

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

## II. THE INFLUENCE OF CLIMATIC CONDITIONS AND AGE FROM PRUNING ON FLUSH SHOOT PRODUCTION

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**Introduction.**—The first paper of this series (Portsmouth 1957a) described the results of a plucking experiment carried out on an area of clonal tea (T.R.I. Clone No. 4) in so far as they were affected by the applied treatments, namely, weekly and fortnightly plucking intervals. For this purpose it was sufficient to utilise only the records obtained during the first year of plucking, although the experiment continued in operation from 14-3-49 to 13-11-50, or for some 21 months. In the present paper it is proposed to make use of the full period of the experiment to determine, if possible, in what way climatic conditions and age from pruning may influence flush shoot production.

With regard to age from pruning it may be noted that the experiment was in operation during a period of 14 to 35 months from pruning. With a cycle length of 36 months the experiment thus covered almost the whole of the period during which flush shoot production might be expected to have settled down and to be determined mainly by plucking procedure, climatic factors and age from pruning. This is not the case in the early months of the cycle since, as Tubbs (1937) points out, there is initially, during recovery from pruning, a very rapid increase in shoot production which subsequently levels off as the plucking table becomes fully formed and factors such as light intensity and internal competition for available nutrients start to limit the rate of new shoot production.

**Weather Conditions.**—St. Coombs estate is situated, at an elevation of 4,500 feet, approximately midway between the towns of Hatton and Nuwara Eliya in the Central Province of Ceylon. The district is one which receives both the south west and the north east monsoons, and weather conditions throughout the year are mainly governed by the prevailing monsoon. There is comparatively little temperature variation. Thus in 1949 the mean maximum temperature ranged from 80.9°F in March to 70.0°F in June, while the mean minimum temperature ranged from 52.0°F in February to 60.1°F in June. Similarly in 1950 the mean maximum temperature ranged from 77.6°F in March and April to 68.3°F in July, while the mean minimum ranged from 52.7°F in January to 60.0°F in June.

Rainfall and mean daily sunshine hours vary over a very much wider range, being essentially monsoonal in character. Conditions from January to April are usually fine and bright with little rainfall or cloud. This is followed by the onset of the south west monsoon, around the middle of May, when conditions become misty and overcast with almost continuous light rain. Towards October the south west monsoon gives way to the north east, which is characterised by bright mornings with heavy showers during the afternoons.

It may thus be reasonably expected that, if there is any influence of climatic factors on flush shoot production, it will be found to operate through changes in

either rainfall or sunshine hours. Monthly data for rainfall, sunshine hours and wet days (days on which more than 0.04 inches of rain fell), at St. Coombs, are accordingly given in Table 3.

\*Table 3. *Meteorological Data—St. Coombs.*

MONTH	RAINFALL Inches	MEAN DAILY SUNSHINE Hours	WET DAYS
1948			
November	6.38	5.53	16
December	6.92	3.58	13
1948 whole year	87.66	5.31	182
1949			
January	3.23	6.88	7
February	0.45	8.42	4
March	1.66	8.42	1
April	8.04	6.02	17
May	7.06	5.28	19
June	11.38	2.63	19
July	11.16	3.17	26
August	9.55	4.07	23
September	8.28	3.17	21
October	10.80	4.87	20
November	8.24	5.17	15
December	7.03	2.62	11
1949 whole year	86.88	4.82	191
1950			
January	0.82	7.10	7
February	2.07	7.03	8
March	1.83	7.58	8
April	2.85	6.70	7
May	9.29	5.32	12
June	9.21	2.72	21
July	13.40	2.17	30
August	7.18	2.77	25
September	12.36	3.53	17
October	5.28	3.97	19
November	6.35	4.98	12
December	2.22	5.03	10
1950 whole year	72.86	4.89	176

\*Note. As the same data are involved tables are numbered consecutively with paper I of this series.

Sunshine hours appear to vary inversely with rainfall and over the period November, 1948, to November, 1950, which is made use of in subsequent calculations,

show a correlation coefficient  $r_{RS} = -0.8241$ , which for  $n=25$  is very highly significant.

The number of wet days is also very closely linked with the monthly rainfall and, over the same period, shows an even stronger correlation  $r_{RW} = +0.8330$ .

It would, therefore, appear to be reasonably justifiable to consider rainfall as the dominant climatic factor operating at St. Coombs.

