FACTORS AFFECTING SHOOT PRODUCTION IN TEA *(CAMELLIA SINENSIS)* WHEN GROWN AS A PLANTATION CROP

III. THE TIME FACTOR AND NEW SHOOT PRODUCTION

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Introduction.—The time taken for a new shoot to develop to a stage at which it is ready for plucking is obviously of great importance in relation to the amount of crop which can be taken off a bush in any given period. This new shoot development time may be expected to depend both on the type of plucking practice adopted and on the condition, either flush or banji, of the shoot itself when plucked. Furthermore seasonal variations in climatic factors are likely to have an effect on shoot development times.

The present paper presents the results of series of field observations on shoot development times carried out on the same area of T.R.I. Clone No. 4 for which previous results have been reported in this series. (Portsmouth 1957a and b). These observations were carried out over the period December 1951 to October 1952 and cover the development of four successive sympodial shoots. The bushes used had been lightly pruned in November, 1950, on the completion of the previous experiment.

Definitions and Methods.—The normal plucking practice adopted in Ceylon has already been described in the general introduction to this series (Portsmouth 1957a). However, rather more rigorous definitions of the various terms used are now necessary for a proper interpretation of the present observations.

It was originally stated that plucking is carried out in such a manner as always to leave one mature leaf below the point of plucking. In actual practice the position of this mature leaf left on the bush is determined by the fact that it is accepted as being the next leaf above the fish leaf. Accordingly, for practical purposes, it is the position of this *fish* leaf which has to be rigorously defined. Bond (1945, p. 199) refers to the *fish* leaf as an appendage intermediate in growth rate between a scale and a foliage leaf. This explanation does not limit fish leaf characters to one appendage only and cases occur where there are two appendages intermediate in size between a scale and a true foliage leaf. Accordingly, to obviate any confusion on this account, the *fish* leaf of the plucker will be defined as *the first appendage showing foliar characters*, borne by the shoot above the last scale leaf. Where, therefore, the shoot carries two fish leaves, the lower and smaller of the two will determine the point of plucking, while the upper and larger will be accepted as the mature leaf to be left below the point of plucking. This leaf may accordingly be either the first true foliage leaf or else the larger of two fish leaves.

Crop shoots, as plucked, may be divided into flush and "banji" shoots. Flush shoots are shoots which are still in active growth at the time of plucking. The

accepted plucking standard is to take two open leaves and the terminal bud, so that flush shoots are ready for plucking as soon as there are three leaves, above the fish leaf, clear of the bud.

In banji shoots, on the other hand, active growth has often ceased before there are three leaves, above the fish leaf, clear of the bud. Although plucking such a banji shoot may only yield one leaf and a bud, it is the general practice to pluck these shoots immediately the terminal bud has become dormant and the shoot is still soft and suitable for manufacture. These shoots constitute what will be referred to as *tender banji*.

However, it is not always easy in the field for a plucker to determine that the terminal bud has become dormant, so that banji shoots are frequently left unplucked. Banji shoots left on the bush appear to mature rapidly with the consequence that, by the time of the next plucking, they have usually become too hard and coarse to be suitable for manufacture and, if plucked, have to be discarded. These shoots will be referred to as *coarse banji*.

When a crop shoot has been plucked, apical dominance is temporarily destroyed and the axilliary bud of the mature leaf left above the fish leaf generally develops into a new crop shoot. In some cases, however, new shoots may also develop from the axillary bud of the fish leaf or even from those of the scales. In the present series of observations all shoots developing from buds other than those subtended by the leaf above the fish leaf have been disregarded.

At the start of these observations, on 11-12-51, groups of 20 crop shoots which had reached the stage at which they were ready for plucking, were chosen, marked and plucked in each of the following conditions:—Flush, tender banji, coarse banji. A further group of 20 tender banji shoots was also chosen and marked, but left unplucked. The marked shoots were examined twice weekly and the dates at which the new crop shoots reached the following fixed points recorded:—

NEW FLUSH SHOOTS

(*a*) when the fish leaf first became clear of the bud.

(*b*) when the third leaf above the fish leaf first became clear of the bud.

NEW BANJI SHOOTS

(*a*) when the fish leaf first became clear of the bud.

