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A QUANTITATIVE STUDY OF THE EARLY GROWTH OF CUTTINGS OF TEA (*CAMELLIA SINENSIS* (L.) O. KUNTZE)

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A quantitative study of the changes in the early growth of two clones, TRI 2025 and DT 1, was made during successive 4-week periods commencing from the 10th week after planting and including the first 10 weeks. Clone TRI 2025 showed better growth compared to clone DT 1.

In DT 1, the relative growth rate, R and the net assimilation rate, E were higher than that of TRI 2025 at 0-10 and 18-22 weeks. In TRI 2025, the R and E showed a steep increase at 10-14 weeks which were the highest values for both clones. In general, in both clones the peak value of E corresponded to the period when insolation was high.

In both clones the leaf area index L, increased with time, being always higher in TRI 2025. It is concluded that the greater increments of dry matter in TRI 2025 compared to DT 1 was largely due to its higher leaf area index than to the inconsistent values of R and E.

INTRODUCTION

Quantitative data of the manner in which assimilatory material is distributed among plant parts in the early developmental stages following rooting are remarkably scanty for tree crops. Tea lends itself to studies of early growth and it was felt that a physiological analysis of growth under nursery conditions should be undertaken to obtain information on the pattern of growth from the time of planting of cuttings until they are normally ready for field planting. The pattern of growth of clones differ widely. These differences are commonly seen at an early age. Information about the differences in the rate of increase of the photosynthetic area, accumulation of dry matter and the manner in which photosynthates are apportioned in the different parts of the developing plant would help to better understand the basic differences in the pattern of growth between clones.

The object of this study was to estimate the changes in growth of plants in terms of dry matter, leaf area, moisture content and their distribution in the plant during successive 4-week periods beginning from the 10th week and including the first 10 weeks after planting of cuttings and to correlate these changes as far as possible with environmental conditions.

MATERIALS AND METHODS

Sufficient cuttings of clones TRI 2025 and DT 1 were put out in the nursery such that assessments could be done at 10, 14, 18, 22, 26 and 30 weeks. The layout was a randomized block type with cuttings for each sampling period replicated 6 times. Fresh and dry weight determinations of a uniform batch of 60 cuttings of each clone were taken at the time of planting.

In this study only uniform cuttings with a standard internode length of 3.5 cm were selected. At each assessment the plant was divided into its component parts and fresh and dry weight determinations were made. The leaf area was also measured. The relative growth rate was computed using the formula

$$\frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

where W_1 and W_2 represent dry weights at time t_1 and t_2 respectively (Fisher, 1921). The net assimilation rate, E was calculated using the formula

$$\frac{W_2 - W_1}{t_2 - t_1} \times \frac{2}{L_1 + L_2},$$

where W and L are dry weight and leaf area respectively (Briggs, Kidd and West, 1920).

RESULTS

Plant height and leaf number

The height of plants of clone TRI 2025 was always greater than that of DT 1 (Table 1). Leaf production was greater in DT 1.

TABLE 1 — *Height and leaf number of plants of clones TRI 2025 and DT 1 (Back-transformed numbers are given in parentheses)*

	Weeks					
Height (cm)	*10*	*14*	*18*	*22*	*26*	*30*
TRI 2025	2.54	9.97	14.40	16.96	21.90	25.45
DT 1	2.26	7.45	9.88	16.96	18.73	22.35
L.S.D. (P=0.05)	0.21	0.36	0.85	NS	1.11	NS
Leaf number $\sqrt{n}$						
TRI 2025	1.65 (2.72)	1.99 (3.96)	2.18 (4.75)	3.39 (11.49)	3.45 (11.90)	3.53 (12.46)
DT 1	1.62 (2.62)	2.11 (4.45)	2.30 (5.29)	3.52 (12.39)	3.56 (12.67)	3.92 (15.37)
L.S.D. (P=0.05)	NS	NS	0.07	0.09	NS	0.08

Leaf area

The leaf area of new leaves was consistently greater in TRI 2025 (Table 2). In TRI 2025 the rate of increase in leaf area reached a maximum at 10-14 weeks and in DT 1 at 18-22 weeks (Table 3).

