Recent Advances in the Improvement of Cotton in Ceylon

BY

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LITERATURE on cotton in Ceylon records repeated attempts over a few hundred years at including cotton as an annual crop in the agriculture of this country. Conflicting reports of failure and success, and divergent views expressed by experts from abroad, indicate that in the instance of this particular crop, factors determining its performance in this country were not clearly recognized. Apart from the effect of economic and social factors—fluctuating world prices in cotton, the size of cotton holdings, and the incidence of malaria, for instance—the lack of precise information on the right variety and its requirements in soil, rainfall, locality and season, resulted in frequent failures. The success achieved in some instances, however, was encouraging, and kept alive the prospect of growing cotton in Ceylon.

All types of cotton have been grown in this country : these include the Asiatic cottons—*Gossypium arboreum* Linn. and *G. herbaceum* Linn., the American Uplands—*G. hirsutum* Linn., the Sea Islands and Egyptians—*G. bardadense* Linn. On the recommendation of Hilson in 1925, Cambodia, an upland variety introduced from India, was exclusively grown, until the Mills complained of its quality in 1937. The absence of a scheme of seed supply and purity maintenance was realized and the Botanist of the Department of Agriculture was requested to initiate a planned programme of cotton improvement.

Work commenced with the introduction of nineteen strains of medium and long-staple cottons from India and Africa during the period 1937–1941. The varieties from India included the Cambodia strains Co 2, Co 3 and Co 4, the Sind Sea-Island strain 2–4, and the Sind-Egyptian Boss III—16. The varieties from Africa included the long-staple Egyptian varieties Domains Sakel, X 1730 A and NT 2/38 from Sudan, the medium-staple varieties SG 29, BP 52, BP 79, BP 116 from Uganda, the Mwanzas 457, 561, 613 and local from Tanganyika and the South African U 4/4, 5143 Cambodia and 5143 Cambodia X 5143.

By 1944, these varieties had been tested in replicated field trials and the strain BP 79 was recommended for cultivation in Ceylon. The results achieved have been reported by Chandraratna in 1945. For the first time a variety that satisfied both grower and consumer was available. The Mills no longer complained of quality ; some of the cottons were, in fact, too long for their machines. Fibre tests on samples of BP 79 grown in Ceylon in

1945/46 were carried out by the Shirley Institute, Manchester, and it was reported that " in each count the Ceylon yarns were stronger and better in appearance than the Uganda yarns and on the whole this particular sample of Ceylon cotton compared very favourably with samples of Uganda BP 52. In each count the Ceylon yarns were less neppy than the BP 52 (Uganda) yarns ". The effective length in 32nds of an inch was 39 and the mean fibre weight per cm. was 152. A more recent report from the Shirley Institute on a sample of the 1949/50 crop shows the effective length at 36, the mean fibre weight per cm. at 147 and the Highest Standard Count at 55.

It should be mentioned that BP 79 has been considerably altered by selection since its introduction into Ceylon in 1940. In Uganda, BP 79 did not receive the same attention and was discarded. On a recent request from Uganda, seed of BP 79, selected in Ceylon, has been sent back to Uganda. The improvement effected in BP 79 and in the other introduced varieties was made possible by the method of selection and maintenance adopted by Chandraratna. Maintenance was not limited to a single plant in each variety. Instead, fifty to hundred plants were carefully selected, each season, on the basis of vigour, balanced vegetative growth and boll production, and finally on fibre qualities, judged by halo-length. The prevention of natural crossing between nineteen varieties, growing side by side on the same station, necessitated selfing of each of the plants selected. The produce of the selected plants in each variety provided seed for the maintenance plots in the next year. Selection and maintenance of purity proceeded hand in hand and was continuous from season to season. It was realized that continuous selfing, though necessary for the purpose of preventing cross-pollination between varieties, had the disadvantage of reducing to a homozygous state a heterozygous crop. The propagation of a single homozygous line, though acceptable for self-pollinated crops such as rice, is certainly undesirable for cotton. Propagation from fifty to hundred plants, provided a group of strains, each reduced to relative homozygosis by continuous selfing, but collectively possessing genetic variability and preserving the gene complex of the variety.

