

## SELECTION CRITERIA FOR TEA (A Review)

V. Shanmugarajah  
(*Tea Research Institute of Sri Lanka, Talawakele, Sri Lanka*)

Selection is one of the methods of plant improvement. Several workers have attempted to identify attributes that could be used as selection criteria for future selection programmes of high yielding tea. In this paper the work carried out by various workers in this regard is discussed.

The ultimate objective 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. Since yield is of primary economic importance, selection programmes have been geared towards identifying high yielding bushes. With escalating costs of production, high yields are essential if the industry is to remain viable. Clonal selection is an important and widely adopted method of plant improvement in tea because of the wide heterogeneity in the existing seedling populations.

Tea is outbreeding in nature and the populations over the years have become extremely heterozygous. The genetic variability in the seedling populations that already exist afford a good opportunity for selection work: a survey of tea bushes showed that 80 % of the yield was given by less than 40% of the bushes (Richards, 1966). The important criteria in the selection procedure have been outlined by Kehl, 1950; Barua, 1964; Richards, 1966; Visser, 1969 and Venkataramani, 1970. The simultaneous selection for all the desirable characters is difficult and impracticable, in addition to being costly and time consuming. Wight (1958) estimates the chances of obtaining a superior clone as 1 in 40,000 from field populations of seedlings. Present methods of selection for high yields are therefore largely empirical, slow and laborious.

Several criteria have invariably been attempted at different stages in the growth of the tea bush in the hope of selecting high yielding clones.

### **1. Selection on nursery performance and in young tea**

Selection in nurseries has long been accepted as an alternative to the selection of mature seedling bushes. If this was effective, it would be most useful.

Harada, Watanabe and Mitsui (1961) obtained a correlation of 0.79 between shoot length of rooted tea cuttings and the yield of a clonal test and recommended this method because nursery selection does not involve much field area and the test can be easily repeated. They also found a high correlation between the weight of new shoots of young seedling plants and the yield of the mature plants.

Kulasegaram (1969) correlated several plant characters in the nursery at different stages from planting with their respective mean first cycle yields. It was noted that the vigour of the plant in the nursery as indicated by such characters as plant height, leaf area (total), tops as well as root dry weight at 8-12 months stage gave a better indication of their subsequent performance in the field than vigour determined at an earlier period in the nursery. If this relationship can be shown to hold true for a larger number of clones, it may help to discard the poorer clones at the nursery stage.

Green (1971) evaluated several attributes and found that the plant height, girth at collar, root weight and branching angle of young seedlings in the nursery are correlated with the sizes and yields of the same plants when mature, but not with the rates of growth in the nursery; the pruning weight, size and yield of a mature plant grown from seed were not related to the rate of growth in the nursery while the proportion of cuttings which form roots and the growth rates of the cuttings of a clone are not related to the yield of the clone. He concluded that these criteria are, at best, of limited value in the selection of high yielding clones.

Sakai and Nakayama (1973) reported that the selection in a cutting bed may be available to presume the yield of a clone at maturity because the light receiving condition of the cutting bed is similar to that of a mature tea garden.

Amma (1973) examined the relationship between seven characters of young tea seedlings during the nursery period and the yield at maturity of these seedlings. All correlations between the yield and each character were low and non-significant except for the total leaf number and the stem diameter and it seemed to be difficult to estimate the yield at maturity from any one character during the nursery period.

Shanmugarajah, Kulasegaram and Senanayake (1991) made an attempt to correlate various plant attributes of ten tea clones in the nursery stage with their proven yields in order to identify attributes that could be employed directly or in combination as selection criteria for future selection programmes; these clones had initially been identified as high and low yielders. They observed that differences in growth attributes were more marked in 8 and 12-month-old

plants than in 4-month-old plants which is in agreement with the work of Kulasegaram (1969). As strong positive correlations were obtained between plant height, number of side shoots, leaf area, girth of stem and dry weight of stem and of plant of 8 and 12-month-old plants with proven yields they concluded that selection of promising clones could be carried out using these parameters at 8-12 months of age.