**Flush Shoot Number.**—The average numbers of each type of flush shoot harvested per pluck each month, reduced to a single bush basis, are given in Table 4.

Table 4. *Average number of flush shoots harvested per bush at each pluck*

	PLUCKED WEEKLY				PLUCKED FORTNIGHTLY				
	*B + 2	B + 3	B + 4	Total	B + 2	B + 3	B + 4	B + 5	Total
1949—									
March ...	1.87	—	—	1.87	2.98	0.40	—	—	3.38
April ...	5.70	1.17	—	6.87	5.88	1.79	0.01	—	7.68
May ...	9.48	4.16	0.03	13.77	6.80	8.38	1.84	0.02	17.04
June ...	2.31	0.03	—	2.34	2.24	0.21	0.01	—	2.46
July ...	15.89	2.68	—	18.57	11.51	12.09	1.63	0.01	25.24
August ...	4.29	1.21	—	5.50	3.40	2.24	0.26	—	5.90
September	9.63	5.53	0.18	15.34	6.16	5.68	0.92	—	12.76
October ...	8.09	2.24	0.04	10.37	9.72	7.11	0.82	—	17.65
November	15.30	4.79	0.02	20.11	12.85	8.49	1.06	—	22.40
December	8.07	3.88	0.01	11.96	7.17	7.44	1.29	—	15.90
1950									
January ...	10.28	3.47	0.06	13.81	4.26	3.49	0.31	—	8.06
February	9.05	1.79	—	10.84	14.16	9.16	0.46	—	23.78
March ...	4.28	1.01	—	5.29	5.85	1.78	0.06	—	7.69
April ...	4.41	0.35	—	4.76	4.46	0.93	—	—	5.39
May ...	3.36	0.52	—	3.88	5.92	1.07	0.02	—	7.01
June ...	11.39	1.66	0.01	13.06	14.34	3.47	0.05	—	17.86
July ...	9.55	0.99	0.01	10.55	7.05	1.31	—	—	8.36
August ...	4.59	0.21	—	4.80	4.13	0.40	—	—	4.53
September	9.16	0.97	—	10.13	12.59	1.35	—	—	13.94
October ...	4.98	0.71	0.01	5.70	6.24	2.03	0.15	—	8.42
November	7.39	2.16	—	9.55	12.00	2.70	0.15	—	14.85

\* Note. In the column headings of this and subsequent tables B + 2 stands for a bud plus 2 leaf shoot, etc. etc.

Considering the totals only; there is no obvious correlation with the meteorological data of Table 3. On the contrary, there would appear to be indications of a regular rhythmic pattern in the form of alternating maxima and minima. Monthly variations of this nature are particularly marked in the case of the weekly plucked bushes from May, 1949, to January, 1950, and again from August to November, 1950. As may be expected from the reduced number of plucks in each monthly mean, the pattern, although still recognisable, is somewhat less pronounced in the case of the fortnightly plucked bushes.

This observed variation in the number of flush shoots harvested month by month presumably owes its origin to a similar innate periodicity to that which manifests itself in the individual shoot in the form of alternate periods of active growth and dormancy (Bond 1942).

The only indication of any influence of climatic conditions on the number of flush shoots produced would appear to be a suppression of the expected periodic maxima, which is observable in the case of the weekly plucked bushes, as a consequence of the very dry weather experienced from January to April, 1950. With only 0.82 inches of rain in January, 1950, and less than 4 inches in each of the three following months this period can be considered as one of true drought. Provided, therefore, that growth is not limited by actual water shortage it appears probable that this rhythmic variation in flush shoot number is completely independent of external climatic factors.

The effect of age from pruning on flush shoot number is probably best brought out by comparing means for the two periods March to November, 1949, and March to November, 1950. The relevant data are accordingly presented overleaf in Table 5.

From this table it is evident that the effect of an increase in the mean age of the bushes from pruning, of one year, has been to bring about a general decrease in the numbers of flush shoots harvested at each pluck. This decrease was 31.3 per cent of the total in the case of the weekly plucked bushes, and 32.1 per cent in the case of the fortnightly plucked bushes. These figures are in remarkably close agreement and undoubtedly represent a real slowing down in the overall growth rates of the bushes.