TABLE 2 — *Area of new leaves (cm^2)*

	Weeks					
	10	*14*	*18*	*22*	*26*	*30*
TRI 2025	1.16	15.18	25.33	34.82	45.59	53.91
DT 1	0.70	5.71	11.10	19.14	26.89	34.40
L.S.D. (P=0.05)	0.06	0.09	1.61	3.70	1.52	3.65

TABLE 3 — *Increment of mean new leaf area (cm^2)*

	Weeks					
	0–10	*10–14*	*14–18*	*18–22*	*22–26*	*26–30*
TRI 2025	1.16	14.02	10.15	9.49	10.77	8.32
DT 1	0.70	5.01	5.39	8.04	7.75	7.51
L.S.D. (P=0.05)	0.06	0.09	1.65	NS	2.99	NS

Moisture content

The moisture content in the plants decreased between planting and 1st sampling (Table 4). In both clones the moisture content of the plants exceeded the initial value at 14 weeks.

TABLE 4 — *Moisture content of plants (g)*

	Weeks						
	0	*10*	*14*	*18*	*22*	*26*	*30*
TRI 2025	2.90	2.28	4.36	5.96	5.61	5.87	5.85
DT 1	1.97	1.54	2.52	3.54	3.58	3.68	3.37
L.S.D. (P=0.05)	0.08	0.07	0.07	0.26	0.30	0.24	0.22

The moisture content was greater in plants of TRI 2025. In TRI 2025 there was a greater increase in moisture content at 10-14 weeks while in DT 1 this was at 14-18 weeks. In both clones the moisture content remained fairly constant from the 18th week until the termination of the experiment.

Plant dry weight

Dry matter accumulation was always greater in TRI 2025 (Table 5). The plant weight of DT 1 at 30 weeks was the same as that of TRI 2025 at the 14th week. The dry weight of new leaves and of roots of TRI 2025 was generally twice that of DT 1.

TABLE 5 — *Dry matter production of plants (g) of clones TRI 2025 and DT 1*

Attribute	*Clone*	Weeks *0*	*10*	*14*	*18*	*22*	*26*	*30*
New leaves	TRI 2025	—	0.01	0.22	0.39	0.38	0.39	0.42
	DT 1	—	0.01	0.05	0.12	0.21	0.21	0.16
	L.S.D. (P=0.05)	—	NS	0.01	0.07	0.07	0.07	0.07
New stem	TRI 2025	—	0.03	0.12	0.17	0.19	0.19	0.20
	DT 1	—	0.03	0.07	0.08	0.14	0.17	0.17
	L.S.D. (P=0.05)	—	NS	0.03	0.01	0.01	0.01	0.02
Roots	TRI 2025	—	0.10	0.20	0.28	0.38	0.41	0.52
	DT 1	—	0.05	0.11	0.14	0.20	0.23	0.35
	L.S.D. (P=0.05)	—	0.01	0.02	0.07	0.04	0.07	0.07
Original leaves	TRI 2025	0.38	0.57	0.56	0.60	0.66	0.64	0.70
	DT 1	0.19	0.38	0.32	0.32	0.40	0.40	0.43
	L.S.D. (P=0.05)	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Original stem	TRI 2025	0.20	0.24	0.29	0.28	0.31	0.34	0.38
	DT 1	0.20	0.19	0.19	0.22	0.23	0.25	0.31
	L.S.D. (P=0.05)	NS	0.01	0.07	0.01	0.01	0.02	0.03
Plant	TRI 2025	0.58	0.95	1.39	1.72	1.92	1.97	2.22
	DT 1	0.39	0.66	0.74	0.88	1.18	1.26	1.42
	L.S.D. (P=0 05)	0.07	0.07	0.07	0.07	0.09	0.07	0.07

The largest increase in dry matter of plant in TRI 2025 was seen during the period 10-14 weeks while in DT 1 this was at 18-22 weeks (Table 6). In both clones this was mainly due to an increase in the dry weight of new leaves during these periods. In TRI 2025 there was very little dry matter acccumulation at 22-26 weeks while in DT 1 it was low at 10-14 and 22-26 weeks.

TABLE 6 — *Dry weight increment of plants (g) of clones TRI 2025 and DT 1*

Clone	Weeks *0—10*	*10—14*	*14—18*	*18—22*	*22—26*	*26—30*
TRI 2025	0.37	0.44	0.33	0.20	0.05	0.25
DT 1	0.27	0.08	0.14	0.30	0.08	0.16
L.S.D. (P=0.05)	0.07	0.11	0.11	0.10	NS	NS

The percentage distribution of dry matter among the components of the cuttings (Table 7) in both clones was greatest in the original leaf during the first 10 weeks. In TRI 2025 during the succeeding two periods larger increases were noted in new shoot growth while during the last 3 sampling periods the major increase was in the roots.