In the instance of the recommended variety BP 79 an additional safe-guard ensures purity of the variety : BP 79 is grown in isolation at Wirawila with no other varieties in its vicinity. Foundation seed is obtained by selecting and selfing, every season, 300 plants from an eight-acre maintenance block. The produce of the 300 plants sows the maintenance block in the next season. Seed from the eight acres is multiplied on an extent depending on the amount of seed available, usually 120 acres. The produce of the 120 acres forms the nucleus of pure seed which is further multiplied on stations of the Department of Agriculture, at Wirawila, and in various parts of the Island, before it is finally distributed free to growers. Fresh seed is supplied to cultivators every season. Maintenance and multiplication of seed therefore proceeds in stages every year. Selfing is limited to the 300 plants in the eight-acre block, the plants in the rest of the eight-acre block and in the entire 120 acres being open-pollinated. Further multiplication provides at least three seasons of open-pollination before the seed is grown by cultivators. Natural crossing is possible in these three seasons, but can occur only between strains of the selected variety, restoring, at least partially, the heterozygosity of the selected variety. Two points in this method of purity maintenance are of considerable importance: (1) selection values are based on the performance of single plants, (2) repeated selfing of 300 plants in the eight-acre maintenance block leads to the production of inbreds. These received consideration and a change-over from the bulk plot of eight acres to replicated progeny rows, that accommodate separately the produce of the 300 selected plants, has now been effected. Selection values are determined on progeny rows instead of single plants. The discontinuance of selfing, the discarding of lines not conforming to desired standards and the selection of single plants from the remaining lines for propagation in rows in the following season, is being adopted, in accordance with Harland's Mass Pedigree System for cotton.

The progress made with BP 79 and with the crop in general can be judged by the rapid increase in the extent grown in cotton in post-war years. In 1944/45 five acres of experimental plots at Wirawila was the only cotton grown in the Island. In the next year, eight acres of BP 79 were sown at Wirawila for seed multiplication. In 1946/47 cultivators grew BP 79 for the first time; sixteen acres was the total extent in cotton in the Island. The acreage increased to 372 in 1947/48 and 2,650 in 1948/49. Ten thousand hundredweight of cotton, entirely BP 79, was harvested in 1948/49. Never before had even half that quantity been produced in Ceylon. In 1949/50 the extent increased to 3,737 acres, but production fell to 2,800 cwt. This was an unusually adverse season with a rainfall of half the average. In 1950/51 the extent was 3,280 acres and production was again 10,000 cwt.

Although BP 79 fulfilled our requirements in yield and quality, and was generally acceptable, further testing of BP 79 against other varieties continued at the Cotton Station, Hambantota. Attention was confined to the medium-staple cottons, as these appeared most suitable for cultivation under rain-fed conditions. In the season *maha* 1948/49, fifteen varieties, grown in observation plots, covered a total area of 3·8 acres and gave a total yield of 55·5 cwt. of seed cotton, which was equivalent to an average yield of 14 cwt. per acre. Variety yields ranged between 9 and 19½ cwt. per acre. Co 4 and Co 2 gave 19½ and 17½ cwt. per acre respectively and outyielded BP 79 which gave 16 cwt. per acre. In respect of halo-length, however, BP 79 maintained its superiority over Co 2 and Co 4. In the next season *maha* 1949/50, BP 79 was tested against nine other varieties in replicated randomized blocks. The season was unusually adverse with a rainfall of half the usual average. The ten varieties yielded between 8 and 9½ cwt. per cwt. per acre, but did not differ significantly from each other. In the season *maha* 1950/51, eleven varieties were tested against BP 79, in three randomized blocks. An analysis of variance of yield indicated differences between varieties, significant at the one per cent. point (Table 1).

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TABLE 1.—Analysis of Variance

	Degrees of Freedom	*Sum of Squares*	*Mean Square*	*Variance Ratio*
Varieties	11	430·85	39·17	3·73*
Blocks	2	71·99	35·99	
Error	22	230·64	10·48	
Total	35	733·48		

* Variance ratio for significance at 1 per cent. point = 3·12.

The yields obtained were remarkably high and are given in Table 2. BP 79 was significantly outyielded by 5143 X Cambodia, Mwanza 561, Mwanza local, Co 2 and Co 3. S 5302, a strain related to BP 79 and recently introduced from Uganda, gave the lowest yield.

