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SHORT–TERM YIELD IN THE IMMATURE STAGE AS AN INDICATOR OF THE YIELD POTENTIAL OF TEA CLONES (*CAMELLIA SINENSIS* (L) O. KUNTZE)

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The yield of 31 clones and one seedling population of tea was assessed over a period of seven years at two locations, namely, Kottawa, 25 m amsl and St Coombs, 1200 m amsl. The yield over this period ranged from 2000-7000 kg/ha/annum at Kottawa and 1000-3500 kg/ha/annum at St Coombs. A highly significant positive correlation between the yield in the immature stages and yield potential based on seven years yield was established. This correlation held irrespective of shade treatments or locations. The weight of prunings was positively correlated with not only the yield of the previous cycle, but also with the mean yield over seven years. The feasibility of using these correlations in a tea breeding programme as a means of accelerating the selection process is discussed. It is also envisaged that this short-term assessment for yield potential would enable estates to identify the most productive clones for their locality well in time for large-scale replanting.

INTRODUCTION

The ultimate object of a tea breeding programme is the selection and introduction of new commercial cultivars that are superior in one or more respects to the existing clones. Yield is of primary importance in all tea-growing districts of Sri Lanka while manufacturing properties receive high priority particularly in some districts. With escalating costs of production, high yields are essential if the industry is to remain viable. Other desirable characters of economic importance, besides yield and quality are pest and disease resistance and drought tolerance. The simultaneous selection for all these characters is difficult and impracticable in view of Wight's (1958) findings. He estimates the chances of obtaining a superior clone as 1 in 40,000 from field populations of seedlings in North-East India. A rational approach to tea breeding in the first instance, therefore, is to select seedlings which, as clones, are likely to be high yielding and also sustain these high levels of production over many years. Richards (1966) and Visser (1969) have described those morphological and agronomic characteristics that are desired in a tea clone. These characteristics, however, need not necessarily be associated with the yield potential of clones (Green 1971). Present methods of selection for high yielders are therefore, essentially empirical and the process is slow and laborious on account of the long juvenile period of seedlings and an even longer productive period during which harvesting is carried out at approximately weekly intervals.

Correlations of agronomic and morphological characters with the yield of various perennial crops have been reported by several workers (Glendinning 1966; Visser & De Vries 1967; Yap & Harvey 1972). Such morpho-physiological characters in tea which would enable the selection of those seedlings which as clones will be high yielders, would be an advance over the existing methods of selection. An examination of the relationship of various agronomic, morphological and physiological characters of seedlings of tea with the yield of clones derived from them has revealed that the correlations are weak and are of limited value. Height, girth at the collar, root weight and branching angle of young seedlings were correlated with the yield of the same plant when mature (Green 1971), but were not related to the rate of growth in the nursery or the yield at maturity, of the clones derived from these seedlings. Although rooting ability and growth rate of cuttings

