green fodder. (1). Being a legume it is considered to be a good soil renovator.

BOTANY AND VARIETIES

Fenugreek, belongs to the family Leguminoseae, and is distinguished botanically as *Trigonella foenum graecum*. It is a herbaceous annual, with a thin, rounded and much branched stem. The plant attains a height of about a foot. The leaves are pinnately trifoliate, petiolate and have two light green stipules. The flowers are sessile, white or light yellow in colour, and are borne singly in the axils of the leaves, The pods are 3-4 inches long and have a persistent beak. There are about 10-20 seeds in each pod.

The crop is under study for the selection of suitable varieties.

ECOLOGICAL ADAPTATION

The crop is suited to tracts of moderate or low rainfall. Suitable soils are well drained loamy, and light alluvial soils.

Areas for cultivation

Present studies at Rahangala indicate that suitable areas for the cultivation of fenugreek, exist in the dry patnas of the Upper Uva. (2).

Planting season

Under Rahangala conditions, the crop is sown down with the first rains during the Yala season.

CULTURE OF THE CROP

Land preparation

Land preparation for fenugreek is similar to that for coriander. When grown as an irrigated crop however, the field is laid out into suitable beds, on completion of preparatory tillage.

Seeds and sowing

Seeds are usually row sown, the rows being spaced 9 inches apart. The seed rate amounts to about 15 to 20 pounds to the acre. In South India, fenugreek is grown as a mixed crop with Bengal gram, gingelly and coriander. When sown as an irrigated crop, the seed is broadcast somewhat thickly and stirred into the soil. The seed rate under these conditions amounts to about 25 to 30 pounds to the acre. Germination occurs in 4-6 days.

Intercultivation

The first intercultivation is given during the 2nd week. A subsequent intercultivation may be given before the rows close in. The plants flower in about 6-7 weeks, and in another 7 weeks the crop is ready for harvest.

Irrigation

Irrigation should commence immediately after sowing, and should be continued thereafter whenever necessary.

CONTROL OF PESTS AND DISEASES

Fenugreek is generally not subject to any serious pests or diseases. Diseases of minor importance are:

1. Ordinary mildew. 2. Rust (*Uromyces trigonellae*) characterized by small brown spots on both leaf surfaces.

Under very wet conditions, seedlings are subject to attack by damping off disease. Sulphur dusting or spraying bordeaux mixture controls the mildew.

Harvest

Under Rahangala conditions the crop is ready for harvest in 3½ to 4 months. The plants are uprooted, dried for a few days, and beaten with wooden flails to separate the seed. The produce is winnowed and dried before storage.

Yields

Under irrigation, good yields amount to about 400 pounds to the acre.

In upper India, practically the whole crop is removed when the pods are just forming, for use as green fodder. Only a thin stand of the crop is left for seed.

REFERENCES

1. Yegna Narayan Aiyer, A. K. *Field Crops of India.* Govt. Press, Bangalore. p. 363-66.

2. De Vaz, C. R. Private Communication.

38. CUMIN

Economic importance

Cumin seeds play a distinct role as an important condiment in daily cooking. They form a vital ingredient of all curry powders. They are also valued for their medicinal properties, and are used in decoctions, or in external applications as poultices.

BOTANY AND VARIETIES

The plant (*Cuminum cyminum*), belongs to the family Umbellifereae. It is a thin stemmed, annual herb. The stem is considerably branched from the base. The plant attains a height of about a foot. The leaves are thin, linear and bluish in colour. The petioles sheath the stem at the base. The inflorescence is a compound umbel. The flowers are white or light red in colour. The seeds are small and laterally compressed.

There are at least two varieties, but probably more. The crop is under study at Rahangala, for the selection of suitable varieties.

ECOLOGICAL ADAPTATION

The crop can be grown from sea-level to an elevation of 10,000 feet. It flourishes however, in a mild climate. It is a rather delicate crop, demanding careful management and moderate to well regulated irrigation. (1). It requires, and in fact tolerates only light rainfall during the growing period. Soils most suited are the deep, friable, well drained loams.

Areas of cultivation

Present studies being conducted at Rahangala, point to the suitability of the dry patna lands in the Upper Uva for the cultivation of this crop. (2).

Planting season

Planting is done during the Yala season, the crop being generally raised under irrigation.

CULTURE OF THE CROP

Land preparation

Land preparation for the crop has to be thorough. Repeated working of the soil is necessary in order to attain a fine tilth. Liberal manuring, up to 10 tons of farmyard manure, at the time of land preparation would be beneficial. The field should be laid out into small beds suitable for irrigation.

Seeds and sowing

Seed is sown broadcast on the prepared beds and well stirred into the soil. Seed rate amounts to about 30-35 pounds to the acre. Germination takes place in about a week.

Irrigation

Irrigation should be given immediately after sowing, taking care to see that watering is not heavy as to move the seeds to a corner of the beds. Thereafter the irrigation is adjusted as required. The crop comes into flower in about 10 weeks, and the irrigation is now reduced to once a week.

Intercultivation

The beds may be hand weeded in about 2 weeks. Thereafter, depending on the extent of weedfall, the intercultivations may be continued, as and when necessary.

Control of pests and diseases

There are no pests and diseases of importance attacking this crop. Leaf eating caterpillars, and plant bugs attacking flower heads are occasionally found. Routine spraying with endrex or arkotine acts as a preventive. (2).

Harvest

The crop is ready for harvest in about 5 months The plants are pulled out, dried in the sun for a few days, and the seeds threshed by beating with wooden flails.

