Tea Q. 48 (1 & 2), 41—47, 1979. *Printed in Sri Lanka*

INVESTIGATIONS ON SOME ASPECTS OF THE INTERRELATIONSHIP BETWEEN YIELD AND QUALITY IN TEA

(*CAMELLIA SINENSIS L.*)

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Some aspects of the factors that contribute to yield and quality in tea were investigated in two experiments. In one, the root/shoot interaction was modified by grafting and, in the other the dry weather influence was modified by irrigation and shade. The results indicate the dominant influence of the shoot system in determining both the yield and quality of the crop from the tea plant.

INTRODUCTION

The yield and quality of the crop from the tea plant is controlled by genetic and environmental factors. Some of these factors have been investigated by Evans (1929), Keegel (1959; 1962), Ramaswamy (1964), Sanderson (1964) and Wickremasinghe (1974). The object of this study was to further existing knowledge in this field by investigating some factors that have not been looked into so far. In one experiment the rootstock - scion interaction between two clones with differing genetic potential for yield and quality was tested by grafting and, in the other, dry weather influence on yield and quality was altered by both irrigation and shade.

MATERIALS AND METHODS

Experiment A (1971 - 1977)

Eleven-months-old nursery plants of clones TRI 777 and TRI 2025 were grafted by, 'inarching' (Tubbs 1933) in November 1971 to form two series of compound plants one with TRI 2025 shoot and TRI 777 root, and the other with TRI 777 shoot and TRI 2025 root. These compound plants were raised in the nursery with similar ungrafted plants of each clone, giving the following four series of plants.

1. Ungrafted plants of clone TRI 2025
2. Ungrafted plants of clone TRI 777
3. Grafted plants with TRI 2025 shoot and TRI 777 root (referred to as TRI 2025/77)
4. Grafted plants with TRI 777 shoot and TRI 2025 root (referred to as TRI 777/2025).

Thirty plants from each of these series were planted in the field at St. Coombs Estate (1500 m amsl), in six blocks conforming to a randomized block design in September 1973, approximately two years after grafting. The plants were brought

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into plucking by 'cutting across' (Manipura 1971). Yield was recorded from November 1975 to February 1977. Periodically, flush from each series of plants was manufactured and quality of made tea assessed. Since profuse flowering was noticed in some series of plants, total fruit weight per plant was assessed in February 1977.

Experiment B (1975- 1976)

Two pairs of plots with the same plucking area, each having 30 bushes of clone TRI 2025, were marked out near a source of water at St. Coombs Estate in December 1975. From 22nd December 1975 crop from the plots was harvested and yield recorded. Periodically, flush harvested from the plots was manufactured and quality of made tea assessed. After the onset of the dry season in January, 1976, one of each pair of plots was irrigated daily beginning from 2nd February 1976. Total rainfall in the four weeks prior to irrigation was 45 mm. After five weeks of irrigation, one pair of plots was shaded to 20% of the open plot, by coir matting. Irrigation was continued up to 7th April 1976 when the first heavy shower of rain was recorded after nearly 12 weeks of dry weather during which the total rainfall recorded was 78 mm, whereas potential evapotranspiration (Et) calculated from meteorological records at St. Coombs Estate for the same period was 374 mm (Kandiah and Thevadasan, 1978).

During the latter half of the dry season, besides yield and quality of crop, other chemical and physical assessments were also made of factors known to show seasonal variation. These included chemical analysis of flush for chlorophyll, amino acids, polyphenols, polyphenol oxidase enzyme activity, root wood carbohydrates, xylem sap amino acids, leaf water content of flush, % soil moisture and feeder root activity.

RESULTS

Experiment A

Of the four series of plants TRI 2025 yielded most and TRI 777 yielded least. When grown as compound trees TRI 2025/777 yielded less than ungrafted TRI 2025 and, TRI 777/2025 yielded more than ungrafted TRI 777 (Table 1). Marked variation in the precocity to flower and fruit was evident in the four series of plants. Assessment of fruit weight in February 1977 indicated an inverse relationship between precocity to flower and fruit, and crop yield (Table 1).