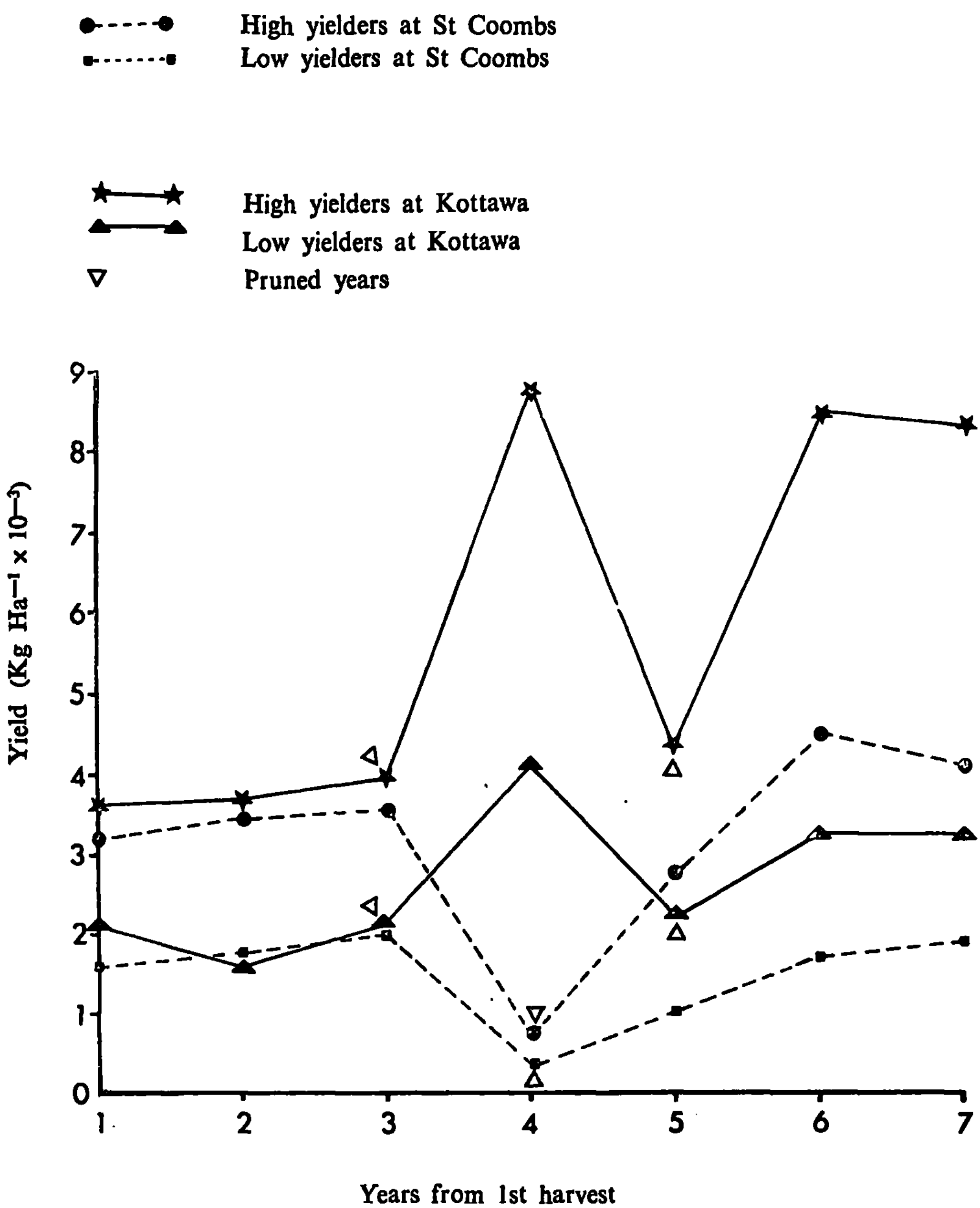


FIG. 1 — *Annual distribution of yield of six high-yielding and six low-yielding clones at St Coombs and Kottawa*

in the nursery were associated with the early growth and survival of the clonal plants in the field (Watanabe & Harada 1955; Harada *et al.* 1961), these parameters were not correlated with the subsequent yield of clones (Green 1971). Even more disappointing is the lack of correlation between the yield of mature seedlings and the yield of clones derived from them (Wellensiek 1938; Van Emden 1941; Visser 1969). Selection schemes based on such parameters (Wellensiek 1938; Tubbs 1946; Visser & Kehl 1958, and Visser 1969) therefore appear to be of limited use in view of Green's observations. Assessments of growth and vigour of young plants and, leaf and bush size and growth habit of mature seedlings still remain the only bases for selection of clones. These schemes based on phenotypic selection allow for the broad categorization of seedling populations into agronomically desirable and undesirable types, thereby reducing base populations to manageable sizes for yield trials with the clonal progeny. At present, direct estimation of yield in statistically designed experiments appear to be indispensable.

This paper examines the patterns of yield development with maturation and attempts to correlate immature yields with long-term yield potential of clones. Such correlations would enable the breeder to utilize the yield of immature plants as an early selection criterion, thereby effecting a considerable reduction in the time required to select new clones of high yield potential.

EXPERIMENTAL

Thirty-one clones and one seedling population were evaluated for yield, using a simple randomized block design, replicated four times. A plot contained 36 plants spaced 60 cm within rows and 120 cm between rows and surrounded by a guard row. The clones were tested at two locations, Kottawa (25 m amsl) and St Coombs (1200 m amsl). At each location two replicates were planted with shade trees. *Gliricidia maculata* and *Erythrina lithosperma* spaced 4.25 m apart were used at Kottawa and St Coombs respectively. The fresh weight of harvests, at approximately weekly intervals was recorded over a period of seven years.

RESULTS

The yearly distribution of yield of a group of high yielding clones were compared with a group of low yielders for each location and the changes occurring in yield with time are presented in Fig. 1. The pattern of yield is cyclic and periods of very low crop coincide with the pruned years. The relatively lower yield values seen in the fourth year at St Coombs and in the third and fifth year at Kottawa coincides with pruned years. If the pruned years are ignored, then there is a gradual increase in the crop harvested over the years for the two groups of clones at both locations. The crop harvested is then at a maximum in the fourth year of plucking at Kottawa and in the sixth year at St Coombs. This period of maximum yield can be assumed to be the mature phase of the tea plant.