Yields

Good crops yield about 400 pounds to the acre. Average yields amount to 250-300 pounds to the acre.

REFERENCES

1. Yegna Narayan Aiyer, A. K. *Field Crops of India*. Govt. Press, Bangalore. p. 366-368.

2. De Vaz, C. R. Private Communication.

39. MUSTARD

Economic importance

The importance of the Mustard crop is due to its seeds, which can be used either as a condiment or as a spice, as a source of a valuable cooking oil, and in native medicine. Traditionally mustard has been a chena crop, being grown either pure or as a mixed crop with kurakkan. On account of its relative importance, mustard was brought under the guaranteed price scheme, in order to encourage its cultivation. The guaranteed price for mustard which stood at Rs. 60/- per cwt during 1959/60 was reduced to Rs. 54/- per cwt. during 1960/61. (1). This reduction in the guaranteed price is reflected in the amounts of mustard purchased under the scheme during the two years 1960 and 1961. While the amount purchased during 1960 stood at 641 cwt, the quantity dropped to the insignificant figure of 2 cwt. during 1961. (2). The quantities purchased on a provincial basis are shown in Table 1.

TABLE 1

Purchases under Guaranteed Price Scheme

Province	1960	1961
Western*	13	—
Central	46	—
Southern	—	—
Northern	55	—
Eastern	—	2
North Western	236	—
North Central	—	—
Uva	291	—
Sabaragamuwa	—	—
Total ..	641	2

* including outstation produce paid for at the Head Office.

The guaranteed price stood at Rs. 54/- per cwt. during 1964, and purchases under the scheme were negilgible. (3).

BOTANY AND VARIETIES

Mustard (*Brassica nigra*) belongs to the family Cruciferae. There are a number of species under cultivation, viz. the South Indian black mustard, which is the species commonly grown in Ceylon, the white mustard (*B. alba*) used as a condiment in Western countries, the sarson (*B. campestris*) which is the source of a valuable cooking oil. Other species include among several others, rape and colza.

The black mustard plant is a fairly tall, herbaceous annual, attaining a height of about 3 to 4 feet. The lower leaves of the plant are large, petiolate, and pinnatifid, with a terminal lobe, while the upper leaves are small, sessile, elongate and serrated. The inflorescence is a long raceme. The cruciferous flowers are yellow in colour, and occur both in the axils of the leaves as well as terminally. The fruit is a silique, thin and cylindrical, about an inch long, and having a thin seedless beak at the end. Each pod contains about 10-12 seeds, which are either black or white in colour. (4).

ECOLOGICAL ADAPTATION

The many species of mustard are adapted to widely different climatic conditions ranging from the tropical to the temperate climates. The black mustard is suited mainly to the tropical areas, and is grown chiefly as a rainfed crop in areas of low or moderate rainfall. The crop is also not exacting in its soil requirements, and is in fact suited to all classes of soils except the very heavy clays.

Areas for cultivation

The crop is cultivated mainly as a chena crop in the dry zone, either pure or as a mixed crop with kurakkan. It is also suited to the dry patnas of the Upper Uva. The Central and North Western provinces are the other areas of cultivation.

Planting season

The crop is planted as a purely rainfed crop during the Maha season.

CULTURE OF THE CROP

Land preparation

When grown as a mixed crop with kurakkan, the land preparation, methods of cultivation etc., are similar to that for kurakkan. The mustard becomes the subordinate crop in the mixture. When grown as a pure crop, land preparation is directed towards attaining a fine tilth, since the seed size is small. Only small extents are sown this way.

Seeds and sowing

In the chenas, mustard is seldom sown as a pure crop. Mixed with kurakkan, the seed is sown broadcast, only small extents being generally grown. When grown as a pure crop, the seed may be drilled in rows, 9 inches apart. Germination is quick, and the first leaves are visible within 48 hours of sowing.

Intercultivation

Intercultivation is similar to that for kurakkan, when grown as a mixed crop in the chena.

CONTROL OF PESTS AND DISEASES

The main pest of the mustard crop is the mustard sawfly (*Athalia proxima* k.) The larvae feed on the leaves of the plants. Spraying with a stomach poison effects satisfactory control.

Different kinds of mildews, appear on the crop destroying the leaves, and causing malformations of the flower heads and pods. Sulphur dusting, or spraying with bordeaux mixture gives some measure of control.

Harvest

The mustard crop flowers in 45 days and is ready for harvest in another 6-7 weeks. The plants are cut and dried on the threshing floor, prior to threshing by beating with wooden flails.

Yields

Pure crops of mustard, under good cultural conditions could be expected to yield about 400 pounds of seed to the acre.

