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EFFECT OF SOME GROWTH REGULATORS ON GROWTH AND APICAL DOMINANCE OF YOUNG TEA (*CAMELLIA SINENSIS* (*L.*) O. KUNTZE) II - GROWTH RESPONSES TO GA_3 AND CCC

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The growth responses of young tea plants of clones TRI 2025 and DT 1 to GA_3 (200 ppm) and CCC (3000 and 6000 ppm) applied alone and in combination were studied. In both clones GA_3 caused more plants to become active earlier than did CCC. Repeating the sprays caused similar activity in TRI 2025 but less so in DT 1. In both clones at the first assessment GA_3 and the combinations increased the number of active phases while CCC (6000 ppm) increased the duration of growth. At the second assessment, the hormone treatments increased the duration of active phases in TRI 2025, while in DT 1, CCC at 6000 ppm increased the number, GA_3 singly and in combination increased the duration of growth.

GA_3 alone and in combination increased plant height over 6 weeks after which both the combinations reversed the initial effects of GA_3 by reducing the height. CCC at 3000 and 6000 ppm reduced plant height. While GA_3 increased internode length, CCC reduced it. GA_3 alone and in combination increased leaf production over 4 weeks while both concentrations of CCC applied singly decreased leaf number. At both assessments GA_3 produced fewer side shoots while CCC produced more. At the first assessment GA_3 increased leaf area and dry weight of stems while CCC (6000 ppm) decreased the dry weight of stems. At the second assessment the combinations reduced the dry weight of leaves while GA_3 in combination with CCC (6000 ppm) decreased the dry weight of plant. In this study GA_3 increased while CCC reduced apical dominance.

INTRODUCTION

The possible involvement of some growth regulators in the correlative inhibition of lateral bud growth of young tea plants has been shown (Kathiravetpillai and Kulasegaram, 1979a). The gibberellins as a class of growth regulators also influence a variety of aspects of growth and development in plants. Their involvement in apical dominance appears to be one of interacting with auxin from the apical bud (Phillips, 1969) enhancing the auxin-directed transport phenomenon. Thus gibberellin treatment of intact plants often causes an increase in apical dominance.

The growth-regulating compound (2-chloroethyl) trimethylammonium chloride (CCC) has an effect in many respects opposite to that of the gibberellins and there is evidence that their actions in altering the growth of plants are often mutually antagonistic (Cathey, 1964).

In this study an attempt has been made to find out how growth of the young tea plant is modified by gibberellic acid (GA_3) or CCC, applied alone or in combination.

MATERIALS AND METHODS

Plants of clones TRI 2025 and DT 1, 16 weeks of age were used. The plants were grown in loamy type of soil with a pH of 4.65. Its nutrient status was organic matter 4.72%, nitrogen 0.17%, phosphorus 4.16 ppm and exchangeable cations (meq. %) potassium 0.34, calcium 0.67 and aluminium 2.95. The following treatments were applied in all factorial combinations:

1. Control — distilled water
2. G1 (GA_3 at 200 ppm)
3. C1 (CCC at 3000 ppm)
4. C2 (CCC at 6000 ppm)
5. C1G1 (CCC at 3000 ppm and GA_3 at 200 ppm)
6. C2G1 (CCC at 6000 ppm and GA_3 at 200 ppm)

GA_3 was applied at 200 ppm as previous work has indicated a response to this concentration (Kulasegaram and Kathiravetpillai, 1972) while preliminary experiments indicated a response to CCC from above 2000 ppm (Kathiravetpillai and Kulasegaram, 1979 b). The layout was a randomized split plot design, the 6 treatment combinations being split on each clone. There were 6 paired rows in each replicate, each such row being replicated 5 times. The paired rows provided sufficient plants for 2 assessments — a total of 1200 plants of both clones.

Five foliar sprays were given at weekly intervals, each plant receiving 3 ml of spray solution for the first 4 sprays and as the plants grew this was increased to 6 ml. Where treatment combinations were given the CCC was sprayed first and the GA_3 sprayed after an interval of 2 hours. The young leaves of plants treated with GA_3 alone and in combination developed a pink colour indicative of N deficiency about 10 weeks from commencement of first application. All plants were sprayed with a 2 per cent solution of urea.