TABLE 7 — *Distribution of dry-matter increments among parts of the plants as percentages of the total of the increases (negative values represent the loss as a percentage of the total increase)*

	Weeks					
	0–10	*10–14*	*14–18*	*18–22*	*22–26*	*26–30*
Clone TRI 2025						
Original leaf	51	(-2)	12	30	(-40)	24
Original stem	11	11	(-3)	15	60	16
Shoots	11	68	67	5	20	16
Roots	27	23	24	50	60	44
Clone DT 1						
Original leaf	70	(-75)	0	27	0	19
Original stem	(-4)	0	21	3	25	38
Shoots	15	100	57	50	38	(-31)
Roots	19	75	21	20	38	75

In DT 1 from the 2nd to the 5th sampling period there was a greater increment in the dry weight of new shoot growth. During the last two sampling periods increases were noted in the roots, the percentage increase in the penultimate sampling being equal to that seen in new shoot growth.

Growth determination

Relative growth rate and net assimilation rate — The relative growth rate, R of each clone followed a closely similar pattern to that of the net assimilation rate, E for the duration of this experiment (Table 8). In DT 1, R and E were higher than that of TRI 2025 at 0-10 and 18-22 weeks. The R and E of TRI 2025 showed a steep increase at 10-14 weeks which were the highest values for both clones. These values then declined to a low value at 22-26 weeks. In both clones R and E increased during the last sampling period.

TABLE 8 — *Relative growth rate (g/g/day $\times$ 10^2) and net assimilation rate (g/dm^2/week) of plants of clones TRI 2025 and DT 1*

	Weeks					
Clone	*0-10*	*10-14*	*14-18*	*18-22*	*22-26*	*26-30*
Relative growth rate						
TRI 2025	0.22	1.38	0.77	0.38	0.10	0.44
DT 1	0.64	0.41	0.59	1.10	0.23	0.39
L.S.D. (P=0.05)	0.20	0.15	0.07	0.15	NS	NS
Net assimilation rate						
TRI 2025	0.0234	0.1729	0.0918	0.0476	0.0128	0.0421
DT 1	0.0729	0.0480	0.0899	0.1227	0.0362	0.0536
L.S.D. (P=0.05)	0.0199	0.0293	NS	NS	NS	NS

In TRI 2025 the peak value of E corresponded to the period when insolation was generally high (Table 9), as seen at the early stages of the experiment (0-14 weeks). Clone DT 1 did not show a response during this period but its peak E corresponded to the second peak of insolation (18-22 weeks). Temperature and rainfall did not appear to have a marked effect on E.

TABLE 9 — *Climatic data for the duration of the experiment*

	Weeks					
	0—10	*10—14*	*14—18*	*18—22*	*22—26*	*26—30*
Mean sunshine (h)	6.80	4.73	2.17	4.78	2.68	5.44
Mean temperature (^{0}C)	20.33	20.48	18.41	18.98	18.80	18.70
Mean rainfall (cm)	0.30	0.23	0.84	0.74	1.22	0.28

Leaf area ratio, specific leaf area, leaf area index, leaf weight ratio and shoot/root ratio — The leaf area ratio was higher in TRI 2025 except at the time of planting of cuttings (Table 10). In both clones, in general, the leaf weight ratio and the leaf area ratio decreased with time. The specific leaf area did not show a time trend. This ratio was higher in TRI 2025 at 0-10 and 10-14 weeks while in DT 1 it was higher at 14-18 and 26-30 weeks. In both clones the leaf area index showed a progressive increase with time, being always higher in TRI 2025. The leaf area index showed a greater increase at 10-14 weeks (TRI 2025) and at 18-22 weeks (DT 1). In general, the shoot/root ratio was higher in DT 1.

TABLE 10 — *Leaf area ratio, specific leaf area, leaf area index, leaf weight ratio and shoot/root ratio of plants of clones TRI 2025 and DT 1*

		Weeks						
		0	*10*	*14*	*18*	*22*	*26*	*30*
Leaf area ratio	TRI 2025	68.92	58.94	51.71	47.01	46.60	49.05	48.51
	DT 1	94.33	50.08	48.26	47.37	42.60	44.21	46.21
	L.S.D. (P=0.05)	15.35	1.23	1.06	NS	NS	3.50	NS
Specific leaf area (cm^2/g)	TRI 2025	105.91	97.25	92.32	81.68	86.20	91.64	95.84
	DT 1	102.33	84.95	89.11	94.37	83.02	89.46	104.00
	L.S.D. (P=0.05)	NS	1.65	2.24	3.75	NS	NS	5.12
Leaf area index	TRI 2025	0.86	0.87	1.13	1.27	1.40	1.52	1.57
	DT 1	0.50	0.52	0.56	0.65	0.79	0.88	1.04
	L.S.D. (P=0.05)	0.11	0.01	0.07	0.07	0.07	0.07	0.33
Leaf weight ratio	TRI 2025	0.66	0.61	0.56	0.58	0.54	0.52	0.50
	DT 1	0.49	0.59	0.50	0.50	0.52	0.48	0.42
	L.S.D. (P=0.05)	0.07	NS	NS	NS	NS	NS	NS
Shoot/root ratio	TRI 2025	—	8.50	5.95	5.14	4.05	3.80	3.27
	DT 1	—	12.20	5.73	5.29	4.90	4.48	3.06
	L.S.D. (P=0.05)	—	0.48	NS	NS	NS	0.36	0.11