REFERENCES

1. Administration Report of the Commissioner of Agrarian Services 1960/61.

2. Statistical Abstract of Ceylon. 1962.

3. Administration Report of the Commissioner of Agrarian Services 1962/63.

4. Yegna Narayan Aiyer, A. K. *Field Crops of India*. Govt. Press, Bangalore. p. 368-71.

GROUP VIII—OIL SEEDS

40. GROUND-NUT

Economic importance

In world markets ground-nuts are valued as an oil seed, although in Ceylon their economic value is due to the fact that large quantities are used directly for human consumption. Ground-nuts can be toasted, fried or salted in which forms they are fast becoming popular or can be used in confectionery. The oil of the ground-nut is a non-drying edible oil. The hydrogenated oil is used in the manufacture of margarine. The content of linoleic acid in the kernels determines the hydrogenation properties and suitability for margarine manufacture. Some of the more promising varieties of ground-nuts cultivated in Ceylon, have shown a higher content of linoleic acid, about 35%, compared to most African varieties, which contain under 30%. Ground-nut oil can be used in cooking. The lower grades of the oil are suitable for soap manufacture. The oil may be extracted by pressure using rotary or hydraulic mills or can be extracted chemically by solvents. The oil cake obtained after the extraction of oil makes valuable cattle food. Ground-nut cake can be used for manuring, on account of its high content of nitrogen. The percentage content of nitrogen in the cake varies inversely with the oil content. Average samples of ground nut cake show the following analysis:(1)

Nitrogen	7.6%
Phosphoric acid	2.0%
Potash	1.5%

In other countries, ground-nuts have found a new industrial use, in the manufacture of a textile-fibre by the name of 'Ardil', from the protein of ground-nuts.

The world harvest of ground-nuts in the mid-fifties approximated 13 million tons and covered an extent of 31 million acres. The main ground-nut growing countries are U. S. A., West Africa, East Indies, India, Burma, China, Japan and Australia, In India, the acreage under ground-nuts amounts to 40% of the world's acreage and ground nuts form one of the most important export crops of India.

Ceylon's ground-nut acreage estimated at around only 400 in 1957 was expected to be increased to 5,000 acres by 1960. (2). The actual extent cultivated with ground-nuts in Maha 1961-62 was 2,460 acres and in the Yala 1,279 acres. (3).

The imports of nut and oil in 1962 was as follows: (4).

	Cwt	Rs.	Cts.
Ground-nuts	13,878	649,364	—
Ground-nut oil	194	14,002	—

It is clear that a further extent of about 3,000 acres would be required to make Ceylon self sufficient in ground-nuts.

BOTANY OF THE CROP

Ground-nuts belong to the family Leguminoseae, sub-family Papilionaceae and the genus *Arachis*. (*Arachis hypogea*). The plants are low growing annuals, which branch profusely, and cover the ground with their foliage. The plants have tap roots 8 to 10 inches long and many adventitious roots arising from the base. Nodulation is usually prominent and heavy on both the tap and the lateral roots. The leaves are compound, with two pairs of leaflets which are ovate in shape. The flowers are yellow in colour and are borne in the axils of the leaves either singly or in clusters of 2 to 4. The flowers are self fertilized, and soon after fertilization the base of the ovary elongates into a long stalk and pushes the developing ovary into the soil where the pod develops.

Pods may be 1-3 inches in length and may contain from 2 to 4 seeds each.

Varieties

There are several varieties in ground-nuts. Broadly, the varieties may be classified into two groups, namely the erect or bunch types, and the spreading or runner types. (Fig. 20) The main difference between the two groups are as follows:

	Erect or bunch types	**Spreading or runner types**
1.	Nuts in erect types are borne in a bunch close to the base of the plants.	Nuts in the runner types are more spread out making harvest more difficult.
2.	Erect types are normally short duration varieties. They take about 3-3½ months to mature.	Runner types are longer duration varieties. They take about 5-7 months to mature.
3.	Seeds have no period of dormancy, sometimes first formed pods may sprout before harvest if conditions are suitable.	Period of dormancy in seeds, characteristic of runner types.

Differences exist also in size and shape of pods, the number of seeds in the pods and their size and colour between the two types. The oil content of the seeds also varies.

The most common South Indian variety of ground-nuts is Mauritius ground-nuts also referred to as Coromandal. This is a vigorous grower and yields are high. It is a long duration spreading type. Erect varieties commonly grown in India are the Spanish, referred to also as 'pea nuts' or Natal and Small Japan also referred to as Red Natal. Foreign varieties introduced into South India include