The relationship of early yields to the yield of clones at maturity is presented in Table 1 and Figs. 2 & 3. All correlation coefficients are positive and significant ($P < 0.001$). When yields of 10 harvests, or the crop for 3 months or 6 months are compared with 7-year yields (Table 1) the correlation coefficient and the corresponding predictability values are low. An improvement in the correlation occurs when first year yields are compared with 7-year yields, at both locations and under shaded and unshaded conditions with predictability values ranging from 70-78%. Thereafter there is a progressive increase in the predictability values when yearly yields are used for comparison. Predictability values were highest when cycle yields were compared with mean yield of seven years.

TABLE 1 — *Relationship between yield computed over different periods and the mean yield for seven years (31 clones + 1 seedling population)*

Parameters under comparison		Correlation coefficients			
		St Coombs		Kottawa	
Yield (Kg/ha/ annum)	Yield (Kg/ha/ annum)	(—) Shade	(+) Shade	(—) Shade	(+) Shade
10 Plucks	7 years	0.791 (63%)	0.805 (65%)	0.614 (38%)	0.716 (51%)
3 Months	,,	0.832 (69%)	0.850 (72%)	0.690 (48%)	0.787 (62%)
6 ,,	,,	0.795 (63%)	0.873 (76%)	0.725 (53%)	0.793 (63%)
Year 1	,,	0.866 (75%)	0.882 (78%)	0.834 (70%)	0.846 (72%)
,, 2	,,	0.920 (85%)	0.912 (83%)	0.865 (75%)	0.909 (83%)
,, 3	,,	0.920 (85%)	0.947 (90%)	*0.900 (81%)	*0.861 (74%)
,, 4	,,	*0.919 (85%)	*0.899 (81%)	0.978 (96%)	0.978 (96%)
,, 5	,,	0.944 (89%)	0.946 (89%)	*0.906 (82%)	*0.867 (75%)
,, 6	,,	0.931 (86%)	0.919 (84%)	0.946 (89%)	0.936 (88%)
,, 7	,,	0.869 (76%)	0.720 (52%)	0.911 (83%)	0.905 (82%)
Cycle 1	,,	0.949 (90%)	0.941 (89%)	0.895 (80%)	0.913 (83%)
,, 2	,,	0.956 (91%)	0.926 (86%)	0.980 (96%)	0.980 (96%)
,, 3	,,	—	—	0.969 (94%)	0.942 (89%)

* Pruned years; Figures in parentheses indicate predictability values.

Significant and positive correlations were also obtained between the weight of prunings and yield. Data was available for one location (St Coombs) only and the correlation coefficients are presented in Table 2 and Fig. 4.

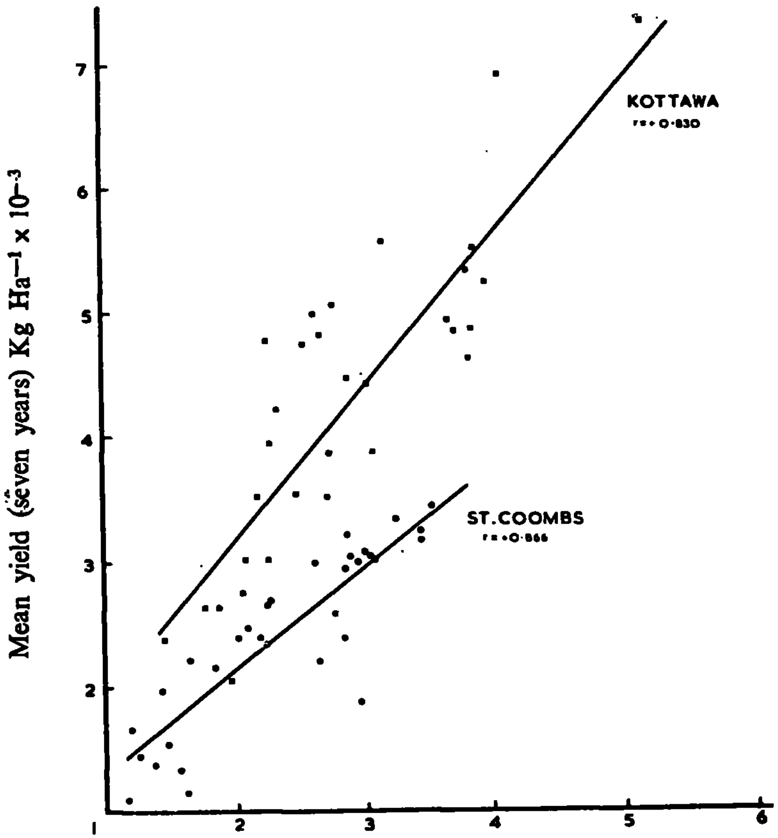
TABLE 2 — *Correlation between weights of prunings and yield (St Coombs)*