Crop growth rate and leaf area duration — DT 1 and TRI 2025 showed higher crop growth rates at 10 and 14 weeks respectively (Table 11). The leaf area duration was 34.81 weeks (TRI 2025) and 19.74 weeks (DT 1).

TABLE 11 — *Crop growth rate ($g/dm^2/week$) of plants of clones TRI 2025 and DT 1*

	Weeks					
Clone	*10*	*14*	*18*	*22*	*26*	*30*
TRI 2025	0.02	0.19	0.12	0.07	0.02	0.07
DT 1	0.04	0.03	0.06	0.10	0.03	0.06
L.S.D. (P=0.05)	0.01	0.02	NS	NS	NS	NS

DISCUSSION

The study of the growth of two clones by the method of growth analysis showed that the major difference in the habit of the two clones was in the pattern of extension growth (Table 1). In TRI 2025 plant height was greater and it maintained its superiority over the duration of the experiment.

The large increase in dry matter in the original leaf over the initial period of sampling (Table 7), showed that the photosynthetic activity of the original leaf was not affected by its severance from the parent plant and that translocation of photosynthates had not commenced. During this period the original leaf served as a storage organ. A similar effect was noted by Goodchild (1967) who studied the early growth of tea cuttings in two situations and under two watering regimes.

In both clones during the second and third sampling periods there were substantial increases in dry matter in the new shoot growth indicating that translocation of metabolites had commenced. In TRI 2025 and DT 1 the largest increment of new leaf area was seen at 10-14 and 18-22 weeks respectively and it is conceivable that the young leaves would have commenced photosynthesis at this time in addition to receiving photosynthates from the original leaves. This is indicated, in TRI 2025, where the increment in dry matter of new shoot growth at 10-14 weeks was in excess of the amount present in the original leaves. This was also seen in DT 1 at 10-14 weeks though it was not at the time of largest increment of new leaf area. Soon, however, these increments decreased with a concomitant increase in the roots at 18-22 (TRI 2025) and 22-26 (DT 1) weeks at which stage the newly established young roots served as a sink.

In DT 1 the largest increment of new leaf area was at a time when the rate of leaf expansion was at a maximum which consequently resulted in an increase in the dry matter of new leaves during this period and hence of the plant. In TRI 2025 though these phases were not seen at the same time the greater increment of new leaf area resulted in larger increase in the dry weight of new leaves and of plant. Several factors affect the rate of leaf production and there is much variation in this respect between plant species. In tea, leaf production is largely limited to the expansion of leaf primordia in the resting bud which shows a periodicity of growth and of dormancy (Bond, 1942).

In a tea cutting the net assimilation rate, E is dependent upon the efficiency of the original leaves for a considerable time. Even at the end of 6 months, the original leaf generally accounts for a larger proportion of the total leaf area. In TRI 2025 the net assimilation rate, E showed a maximum value at 10 - 14 weeks. This suggests that during the second sampling period the new leaves have taken over the function of the original leaves. It was seen in another experiment in which orginal leaves were removed at periodic intervals from the commencement of putting out the cuttings, defoliating the original leaves up to the 12th week arrested growth but not subsequent defoliation. The results of this study lend further support to these conclusions. The growth of DT 1 is comparatively slow during the early stages and it may be that in this clone the new shoot growth takes a relatively longer time to become independent of the reserves in the original leaves.

In both clones the relative growth rate, R and the net assimilation rate, E were not regular. In DT 1, R and E were greater at 0 - 10 and 18 - 22 weeks. In TRI 2025, R and E showed higher values at 10 - 14 weeks and 14 - 18 weeks. Generally when E values were high in one clone the R values were also high. Thus the peaks of R are clearly associated with contemporary increases in E. These peaks also correspond to the periods of increment in new leaf area and of plant dry weight.