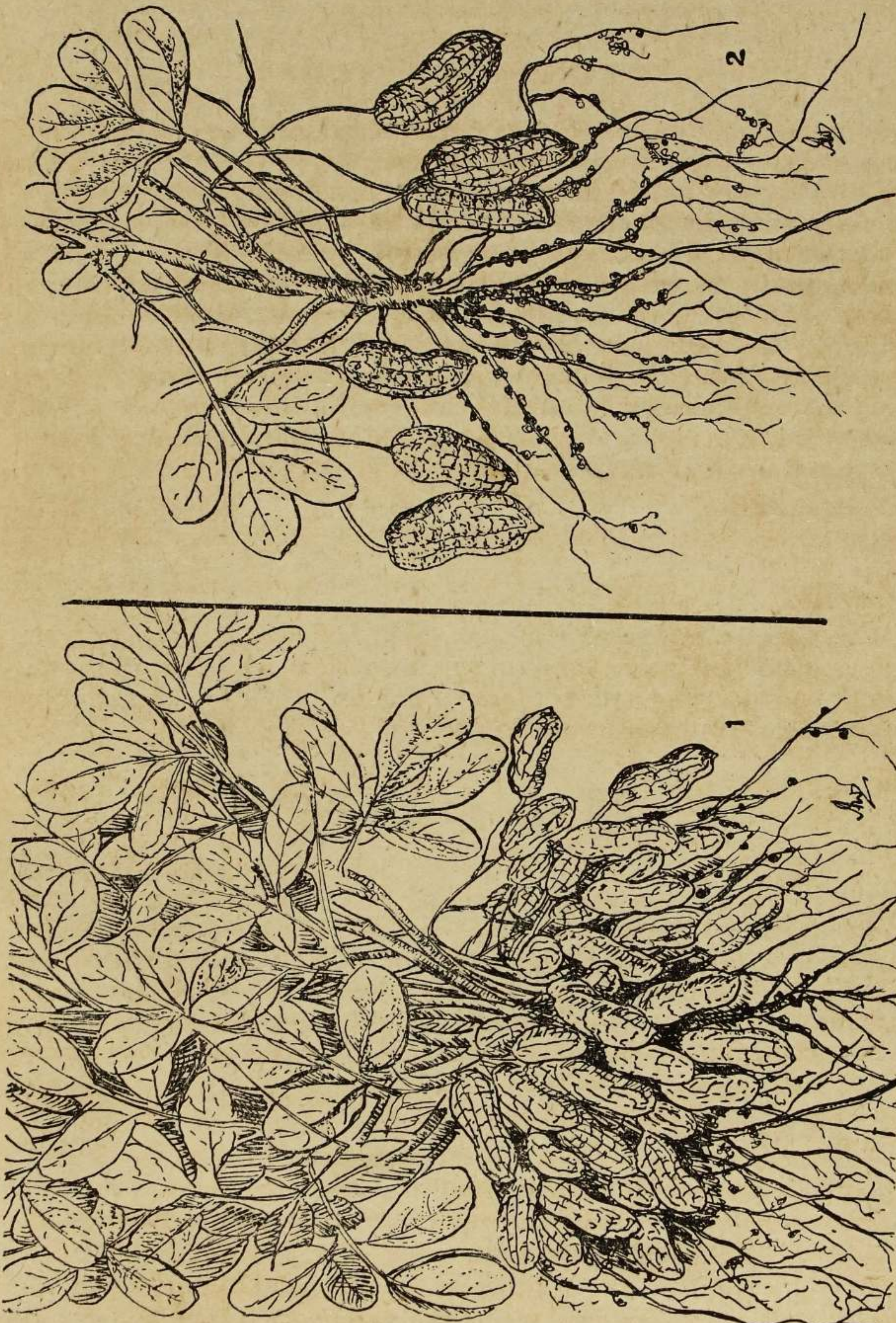


Figure 20. Ground-nuts 1. Bunch type 2. Runner type.

Virginia runner and Big Japan which are runner types, and Virginia bunch and Valencia which are erect types. Variety trials conducted both at Maha Illupalama and also in Gal Oya have shown that two erect types of ground-nuts are eminently suited for cultivation in Ceylon. (2). These are Uganda erect and Red Spanish, both of which are short duration varieties, taking about 3½ to 4 months to mature. These two varieties not only give a high yield of nuts but their kernels have a high content of linoleic acid ranging about 35% which is higher than most African varieties which average 30%. Indications are also that the recent introductions from the Belgian Congo, namely A 20 and A 92 which are both 3½ month duration varieties and can be expected to be good yielders under rainfed conditions in the Maha. Expected yields amount to between 1,200-1,600 pounds of unshelled seed per acre. (3) In Tinnevely, the variety Big Japan has shown considerable promise, out-yielding Uganda erect by 18.8%. (3).

ECOLOGICAL ADAPTATION

The ground-nut is believed to be a native of Brazil. The greatest expansion in ground-nut cultivation occurred however from West Africa. Though essentially a tropical crop it is widely cultivated in both tropical and sub-tropical countries and sometimes even in the higher latitudes where summer conditions last long enough to mature the crop.

Ground-nuts can be grown both as a rainfed crop and under irrigation. In order to get really satisfactory yields, a rainfall of about 30-35 inches is necessary. Yields become considerably reduced in areas where the rainfall drops below 20 inches. On the other hand the crop can stand a fairly heavy rainfall, even 50-55 inches, as is the case in the dry zone of Ceylon, provided there is an effective rainfall period of at least 3½ months, which is necessary to mature the crop. Too heavy or too deficient rain at the commencement of the season, makes ridging operations difficult. Again at harvest time, the soils should not be too dry as this results in reduced yields and small pods. If the soils are too wet at this time, the seeds may also germinate in the pods.

A light sandy loam is ideal for ground-nut cultivation. Such a soil favours the setting and development of the pods, and also makes harvest operations easier. Red loams both light and heavy are also suitable for ground-nut cultivation.

Areas for cultivation

Soils suitable for ground-nut cultivation occur extensively in the Northern, North-Central and Eastern provinces. Ground-nuts can be grown in the Yala, anywhere in the dry zone provided irrigation facilities are available. Light sprinkler type irrigation is ideal under such conditions. Most of the ground-nuts are grown however in the Maha, and the main ground-nut growing districts are Jaffna, Vavuniya, Moneragala, and Batticaloa.

Rotations

In the case of the long duration varieties, they become the only crop of the year, as they occupy the soil for nearly 5 to 7 months. Sometimes the digging or harvest has to be postponed for a longer period and in this case no other cultivation would be possible during the year. With the short duration erect varieties however, it would be possible to either take two crops, or rotate them with other crops. It is also a popular practice in India to resort to mixed cropping, on account of the fact that ground-nuts are a low crop and lend themselves to mixed cropping with taller crops like cotton and castor. A suggested rotation for Ceylon is to grow ground-nuts in rotation with cotton, tobacco, and in certain instances even sugar-cane. In the latter case however, land preparation, involving deep tillage to get rid of the sugar-cane stubble, becomes imperative, and might add to the costs of cultivation.