(*b*) when terminal bud activity was observed to have ceased and it was clear that the shoot had become a tender banji.

As soon as point (*b*) was reached the shoots were plucked, either as flush or tender banji, and the observations continued with the new shoots subsequently developed to a total of 4 successive shoots.

During these observations the unmarked crop shoots produced by the experimental bushes were regularly plucked at the normal 9 day intervals usual at the elevation of St. Coombs.

Results.—The times obtained from observations of the first batch of new crop shoots produced related to eight different conditions of new shoot development:—

(i) Flush shoots plucked to new pluckable flush shoots.
(ii) Flush shoots plucked to new pluckable banji shoots.
(iii) Tender banji shoots plucked to new pluckable flush shoots.

(iv) Tender banji shoots plucked to new pluckable tender banji shoots.
(v) Tender banji shoots left unplucked to new pluckable flush shoots.
(vi) Tender banji shoots left unplucked to new pluckable tender banji shoots.
(vii) Coarse banji shoots plucked to new pluckable flush shoots.
(viii) Coarse banji shoots plucked to new pluckable tender banji shoots.

For the second and subsequent periods the observations were combined as necessary and relate only to the conditions described in (i) to (iv) above, since all banji shoots produced were plucked as tender banjis.

(i) FLUSH SHOOTS PLUCKED TO NEW PLUCKABLE FLUSH SHOOTS.—The mean times, in days, recorded under this heading, together with their standard errors are given in Table 1.

Table 1. (i) *Flush shoots plucked to new pluckable flush shoots.*

(1) Period	(2) Season	(3) No. of Shoots	(4) Days to unfolding of FISH leaf (a)	(5) Days to unfolding of THIRD leaf (b)	(6) Mean interval (b) — (a) in days.	(7) Days for unfolding of one FOLIAGE leaf
1	Dec. 1951 to Feb. 1952	16	46.63 ± 1.50	74.56 ± 1.63	27.94 ± 1.19	9.31
			(6.70 ± 2.00)*	(2.63 ± 2.52)	(4.09 ± 1.53)*	
2	Feb. 1952 to May 1952	48	53.33 ± 1.33	77.19 ± 1.92	23.85 ± 0.96	7.95
			(1.31 ± 1.76)	(8.45 ± 2.53)*	(9.78 ± 1.94)*	
3	May 1952 to Aug. 1952	59	52.02 ± 1.15	85.64 ± 1.65	33.63 ± 1.68	11.21
			(4.24 ± 1.32)*	(4.76 ± 1.97)*	(9.01 ± 1.89)*	
4	Aug. 1952 to Oct. 1952	66	56.26 ± 0.65	80.88 ± 1.19	24.62 ± 0.87	8.21
1—4	Dec. 1951 to Oct. 1952	189	53.38 ± 0.59	80.89 ± 0.85	27.52 ± 0.69	9.17

In this and subsequent tables the figures given in brackets are the differences between the mean times recorded for any two successive periods. The standard errors of these differences have been calculated from the formula

$$SE_{1-2} = \sqrt{(SE_1)^2 + (SE_2)^2}$$

In accordance with convention, differences greater than twice their standard errors will be considered significant. Such significant differences are marked by asterisks.

The mean intervals between the two fixed points (*a*) and (*b*), which are given in column (6) of all tables, have been independently calculated from the intervals

recorded for each individual shoot and not by subtraction of the mean times given in column (4) from those given in column (5). The standard errors given in column (6) are, accordingly, specific to the mean intervals (*b*) — (*a*) and are independent of those given in columns (4) and (5).

In cases (i), (iii), (v) and (vii), where new flush shoots are developed, the mean interval given in column (6) is the time taken for the unfolding of the first three foliage leaves above the fish leaf. In such cases, therefore, the average time taken for the unfolding of one foliage leaf is directly ascertainable. This data is presented in column (7) of the tables.

Coming now to a more detailed consideration of the data of Table 1, it will be seen that, with only two exceptions, all seasonal differences in development times are obviously highly significant. This clearly indicates the existence of some climatic influence. Unfortunately, owing to the overlapping of individual observations, it is not possible to sharply delimit the different periods during which successive new shoots were produced. Accordingly, relevant meteorological averages for the four overlapping observational periods have been calculated and are presented in Table 2.