If the growth rates of the individual flush shoots had remained constant it could have been expected that the percentage composition of the crop harvested would have remained more or less unaltered. As it is the proportion of bud plus 2 leaf shoots, which require the least time to reach a state of readiness for plucking, has increased very considerably with time, which again indicates a slowing down of the general growth rate. This increase in the proportion of bud plus 2 leaf shoots was from 76.3 per cent to 88.0 per cent, in the case of the weekly plucked bushes, and from 52.5 per cent to 82.3 per cent, in the case of the fortnightly plucked bushes. This latter increase is particularly striking since, with the longer plucking interval, there should have been ample time for more bud plus 3 leaf shoots to have developed had not there been a decrease in the individual shoot growth rate.

Table 5. *Effect of age from pruning on mean numbers of flush shoots harvested per bush at each pluck.*

PERIOD	Months from pruning	PLUCKED WEEKLY				PLUCKED FORTNIGHTLY				
		B + 2	B + 3	B + 4	Total	B + 2	B + 3	B + 4	B + 5	Total
Mar.—Nov. 1949 ...	14—23	8.16 (76.3%)*	2.51 (23.4%)	0.03 (0.3%)	10.70	7.19 (52.5%)	5.67 (41.4%)	0.83 (6.0%)	0.01 (0.1%)	13.70
Mar.—Nov. 1950 ...	26—35	6.47 (88.0%)	0.87 (11.9%)	0.01 (0.1%)	7.35	7.65 (82.3%)	1.60 (17.2%)	0.05 (0.5%)	—	9.30
Decrease after 1 year ...	—	1.69	1.64	0.02	3.35	— 0.46	4.07	0.78	0.01	4.40

\* *Note.*—Figures in brackets represent the percentage composition of the crop harvested.

**Flush Shoot Weight.**—The average fresh weights of the various types of flush shoot harvested each month are given in Table 6.

Table 6. *Average fresh weights of individual flush shoots (gm).*

	PLUCKED WEEKLY			PLUCKED FORTNIGHTLY			
	B + 2	B + 3	B + 4	B + 2	B + 3	B + 4	B + 5
1949—							
March ... ..	0.25	0.40	—	0.29	0.48	—	—
April ... ..	0.34	0.57	1.10	0.31	0.48	0.90	—
May ... ..	0.37	0.61	1.20	0.41	0.73	1.25	2.10
June ... ..	0.41	0.93	—	0.41	0.63	1.90	—
July ... ..	0.46	0.70	—	0.50	0.95	1.49	2.40
August ... ..	0.44	0.72	—	0.48	0.88	1.42	—
September ... ..	0.49	0.79	1.28	0.51	1.03	1.76	—
October ... ..	0.45	0.77	1.41	0.47	0.89	1.48	—
November ... ..	0.48	0.73	1.10	0.51	0.96	1.59	—
December ... ..	0.48	0.78	1.05	0.53	1.02	1.63	—
1950—							
January ... ..	0.41	0.65	1.09	0.46	0.89	1.27	—
February ... ..	0.31	0.51	—	0.32	0.56	1.02	—
March ... ..	0.34	0.48	—	0.36	0.66	1.12	—
April ... ..	0.23	0.36	—	0.28	0.44	—	—
May ... ..	0.20	0.29	—	0.22	0.30	0.55	—
June ... ..	0.25	0.35	0.35	0.27	0.39	0.63	—
July ... ..	0.30	0.50	0.55	0.32	0.58	—	—
August ... ..	0.39	0.64	—	0.46	0.68	—	—
September ... ..	0.43	0.70	—	0.42	0.74	—	—
October ... ..	0.49	0.89	1.65	0.50	0.87	1.41	—
November ... ..	0.46	0.68	—	0.58	0.89	1.48	—

As soon as the curves for the monthly variations in weight of the bud plus 2 leaf shoots were plotted it was evident that they were markedly similar in shape to the curves obtained by plotting the meteorological data of Table 3. This suggested the existence of a definite relationship between climatic conditions and shoot weight. Accordingly, a series of correlation co-efficients were calculated in which shoot weight was related to rainfall over a period extending backwards in time from the month of plucking up to 4 months before plucking. The respective correlation co-efficients obtained in this way are given in Table 7.