TABLE 2.—Variety Yields in Hundredweight

Variety	*Yield per acre*
5143 X Cambodia	22·06
Mwanza 561	21·59
Co 2	20·97
Mwanza local	20·41
Co 3	20·16
5143 Cambodia X 5143	19·19
Co 4	19 10
BP 52	17·34
Mwanza 457	16·84
BP 79	15·38
Mwanza 613	15·23
S 5302	14·70
Significant difference	3·95

The improvement of varieties in respect of yield and fibre qualities has been considered so far. Other factors, composing the locality and its environment, affect yield, and a discussion on this aspect follows.

Mee and Willis (1906) suggested that cotton can be grown " anywhere north of a line extending from Negombo to Trincomalee or south of one extending from Matara to Batticaloa. " We now know that the area suitable for cotton is not so extensive. In fact, Hilson in 1925 suggested that the Hambantota-Ambalantota-Liyangahatota tract was the most suitable for cotton. The deciding factors are rainfall and soil. It is well known that too much rain accompanied by water-logging of the soil, where drainage is unsatisfactory, particularly in heavy soils, can retard growth in cotton in the early stages and cause bud and boll-shedding later. In Ceylon, cotton is grown entirely rain-fed. A rainfall of 25–35 inches from sowing to harvest is considered satisfactory, but the distribution of rainfall is important. Rainfall distributions in the Hambantota District are given in Table 3. The advantage of sowing with the earliest *maha* rains at the end of September or early in October is accepted, and though practised in *chenas* is not always possible where soil tillage is delayed for lack of rain. Flowering commences just two months from sowing. If sowing is done in early October, flowering occurs in December, just after the heavy rains in November. From December onwards occasional light showers are necessary to provide sufficient soil moisture ; too much rain interferes with flowering and setting, and can prolong vegetative growth at the expense of boll-production.

TABLE 3.—Rainfall distributions in the Hambantota District, averaged over a period of twenty years

	September	*October*	*November*	*December*	*January*	*February*	*March*	*Total September-March*
Hambantota	3·08	4·83	7·76	5·63	3·75	1·03	3·83	29·91
Tissamaharama	2·17	5·21	9·40	7·06	4·31	1·24	4·26	33·65
Ambalantota	2·63	6·03	7·81	6·90	3·56	0·90	3·76	31·59

It has been observed that flowering commences simultaneously in the full range of cottons tested in this country. The difference of less than a week between the first and last variety to flower, allows no separation into early and late varieties, at least in this country, except that some varieties extend their flowering duration, when soil moisture is not limiting, resulting in prolonged harvests. Dastur (1950) maintained that climatic conditions determine the rate of development and maturation in cotton. He stated that it was difficult to say precisely what the contributing climatic factors were, but was certain that temperature was one of them. In a study of the effect of climate on the same varieties of cotton grown in Sind and in Punjab, he found that flower buds were initiated at a critical minimum temperature of 82°F. This temperature was reached earlier in Sind than in Punjab, resulting in an earlier initiation of the flowering phase in Sind. After the initiation of buds, higher minimum temperatures favoured rapid development of buds into flowers, and flowers into bolls ; during this phase higher minimum temperatures prevailed in Sind than in Punjab. He considered climatic conditions more favourable for cotton in Sind than in Punjab. In Sind, maximum temperatures during the cotton season ranged between 107 and 76 degrees Fahrenheit and minimum temperatures between 82 and 50 degrees. In the Hambantota District of Ceylon, climatic conditions are even more favourable : the range of minimum temperatures during the cotton season is 65 to 80 degrees Fahrenheit ; the critical minimum temperature for flowering always obtains, and flowering is accordingly not delayed. At the same time, minimum temperatures are not too low to retard development and maturation. Harvests are completed five to six months from sowing, even when yields reach fifteen to twenty hundredweight per acre.

Spacing and manuring in cotton are other factors that have received attention. The spacings adopted by growers are surprisingly wide: four to six feet spacings with three or more seedlings per hill are not uncommon. On stations of the Department of Agriculture, a spacing of three feet by two feet, with two seedlings per hill is usual. An experiment, designed for the purpose of investigating the effects of spacing, seedling number per hill, and levels of organic manure on three varieties of cotton was set down at Hambantota in the season *maha* 1950/51. The design of the experiment was factorial, with four factors, each at three levels. A single replicate, with nine blocks of nine plots each, accommodated the eighty-one treatment combinations. The main effects and first-order interactions alone were evaluated; the higher order interactions, other than those confounded with blocks, were lumped in error. The analysis of variance of yield is presented in Table 4.