Table 2. *Meteorological averages—St. Coombs.*

(1) Period	(2) Season	(3) Mean monthly rainfall (inches)	(4) Mean daily sunshine (hrs.)	(5) Mean number of wet days per month.*
1	Dec. 1951 to Feb. 1952.	4.60	5.89	8.67
2	Feb. 1952 to May 1952.	10.24	6.05	14.25
3	May 1952 to Aug. 1952.	14.23	3.33	22.75
4	Aug. 1952 to Oct. 1952.	10.83	4.32	18.00

*Days on which more than 0.04" of rain fell.

Comparing the data of Table 2 with the times required for the unfolding of each successive foliage leaf, given in column (7) of Table 1, it will be seen that this time interval was least in period 2, February 1952 to May 1952, when sunshine hours were greatest and there was a monthly average of more than 10 inches of rain. Although rainfall was even higher during period 3, which was the period of the south west monsoon, sunshine hours were at their lowest and the time taken for the unfolding of each successive leaf was greatest. In period 1, on the other hand, although sunshine hours were ample, there would appear to have been insufficient rain to permit of rapid growth. In general, therefore, it would appear that the shoot growth rate, as measured by the unfolding of successive leaves, is dependant on both sunshine and rainfall.

Whilst there are also significant differences between successive periods in the times at which the fish leaf was first unfolded it is not possible to analyse this result further with the data available. This time interval, as recorded, includes two distinct physiological stages. Firstly an unknown number of days must elapse while the axilliary bud of the mature leaf left above the fish leaf is preparing itself to break into active growth. Secondly, once active growth has started, the young shoot may produce an unknown number of scale appendages before producing a fish leaf. The division between these stages being unknown it is obviously useless to speculate as to whether seasonal influences are operative on either or both of them.

(ii) FLUSH SHOOTS PLUCKED TO NEW PLUCKABLE BANJI SHOOTS.—The mean times in days, recorded under this heading, together with their standard errors are given in Table 3.

Table 3. (ii) *Flush shoots plucked to new pluckable banji shoots.*

(1) Period	(2) Season	(3) No. of Shoots	(4) Days to unfolding of FISH leaf (a)	(5) Days to pluckable BANJI (b)	(6) Mean interval (b) — (a) in days
1	Dec. 1951 to Feb. 1952	4	49.75 ± 3.71	75.00 ± 2.12	25.25 ± 1.70
			(10.75 ± 5.10)*	(1.00 ± 2.12)	(11.75 ± 3.89)*
2	Feb. 1952 to May 1952	2	60.50 ± 3.50	74.00 ± 0.00	13.50 ± 3.50
3		0	—	—	—
4		0	—	—	—
1—2	Dec. 1951 to May 1952	6	53.33 ± 3.38	74.67 ± 1.36	21.33 ± 2.85

Here again, although the table only covers the first two observation periods, the times given in columns (4) and (6) show significant differences between periods. The results accordingly confirm the existence of the seasonal effect demonstrated in the previous section.

(iii) TENDER BANJI SHOOTS PLUCKED TO NEW PLUCKABLE FLUSH SHOOTS.—The mean times, in days, recorded under this heading, together with their standard errors are given in Table 4.

Table 4. (iii) *Tender banji shoots plucked to new pluckable flush shoots.*

(1) Period	(2) Season	(3) No. of Shoots	(4) Days to unfolding of FISH leaf (a)	(5) Days to unfolding of THIRD leaf (b)	(6) Mean interval (b) — (a) in days	(7) Days for unfolding of one FOLIAGE leaf
1	Dec. 1951 to Feb. 1952	11	54.36 ± 3.43	83.09 ± 5.43	28.73 ± 2.99	9.58
			(1.91 ± 3.66)	(0.31 ± 6.01)	(1.60 ± 3.43)	
2	Feb. 1952 to May 1952	15	56.27 ± 1.30	83.40 ± 2.58	27.13 ± 1.67	9.04
			(3.14 ± 1.65)	(2.52 ± 3.10)	(0.62 ± 2.01)	
3	May 1952 to Aug. 1952	8	53.13 ± 1.03	80.88 ± 1.72	27.75 ± 1.11	9.25
4		0	—	—	—	—
1—3	Dec. 1951 to Aug. 1952	34	54.91 ± 1.25	82.71 ± 2.08	27.79 ± 1.21	9.27

There were no significant seasonal differences between periods.