Table 7. *Correlation co-efficients. Monthly rainfall and average fresh weights of B + 2 flush shoots.*

MONTH IN WHICH RAIN FELL	PLUCKED WEEKLY	PLUCKED FORTNIGHTLY
Same month as plucking	+ 0.2320	+ 0.1291
1 month before plucking	+ 0.6336**	+ 0.6245**
2 months before plucking	+ 0.7036**	+ 0.7238**
3 months before plucking	+ 0.6911**	+ 0.6587**
4 months before plucking	+ 0.4499*	+ 0.4722*

Significance levels where n = 21

	P	r
**	.01	0.5487
*	.05	0.4329

The correlations with the rainfall, from 1 to 3 months before plucking, are all highly significant at the 1 per cent level. From the relative value of the co-efficients it is evident that a maximum correlation is reached with rainfall about 2 months before plucking and that all the co-efficients fall on a regular second order curve. By combining the data from both sets of pluckings the following curve of closest fit was calculated:—

$$r = 0.2037 - 0.4743 t - 0.1034 t^2$$

where t represents the time in months. Differentiating this expression and equating to zero gives a maximum calculated value of  $r = + 0.7476$  at 2.29 months before plucking.

The extent of this correlation with rainfall and the goodness of fit of the calculated curve is shown in Figure 1.

Correlation co-efficients, calculated in the same way as above, for rainfall and the fresh weights of bud plus 3 leaf shoots are given in Table 8.

Table 8. *Correlation co-efficients. Monthly rainfall and average fresh weights of B + 3 flush shoots.*

MONTH IN WHICH RAIN FELL	PLUCKED WEEKLY	PLUCKED FORTNIGHTLY
Same month as plucking	+ 0.2988	+ 0.1052
1 month before plucking	+ 0.5893**	+ 0.5940**
2 months before plucking	+ 0.6525**	+ 0.6877**
3 months before plucking	+ 0.5516**	+ 0.7065**
4 months before plucking	+ 0.2806	+ 0.4824*