TABLE 4.—Analysis of Variance

	Degrees of Freedom	*Sum of Squares*	*Mean Square*	*Variance Ratio*
Main effects				
Varieties	2	174·83	87·42	13·21**
Seedling number/hill	2	22·67	11·34	1·71
Spacing	2	16·83	8·42	1·27
Organic manure	2	142·12	71·06	10·73**
First-order interactions				
Varieties × Seedling numbers	4	33·39	8·35	1·26
Varieties × Spacings	4	9·69	2·42	0·37
Varieties × Organic manure	4	24·26	6·07	0·92
Seedling numbers × Spacings	4	36·13	9·03	1·36
Seedling numbers × Organic manure	4	15·63	3·91	0·59
Spacing × Organic manure	4	50·07	12·52	1·89
Blocks	8	297·31	37·16	
Error	40	264·82	6·62	
Total	80	1087·75		

F values for significance = 3·23 (5%)* , = 5·18 (1%)** $\left\{ n_1 = 2, n_2 = 40 \right.$

= 2·61 (5%)* $\left\{ n_1 = 4, n_2 = 40 \right.$

The differences between varieties and between levels of organic manure were found significant. The effects of spacings and seedling numbers per hill did not reach the five per cent. level of significance. None of the first-order interactions were significant. A summary of the results is presented in Table 5.

TABLE 5.—Summary of Results

Treatments	*Yield per acre (hundredweight)*
Varieties	
Co 4	16·13
BP 79	13·62
5143 C X 5143	16·84
Organic manure	
Nil	14·30
6 tons/acre	15·05
12 tons/acre	17·23

Treatments			Yield per acre (hundredweight)
Spacings			
36″× 9″	..	..	16·08
36″×18″	..	..	15·48
36″×36″	..	..	15·03
Seedling numbers/hill			
one ..	..	..	14·87
two ..	..	..	16·07
three ..	..	..	15·65
	Significant difference	..	1·33

Increases in yield with the application of compost, though significant, were not striking. The increase in yield with six tons per acre did not reach the required level of significance; the poor quality of the compost accounts for this. In regard to spacings and seedling numbers, there was no support for a change from the spacing of three feet by two feet with two seedlings per hill, which is adopted at present. This was particularly so for the variety BP 79; the other varieties did show some benefit from the closest spacing, viz., 36 inches by 9 inches.

The effects of organic and artificial fertilizers were investigated further at Hambantota in the season *maha* 1950/51, in a factorial design with three factors, each at three levels. The 27 treatment combinations were assigned to three blocks of nine plots each. Two replicates provided six blocks in all. A summary of the yields is presented in Table 6.

TABLE 6.—Summary of Yields

Treatments			Yield per acre (hundredweight)
Organic manure			
Nil ..	..	..	13·89
6 tons/acre	..	..	15·91
12 tons/acre	..	..	16·63
Sulphate of ammonia			
Nil ..	..	..	15·70
1½ cwt./acre	..	..	15·60
3 cwt./acre	..	..	15·13
Superphosphate			
Nil ..	..	..	15·55
1 cwt./acre	..	..	15·55
2 cwt./acre	..	..	15·33

There was no response to applications of sulphate of ammonia and superphosphate, confirming the results obtained at Hambantota in previous seasons. Joachim *et al.*, however, have demonstrated significant increases in yield with applications of cattle manure (5 tons per acre) and with sulphate of ammonia (2 cwt. per acre) at Vavuniya and Pelwehera in 1936. The yield at Vavuniya was twice that at Pelwehera. The fact that cotton followed sunnhemp at Vavuniya needs emphasis. At Hambantota too organic manure was found beneficial, except in instances where the quality was poor or the quantity insufficient. It is possible that the lack of structure and organic matter in these soils results in a poor physical condition, particularly in respect of drainage, aeration and soil moisture. Under these conditions roots function inadequately and fertilizers are not fully utilized. The improvement of soil structure must therefore precede the use of artificial fertilizers.

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