

## THE INFLUENCE OF CLIMATE AND GIBBERELIC ACID ON YIELD OF TEA CLONES (*CAMELLIA SINENSIS* L.)

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Four clones were used in two field experiments, conducted at different times, in this study. Differences in their yields were largely due to differences in the numbers of shoots harvested. The high yielding clones C and B had a greater percentage of active shoots and relatively low percentage dry matter in the harvested shoots compared with the low yielding clones D and A. The clones also differed in the size of the harvested shoots.

Yield of clones was affected by climate, particularly rainfall. Low rainfall resulted in reduced crop due to the presence of fewer shoots of smaller size. The percentage dormant shoots and percentage dry matter were higher when rainfall was low.

Clones differed in their response to gibberellic acid. In clones which responded, increased crops were obtained over a period of about six months in experiment 1. This was followed by reduced yields, although cumulative yields were still higher at the end of nine months, for clone D. On the average, crop increases were of the order of 10 to 15% in clones B and C and in clone D which responded best, the increase was 30%, though increases of 50 to 75% were obtained during the first month. In clone D, when low crop was obtained due to low rainfall, as in experiment 2, the yield increase due to gibberellic acid+urea was, on average, about 10 to 15% and cumulative yields were still higher at the end of 12 months. The increased yields due to gibberellic acid could not be maintained even with additional sprays. Variations in yield were due to corresponding changes in the numbers of shoots harvested. Better responses to treatment were obtained with increased crops harvested due to adequate rainfall. At the concentration used (50 ppm), there was no effect of treatment on percentage active shoots, size of shoots or dry matter content.

The possible reasons for the change in response with time, due to gibberellic acid, are given and discussed.

### INTRODUCTION

The tea of commerce is made from the tender apical vegetative portions of secondary and higher order shoots which are harvested at frequent intervals of 7-9 days and over long periods of 3-5 years at this elevation (1372 m amsl). Since the yield depends on the number, size and dry matter content of shoots harvested over the entire harvesting period, it is important from the commercial point of view, that the plant shows vigorous vegetative growth and produces more shoots. All cultural operations such as harvesting, pruning, fertilizer application *etc* are aimed at achieving this.

\* Clone A=DG; Clone B=TKG; Clone C=B275; Clone D=TRI 2024

Harvesting temporarily destroys apical dominance and encourages the growth of axillary shoots. Clonal variations have been shown to exist in this regard (Portsmouth 1957c). Seasonal changes in climate, particularly rainfall, are known to affect tea yields (Portsmouth 1957b; Portsmouth and Rajiah 1957; Sen, Biswas and Sanyal 1966). Tea, growing near the equator, as in Sri Lanka and Kenya, is harvested throughout the year but at latitudes away from the equator, as in north-east India, Japan and the Soviet Union, the tea plant goes through a period of complete dormancy during winter, when harvesting is not possible, resulting in low yields. The duration of this winter dormancy increases with increasing distance from the equator. The longer the period of short days (long nights) the longer the dormancy (Barua 1969).

Attempts have been made in different countries to increase vegetative growth and yield of tea by spraying gibberellic acid but the results have sometimes been inconclusive. It was shown that gibberellic acid stimulated the growth of dormant buds thereby reducing the dormant phase and increased the height of young tea plants (Torii and Nakagawa 1960; Ahamed, Chakraborty and Hasan 1965; Kulasegaram 1969; Kulasegaram and Kathiravetpillai 1972). In the Soviet Union (Ali-Zade 1963) it was shown that gibberellic acid increased growth by increasing shoot length and number of leaves. In a field trial, gibberellic acid produced maximum effects in the first 45 to 50 days and thereafter the response declined. Yield of green leaf was increased by 10 to 19% in the summer and 49 to 75% in the autumn by gibberellic acid treatment. In Indonesia, a spray of 50 ppm was found to damage the buds. In north-east India (Barua and Barua 1969; Barua 1969; Anon. 1971) it was shown that winter dormancy was due to short days (long nights) and that gibberellic acid was effective, as was supplementary illumination, in increasing the green leaf yields in mature tea.

This paper analyses the yield responses of four clones to climatic changes and to gibberellic acid application, based on the results of two field experiments.

## MATERIALS AND METHODS

Two additional blocks of 12 clones of a clonal testing experiment planted in 1963 at St Coombs (1372m amsl) and in the second plucking cycle were available for the experiments. The plants were spaced 120 cm between rows and 60 cm in the rows and each plot was surrounded by guard row plants of a different marker clone. Each plot had 24 plants and was subdivided into two, one half of which was treated while the other half was used as the control. Four clones\* A, B, C and D were selected for study and the treatments were replicated twice. Fertilizer applications were given according to current recommendations for tea in Sri Lanka.