TABLE 1 — *Fresh weight of flush harvested per bush from November,* 1975 *to February,* 1977 *and fruit weight per bush in February,* 1977

Clone	Flush weight (g)	Fruit weight (g)
TRI 2025	845	22
TRI 777	327	809
TRI 2025/777	585	192
TRI 777/2025	438	383
LSD ($P = 0.05$)	158	161

During the course of the study, flush from the four series of plants was manufactured and tasted by the Tea Research Institute's tea taster on nine occasions between November 1975 and August 1976. Except for one occasion (22nd December) TRI 777 and TRI 777/2025 were consistently scored superior to either TRI 2025 or TRI 2025/777 (Table 2). Unlike yield there was negligible difference in quality, between ungrafted and compound trees with a similar shoot system. The shoot determined quality irrespective of the genotype of the root system or variation in yield.

TABLE 2 — *Quality valuation (Marks) of tea manufactured from the flush harvested from the four series of plants.*

Clone	Date of harvest 11 Nov	22 Dec.	6 Jan.	21 Jan.	16 Feb.	27 Apr.	20 May	16 Jun.	11 Aug.	Mean
TRI 2025	30	58	48	40	43	40	43	48	37	43
TRI 777	40	50	58	63	45	50	50	69	45	52
TRI 2025/777	32	56	50	40	37	45	43	48	34	43
TRI 777/2025	40	50	58	67	53	48	56	69	40	53
R/E_t = ...	5·33	0.76	0.69	0.59	0.05	1.89	0.50	0.22	2.48	

R/E_t = Rainfall/Potential evapotranspiration ratio in the 4 weeks period preceding each harvest.

From November, 1975 to August, 1976 maximum valuation for quality in both ungrafted and grafted plants of the two clones was given for the harvest made in the dry periods in December/January and then during the short dry spell in June. The development of quality in June however was not very marked in TRI 2025 or TRI 2025/777.

Experiment B.

Yield per bush during the dry period from 21st January to 7th April expressed as a percentage of the dry plot was open wet = 169, shaded wet = 134 and shaded dry = 76. Irrigation had enhanced yield during the dry period by 69% in the open plot and by 34% in the shaded plot. There was, therefore, a 50% reduction in yield response to irrigation during this period by the introduction of shade five weeks after the commencement of irrigation.

After the rains in April although irrigation was stopped, shade was not removed until November. Yield from April to November expressed as a percentage of the open dry plot was open wet= 123, shaded wet = 88 and shaded dry = 72. The reduction of light intensity to 20% of full sunlight had not reduced yield to the same extent.

Quality evaluations of made tea during the period of irrigation are given in Table 3.

TABLE 3 — *Quality valuation (Marks) of tea manufactured from the flush harvested from the open and shaded plots irrigated from 16th February to 8th April, 1976.*

Treatment	Weeks after irrigation (shade)				
	2	4	6(1)*	8(3)*	9(4)*
Open dry	40	56	56	67	60
Open wet	40	40	34	37	40
Shade dry	40	56	40	45	45
Shade wet	40	40	30	25	35

Quality valuation varied little until four weeks after the commencement of irrigation, after which marked variation between dry and wet plots was recorded, where the quality difference was more marked in the open plots than in shaded plots. The overall effect of shade was a reduction in quality.

Total amino acids, polyphenol and flavanol contents were estimated from flush sampled from the harvest of 16th March. The results are presented in Table 4.