Planting season

Under rainfed conditions in the Northern, North-Central and Eastern provinces, ground-nuts are cultivated in the Maha, where the planting commences around mid October with the first Maha rains. Under irrigated conditions in the Yala planting could begin in mid April.

CULTURE OF THE CROP

Seed bed preparation

Thorough preparation of the seed bed is essential for ground-nuts A properly prepared soil aids in the penetration of the pegs. For this purpose several tillage operations become necessary. Ground-nuts may be planted on the flat or on ridges. When planting on the flat, seeds could be dropped in the plough furrow, which gets covered when the next furrow slice is turned, or it can be planted in rows using a seed drill. Special seed drills which sow 2 to 4 rows of ground-nuts are used in South India. With ridge planting, the soil has to be ridged, using a ridger.

Seeds and seeding

Seed is chosen from good pods that have not suffered from damp or mouldiness. Ground-nuts can be planted by using either shelled or unshelled seed. Unshelled seed takes a longer time to germinate. When using shelled seed it is preferable to use hand shelled seed, as machine shelled seed are quite often damaged.

The seed rate in the case of erect varieties is around 80 pounds of shelled nuts per acre. If unshelled nuts are used, the seed rate would amount to 120 to 140 pounds per acre. In the case of the spreading varieties, the seed rate is around 40 to 50 pounds of shelled seed per acre.

In a moist seed bed germination is quick and braids appear above the soil in a week.

Spacing

The usual spacing adopted for creeping varieties is 12 inches between rows. In the case of erect varieties a spacing of 9 inches between rows is common. Sometimes, closer spacings of 6 inches between rows, and 4 inches within the rows gives higher yields, but intercultivation even in the early stages, becomes difficult under such close spacings.

Nutrition

The ground-nut plant has the ability to absorb from the soil residual nutrients that are usually not available to other crops. This is one of the reasons why on fertile soils, ground-nuts often fail to show any response to added fertilizers. In fertilizer and manurial trials conducted at Maha Illupalama and Vakaneri, ground-nuts showed no response to direct manuring either with artificial fertilizers or with bulky organic manures. (2). This phenomenon has been observed also in other countries. In the United States for instance only a small part of the acreage under ground-nuts is fertilized. Ground-nuts are however a soil exhausting crop. They remove large quantities of potash from the soil. (5). Combinations of lime and potash, or phosphorus and potash are often advocated for ground-nuts. In the United States, N—P—K in equal ratios are sometimes used. In soils low in Calcium the nuts fail to fill out. In such cases gypsum applied at the rate of 300-500 pounds per acre, as a dust on the tops at blooming time, remedies this deficiency. (6). Ground-nuts are also known to respond to fertilizers applied to a previous crop in the rotation. For this reason, it is sometimes desirable to have ground-nuts follow a heavily manured crop, though it need not itself be directly fertilized.

Weed control

Two to three weedings become necessary till the plants produce sufficient foliage to shade out the weeds. In recent times the efficacy of chemical methods of weed control under ground-nuts have been studied at Maha Illupalama. (3). Amiben applied as a pre-emergence treatment at 4 lbs. active ingredient in 40-50 gallons of water per acre controlled most annual weeds in the crop without adversely affecting yields. Preliminary studies undertaken with IPC (Pure isopropyl-N-Phenyl carbamate) and CIPC, (isopropyl-N-(3-chlorophenyl) carbamate) in order to evaluate their effects on ground-nuts as a preliminary to their use for weed control purposes in this crop, showed that resistance to the effect of the chemicals increased with the age at application. (7). Further, while CIPC depressed final yields of pods by application at all the five different stages of growth from pre-emergence to 24-25 days after emergence, IPC depressed yields only by application at or earlier than the 4-leaf stage i.e. 7-8 days from emergence.

CONTROL OF PESTS AND DISEASES

Pests

1. The red hairy caterpillar. *Amsacta albistriga.* This pest attacks young plants completely defoliating them. The caterpillar has a reddish body, with bushy, blackish brown hairs. Its adult is a moth, which lays a large number of eggs on various plants. The caterpillars that hatch out eat up the leaves. Caterpillars pupate in the soil and may remain in that state till the first rains of the succeeding season. The caterpillar can be controlled by the application of a DDT spray, at the rate of 1 fluid oz. of DDT 25% EC in one gallon of water. An application of 30 to 40 gallons is required per acre.

2. Leaf roller. *Stomopteryx nerteria.* The pest is the larva of a small moth. Larvae bind the leaves together into small rolls and feed on them. Later they pupate inside webs of leaves, and cause much damage. The larva can be controlled by the application of a DDT spray as recommended above.

Diseases

3. Leaf spot. This is a serious disease only if it appears early. It occurs normally during wet weather. The disease is characterized by the appearance of circular large, brown spots on the leaves. The disease is controlled either by sulphur dusting or by spraying the crop with a copper fungicide, 3 to 5 times, once every week.

4. Collar rot. This is sometimes referred to as root rot. The causative organisms are two soil dwelling fungi that attack the plants at or below soil level. They may later spread into the pods. Attacked plants pale and wither, showing the fungal mycelium and sclerotia on the affected portions.

Seed treatment prior to planting with an organo-mercurial dust such as agrosan or cerasan at the rate of 1 oz. for every 30 lbs. of seed will help to reduce the attack. If the disease occurs, field sanitation must be meticulously resorted to by disinfecting the sites with formalin at the rate of 1 fluid oz. in 1 gallon of water. Ceresan at the rate of 1 oz. in 5 gallons of water may be applied to neighbouring healthy plants.