The control of pests and diseases was carried out as a routine measure. The first experiment covered a period of nine months commencing on 19.3.71 and the second, which was done on the same four clones, was started on 13.12.71 when the yields from the treated and control plots were similar, and covered a period of 12 months. In the first experiment, the effect of gibberellic acid (50 ppm) treatment was compared with the control (sprayed with water). In the second trial,

the spray solution contained gibberellic acid (50 ppm) and a 4% solution of urea, because earlier experience showed that urea, in addition to improving the colour of the leaves, enhanced the response to gibberellic acid.

The spray solutions included a non-ionic wetting agent Lissapol at 0.05% and 1.13 l were used on 12 bushes for each treatment on each occasion. The plots were sprayed six times in the first experiment and three times in the second. While spraying, a polythene sheet was held to prevent spray drift to the adjoining plot. Spraying was always done on bright days using a knapsack sprayer. As the experiments were conducted on clonal plants and as pre-treatment yields determined twice showed negligible variation between the subplots, the treatments were commenced without such records. Sprays were always given immediately following a harvest which was done every seven days over the full duration of the experiments. Fresh weights, shoot numbers and the condition of their terminal buds, whether active or dormant, were recorded and dry weights determined on samples after every harvest.

## RESULTS

### *Influence of climate on yield of clones*

#### *Climate*

The climatic conditions that prevailed showed variation in respect of monthly rainfall distribution and mean daily sunshine hours, which appeared to be inversely related (Fig.3). The mean daily temperatures did not show sufficient variation to affect changes in crop. It appeared that the few months of low rainfall in experiment 2 was more critical in restricting crop than the lowest level of sunshine hours recorded which was probably adequate. It would, therefore, appear to be reasonably justifiable to consider rainfall as the dominant climatic factor at St Coombs (see Portsmouth 1957).

#### *Weight of shoots*

Based on the yields obtained from the control plots, the order of merit of the clones was clone C, B, D and A in both experiments. The crop harvested varied from week to week in the control as well as in the treated plots. The pattern of variation was similar for the four clones but differences in magnitude were noted. Table 1 gives the monthly crop distribution for the clones in both experiments. The variation in crop was found to be related to rainfall. Thus in experiment 1, the climatic conditions that prevailed were favourable and the crop harvested was high in comparison with that in experiment 2 where a few months of low rainfall resulted in markedly reduced crop although temperature and sunshine were presumably adequate (Fig.3).

#### *Number of shoots*

Table 2 gives the numbers of shoots harvested each month for the clones in both experiments. The distribution of shoot numbers followed a similar pattern as seen for shoot weights in respect of clones as well as that for rainfall. In experiment 1 shoot counts were commenced only from the fourth month and, therefore, the figures for the previous months are not available.