(iv) TENDER BANJI SHOOTS PLUCKED TO NEW PLUCKABLE TENDER BANJI SHOOTS.—The mean times, in days, recorded under this heading, together with their standard errors are given in Table 5.

Table 5. (iv) *Tender banji shoots plucked to new pluckable tender banji shoots.*

(1) Period	(2) Season	(3) No. of Shoots	(4) Days to unfolding of FISH leaf (a)	(5) Days to pluckable BANJI (b)	(6) Mean interval (b) — (a) in days
1	Dec. 1951 to Feb. 1952	8	54.00 ± 2.77	80.75 ± 3.10	26.75 ± 1.46
			(2.20 ± 4.24)	(3.85 ± 4.50)	(1.65 ± 2.31)
2	Feb. 1952 to May 1952	10	51.80 ± 3.20	76.90 ± 3.26	25.10 ± 1.79
3		0	—	—	—
4		0	—	—	—
1—2	Dec. 1951 to May 1952	18	52.78 ± 2.12	78.61 ± 2.26	25.83 ± 1.17

Here again there were no significant differences between periods.

(v), (vi) TENDER BANJI SHOOTS LEFT UNPLUCKED. (vii), (viii) COARSE BANJI SHOOTS PLUCKED.—The various times, in days, recorded when either tender banji shoots were left unplucked or coarse banji shoots plucked are given in Table 6. The implications of these results will be considered in the discussion which follows.

Table 6. (v), (vi) *Tender banji shoots left unplucked.* (vii), (viii) *Coarse banji shoots plucked. Period* 1, *December* 1951 – *February* 1952.

(1) Initial treatment	(2) Type of shoot developed	(3) No. of shoots	(4) Days to unfolding of FISH leaf (a)	(5) Days to pluckable shoot (b)	(6) Mean interval (b) — (a) in days	(7) Days for unfolding of one FOLIAGE leaf
Tender banji left	Flush	15	59.13 ± 6.59	83.80 ± 6.28	24.67 ± 1.78	8.22
,, ,, ,,	Tender banji	3	69.67 ± 8.33	102.33 ± 8.67	32.66 ± 0.33	—
Coarse banji plucked	Flush	8	46.88 ± 3.08	74.38 ± 1.68	27.50 ± 2.16	9.17
,, ,, ,,	Tender banji	10	60.50 ± 3.74	87.70 ± 5.51	27.20 ± 2.99	—

Discussion and Conclusions.—The agricultural implications of the present results are best brought out by comparing the various times taken to produce new crop shoots, following different plucking treatments. However, in view of the seasonal effect which has already been demonstrated, it is obvious that any such comparison will only be valid if it is made during the same growth period. As period 1, December 1951 – February 1952, covered the widest range of different developmental conditions, the results for this period have accordingly been brought together and re-arranged in Table 7.

Table 7. *Summary of crop shoot development times. Period* 1, *December* 1951–*February* 1952.

(1) Type of shoot produced	(2) Initial treatment	(3) No. of shoots	(4) Days for development of pluckable shoot (b)	(5) Difference from general mean
Flush	Flush plucked	16	74.56 ± 1.63	— 6.63 ± 2.48*
,,	Tender banji plucked	11	83.09 ± 5.43	+ 1.90 ± 5.74
,,	Tender banji left	15	83.80 ± 6.28	+ 2.61 ± 6.55
,,	Coarse banji plucked	8	74.38 ± 1.68	— 6.81 ± 2.51*
Tender banji	Flush plucked	4	75.00 ± 2.12	— 6.19 ± 2.82*
,, ,,	Tender banji plucked	8	80.75 ± 3.10	— 0.44 ± 3.61
,, ,,	Tender banji left	3	102.33 ± 8.67	+ 21.14 ± 8.86*
,, ,,	Coarse banji plucked	10	87.70 ± 5.51	+ 6.51 ± 5.82
	ALL CROP SHOOTS	75	81.19 ± 1.86	

Combining all the observations for this period, it will be seen that the average time taken for a new pluckable crop shoot to be developed was 81.19 ± 1.86 days. The differences from this general mean, which are presented in column (5) of the table, should therefore serve to indicate whether or not a particular type of initial plucking treatment had accelerated the production of new crop shoots.