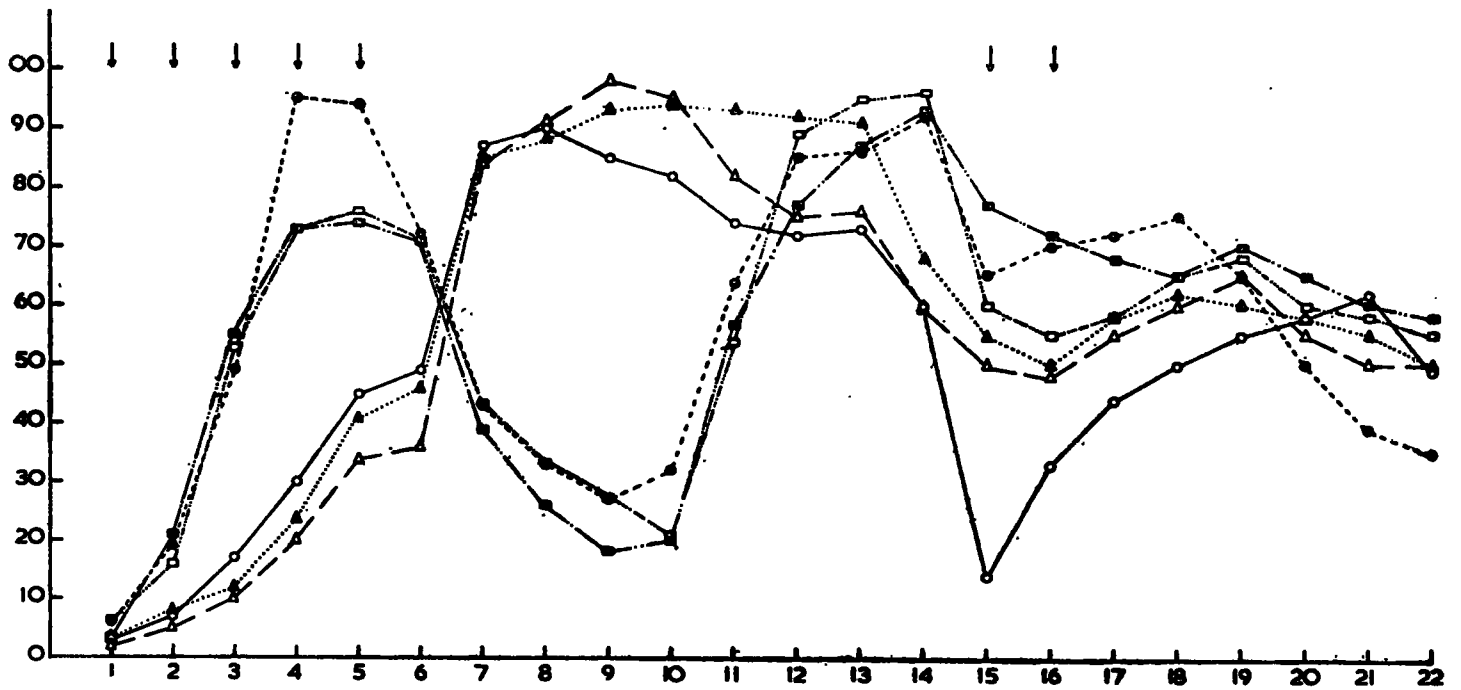
Records of the condition of the terminal bud of individual plants were made by classifying the bud as active if the young leaves were separate and unfolded from the apex and as dormant if the primordial leaves were enclosed by the rudimentary 'scale leaves'' The term active bud thus refers to a visibly growing condition when extension growth takes place. The active phase refers to the duration of this condition.

The length of internodes of the new stem growth was measured at 3, 6 and 10 weeks after commencement of first application. The new growth was that seen above the last dormant cycle as indicated by scale leaf scars. The first harvest was done on half the number of plants, 14 weeks from first application. The remaining plants received two more sprays at a week's interval apart while the fertilizer level was increased from 0.56 to 1.12 g per plant. The final assessment was done 8 weeks after the first.