Crown rot and Pre-emergence rot

Can be serious when the crop is young. Crown rot results in a wilting of plants, along with a rotting of the stem at ground level.

The plant tissue at this level, is dark and shredded in appearance. Black masses of spores may be seen on the affected tissues.

Pre-emergence rot occurs before the seedlings emerge. Control measures amount to seed treatment described as above. Regular rotation with grain crops controls the disease.

Others

Rats and termites cause considerable damage by attacking the seed soon after planting. Planting in moist soil reduces this damage. Sometimes it may become necessary to use poison baits.

Harvesting

In erect varieties flowering commences in 60 days and the bulk of the flowering is completed in a fortnight. If irregular flowering continues, the later flowers do not set seed. Harvesting can be commenced by about 100 days. Samples should be pulled out of the ground to see whether the pods have matured. With erect varieties, harvesting is simple, provided the ground is slightly moist. The whole plant can be pulled out with the pods, by tugging from the base. With creeping varieties however, other difficulties arise, since these varietes set pods all along the creeping stem, and the whole field has to be dug up during harvest. This adds to the costs of harvest. Irrigated ground-nuts, should be dried thoroughly soon after harvest, since they are often far too wet.

Yields

Yields vary according to whether the varieties are of short duration, and whether the crop is rainfed or irrigated. Short duration varieties under rainfed conditions yield on the average about 800 pounds of unshelled nuts per acre. High yields can go up to 1,500 pounds. Long duration varietes under rainfed conditions yield on the average about 1,000 pounds. High yields may amount to 1,800 pounds. Irrigated yields are usually higher in both varieties. Experimental yields obtained at various places in Ceylon are as follows:

Maha Illupalama	—	About	1,000 pounds per acre
Vakaneri	—		985-1,115 pounds per acre
Wirawila	—		750-880 ,, ,, ,,
Gal Oya	—		1,200-2,950 ,, ,, ,,

Costs of cultivation and returns (8)

At Maha Illupalama cultivation costs for ground-nuts average Rs. 355/- per acre, using tractor drawn implements for tillage, but using manual labour for planting, harvesting and grading. On the basis of the present guaranteed price of 44 cents per pound of unshelled nuts, and a yield of 12 cwt., the income amounts to Rs. 591/36 per acre. The profit per acre works out to a little over Rs. 236/36, and this includes the wages of hired labour. As a peasant undertaking, wherein family labour is utilized, therefore ground-nut cultivation shows considerable promise.

Detailed costs of cultivation and returns are as follows:

	Costs Rs. cts.
Rainfed ground-nuts	
Tillage	22.00
Basal fertilizer and application:	
1 cwt. sulphate of ammonia, ¼ cwt. muriate of potash } 2 men	25.00
Ridging and levelling: 4 women	30.00
Cost of seed and planting: 15 women	80.00
PCP 4 gallons Rs. 5/80 per spraying: 2 men ...	42.50
Bird scaring: 1 woman for 1 week ...	14.00
Top dressing: ½ cwt. sulphate of ammonia: 3 women ...	15.00
Weeding: 10 women	20.00
Pest control	20.00
Harvest: 30 women	60.00
Processing etc.: 12 women 1 man	26.50
	355.00

G. P. S. rate Rs. 49/28 a cwt.

Approximate yield —12 cwt.

Value of seed	Rs 591.36
Expenditure	Rs. 355.00
Profit ...	Rs. 236.36

Irrigated ground-nuts

Costs of cultivation as above	Rs. 355.00
1 additional man for 1 month	67.50
15 irrigations at Rs. 8.00	120.00
	Rs. 542.50

REFERENCES

1. Yegna Narayan Aiyer, A. K. *Field Crops of India.* 1947. p. 154-166.

2. Agricultural Plan, 1958. First report of the Ministry Planning Committee, Ministry of Agriculture and Food. p. 87-89.

3. Administration Report of the Director of Agriculture. 1961-62.

4. Customs Returns. 1962.

5. Collins, E. R. and Morris, H. D. 1941. Soil fertility studies with peanuts. N. C. Agric. Exp. St. Bull. 330.

6. Martin, J. H. and Leonard, W. H. *Principles of Field Crop Production.*

7. Kirinde, S. T. W. 1959. Some effects of IPC and CIPC on ground-nuts. Tropical Agriculturist Vol. CXV No. 1. p. 7-13.

8. Costs from Dry Zone Research Station, Maha Illupalama.

41. GINGELLY

Economic importance

The economic importance of gingelly derives from the use of gingelly seed both directly for human consumption and also as a source of edible oil. In Ceylon it is one of the money crops of the chena. The oil is the poor man's substitute for ghee. In Jaffna it occupies a pre-eminent place as a cooking oil. In Europe the oil is used along with olive oil as a salad oil. Lower grades of the oil can be used in the manufacture of soap. The raw seed both whole and crushed when mixed with sugar makes excellent sweet meats. Gingelly seed, besides being one of the richest sources of oil, contains a high proportion of protein, calcium and phosphorus. Table 1 shows the analysis of the seed. (1). The oil cake when fed to cattle is reputed to improve milk yields.

TABLE 1

Analysis of gingelly seed

Protein	20.14
Fat	50.76
Calcium	1.38
Phosphorus	0.50
Iron	0.015
Carbohydrate	16.59

In Ceylon, gingelly is one of the subsidiary food crops brought under the Guaranteed Price Scheme. A price of Rs. 38/- per cwt. is offered, as an inducement to cultivators.