Considering first the plucking of flush shoots, it will be seen that, irrespective of the type of crop shoot subsequently produced, the average development times were both significantly less than the mean. As the remainder of the treatments all relate to the plucking or not plucking of banji shoots, it is obvious that when flush shoots were plucked there was a more rapid development of new crop shoots than when banji shoots were being dealt with. Accordingly, any cultural treatment which leads to an increase in the percentage of banji shoots produced must be avoided if maximum crops are to be secured.

Considering now the various initial banji treatments, it will be seen that there are only two cases which show significant differences from the general mean. In one case plucking of coarse banji has resulted in a more rapid production of new flush shoots, while in the other the leaving of tender banji unplucked has resulted in

a less rapid production of new pluckable tender banji. The implication of both these results is the same, namely, that all banji shoots should plucked without delay, if future reduction in crop is to be avoided. Furthermore, it is clearly most important for the planter to ensure that all banji shoots are plucked as tender banji, which is still suitable for manufacture, since, if they are allowed to remain on the bushes long enough to harden into coarse banji, they will have to be discarded as unsuitable for manufacture and crop will thus be lost.

The foregoing can be conveniently summarized in the statement that all crop shoots should be plucked immediately they have reached a state of readiness for plucking.

From Table 1 it will be seen that the average time interval between the unfolding of each successive foliage leaf, over the whole period of 11 months covered by the observations, was 9.17 ± 0.23 days. Table 4, however, which covers only the first three observational periods, gives the slightly higher figure of 9.27 ± 0.40 days, for this time interval. In view of the seasonal effect already demonstrated, this latter value is in accordance with expectation, since period 4, in which a shorter time interval could have been anticipated from the date of Tables 1 and 2, has not been taken into account.

It would thus appear reasonably correct to assume that the average time interval, over the full year, for the unfolding of successive foliage leaves does not differ appreciably from 9 days, which, as stated in the first paper of this series (Portsmouth 1957a) is the length of the interval between plucking rounds adopted by most planters on estates at this elevation. The present result accordingly affords further confirmation of the correctness of this plucking interval, since plucking rounds based on the time taken for the unfolding of one leaf will undoubtedly permit of the greatest proportion of the desired bud plus 2 leaf flush shoots being harvested.

The results presented earlier, however, indicate that this time interval does not remain constant throughout the year but varies to a considerable extent with seasonal changes in climatic factors. Used as a measure of shoot growth rate, the rate of unfolding of successive foliage leaves would appear to be dependant on the amounts of both sunshine and rainfall which are received during the given period of observation. Taken in conjunction with the fact that the weights of the individual flush shoots harvested are related to the amount of rainfall some two and a quarter months prior to plucking (Portsmouth 1957b), it would seem that much of the fluctuation in yield, which is observed on estates from month to month, is climatic in origin.

One further feature of the present observations requires comment. This is the almost complete disappearance of any new banji shoot production by the time the fourth period was reached. The increasing proportion of new flush shoots produced in each successive period can be clearly seen from column (3) of Table 1. This increase in the proportion of flush to banji shoots with time was, however, entirely contrary to ordinary field experience and requires further investigation. The fact that, in the course of these observations, some change in the environmental or other conditions of the marked shoots had occurred, which had tended to inhibit the early onset of dormancy, suggests that it may yet prove possible to devise methods of reducing the proportion of banji shoots formed under normal field conditions.

Summary.—The results of a series of observations on the times taken by T.R.I. Clone No. 4 to develop new crop shoots after plucking are presented and discussed.

During the period December 1951 to February 1952, which covered the maximum number of different plucking treatments, the average time taken for a new crop shoot to be developed was 81 days.

Differences in development times with different treatments indicate that all crop shoots should be plucked immediately they are ready, if maximum crops are to be secured.

Over the whole 11 months during which observations were carried out, the average time taken for the unfolding of successive foliage leaves was approximately 9 days, which corresponded with the plucking interval adopted by estates.

Shoot growth rate, as measured by the unfolding of successive leaves, was shown to be related to both sunshine and rainfall. Monthly fluctuations in yield thus appear to be largely climatic in origin.

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