RESULTS

Activity of terminal buds

In both clones the GA_3 treatment caused more plants to remain in the active condition, the peaks of activity being reached comparatively early (Fig. 1). In clone TRI 2025 there was one peak of activity which was reached at the 6th week after the first application, while in clone DT 1 there were 2 peaks of activity, the first being reached at the 4th week after first application. In both clones the 2 concentrations of CCC showed peaks of activity similar in magnitude to that shown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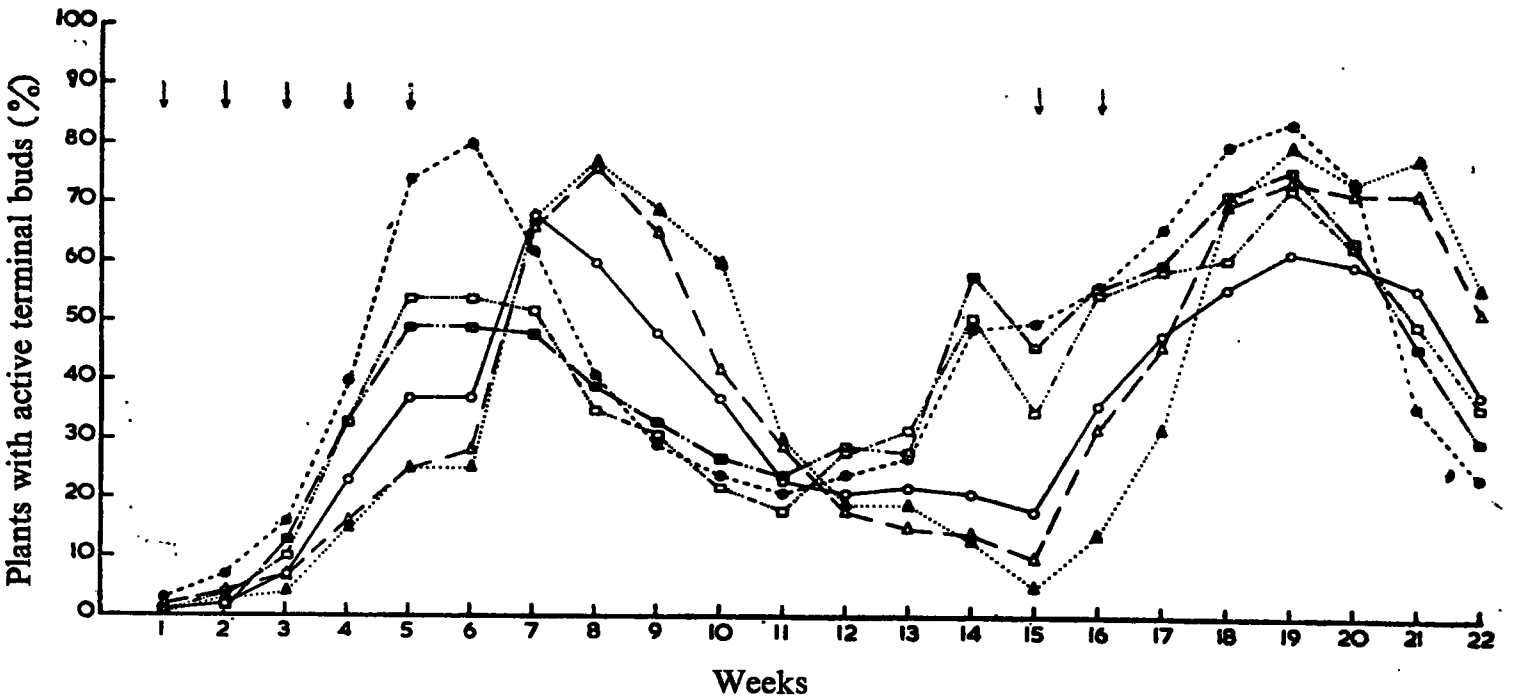

Fig. 1.—Activity of terminal buds of plants of clones DT 1 (top and TRI 2025 (bottom) given foliar applications of GA_3 and CCC. ○=*Control*; ●=*G1*; ▲=*C1*; ▲*C2*; □=*C1G1*; ■=*C2G2*. Arrows indicate time of application of treatments.

by GA_3, the peak of activity being reached 8 weeks (TRI 2025) and 9 weeks (DT 1) after first spray. Repeating the sprays caused peaks of activity similar to that obtained by the first set of sprays in clone TRI 2025 and comparatively low peaks in clone DT 1, the plants remaining active over a longer period. In general, in both clones the combinations produced minor peaks of activity.