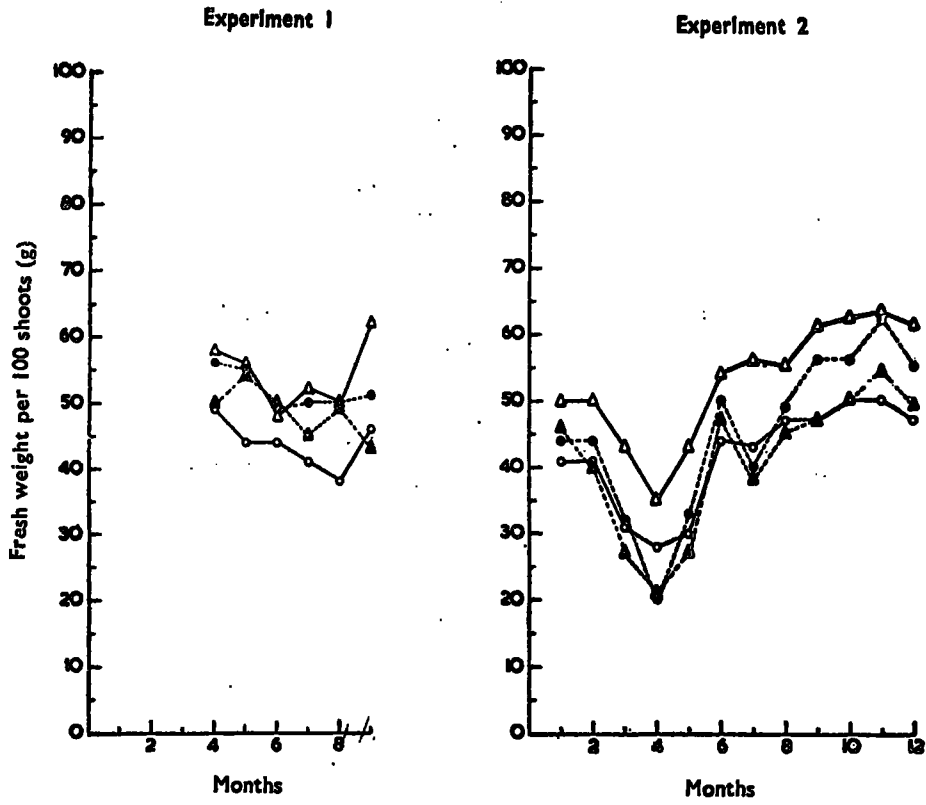


FIG. 1—Size of harvested shoots

○ = Clone A, ● = Clone B, △ = Clone C, ▲ = Clone D

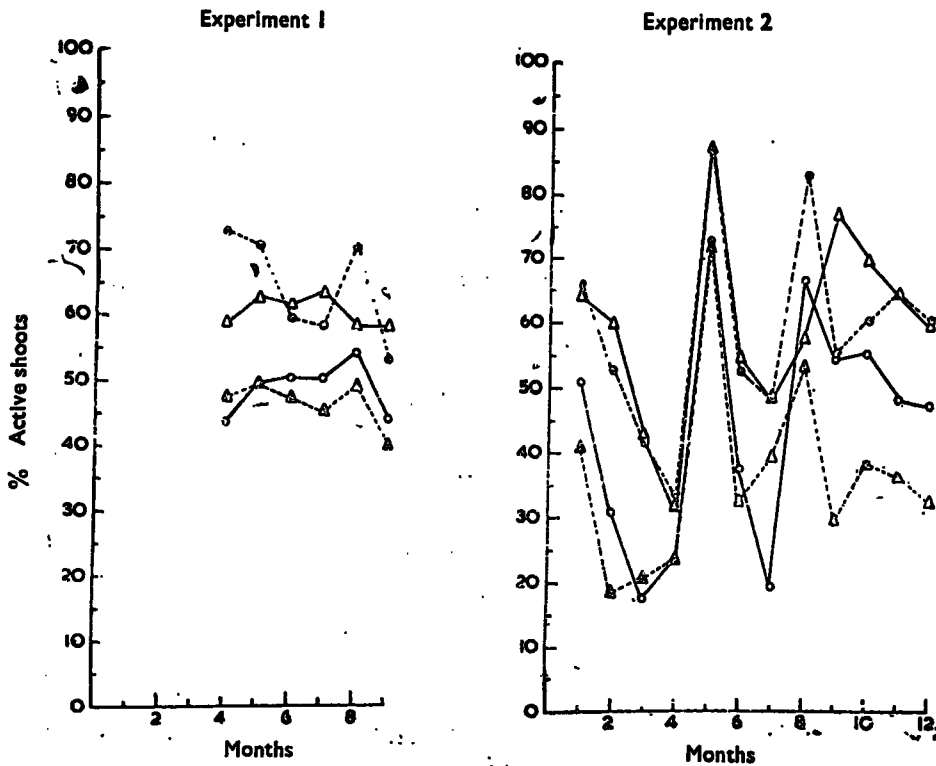


FIG. 2—% Active shoots in harvested crop

○ = Clone A, ● = Clone B, △ = Clone C, ▲ = Clone D

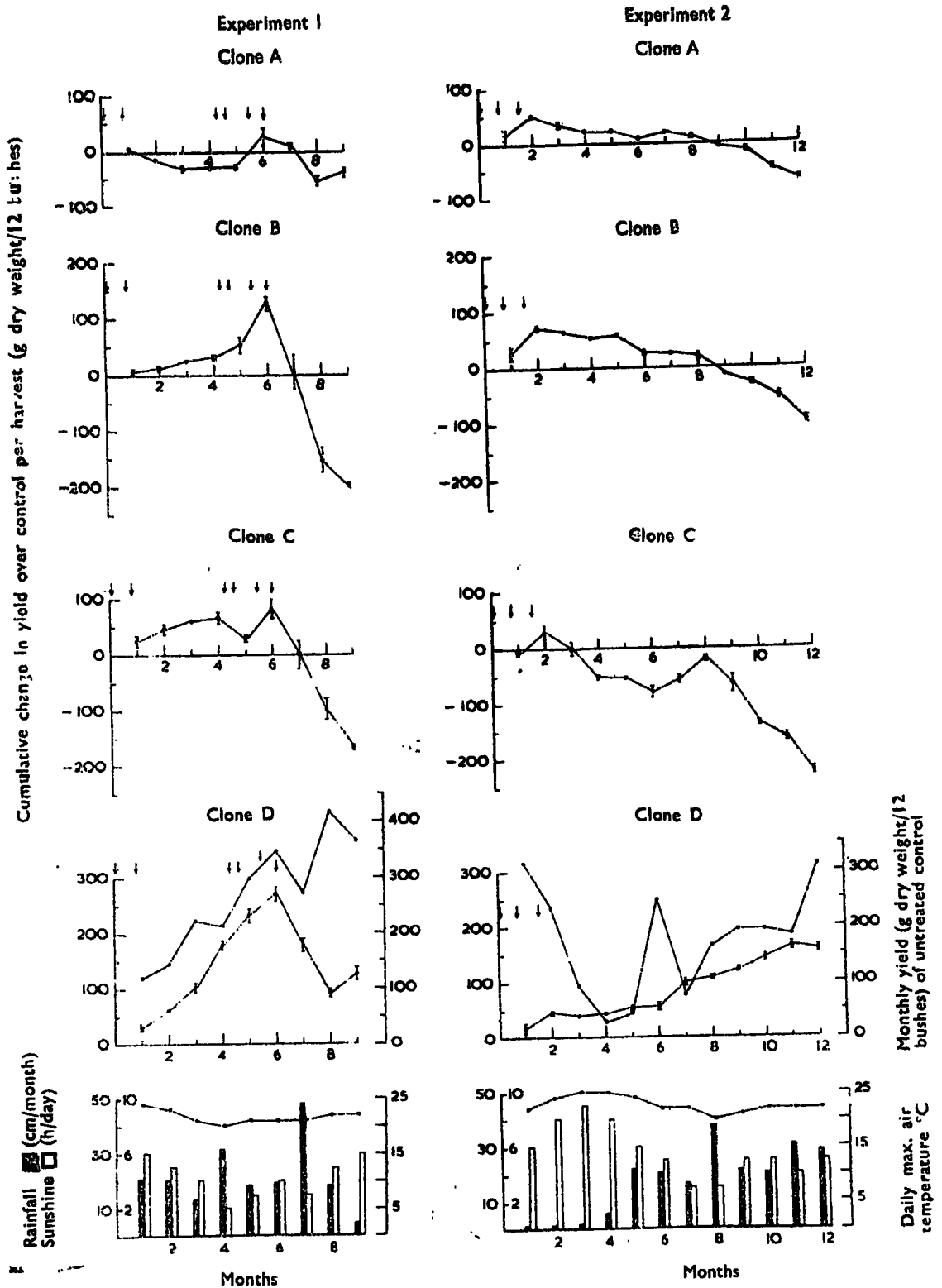


FIG. 3—Yield response of tea clones to gibberellic acid in relation to climate—vertical arrows indicate time of gibberellic acid application.

### *Weight per 100 shoots*

Size of flush as determined by the fresh weight of 100 harvested shoots also showed a variation between clones as well as due to rainfall. In general, the same order of merit of the clones was maintained in respect of shoot size. It will be noted that the size was reduced when moisture stress developed due to low rainfall seen during the first four months in experiment 2. Clone D appeared to be most sensitive to low rainfall while clone C was the least affected (Fig.1).

### *Percentage dry matter of shoots*

The percentage dry matter of the shoots showed little variation amongst the clones tested. The trend was for the high-yielding clones to give a lower percentage dry matter compared with that for the lower yielding clone. Rainfall distribution affected the percentage dry matter in all clones. Low rainfall months were generally associated with a high percentage dry matter compared with the high rainfall months.

### *Percentage active shoots*

Fig.2 gives the percentage active shoots in the crop harvested each month for the clones in both experiments. Clones differed in the proportion of active to dormant shoots in the crop shoots harvested, the higher yielding clones generally having a higher percentage of active shoots. Low rainfall decreased the percentage active shoots in all the clones. Clones D and A were most sensitive in this regard.