TABLE 4 — *The concentration of total amino acids, polyphenols and individual flavanols in fresh flush harvested on 16th March, 1976 six weeks after irrigation*

Treatment	Amino acids (mg Alanine/g flush)	Polyphenols (mg D-catechin/g fresh flush)	flavanols (mg/g fresh flush) EGC	EGCG	EGC	EC
Open dry	3.20	73.0	15.6	48.2	11.6	5.2
Open wet	4.40	54.0	7.5	46.4	7.3	2.1
Shade dry	2.96	64.0	11.8	36.9	10.6	3.9
Shade wet	3.66	40.0	5.9	25.8	5.8	1.4

EGC = 1—epigallocatechin, EGCG = 1 — epigallocatechin gallate
ECG = 1—epicatechin gallate, EC = 1 — epicatechin

Removal of water stress by irrigation had opposite effects on amino acid and polyphenol content in the flush. The former was more and the latter less in the flush from irrigated plots compared with that from dry plots. The level of both amino acids and polyphenols was less under shade. Variation of individual flavanol components resembled that of total polyphenols. The increase resulting from water stress was largely due to increase in epigallocatechin (EGC) levels in the open, but in shade epigallocatechin gallate (EGCG) too, increased markedly. Estimation of polyphenol oxidase activity indicated no marked difference between treatments. Chlorophyll and relative leaf water content of the first two leaves below the terminal bud of the flush, and percentage soil moisture in soil samples obtained to a depth of 6-inch were determined on the 24th March. The results are presented in Table 5.

TABLE 5 — *Chlorophyll and relative leaf water content in the first two leaves below the terminal bud (active), and soil moisture percentage on 24th March,* 1976.

Treatment	Chlorophyll (absorbance of extracts at 663 & 645 nm)	Relative leaf water content (%)	Soil moisture (%)
Open dry	0.022	82.4	20
Open wet	0.020	88.9	44
Shade dry	0.046	85 6	25
Shade wet	0.038	91.3	46

Xylem sap was sampled on 23rd March by the method of Selvendran and Sabaratnam (1971). It was found possible to collect sap overnight from unpruned plants from the cut stump of a branch, in the irrigated plots and not from plants in dry plots. After the rains, however, sap could be collected even from plants in the dry plots though the volume collected was less than from plants in the irrigated plots. Estimation of amino acids in the sap indicated higher amino acid content in the sap of plants from shaded dry plots following the rains.

Proportion of active feeder roots in a feeder root sample obtained on 4th April was found to be markedly less in the dry plots. The level of reserves (carbohydrates - g/100 g residue) in mature roots sampled on the same day was open dry = 52, open wet = 55, shade dry = 69 and shade wet = 47 [LSD (P=0.05) = 13.]

DISCUSSION

In the grafting experiment, clone TRI 2025 with above-average yield and little quality, and clone TRI 777, an average yielder but with excellent quality, were compared with compound trees of these clones where each of the clones was used as a scion and a rootstock. In compound trees formed from grafts it has been found that the rootstock clone influence the characters of the shoot clone (Tubbs 1973). In his studies with intraclonal reciprocal grafts in tea, Kulasegaram (1969) noted that shoot activity could be related to root activity. Kandiah and Wimaladharma (1978) found a reciprocal relationship between leaves and feeder root activity indicating their functional interdependence. Further, it has also been observed that biosynthesis of quality-inducing factors may take place in the root system (Wickremasinghe *et al.* 1972). The objective of the treatments was to elucidate shoot/root interaction between TRI 2025 and TRI 777 that markedly influenced yield and quality of made tea.

Comparing the yield of compound trees it appears that though yield is determined by shoot-root interaction, the shoot influence seem to predominate over that of the root. A high-yielding clone growing on the rootstock of a poor-yielding clone yields more than when the combination is reversed (*eg* Table I compare TRI 2025/777 with TRI 777/2025). The negative relationship between fruit weight and yield seem to indicate that partitioning of assimilates into fruit could be one of the factors responsible for low yields, especially in view of the appreciable fruit load in some treatments.