Number and duration of active phases

At the first assessment GA_3 increased the number of active phases in both clones but the duration and percentage duration of growth was markedly increased only in TRI 2025 (Table 1). In both clones CCC at 6000 ppm increased the duration and percentage duration of growth while it reduced the number of active phases. In both clones the combinations increased the number of active phases. While in TRI 2025 both combinations increased the duration and percentage duration of growth, in DT 1 only GA_3 in combination with the lower concentration of CCC increased the duration and percentage duration of growth.

At the second assessment, in TRI 2025 none of the growth regulator treatments markedly affected the number but increased the duration of active phases. In DT 1 only CCC at 6000 ppm increased the number of active phases while in both clones GA_3 applied singly and in combination increased the duration of growth.

TABLE 1 — *Effect of GA_3, and CCC on the mean number and duration of active phases per plant*

Treatment	*Active phases per plant*					
	1st assessment (14 weeks)			*2nd assessment (8 weeks)*		
	Number	*Duration (weeks)*	*% Duration*	*Number*	*Duration (weeks)*	*% Duration*
Clone TRI 2025						
Control	1.18	4.08±0.12	29	1.10	4.08±0.22	51
G1	1.49	4.55±0.13	33	1.18	4.74±0.23	59
C1	1.08	4.08±0.14	29	1.04	4·36±0.24	55
C2	1.08	4.30±0.11	31	1.06	4.22±0.17	53
G1C1	1.44	4.26±0.13	30	1.10	4.74±0.23	59
G1C2	1.50	4.22±0.13	30	1.12	4.38±0.17	55
Clone DT 1						
Control	1.14	4.64±0.25	33	1.40	4.80±0.39	60
G1	1.71	4.60±0.19	33	1.08	5.20±0.30	65
C1	1.07	4.63±0.23	33	1.10	4.67±0.30	58
C2	1.10	5.43±0.24	39	1.56	4.79±0.32	60
G1C1	1.78	4.95±0.20	35	1.10	5.31±0.30	66
G1C2	1.83	4.52±0.53	32	1.10	5.04±0.34	63

Increase in height

GA_3 applied alone and in combination increased plant height a fortnight following first application which remained apparent for a period of 6 weeks (Fig. 2). Subsequently, both concentrations of CCC in combination with GA_3 reversed the initial effects of GA_3 by reducing plant height from the 8th week, the effect lasting for 6 weeks. CCC at 3000 ppm reduced height 4 weeks after first application, the effect lasting for 4 weeks while CCC at 6000 ppm reduced plant height 6 weeks after first application, the effect lasting for 2 weeks.

At the second fortnight after the treatments were repeated only the higher concentration of CCC reduced height, the effect lasting for 2 weeks.