### *Influence of gibberellic acid on yield of clones*

#### *Weight of shoots*

The yield response of the clones to gibberellic acid or to gibberellic acid + 4% urea is represented graphically in Fig. 3 where the mean difference in the cumulative yields over the control on a weekly basis is plotted for each month. In experiment 1 except for clone A, the other clones showed a response to gibberellic acid with peak response being obtained at six months, after which the treated plots were yielding lower than the control plots and the cumulative yields decreased. At eight months, while clones B and C gave lower cumulative yields for the treatment compared with the control, clone D still gave higher cumulative yields, although the treated plots were yielding lower than the control plots. There was a tendency for the yields of the treated plots to recover in all the clones after nine months and when the experiment was terminated the yields obtained from the treated and the control plots were similar. It will be noted that four spray applications were given just before the peak response was reached but such applications failed to prevent the drop in yield. In clone D, which gave the best response to treatment, the response increased with increasing crop harvested as will be seen from the monthly crop distribution represented graphically in Fig. 3. The percentage increase in crop resulting from gibberellic acid applications were of the order of 10 to 15% for clones B and C and 30% for clone D, although higher responses of 50 to 75% were obtained during the first month.

In experiment 2, the crops harvested were lower and the response to gibberellic acid + 4% urea was small. All clones showed a small peak response at two months which was of the order of 10 to 15% after which the yields declined except for clone D. In clone D, after the initial response at two months there was hardly any response till the seventh month, when small increases were obtained. This increased response appeared to coincide with increased crop due to sufficient rain. The cumulative yield at the end of twelve months was still higher for the treatment.

#### *Number of shoots*

The response to gibberellic acid or to gibberellic acid + 4% urea in terms of shoot numbers is represented graphically in Fig. 4 on the same basis as for shoot weights. It will be noted that the response is closely similar to that for shoot weights for the four clones in both experiments. The response was again related to the monthly distribution of shoot numbers which was associated with the rainfall distribution (Fig.3).

#### *Weight per 100 shoots*

At the concentration used in this study no differences were noted in regard to the size of shoots. Results from other experiments (unpublished) showed that higher concentrations (200 ppm or more) applied repeatedly (4 or 5 times at weekly intervals) reduced the size of flush and damaged the terminal buds thereby restricting growth. Buds which are entering the dormancy phase or those which have recently become dormant cannot be made to continue growth and repeated applications of high concentrations of gibberellic acid reduced size and damaged the terminal buds.

#### *Percentage dry matter*

Percentage dry matter did not appear to be affected by gibberellic acid in the present study. Mature dormant shoots and actively-growing shoots are known to differ in their percentage dry matter content, the former having a higher value. As crop shoots harvested are actively-growing shoots or shoots which have recently become dormant and are still tender, it appears unlikely that gibberellic acid, which normally induces succulent growth, can appreciably alter the percentage dry matter content of harvested shoots.

#### *Percentage active shoots*

The percentage active shoots determined at successive harvests also did not show any significant variation that could be due to gibberellic acid treatment. This is conceivable in view of the fact that frequent harvesting results in a strong stimulus for the growth of secondary and higher order shoots. Bushes which are harvested regularly, produce shoots which become dormant on average after producing two to five leaves although clonal differences do exist.

### DISCUSSION

As the yield of tea is composed entirely of the tender vegetative growth, the rate of growth of shoots is obviously of great importance in relation to the crop that can be harvested at any given time. Clones are known to differ in this respect and cultural as well as climatic factors have been shown to affect shoot growth, thereby affecting crop (Portsmouth 1957a, b, c; Portsmouth and Rajiah 1957).

The monthly dry matter yields of the four clones are given in Table 1 for the two experiments. It will be seen that the order of merit of the clones is C, B, D and A. It must be pointed out that clone D was until recently, considered one of the

TABLE 1 — *Monthly crop distribution for clones from the control plots*

EXPERIMENT 1

Clones	Months	Crop (g dry weight/12 bushes)											
		1	2	3	4	5	6	7	8	9	10	11	12
A		187.1	193.1	219.5	159.7	239.0	239.0	177.7	267.6	289.9	—	—	—
B		219.8	234.5	291.4	277.0	388.5	445.3	382.2	476.6	398.7	—	—	—
C		358.6	381.0	449.7	381.4	491.4	441.1	381.1	471.5	500.8	—	—	—
D		119.5	145.0	222.9	213.1	299.9	348.3	272.8	416.7	366.2	—	—	—

EXPERIMENT 2

A	194.0	203.4	134.7	43.7	28.5	196.8	58.4	91.7	140.3	164.7	186.1	188.6
B	295.6	341.8	152.1	40.0	40.4	351.1	103.4	237.4	319.8	271.2	292.2	385.8
C	390.5	397.6	280.0	99.8	56.8	367.1	184.2	226.3	352.4	385.7	399.9	462.2
D	315.1	232.8	92.2	28.6	43.5	248.7	78.4	163.8	195.1	194.8	185.7	310.4