Quality of made tea seems to be determined entirely by the shoot system, being independent of the genotype of the root system. Alteration in yields by grafting has had negligible effect on quality (Table 2). Seasonal effects on the composition of green flush and quality of made tea have been investigated before by Evans (1929), Ramaswamy (1964), Sanderson (1964 a, b) and Wickremasinghe (1974). In all these studies comparison was made between dry flavoury season and the wet-monsoon non-flavoury season. In this study an attempt has been made to create growth conditions not conducive to quality development in the dry season itself by modifying soil water content and light intensity with the objective of reducing water stress in the plant, as water stress is said to be one of the factors contributing to quality development in tea.

Water stress during the dry season, which lasted for about 12 weeks in 1976 from January to April, was found to reduce yield markedly. Partial reduction of water stress by heavy shade depressed yield further compared with plants in the open. Yield during the dry season was least from the plants growing in the shaded dry plot. This supports previous observations on the growth of tea under shade (Kulasegaram and Kathiravetpillai 1976). The response to irrigation was not fully realised under heavy shade. Yield depression, however, by shade *per se* appears less severe than expected since after the rains, from April to November, yield from plants in plots shaded to 20% of that in the open plot has been as much as 72% of that from control (open dry) plots. Yield was even more (88% of control) in the plot irrigated in the dry season. The higher level of root reserves noted in the plants in the dry plot under shade in April did not appear to benefit yield from April to November, though the higher proportion of active feeder roots in the irrigated plots seem to have benefited yield.

Both irrigation and shade suppressed the development of quality in the dry season, but it took around four weeks for the water stress effects to alter quality while the shade effect was apparent after a week (Table 3).

Evans (1929), and Ramaswamy (1962) noted an increase in nitrogen content of extracts of green leaf in the dry season. Sanderson (1964 b), however, failed to notice a significant effect for nitrogen constituents of the flush, though he found that these were higher in quality clones. Total amino acids in the flush and quality of made tea in this study (Tables 3 and 4) indicated a negative relationship between total amino acids and quality.

Total flavanol content was high under conditions that favoured quality, furthermore the variation noted for EGC and EGCG components appeared more relevant to quality than variation in ECG and EC (Table 4). In this context the association between EGC content of flush and theaflavin content of black tea noted by Hilton and Palmer Jones (1973) is worth noting. No difference in polyphenol oxidase enzyme activity, however, could be detected.

Comparing the open and shade treatments, poor quality from tea under shade was associated with a higher chlorophyll content in the flush, whereas in the open, a similar relationship was not evident (Table 5). Analysis of individual amino acids in the flush, however, indicated higher concentrations of aspartic and glutamic acids in the irrigated plants compared with that in plants in dry plots in the open. This indicates greater photosynthetic activity in irrigated plants. These observations are in agreement with the results presented by Wickremasinghe (1974) who showed that greater photosynthetic activity is detrimental to quality. Perhaps in the open, water stress could be more important in limiting photosynthesis than the content of chlorophyll in the leaf.

These results indicate the dominant influence of the shoot system in determining both yield and quality of the crop from the tea plant. This may be due to the root influence being basically dependent on precursors originating in the shoot *via* perhaps, the photosynthetic pathway. The observations made in this study may be of help in deciding on the merits of some of the cultural practices aimed at increasing yield and quality of tea, *eg* in the interplanting of trees for shade (and for fuel, recently) within tea plantations and also in clonal selection.

ACKNOWLEDGEMENTS

We thank Dr. G. R. Roberts, Biochemist of the Tea Research Institute for technical advice in the estimation of amino acids, polyphenols and polyphenol oxidase enzyme activity. We are also grateful to Messrs. S. Jeyaratnam and T. Kularatne who manufactured and tasted the flush samples, and to Miss R. Subramaniam for able technical assistance. The comments made on the manuscript by Professor G. W. Schneider of the University of Kentucky, USA, are much appreciated.

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Accepted for Publication — 20th October, 1978.