In 1960-61, the acreage under gingelly cultivation amounted to 2,736 acres in the Maha, and 10,056 acres in the Yala. In 1961 the imports of gingelly seed amounted to 5,395 cwts. and on the basis of the 1961 imports it was estimated that an additional acreage of 1,800 acres would be required to make Ceylon self-sufficient in its requirements of gingelly seed. (2).

Gingelly, a native of India, is one of the oldest oil seeds in the world. India is the world's largest producer. It is also cultivated in a number of other countries, chief among which are China, Russia, Brazil, Argentina, Mexico, Sudan, Egypt and Nigeria. In North India gingelly is commonly referred to as til.

BOTANICAL CHARACTERS

The gingelly plant (*Sesamum indicum* D. C.) belongs to the family Pedaliaceae, which is a small family comprising mainly herbs. The plants can attain a height of 3½ to 4½ feet, under suitable cultural conditions. The cultivated plant has a squarish stem, which shows considerable branching. Flowers are borne in the axils of leaves, generally singly but occasionally they may be borne in two's or three's. Flowering commences from the base of the stem upwards in 3-8 weeks time from sowing according to the variety. The shape of the flowers is such that they resemble the flowers of the family Begoniaceae. The corolla is tubular and bilabiate. The flowers may be of varying hues ranging from pure white to deep violet. The fruit is a bilocular capsule, quadrangular in shape, 1½ to 2 inches long, and ½ to 1 inch around. The number of locules varies with the varieties and may range from 2 to 10. When the seeds mature, the capsules split open at the top, and shed the seeds which fall easily. Seeds are small, numerous, flattened and oval in shape, and may be of various hues ranging from white to black.

Varieties

Varietal differences in gingelly are based mainly on the colour of the seed. They may also be distinguished as in India, on their suitability for sowing in different seasons. (3). Here the main distinction is a photoperiodic one. There are the short day neutral, and long day varieties. The day neutral character behaves as a mono-genic Mendelian character. Other varietal differences of importance are time of maturity, degree of branching, number of capsules per leaf axil, yield, and the quality and quantity of oil. The two main varieties grown in Ceylon are gingelly white, and gingelly black, based on differences in colour. White seeded varieties are considered better since they usually contain a higher percentage and better quality of oil than the brown or black seeded varieties. Some of the earlier varieties grown in Ceylon and their characters are shown in Table 2. (1).

TABLE 2

Varietal Characters

	Colour of seed	Age in days	Moisture %	Oil %
Gujerat	White	64	5.58	47.3
Burma No. 3	Black	68	5.62	39.4
Local	Brown	80	5.66	42.3

Other varieties evaluated in yield trials in recent years are, Til 40, and two local selections MI2 and MI3, all of which are black seeded strains, and strain 1 which is a white seeded strain. (5). Strain B3 which was for some time the recommended variety has been superseded by Til 40, a black seeded strain which has a yield of about 880 pounds seed per acre. Its performance in yield trials was found to be 17% better than the strain B3 and is now recommended for issue to growers. (4).

ECOLOGICAL ADAPTATION

Gingelly is a crop that is suited to warm areas and is in fact grown during the warmer part of the year, when the temperatures are above 70°F. Gingelly is a crop that is grown generally under rainfed conditions. Its moisture requirements are not exacting, and are in fact minimal. In Ceylon most of the gingelly is grown in the dry zone during the Yala season. The short Yala rains during this season are usually sufficient to produce and mature the crop. It is best grown however, in areas where the rainfall during the growing season does not fall below 20 inches. If sown for the North-east monsoon (Maha) the crop is severely affected by pests and diseases. (1).

The soils that are most suited to the cultivation of gingelly are the light sandy loams which are well supplied with lime. In practice however, gingelly is grown on a wide variety of soils. In Jaffna, gingelly is rotated with paddy, during the Yala and is cultivated in the rice fields

Areas for cultivation

The bulk of the gingelly crop is grown in the North Central, North Western and Northern provinces. The distribution of the acreage in 1960-61 is shown in Table 3. (4).

TABLE 3
Extents under Gingelly 1960-61

District	Maha 1960-61	Yala 1961
Jaffna	—	231
Vavuniya	—	—
Mannar	45	5
Trincomalee	6	47
Anuradhapura	26	2438
Polonnaruwa	—	100
Puttalam	1000	1332
Kurunegala	6	3455
Batticaloa	160	102
Badulla	511	550
Hambantota	750	63
Matara	—	—
Galle	—	—
Kalutara	—	—
Colombo	—	—
Ratnapura	170	158
Kegalle	—	—
Kandy	52	134
Matale	—	429
Nuwara Eliya	10	12
Total ..	2736	10056

Rotations

Gingelly is commonly grown in chenas after the previous Maha crop. In Jaffna gingelly follows paddy or tobacco in the paddy lands. It is sometimes mixed with kurakkan and green gram. Gingelly could be grown in the dry zone during the Yala in rotation with other typical dry zone crops such as kurakkan, green gram, dhal, chillies or cowpea.

Planting season

The main planting season in Ceylon is during the Yala. The crop is sown with the first rains around April. In certain areas, the crop is cultivated in the Maha, but this accounts for only 1/5 of the area cultivated in the Yala. Sowing time in the Maha is around the end of November, after the heavy rains have abated.

CULTURE OF THE CROP

Land preparation (other than chenas)

A seed bed worked to a fine tilth is essential for high yields. Preparatory tillage should accordingly be thorough. The land should be worked several times, in order to obtain a weed free seed bed.