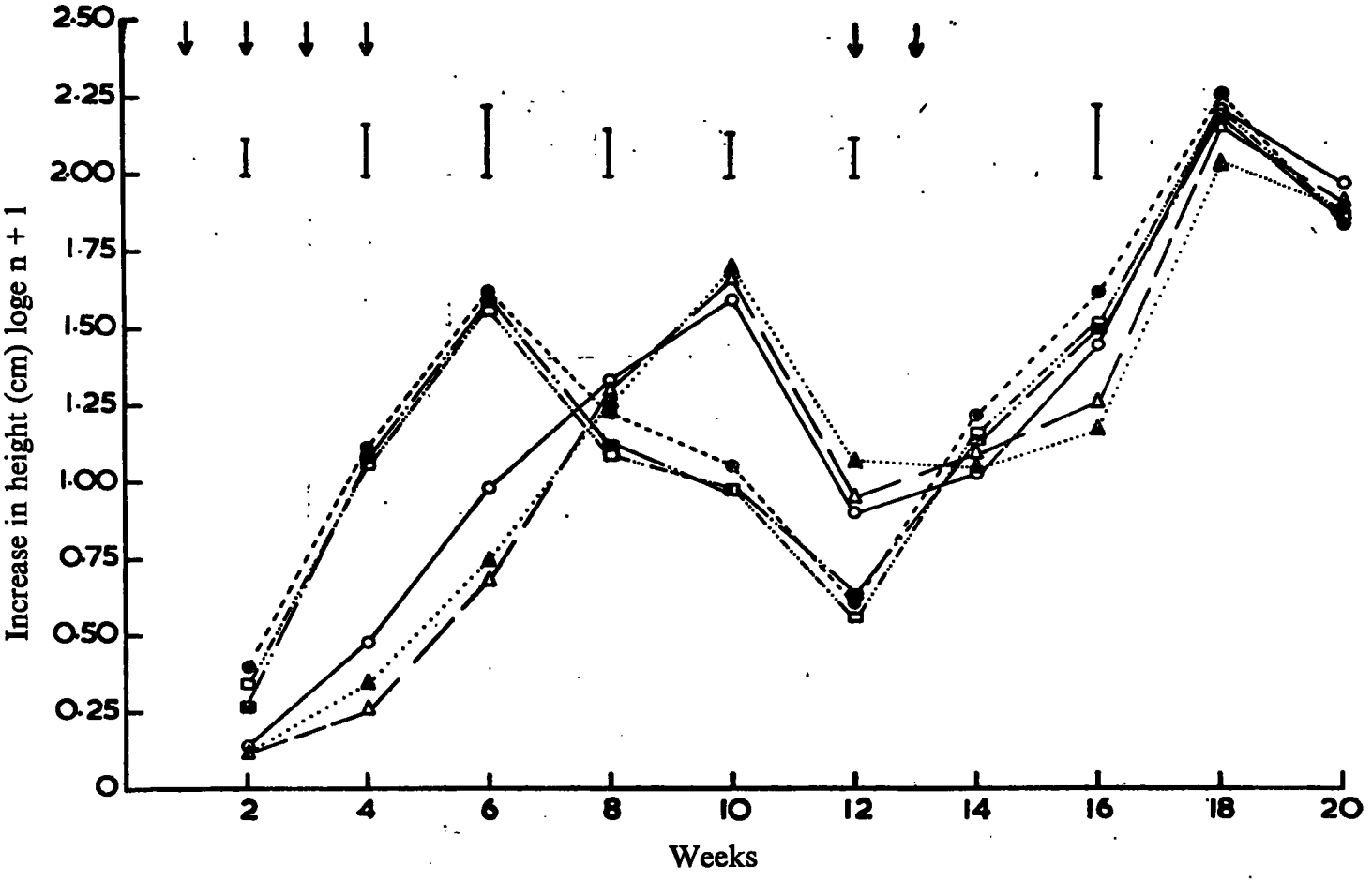

Fig. 2.—Effect of foliar applications of GA_3 and CCC on increase in height averaged over two clones. ○=*Control*; ●=*G1*; =*C1*; ▲=*C2*; □=*C1G1*; ■=*C2G1*. Vertical lines =L.S.D. for P=0.05. Arrows indicate time of application of treatments.