Parameters under comparison		Correlation coefficients	
Pruning weights Kg/bush	Yield Kg/ha/annum	(—) Shade	(+) Shade
1st Cycle	1st Cycle	0.854	0.855
1st Cycle	7 years	0.863	0.775
2nd Cycle	2nd Cycle	0.813	0.879
2nd Cycle	7 years	0.777	0.789
1st & 2nd Cycle	7 years	0.893	0.869

TABLE 3 — *Ranking of clones on the basis of clones computed over different periods*

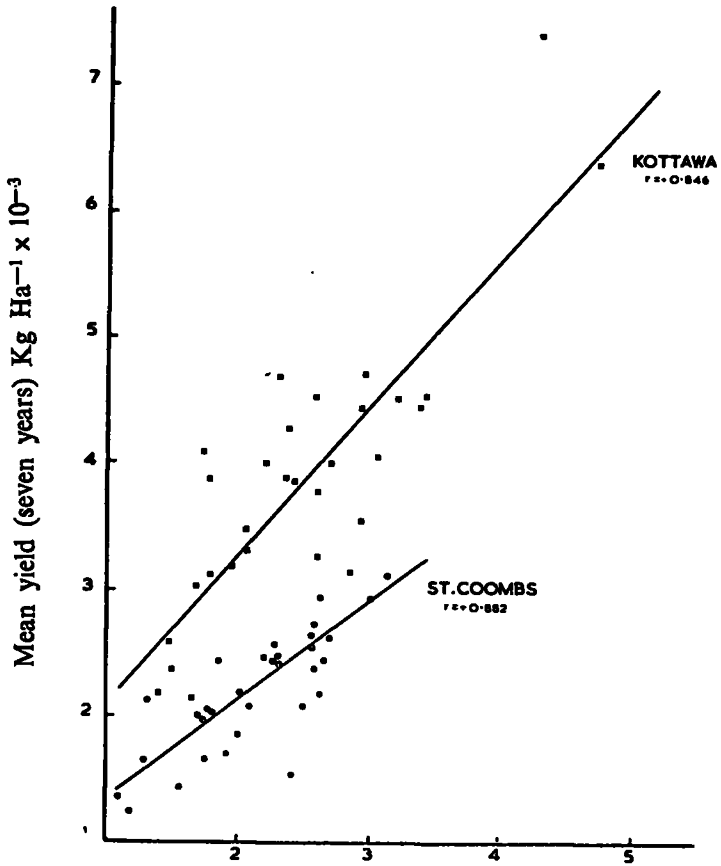
	Selection criteria			
	1st Year Yield	2nd Year Yield	1st Cycle Yield	7 Year Yield
St Coombs (—) Shade	TRI 2025	TRI 2023	TRI 2026	TRI 2025
	,, 2024	,, 2026	,, 2025	,, 2023
	,, 2026	,, 2025	,, 2023	,, 2026
	,, 2023	DG 39	,, 2024	TK 48
	CY 9	TRI 2024	DT 1	TRI 2024
	DT 1	DT 1	TK 48	DT 1
	(5)	(5)	(6)	(6)
St Coombs (+) Shade	TRI 2025	TRI 2023	TRI 2025	TRI 2025
	GMT 9	GMT 9	GMT 9	2023
	MT/BG	TRI 2025	TRI 2023	GMT 9
	TRI 2024	,, 2151	TK 48	KEN 16/3
	,, 2023	KEN 16/3	TRI 2027	TRI 2027
	,, 2027	TK 48	,, 2151	TK 48
	(4)	(5)	(5)	(6)

Note: Figures in parentheses indicate the number of high yielding clones selected on the basis of each of the selection criterion.