Significance levels where n = 21

	P	r
**	.01	0.5487
*	.05	0.4329

$$\gamma = 0.2037 - 0.4743t - 0.1034t^2$$

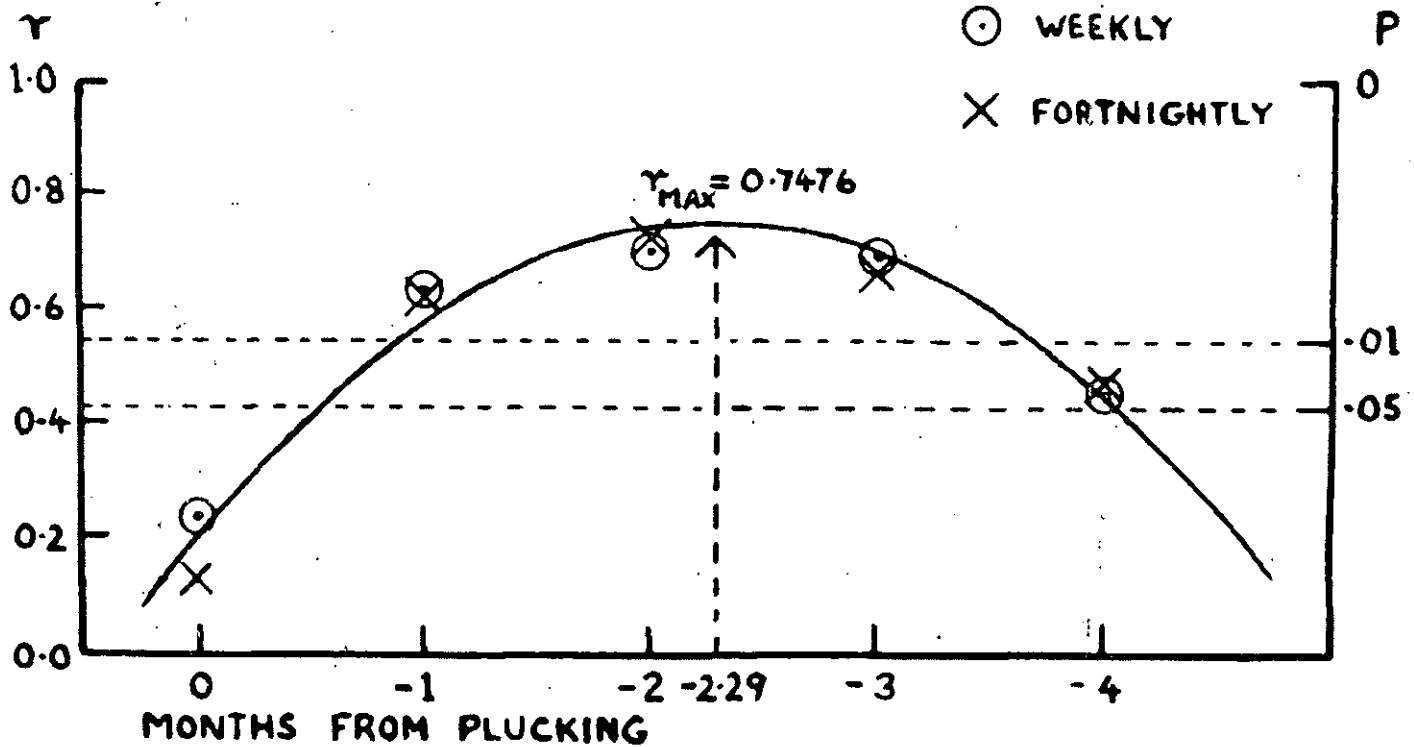


Figure 1. Diagram to show extent of correlation between rainfall and fresh weights of bud plus 2 leaf shoots. The calculated curve of closest fit is drawn in.

The pattern is very similar to that of Table 7 and again all correlations with rainfall from 1 to 3 months before plucking are highly significant at the 1 per cent level. Combining the data as before gives the following curve of closest fit:—

$$r = 0.2165 - 0.4379 t - 0.09956 t^2$$

which, on differentiating and equating to zero, gives a maximum calculated value of  $r = + 0.6980$ , at 2.20 months before plucking.

As might be expected, from the greater variability of the bud plus 3 leaf material, the goodness of fit of this second curve is somewhat less close (see Figure 2) than in the case of the bud plus 2 leaf material. However, both calculated maximum correlation co-efficients are obviously very highly significant and, indicate that the average weight of a plucked flush shoot is very largely influenced by the weather conditions prevailing some two and a quarter months before the date of plucking.

Similar data, to that already presented in Table 5 to show the effect of age from pruning on flush shoot number, is given for individual flush shoot weight in Table 9.

Table 9. *Effect of age from pruning on mean fresh weights of individual flush shoots (gm).*

PERIOD	Months from Pruning	PLUCKED WEEKLY			PLUCKED FORTNIGHTLY			
		B + 2	B + 3	B + 4	B + 2	B + 3	B + 4	B + 5
March—Nov. 1949	14—23	0.44	0.71	1.27	0.46	0.88	1.45	2.18
March—Nov. 1950	26—35	0.34	0.54	0.85	0.37	0.61	1.24	—
Decrease after 1 year	—	0.10	0.17	0.42	0.09	0.27	0.21	—

Little need be said about this table except that it shows that an increase of one year in the mean age of the bushes from pruning has brought about a similar decrease in all individual shoot weights. The effect is very like that previously demonstrated for flush shoot number and again points to a decrease in the individual shoot growth rate with time.

**Discussion and Conclusions.**—Before discussing the results reported in the present paper it is as well to obtain a clear idea as to how far any conclusions drawn may be generally applicable. As mentioned in the previous paper (Portsmouth 1957a), one of the commonest difficulties that arises in reconciling the results of scientific experiments with estate practice is due to the very large extent to which the human element may influence estate results. At present the tea crop in Ceylon is harvested entirely by hand. Accordingly, although definite plucking programmes and standards of plucking are laid down, these are seldom rigidly adhered to. The