TABLE 2 — *Monthly distribution of shoot numbers for clones from the control plots*

EXPERIMENT 1		Shoot numbers per 12 bushes $\times 10^{-3}$											
Clones	Months	1	2	3	4	5	6	7	8	9	10	11	12
A	---	---	---	---	1.83	2.65	2.40	2.00	3.08	2.50	---	---	---
B	---	---	---	---	2.54	3.43	3.97	2.95	4.10	3.46	---	---	---
C	---	---	---	---	3.43	4.54	4.13	3.48	4.62	3.78	---	---	---
D	---	---	---	---	2.30	2.79	3.14	2.86	3.74	3.65	---	---	---
EXPERIMENT 2													
A	2.14	2.05	1.63	0.43	0.50	2.31	0.64	0.89	1.32	1.41	1.71	1.72	
B	2.84	3.17	1.69	0.58	1.14	3.25	1.16	2.24	2.53	2.09	2.15	3.02	
C	3.59	3.47	2.55	0.93	1.78	3.38	1.61	1.95	2.37	2.82	3.02	3.41	
D	3.03	2.20	1.07	0.40	0.89	2.56	0.91	1.76	1.84	1.65	1.57	2.80	

most popular high yielding clones and was planted very extensively. It was also used as a reference clone in clonal-testing experiments. It is known to be susceptible to eelworm (*Pratylenchus loosi* Loof) which is a problem at this elevation and also to drought conditions, amongst other shortcomings. Under satisfactory soil and climatic conditions the clone is still a good yielder.

It will be seen from Table 1 that clones C and B consistently yielded more than clones D and A in both experiments. The differences in yields were largely due to differences in the numbers of shoots harvested (Table 2). Clones C and B also had bigger shoots with a higher percentage of active shoots in the harvested crop and relatively low percentage dry matter in comparison to clones D and A (Figs 1 and 2).

Of the climatic factors rainfall, sunshine and temperature, only rainfall and sunshine varied sufficiently to be of importance in yield variations. Temperature variations in both experiments were small and was, therefore, considered to be less important. Rainfall and sunshine appeared to be inversely related. Variations in the yield of clones were found to be closely related to rainfall which was considered to be the dominant factor (Table 1 and Fig. 3). Portsmouth (1957b) showed that rainfall 2½ months before harvest determined the weight of shoots harvested. This received support in the present study in experiment 2. The lowest rainfall recorded was during the first four months but the crop harvested during the first two months was high due to previous rainfall and low yields due to low rainfall were obtained for the third, fourth and fifth months (Table 1 and Fig. 3). Changes in yield were due to changes in the numbers of shoots harvested. Low rainfall reduced crop by reducing the numbers of shoots harvested, which were smaller in size with a higher percentage of dormant shoots (Table 2; Figs 1 and 2). Their percentage dry matter was, however, slightly higher. Except during a drought, the numbers of shoots harvested were thought to be independent of climatic conditions and were determined by an innate periodicity (Portsmouth 1957b). Figs 3 and 4 give the monthly distribution of yield and numbers of shoots respectively for clone D.

Gibberellic acid or gibberellic acid + 4% urea was shown to influence the harvested crop and clones were shown to differ in their response to treatments. While clones B, C and D responded to varying extents, clone A did not show any response. Gibberellic acid increased dry matter yields showing peak response at six months after which the yields declined rapidly. In clone D, the cumulative yields were still higher at the end of nine months in experiment 1. Yield increases were of the order of 10 to 15% in clone B and C and 30% in clone D although higher responses of 50 to 75% were obtained during the first month in clone D. In experiment 2, where gibberellic acid + 4% urea was used, the results were somewhat similar except that the magnitude of the response was smaller. Again clone D gave the best response over a long period compared with B and C, the increases in yield being around 10 to 15%. Cumulative yields at the end of a year were still higher for the treatment in clone D. Increases in green leaf yields due to gibberellic acid have been obtained for tea in north-east India (Anon 1971), in the Soviet Union (Ali-Zade 1963) and for pastures (Wittwer and Bukovac 1957; Arnold, Bennet and Williams 1967) which is also a perennial where vegetative growth comprises the yield. Yield increases due to gibberellic acid have generally been followed by a yield decline compared with the controls. In India it was found that the stimulus to three sprays to 100 ppm gibberellic acid given at fortnightly intervals in January/February, produced more flush up to May only. It was also shown that although gibberellic acid increased cumulative yields for about a year, monthly yields started to decline from August (Anon 1971). In the Soviet Union, Ali-Zade (1963) obtained maximum effects in the first 45 to 50 days after which the response declined. He obtained increases in green leaf yield of 10 to 19% in the summer with 100 ppm gibberellic acid and 49 to 75% in the autumn with 200 ppm solution of gibberellic acid.