First Year yield Kg Ha^{-1} x 10^{-3}

FIG. 2 — *Correlations between first year yield and mean yield for seven years of 32 clones at St Coombs and Kottawa in the absence of shade trees*



First year yield Kg Ha^{-1} x 10^{-3}

FIG. 3 — *Correlations between first year yield and mean yield for seven years of 32 clones at St Coombs and Kottawa in the presence of shade trees*

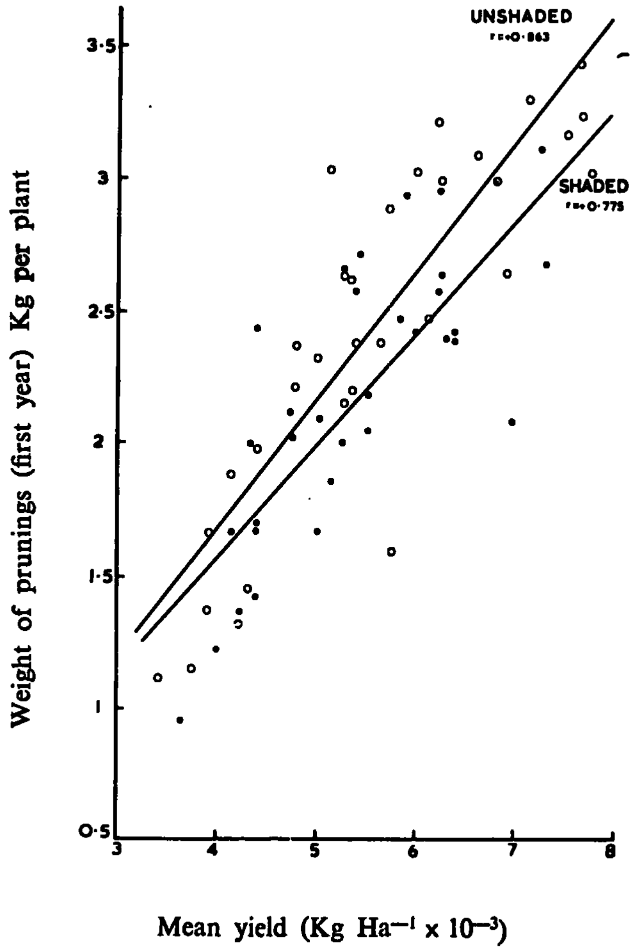


FIG. 4 — *Correlations between weight of prunings and mean yield for seven years of 32 clones at St Coombs*

	1st Year Yield	2nd Year Yield	1st Cycle Yield	7 Year Yield
	TRI 2023	TRI 2026,	TRI 2026	TRI 2023
Kottawa	„ 2026	PA 22	„ 2023	„ 2026
	MT 18	T 5/35	MT 18	„ 2024
(—) Shade	MT/BG	DT 1	PA 22	MT/BG
	PO 26	TRI 2023	DG 39	DG 39
	UH 9/3	DG 39	T 5/35	MT 18
	(4)	(3)	(4)	(6)
	TRI 2026	TRI 2023	TRI 2023	TRI 2023
Kottawa	„ 2023	„ 2026	„ 2026	„ 2026
	DG 39	DG 39	DG 39	MT/BG
(+) Shade	TRI 2024	MT/BG	MT 18	TRI 2027
	MT 18	MT 18	MT/BG	DG 39
	T 5/35	UH 9/3	TRI 2024	TRI 2151
	(3)	(4)	(4)	(6)

DISCUSSION

Three distinct phases can be recognized during the growth cycle of the tea plant in the field. The early juvenile phase which is unproductive lasts for about two years in the field, followed by an immature, but productive stage which is of four years duration at St Coombs and two years at Kottawa (Fig. 1). Yield is at a maximum during the subsequent period which is considered to be the mature phase in the growth cycle of the tea plant. On this time scale it can be said that clones at St Coombs reach maturity in eight years, while at Kottawa the clones matured faster in six years from planting. Tea has been said to reach full maturity around the tenth year from planting in Java and North India (Anon. 1952). Yield during these mature years would be expected to make a significant contribution to the total yield. Computation of yield potential of clones should therefore take into account yield in the mature years.

Visser (1958) showed that a series of ten consecutive test plucks during a three-year cycle was correlated with the mean yield of tea for the cycle and suggested the possibility of using these short-term yields in clonal selection programmes. At the other extreme, Green (1971) advocates the use of ten-year yield as a fair judgment of the yield potential of clones. Selectionists, however, have been wary of using short-term yields as a measure of the yield potential of clones. This is evident from the lack of any further reports from other workers. Tea is a perennial plant and yield is a vegetative product which is distributed over many years. It seems unsound therefore to predict such long-term yields based on ten consecutive plucks in the immature stage of the tea plant. Moreover, Visser's estimate of yield potential is based on crop harvested in the immature years and ignores the increased contribution of crop during the mature stages to the total yield. These restrictions seem to justify the caution exercised by tea breeders in the past.