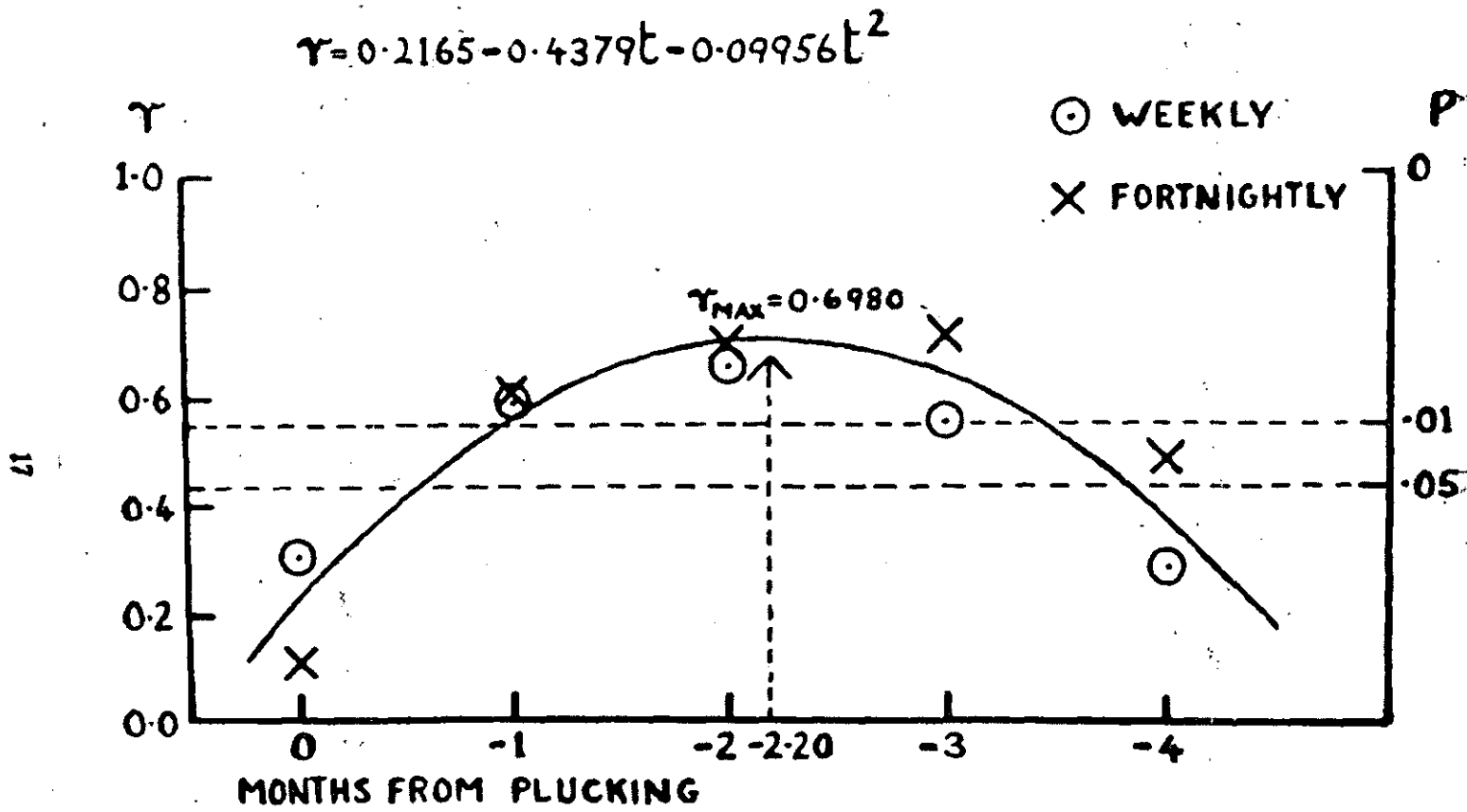


Figure 2. Diagram to show extent of correlation between rainfall and fresh weights of bud plus 3 leaf shoots. The calculated curve of closest fit is drawn in.

number of pluckers carried by an estate is more or less fixed so that, when seasonal "rushes" of crop are experienced, plucking intervals increase and many crop shoots that should be harvested remain ungathered. On the other hand, when crop is short, although the plucking intervals are correct, many immature shoots are prematurely gathered as a direct consequence of the pluckers' need to bring in their daily poundage. Under such conditions, therefore, it is not surprising that the result of rigidly controlled scientific experiments are not always strictly reproducible when put into practice on an estate scale. However, this is a relatively minor difficulty, since the validity of the experimental result is uncontested, and it merely remains for the working planter to bring his estate practice more closely into line with scientific knowledge.

The degree to which climatic conditions vary from estate to estate in Ceylon presents a much more serious difficulty when it comes to considering how far any conclusions based on climatic data can be justifiably extended. Variations in annual rainfall, from under 100 inches to more than 200 inches in only a few miles, are common, while many tea growing areas receive only one monsoon instead of the two experienced at St. Coombs. Accordingly, until such time as similar results have been obtained in other areas, it seems advisable to restrict the validity of any climatic effects reported to the immediate neighbourhood in which the experiment was carried out.

There is also considerable uncertainty at present as to how far the results obtained, using one particular clone for experimentation, will be reproducible when different clones are employed. However, such evidence as is available indicates that responses tend to differ in degree rather than in kind. Accordingly, in the absence of evidence to the contrary, it seems reasonable to suppose that most clones will respond in the same way to similar conditions, although the response levels will vary from clone to clone. Experiments are actually in progress with a wide selection of different clones and this question will, therefore, be discussed in more detail when results are reported in later papers.