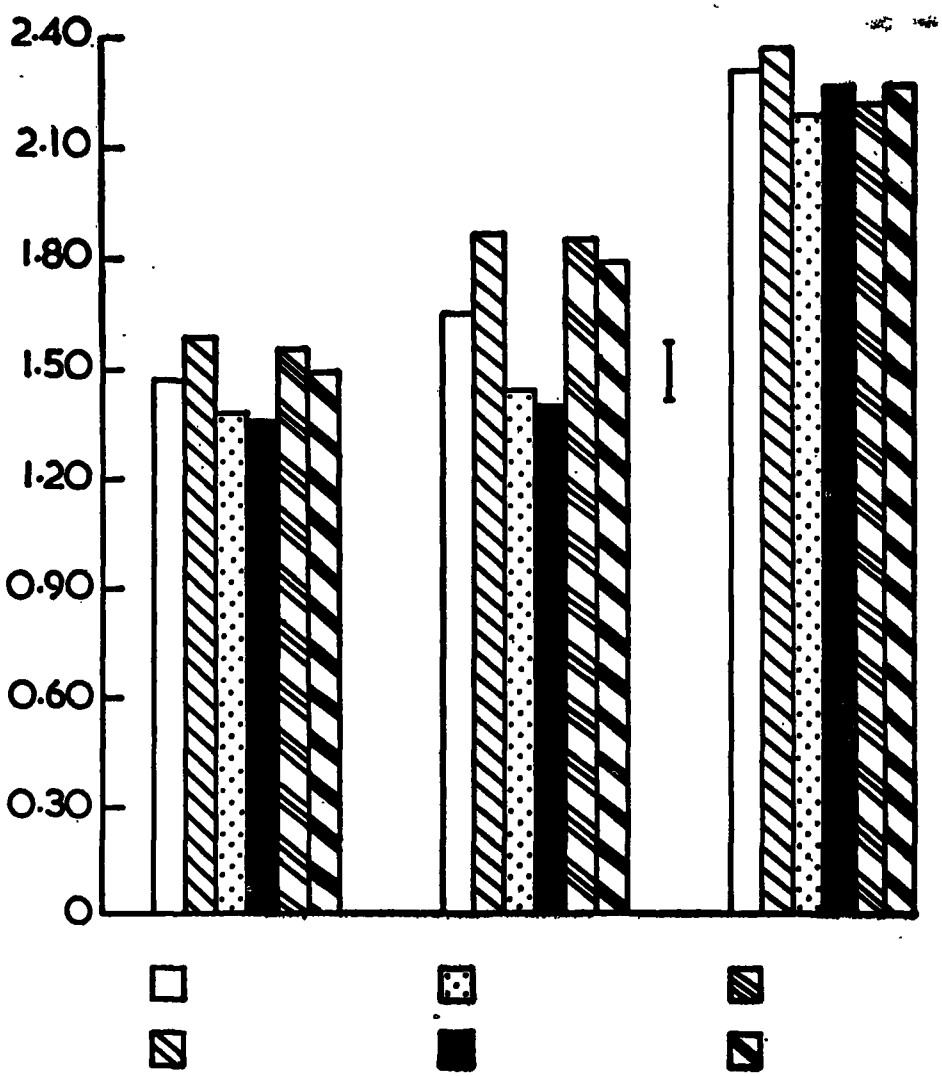

Fig. 3— Effect of foliar applications of GA_3 and CCC on mean length of internodes measured at 3 weeks (left), 6 weeks (middle) and 10 weeks (right) from first spray application (mean of 2 clones). □=Control: ▨=GA_3; ▩=C1; ■=C2; ▨=C1G1; ▨= C2G1. Vertical lines — L.S.D. for P=0.05.

Internode length of new stem growth

Six weeks after the first spray GA_3 applied alone and in combination with the lower concentration of CCC increased internode length while both concentrations of CCC when applied alone reduced it (Fig. 3).

Leaf production on the main axis

The effect of the initial sprays showed that GA_3 applied alone and in combination increased leaf production 4 weeks after the first spray, the effect lasting for 4 weeks while both concentrations of CCC when applied singly reduced leaf production (Table 2). Repeating the sprays did not affect leaf production.

TABLE 2 — *Effect of GA_3 and CCC on leaf production per month averaged over the two clones. (Figures in parentheses indicate back-transformed numbers).* $\sqrt{n+1}$

Treatments	*Month* 1	2	3	4*	5
Control	1.34(0.80)	1.86(2.46)	1.71(1.92)	2.50(5.25)	2.22(3.93)
G1	1.70(1.89)	1.66(1.76)	1.79(2.20)	2.47(5.10)	2.38(4.66)
C1	1.18(0.39)	1.89(2.57)	1.76(2.10)	2.55(5.50)	2.32(4.38)
C2	1.20(0.44)	1.86(2.46)	1.88(2.53)	2.35(4.52)	2.18(3.75)
C1G1	1.61(1.59)	1.62(1.62)	1.77(2.13)	2.44(4.95)	2.30(4.29)
C2G1	1.53(1.34)	1.67(1.79)	1.80(2.24)	2.46(5.05)	2.34(4.48)
LSD (P=0.05)	0.14	0.15	NS	NS	NS

*Treatments were repeated at the end of 3 months from first spray application.