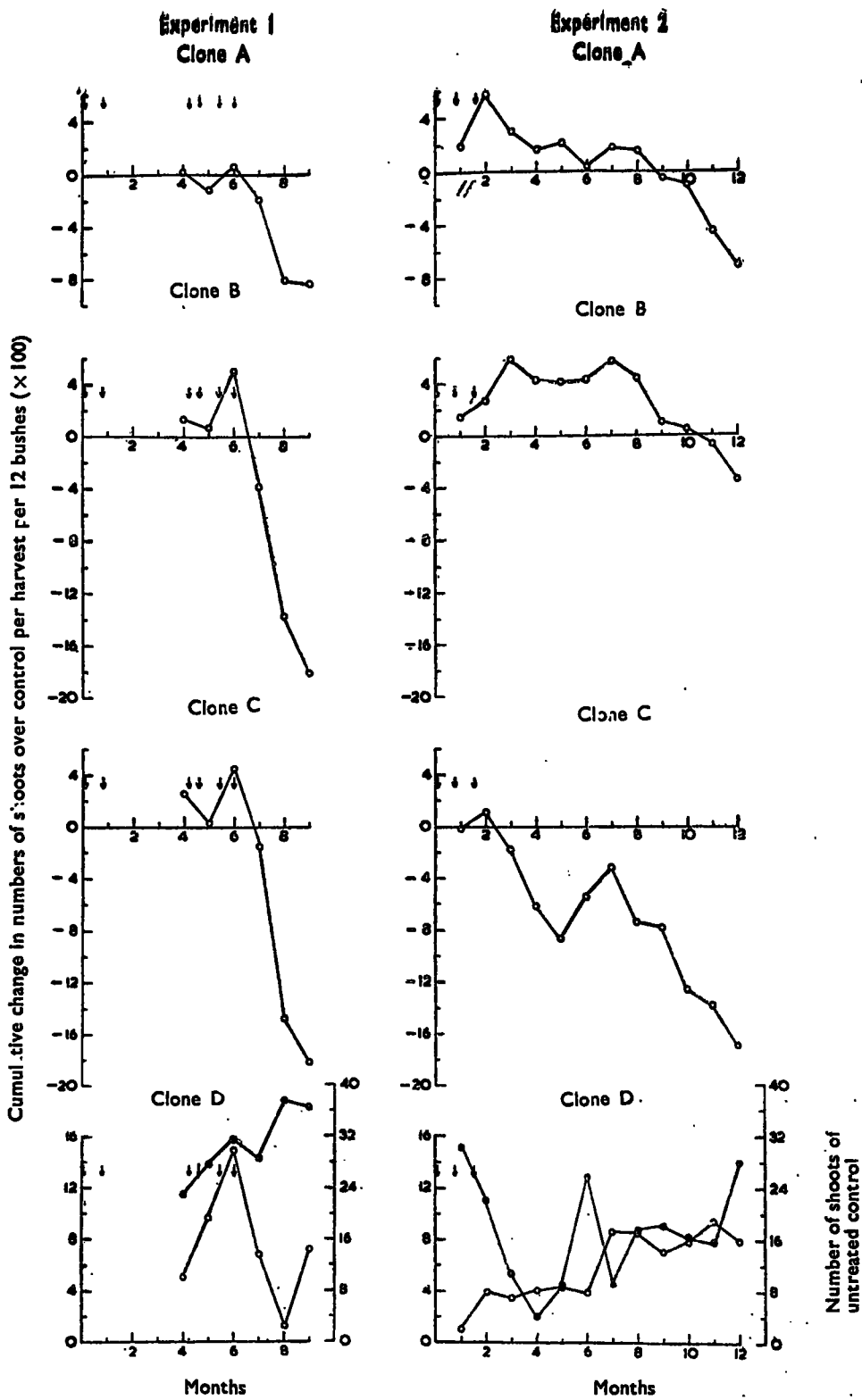


FIG. 4—Change in shoot numbers of tea clones in relation to gibberellic acid application. Vertical arrows indicate time of treatment.