The present analysis takes into account the crop harvested during a part of the mature phase for estimating yield potential of clones. Correlations of the mean yield of seven years with those of 10 plucks, 3 months or 6 months though significant, were low, for practical purposes of prediction of yield potential. An improvement in the correlation and corresponding predictability value occurs when first year yields are compared with the mean yield of seven years. This suggests that yield estimated over short periods of less than one year may not be a reliable indicator of the yield potential of clones. It would appear more likely (Table 1) that yield in the second year with predictability values of 75-85%, or cycle yield with predictability values of 80-90% would reflect better the yield potential of clones (Table 1).

The practical usefulness of these correlations is evident from Table 3. An intensity of selection of 20% for the highest yielders would mean the isolation of six of the best clones among the 32 clones under test. The clones are ranked in decreasing order of yield on the basis of first year, second year, first cycle and 7-year yields for each location. At St Coombs five of the six clones selected on 7-year yields were identified on the basis of first year, second year or the first cycle yields under unshaded conditions. All six clones were identified only when first cycle yield under unshaded conditions was used. In other words 80% of the highest yielders under consideration were isolated by using first year yields only. It is therefore concluded that the first year's yield is an adequate measure of the yield potential of clones at St Coombs. This period of one year for the assessment of yield potential also provides the opportunity to observe the variation in yield with changes in weather and their reaction in areas prone to prolonged droughts. An evaluation of the quality characteristics and their tolerance or susceptibility to pests and diseases is also possible during this period. The use of this parameter may, however, result in an insignificant number of potentially high-yielding clones being left out, but when a large number of clones are being evaluated this would probably not be a serious loss. This loss will be more than compensated for, by the saving in time and labour that will be effected.

The selection of high yielding clones based on first-year yields in Kottawa was less efficient than at St Coombs (Table 3). About 65% of the highest yielders were isolated on this basis as compared to 80% at St Coombs. The improvement in the efficiency was insignificant or only small when second year yields or cycle yields were used. It is known that clones are sensitive to changes in the environment. Estimations of yield change profoundly with changes in the environment. It may be argued that under the particular weather conditions prevailing in Kottawa, clones yield differentially. While it was possible to identify about 65% of the high yielders on first year yields, the balance 35% may be regarded as genetically high-yielding clones that are slow to express their potential in the immature stages. These clones are inherently slow to develop and their contribution to the total yield is small in the early stages, but are capable of giving high yields with increasing maturity. Such clones when present in test populations would reduce the efficiencly of selection if it is based on immature yields. The identification of this group of clones would be possible only when mature yields are considered for comparison. This preferential response of clones in different environments makes it obvious that the selected clones will have a preference for localities in which they were tested.

Weights of prunings were not only correlated with yield preceding the pruning operation but were also related to mean yield over seven years (Table 3). Wight & Saikiah (1958) and Visser (1969) have established similar relationships when they compared weight of prunings and the crop harvested in the preceding period. This relationship is perhaps an expected one because the crop harvested as green leaf and the wood and leaves removed at pruning are probably functions of the total growth of a tea plant. Weight of prunings as a selection parameter would considerably cut down on the labour involved in selection but would not effect a saving in time. Under conditions such as those prevailing at Kottawa, a combination of first cycle yield and weight of prunings at the end of the cycle may prove to be reliable bases for the isolation of high yielding clones which were not identified on first-year yields.

A practical approach to the selection of tea clones would therefore be the isolation of high-yielding clones in clonal test plots on first year yields. Further confirmation, if necessary, of the accuracy of these selections may be obtained by comparing the weight of prunings. This scheme will considerably reduce the time lag between selection and release of clones to the industry. Further progress with tea selection will be possible only when early parameters of growth or other morpho-physiological traits can be correlated with yield. Pochet *et al.* (1974) have reported a relationship between leaf anatomy and productivity in the tea plant. Wickremasinghe (personal communication) suggested a relationship between yield and the activity of root hormones in tea. If many such even unlikely correlations could be found, it would greatly reduce the number of economically useless clones reaching the final yield trials in tea breeding programmes. This could greatly increase the efficiency of the final stage of clonal selection and would inevitably lead to a wider range of high-yielding clones becoming available within a reasonable period of time.

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