Seed rate and sowing

The seeds can be sown either broadcast or drilled in rows. The former is the common practice in peasant agriculture. Gingelly seed being small, the seed rate is low, and amounts to only 3 pounds to the acre, when sown broadcast. In order to increase the volume of seed so as to facilitate uniform sowing, the seed is generally mixed with sand prior to sowing. When row planting is adopted, the seeds are sown using a seed drill. Rows are spaced about 12 inches apart. The seed rate for row seeding is 1 pound per acre.

After-care

Germination is slow in gingelly the braids taking about 10 days to appear above ground. If the sowing results in a thick stand, the usual practice is to thin the crop to the required stand of 6 to 8 inches in the row after a fortnight.

Weed control

At the early stages of the growth of the crop, particularly in row sown crops, one or two intercultivations may be given between the rows. This is done mainly for the purpose of weed control. Recent trials with pre-emergence herbicides for the control of weeds, have demonstrated the efficacy of a pre-emergence treatment with diuron applied at the rate of $\frac{1}{2}$ to $\frac{3}{4}$ pounds of active ingredient per acre.

Nutrition

The major portion of the gingelly crop grown in Ceylon is sown as a chena crop. Under these conditions, no fertilization is practised. In trials carried out on observation plots in Peradeniya, marked responses to the application of nitrogen at the rate of 20 pounds per acre were observed. The addition of nitrogen in the dry zone during the Yala season may however lead to enhanced vegetative growth at the expense of pod yields under conditions of limiting moisture availability.

Under intensive culture it is common to apply artificial fertilizers, both as a basal dressing, and later as a top dressing. Basal application includes 1 cwt. of superphosphate and a ¼ cwt. of muriate of potash per acre. Top dressing, at a later stage involves the application of 1 cwt. of ammonium sulphate per acre.

CONTROL OF PESTS AND DISEASES

Insect pests that attack the gingelly plants are:

1. Caterpillar pest—*Antigastra catelannalis* D. This pest eats the leaves and also bores into the shoots and pods. Sometimes the pest also webs the leaves together. No effective control is known. Handpicking and destruction of the pest prevents its spread.

2. Gingelly gall fly—*Aspondylia sesami* F. The maggots of this fly feed on the young flower buds, causing a gall. These finally drop off. If the attack is serious this can result in a serious loss of yield. Again no satisfactory method of control is available.

3. Aphids cause a certain amount of damage. Routine spraying with endrin can be adopted as a measure of control.

Diseases

4. Mildew (*Oidium*). Gingelly plants are subject to severe attacks of white mildew on the leaves. Numerous white patches of the grey powdery mildew can be seen on the affected leaves, which drop off after some time.

5. Malformation of flowers. Occasionally the flowers of the gingelly plant become sepaloid and remain green and sterile. The cause of this malformation is not fully understood, but affected plants do not set seed, and hence yields are reduced.

6. Cercospora leaf spot. Under certain conditions the leaves get affected by a leaf spot disease, which results in greyish brown spots on the leaves. The plant gets considerably weakened, and yields get reduced. Control measures include regular sprayings with a copper fungicide.

Harvesting

When ready for harvest, the leaves and the stem of the gingelly crop begin to yellow, and the leaves begin to drop. The capsules get well filled and assume a yellowish tinge. Harvesting should be done at this stage, well before the capsules begin to burst. The plants are usually cut at the base and stacked on a threshing floor, with the butt ends up. Frequently the stack is opened and dried in order to prevent any mould formation. When fully dry the capsules burst and shed their seed. Any seeds left in the capsules are dislodged by shaking the plants or gently beating them on the floor. The seed is then collected, cleaned and winnowed, to free it from any dirt and grit.

Yields

The average yields obtained in Ceylon, under chena cultivation amount to 3 cwt. per acre. Under good conditions of culture, it should be possible to get about double this yield.

Extraction of oil

The harvested seeds are soaked, and then rubbed to remove the seed coats. The seeds are then dried, and the oil extracted by a bullock drawn chekku. Under these conditions the oil recovery is low, usually around 35% The use of hydraulic mills, leads to a higher yield of oil, around 42%.

Costs of cultivation and returns (6)

	Cost Rs. cts.
Preparatory tillage:	
1st tillage	22.00
2nd tillage	22.00
Basal fertilizer and application:	
1 cwt. superphosphate, ½ cwt. muriate of potash } 2 men	25.00
Cost of seed and planting: 8 women	16.00
Intercultivation and thinning out: 10 women	20.00
Top dressing: 1 cwt sulphate of ammonia: 5 women ...	25 00
Pest control	10.00
Harvesting and processing	28.00
	168.00

G. P. S. rate Rs. 38/- a cwt.

Approximate yield—9 cwt.

Value of Crop	Rs. 342.00
Expenditure	Rs. 168.00
Profit ...	Rs. 174.00

REFERENCES

1. Paul, W. R. C. and Gaywala, P. M. The cultivation of gingelly in Ceylon. Tropical Agriculturist Vol. XCVII. No. 6. 1941. p. 321-326.

2. Short Term Implementation Programme 1962.

3. Yegna Narayan Aiyer, A. K. *Field Crops of India.* p. 147-154.

4. Administration Report of the Director of Agriculture for 1960-61.

5. Administration Report of the Director of Agriculture for 1961-62.

6. Costs from Dry Zone Research Station, Maha Illupalama.

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