Yield increases due to gibberellic acid were shown to be related to climate. Factors favouring increased crop resulted in a greater yield response (Fig.3). It will be noted from the figure, where monthly yields have been given for clone D, that the response to treatment was closely related to the crop harvested, increasing responses being obtained with increasing crop harvested from the control plots. In experiment 2, when low yields were obtained, due to low rainfall, the response was negligible and only when the yields of the control plots increased, was an enhanced response obtained.

Yield restrictions can be brought about by short days as seen for tea in north-east India (Barua 1969), by low temperatures as seen for pastures (Wittwer and Bukovac 1957; Arnold *et al.* 1967), by low soil moisture resulting from low rainfall as seen in experiment 2 of the present study and a host of other factors. Gibberellic acid was shown to be effective in increasing growth and yield of tea and the yield of pastures. Arnold *et al.* (1967) showed that in *Phalaris tuberosa*, *Trifolium subterraneum* pastures, the response to gibberellic acid increased with decreased growth rate of control pastures due to low temperature but we have noted an increased response in tea with increased yield obtained from the control plots. The response was small when soil moisture was inadequate to permit satisfactory growth. It appears that while restricted growth due to low temperatures and short days can be readily overcome by treatment with gibberellic acid, that due to insufficient soil moisture is rather more difficult to overcome.

Increase or decrease in yield in both experiments was shown to be due to corresponding changes in shoot numbers and increasing response to gibberellic acid in terms of shoot numbers was obtained when the numbers of shoots harvested were high (Fig.4) as seen for shoot weights (Fig.3). The percentage active shoots, dry matter contents and size of shoots did not appear to be affected by treatment, at the concentration used. In India, gibberellic acid sprayed three times at 100 ppm was found to reduce the size of the harvested shoots (Anon 1971). In Indonesia, a concentration of 50 ppm was found to damage the buds. We have noted from other studies (unpublished) that gibberellic acid will reduce the size of shoots and damage the terminal buds if high concentrations are sprayed repeatedly at short intervals. Gibberellic acid reduced dormancy and increased the rate of growth of shoots in young tea plants. Although the number of active phases were increased by some hormones including gibberellic acid, the duration of growth appeared to be unaffected (Kulasegaram 1969; Kulasegaram and Kathiravetpillai 1972). Shoots of mature bushes which are being harvested produce about two to five leaves before entering the dormant phase. As gibberellic acid does not appreciably increase the number of leaves, the growth cycle is only completed earlier but growth is not prolonged (Kulasegaram and Kathiravetpillai 1972). The increased shoot numbers obtained at the early harvests in this study may have been due to more shoots reaching the stage ready for harvesting. Portsmouth and Rajiah (1957) showed that in the particular clone studied, the average time taken for a crop shoot to be developed was 81 days. It is thought that gibberellic acid increases the numbers of shoots during the early stages by reducing this period. It should be pointed out that in experiment 1 although four additional sprays were given, the increased yields could not be maintained and the yields declined rapidly. Other experiments showed that gibberellic acid cannot prevent dormancy. It is also not capable of inducing the growth of

recently formed dormant buds. It, however, effectively breaks dormancy in mature dormant buds and increases their growth rate by increasing the rate of unfolding of the leaf primordia that are already present in the bud. It has not appreciably increased the number of leaves in our studies with young plants (unpublished) although increases have been reported in freely-growing shoots in mature bushes (Ali-Zade 1963). He used a 200 ppm solution and sprayed the bushes three times and determined the leaf counts in the shoots in just under a month from treatment. Since the increase in number of leaves due to treatment has not been related to the complete growth cycle, it is possible that the increases noted at that time were due to a faster rate of unfolding of the leaves. Shoots of unplucked bushes often produce a larger number of leaves in each cycle compared with shoots of bushes being harvested. For prolonged growth, the rate of leaf primordia initiation should exceed the rate of unfolding of the leaf primordia. As treatment with gibberellic acid increases the latter only appreciably, growth is completed early when all the primordia have grown out. Growth resumes only after a period of rest when sufficient numbers of leaf primordia have been formed which probably takes place during the dormant phase. The advantages of using gibberellic acid, if any, in tea appear to be only in early increased crop as seen for pastures. For prolonging the growth in tea shoots, it appears that the rate of leaf primordia initiation has also to be increased. For this, probably other factors are involved and cytokinins may be one of the major factors. It is likely that the levels of such factors build up during the dormant phase, aiding leaf primordia initiation and later bud-break as well, since cytokinins have also been shown to break dormant buds (Kulasegaram 1969) although benzyl adenine at the concentration used did not have any effect on bud-break (Kulasegaram and Kathiravetpillai 1972). Investigations are presently being undertaken to study the above aspects of shoot growth.

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