Since E contributes directly to net increase in dry matter by photosynthesis, it would be greatly affected by climatic variations, and hence would be expected to affect R as well. Comparison of the data for E with those given for climatic conditions suggests a relationship between peak E, daily insolation and temperature while rainfall appear to have little direct effect. In this respect, clonal differences exist as not all clones will respond to these somewhat unusually favourable conditions. Blackman and Rutter (1948) studying the effect of varying light intensity on the growth of bluebell found that E increased linearly with increase in the log of light intensity. This was further confirmed by Blackman and Wilson (1951). At low light intensities E shows a low value presumably because of the decreased quantity of light reaching the leaves. It is known that shading reduces E (Blackman *et al.*, 1948; Kulasegaram and Kathiravetpillai, 1976) which is also due to light intensities.

Although DT 1 had an initially higher leaf area ratio, the values were consistently lower during the subsequent periods compared to the values seen for TRI 2025 in which there was a greater increase in leaf area to plant weight. Leaf weight ratio was generally greater in TRI 2025 indicating a diversion of more reserves to the leaf. The specific leaf area and shoot/root ratio did not show a consistent pattern.

Greater dry matter production in a clone must depend on increase in either its photosynthetic capacity or its photosynthetic efficiency, or both. The differences in dry matter accumulation between the two clones can be accounted for almost completely by differences in leaf area. Values of E were generally higher in DT 1 so that the greater production of dry matter in TRI 2025 is mainly due to its larger leaf area. This superiority was gained not by more leaf number but by larger increments in leaf area over the period of sampling which resulted in an almost twofold increase in the leaf area duration, LAD of this clone. Watson (1947) states that the measure of leaf area for comparisons of total dry matter accumulation in different species is clearly the leaf area duration as it takes into account the magnitude of the leaf area and its persistence in time. He also states that a plant will operate with maximum efficiency as a producer of dry matter if its greatest leaf area is developed at the time when seasonal conditions are most favourable for photosynthesis. Since leaf area ratio, L and LAD represent indices of greater photosynthetic capacity these factors were probably largely responsible for the greater increments in dry matter in TRI 2025 compared to DT 1 than the inconsistent values of R and E.

It is to be noted that the initial weight and leaf area of the fresh cutting of TRI 2025 was greater than that of DT 1. Hence even if R and E of TRI 2025 were lower the greater weight and leaf area in this clone would have also contributed to the larger dry matter accumulation in the plant.

The total dry weight of a crop depends on the length of the growth period and the crop growth rate (C). Since C depends on E and the leaf area index L, at any one time, variations in any one of its components will affect C. It is to be noted that E fluctuated over a range from 0.01 to 0.17 while L varied in TRI 2025 from 0.86 to 1.57 and in DT 1 from 0.50 to 1.04. As L increases mutual shading of the leaves would at some stage be expected to decrease photosynthesis and so to decrease E. Watson (1958) found that the E of Kale decreased linearly with increase of L while E of sugar-beet was less affected. However it is unlikely that the low values of L obtained in this study would have substantially reduced E and probably the optimum value was not reached.

There are only a few recent studies on the growth of woody perennials using the technique of growth analysis e.g. Goodall (1950), Rutter (1957), Rees (1963), Goodchild (1967) and Sweet and Wareing (1968). Most of the work has been done on herbaceous crops in temperate climates. There is a great paucity of data of this type of work in the tropics. Watson (1962) mentions only 3 tropical plants but in these E was calculated on a leaf-weight basis. The values for E obtained in this study compare favourably with those obtained by Goodchild (1967) for tea cuttings of comparable age while the values obtained by Barua (1957) are somewhat higher. Visser (1962) also obtained higher values with 1-year-old tea plants and concluded that R and E varied with environmental conditions. Goodall (1949 ; 1950) estimated that the maximum E of cocoa seedlings during their first 7 weeks of growth under shade was 0.090 $g/dm^2/week$ while the mean E for seedlings between 6 and 30 weeks was 0.072 $g/dm^2/week$. These values including those obtained in this study are much below any of those tabulated by Heath and Gregory (1938) for herbaceous crops which varied between 0.125 to 0.720. Rutter (1957) using *Pinus sylvestris* found that E fell with age from 0.40 to 0.10 $g/dm^2/week$. Rees (1963) obtained values of 0.15 to 0.32 $g/dm^2/week$ in oil palm seedlings grown in full daylight. He suggests that the low values of E found in cacao, *Pinus*, citrus, and the oil palm are associated with the evergreen habit. In this respect tea plants are no exception.

In both clones the water content of the cuttings showed rapid gains during the early stages but remained almost constant from the 18th week suggesting that the plant tissues were becoming more rigid with age.

The results of this study suggest that the differences in the pattern of growth between the two clones were largely due to differences in L and the leaf area duration and to a lesser extent to E.

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