Effect of treatments on growth and dry matter production and distribution

At both assessments GA_3 when applied alone and in combination produced fewer side shoots (Tables 3 and 4). Both concentrations of CCC produced more side shoots at the first assessment while when the sprays were repeated only the lower concentration increased them. GA_3 applied alone and in combination as well as the lower concentration of CCC produced smaller side shoots. When the sprays were repeated the combinations produced smaller side shoots. At the first assessment GA_3 increased the leaf area and dry weight of stems while the higher concentration of CCC decreased the dry weight of stems. At the second assessment the combinations reduced the dry weight of leaves while GA_3 in combination with the higher concentration of CCC decreased the dry weight of the plant.

TABLE 3 — *Effect of GA_3 and dry matter production at the 1st assessment averaged over two clones (Back-transformed numbers are given in parentheses) (means of 200 plants).*

Treatments	*Side shoots*		*Total leaf area*	*Dry weight (g)*			
	Number $\sqrt{n+1}$	*Length (cm)*	*(cm²)*	*Leaves*	*Stems*	*Roots*	*Plant*
Contol	1.38(0.90)	4.45	155.91	1.89	1.10	1.11	4.10
G1	1.15(0.32)	0.90	177.11	1.93	1.24	1.33	4.50
C1	1.46(1.13)	3.51	152.37	1.81	1.01	1.11	3.93
C2	1.47(1.16)	3.90	149.59	1.80	0.98	1.12	3.90
C1G1	1.16(0.35)	1.48	169.68	1.89	1.19	1.26	4.34
C2G1	1.10(0.21)	0.36	167.33	1.70	1.12	1.05	3.87
LSD (P=0.05)	0.08	0.84	20.62	NS	0.11	0.06	0.44

TABLE 4—*Effect of GA_3 and CCC on growth and dry matter production at the 2nd assessment averaged over two clones (Back-transformed numbers are given in parentheses) (means of 100 plants)*

Treatments	Side shoots		No. of leaves on side shoots	Total leaf area	Dry weight (g)			
	Number $\sqrt{n+1}$	Length (cm)	$\sqrt{n}$	(cm^2)	Leaves	Stems	Roots	Plant
Control	2.02(3.08)	19.36	4.37(19.10)	181.39	3.91	2.45	1.66	8.02
G1	1.69(1.86)	17.55	3.45(11.90)	179.54	3.76	2.58	1.58	7.92
C1	2.17(3.71)	21.71	4.71(22.18)	180.62	3.94	2.31	1.75	1.80
C2	2.08(3.33)	18.64	4.64(21.53)	178.54	3.75	2.39	1.69	7.83
C1G1	1.61(1.59)	13.86	3.15(9.92)	179.35	3.27	2.44	1.61	7.32
C2G1	1.69(1.86)	13.22	3.33(11.09)	176.19	2.77	2.04	1.53	6.34
LSD (P=0.05)	0.13	4.05	0.42	NS	0.63	NS	NS	1.05

DISCUSSION

When GA_3 and CCC were sprayed alone and in combination the principal effect of GA_3 was to hasten the breaking of dormancy in both clones TRI 2025 and DT 1 resulting in more plants resuming active growth comparatively early (Fig. 1). The growth-promoting effect of gibberellin on tea shoots was reported by Torri and Nakagawa (1960). Kulasegaram (1969) showed that GA_3 and GA_3 + IAA at 200 ppm each caused 100% of dormant tea shoots to grow in 2 weeks while Kulasegaram and Kathiravetpillai (1972) using young tea plants observed responses similar to that seen in this study.

It was noted that repeating the sprays caused peaks of activity which lasted over a longer duration. This may be due to the enhanced N applied as a 2% solution of urea when the young leaves of the GA_3 treated plants showed a general paling of colour. Enhanced effects were noted when mineral nutrient sprays were combined with GA_3 under favourable conditions (Bora and Selman, 1969).

In both clones the peaks of activity due to the combined treatments clearly showed the effect of GA_3 as the appearance of the peaks corresponded to the period when GA_3 alone was effective. At the first assessment, in both clones the effect of the combinations in increasing the number of active phases was also due to GA_3 as the CCC treatments when applied alone reduced the number of active phases (Table 1).