With the above considerations in mind, it appears safe to conclude that in, the St. Coombs neighbourhood, climatic conditions, of which rainfall is the dominant factor, have a marked influence on the individual weights of all flush shoots harvested. The correlations with rainfall, one, two and three months prior to plucking, are all positive and highly significant. The calculated correlation co-efficients for bud plus 2 leaf and bud plus 3 leaf shoots reach maxima at an average time about two and a quarter months before plucking. The rainfall some two and a quarter months prior to plucking thus appears to largely predetermine the individual weights of the flush shoots harvested.

This finding is of considerable interest since it indicates the possibility, when other factors have been more fully investigated, of being able, on the basis of recorded climatic data and growth observations, to predict crop levels two months or more in advance.

Consideration of the manner in which climatic influences operate to control final flush shoot weight is naturally somewhat speculative. However, it is known from other work on T.R.I. Clone No. 4 (Portsmouth and Rajiah) that the interval between the unfolding of each successive foliage leaf on the developing shoot is approximately 9 days. Now a shoot, which is harvested as a bud plus 2 leaf shoot, may be expected to consist of two scales, 1 fish leaf and 3 foliage leaves, making a total of some six expanded appendages in all. The three foliage leaves will have taken a total of 27 days to unfold and even, if, following Bond (1945), a somewhat longer interval, say 12 days, is allowed for the unfolding of each of the other three appendages, the whole shoot may be expected to have taken not more than about

63 days to develop from bud-break. This period is rather less than that represented by the two and a quarter months before plucking when climatic influences reach their maximum. As growth in size and weight of the developing shoot is presumably exponential in character in, at least, the early stages it seems reasonable to suppose that it is through their effect on the initial sizes reached by the shoot primordia, prior to the bud breaking into active growth, that these climatic influences may operate. On this suggestion it is supposed that greater rainfall will almost immediately lead to an increase in the supplies of water and soluble nutrients at the growing points, and so enable the primordia to increase in size before bud-break and active growth commences.

Except during periods of drought climatic conditions appear to have little or no effect on the number of flush shoots produced per bush. On the contrary, flush shoot number exhibits a rhythmic variation with a series of maxima and minima which, in the case of T.R.I. Clone No. 4, are spaced about two months apart. During conditions of actual drought the expected maxima are suppressed. This observed periodicity, which obviously owes its origin to the number of buds which "break" at any given time, is considered to be innate and similar in character to that which manifests itself in the individual shoot in the form of alternate periods of active growth and dormancy (Bond 1942).

The effect of increasing age from pruning is evident as a decrease in both flush shoot number and individual shoot weight, which indicates a decrease in the general growth rate with time. There is, of course, a slight possibility that climatic factors are also concerned in bringing about this effect since rainfall in 1950 was some 16 per cent less than in 1949. However, as the decreases in shoot numbers alone reached twice this figure, without taking into account the equally large weight decreases it seems reasonable to suppose that age from pruning had played a major part in bringing about the observed effect.

In this connection it may be noted that the type of growth induced by plucking is essentially sympodial in nature. As a consequence, as the age from pruning increases, the new crop shoots tend to develop from branches of higher and higher order. It is, accordingly, suggested that it is this increase in the complexity of the bushes' branch system, during the course of the pruning cycle, which operates to bring about this decrease in the general growth rate with time.

**Acknowledgement.**—The assistance and enthusiastic co-operation of Messrs. F. H. Kehl and E. S. Rajiah in supervising the field work and collecting all the varied data required in connection with this experiment is gratefully acknowledged.

**Summary.**—This paper presents the results of a further analysis of the data obtained from the experiment previously described (Portsmouth 1957a).

Climatic conditions, of which rainfall is the dominant factor, existing some two and a quarter months prior to plucking, appear to largely predetermine the individual weights of the flush shoots harvested.

It is suggested that this effect is brought about by increased rainfall increasing the supplies of water and soluble nutrients available at the growing points, thus enabling the shoot primordia to increase in size before active growth begins.

Except during drought, the numbers of flush shoots harvested were independent of climatic conditions, being apparently determined by an innate periodicity.

An increase in the age of the bush from pruning resulted in (1) a decrease in flush shoot number, (2) a decrease in the individual flush shoot weight.

These two results are considered to be due to a decrease in the general growth rate, brought about by the increasing complexity of the bushes, branch system.

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