GA_3 alone and in combination caused stem elongation (Fig. 2). The stimulatory effect of GA_3 on stem elongation is well documented (Stuart and Cathey, 1961). Ahmed, Chakraborty and Hasan (1965) showed that low concentrations of GA_3 increased the height of tea seedlings. Kulasegaram (1969) found that higher concentrations of GA_3 (800 ppm) promoted shoot growth in clone TRI 2025 while Kulasegaram and Kathiravetpillai (1972) showed that GA_3 and GA_3 + BA increased the height of young tea plants.

The increase in height caused by GA_3 was largely the result of internode elongation (Fig. 3). The response of the stem is usually due to an increased elongation of internodes and generally there is no increase in number of internodes formed (Wareing and Phillips, 1970). Both concentrations of CCC reduced plant height by reducing the internode length. Marcelle (1966) found that CCC reduced plant height, internodes and node number in 'Tydeman's Early Worcester' young apple trees.

The initial effect of the combinations on height was clearly dominated by GA_3 which, however, was soon reversed by CCC. There is evidence that the actions of gibberellins and growth retardants in altering the growth of plants are mutually antagonistic (Cathey, 1964). Harada and Lang (1965) showed evidence of complete agreement between the effectiveness of CCC in inhibiting growth in higher plants and in inhibiting gibberellin biosynthesis in *Fusarium*. More recently, Robinson and West (1970) showed that CCC inhibits a single reaction in the biosynthetic pathway of gibberellins.

Sachs (1965) has argued persuasively that it is the subapical meristem rather than the apical meristem which is responsible for the gibberellin-induced morphogenetic differences in stem elongation while growth retardants severely inhibit subapical meristematic activity. Gibberellin treatment of intact plants can enhance elongation of existing internode cells and also increase the number of cells present in each internode, principally by an increase in mitoses in the subapical region (Wareing and Phillips 1970).

It is to be noted that at the first assessment GA_3 increased the leaf area per plant (Table 3). Though GA_3 increased leaf number the differences disappeared at the time of the first assessment. Hence the increase in leaf area is not a consequence of increased leaf number but is possibly due to larger leaf size.

Both concentrations of CCC applied alone reduced apical dominance and produced more side shoots, while GA_3 and the combinations showed fewer side shoots. Marcelle (1966) found that 15 sprays of CCC only weakly reduced apical dominance. There is good evidence that application of gibberellins leads to increased endogenous auxin levels (see Phillips, 1969) by stimulating some step in their biosynthetic pathway. Since young leaves are a source of gibberellins, any inhibition of the gibberellin produced by the young leaves by the CCC sprays used in this study would reduce the output of auxin-induced transport of metabolites to the apex which could be expected to result in at least a partial loss of apical dominance. Moreover, the inhibition of gibberellin synthesis would be expected to result in shorter internodes. There is a hard core of information showing that gibberellin treatment of intact plants often causes an increase in apical dominance (see Phillips, 1969). In general it appears, that exogenous gibberellin enhances the growth of vigorously growing shoots, but with a concomitant increase of correlative inhibition.

There are conflicting reports on the influence of GA_3 on the photosynthetic activity of leaves and on dry matter production. Haber and Tolbert (1957) found that GA_3 did not affect the assimilation rate of detached leaves. Alwim (1960) using intact bean plants found that GA_3 increased the rate of photosynthesis as a result of accelerating the mobilisation of photosynthates from the leaves to the stem. In this study, there was no evidence of translocation of photosynthates from leaves to stems though the rate of photosynthesis may have been increased on account of increased leaf area. However, among the growth regulator treatments, GA_3 applied alone and in combination increased the dry weight of stems (Table 3).

It is to be noted that total dry matter was not affected by GA_3. Kulasegaram and Kathiravetpillai (1947) showed that GA_3 (50 ppm) did not affect the dry matter content of shoots of bushes in plucking. Other studies (unpublished) indicated that high concentrations of GA_3 applied repeatedly at short intervals reduced the size of the growing shoot and damaged the terminal buds.

In this study, a general yellowing was seen in the young leaves of GA_3 treated plants. This is commonly noticed after GA_3 sprays. Such symptoms have been

considered to be associated with moisture stress and temporary mineral nutrient deficiencies, the concomitants of an unfavourable shoot/root ratio, particularly when soil moisture and fertility levels are marginal (Wittwer and Bukovac, 1958).

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