Sebastiampillai and Solomon (1976) examined the patterns of yield development with maturation and attempted to correlate immature yields with long-term yield potential of clones. They assessed the yield of 31 clones and one seedling population, with and without shade, in a randomized block design at two different agroclimatic regions and established a highly significant and positive correlation between the yield in the immature stages and the yield potential based on seven years yield. This correlation held irrespective of shade treatments or locations. Short-term yields gave low correlation coefficient and predictability values with 7-year yield. But when first year yields were compared with 7-year yields under shaded and unshaded conditions at both locations, they observed improvement in the correlation and predictability values. This suggested that the yield estimated over short periods of less than one year may not be a reliable indicator of the yield potential of clones. Progressive increase in the predictability values were observed when second year yields were used for comparison. Highest predictability values were obtained when cycle yields were compared with mean yield of seven years. They found that 80 % of high yielders under consideration in the up-country were isolated by using first year yields only and concluded that the first year yield was an adequate measure of the yield potential of clones in the up-country. 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 an evaluation of the quality characteristics and their tolerance or susceptibility to pests and diseases.

The selection of high yielding clones based on first-year yields in the low-country was less efficient than in the up-country as only 65 % of the highest yielders were isolated on the above basis as compared to 80 % in the up-country. The improvement in the efficiency was insignificant when second year yields or cycle yields were used. This may be due to the fact that clones are sensitive to changes in the environment. Estimations of yield change profoundly with changes in the environment.

These workers also showed correlations not only between the weight of prunings and the yield preceding the pruning operation but also with the mean yield over seven years and suggested that selection on a combination of first-year yield and weight of prunings at the end of the cycle would be reliable in the low-country, where the isolation of high yielding clones on the basis of first-year yield was less efficient.

## **2. Mature bush characters as a basis for selection**

In spite of the extreme variability seen in a stand of seedling tea, selection from existing populations still appear to be the easiest and quickest method of effecting improvements. Initial selection is visual although largely subjective. Some of the important characters sought are high density of harvesting points, strong spreading bush frame, evenness of flush, absence of tendency to dormancy or free flowering, resistance to pests, diseases and drought, pubescent buds and leaves, speedy recovery after pruning, high pruning and tipping weights, light coloured flush, ease of rooting of cuttings, pigmentation of petiole, high rate of fermentation as determined by the chloroform test, etc. (Kehl, 1950; Barua, 1964; Richards, 1966; Visser, 1969; Venkataramani, 1970).

Amongst other characters, high yield is one of the more important characters that is sought in newly developed cultivars. Yield potential which is the yield per unit area of plucking surface of the selection divided by yield per unit area of the field provides a firm guideline for the initial selection of a bush, but necessitates the regular recording of yields of selected seedling bushes over a period of time. Venkataramani (1966) suggested that it is useful to compare this ratio. If vigorous bushes have a yield potential of over 2.5 such bushes will form useful material for multiplication and further study. Tubbs (1938, 1939) and Eden (1941) recommended the yield of seed tea as a basis for selecting high yielding clones.

While simultaneous selection for all characters is impracticable, some characters need not necessarily be associated with the yield potential of the clones (Green, 1971). On the other hand, no single criterion should be expected to give high reliability but a combination of a few of the more important characters should improve the chances of obtaining better selections.

### **2.1. Morphological characters and yield**

Toyao (1965) using nine genotypes of tea clones found that the number of leaves per plant, leaf length and leaf width had high heritability values (0.67 - 0.79); the genetic coefficient of variation for number of leaves was also large. Using single, partial and multiple correlation coefficients he showed the relationship among these five characters and the yield in the year and concluded that clones grown under the same environmental conditions could be examined for relative yielding capacity by the number of leaves.

Kulasegaram (1969) made some observations on the growth of shoots and the increase in the height of plucking table of several clones following pruning and tipping done uniformly on all the clones under test. He showed that there was a correlation between the rate of development of the plucking table and yields, provided the clones are plucked on their respective merits and no attempt is made to maintain a level table over the entire clonal area. He

obtained a strong positive correlation ( $r = 0.76$ ) between mean heights of plucking table and the yields recorded over 84 plucks following pruning.

Barua and Sarma (1982) carried out long-term trials with tea clones with erect, semi-erect and flat leaves under shaded and unshaded conditions with each group being classified according to the leaf angle. During the first nine years from planting the mean yield of clones with erect and semi-erect leaves was similar but higher than those with flat leaves.

Four clones possessing differences in morphology, physiology and yield potential were used in an experiment and from the measurements done on the canopy structure it was found that there was no difference between high and low yielding clones in respect of ground cover, branch density and leaf pose angle (Othieno, 1987). The high yielding clones had deeper canopy and greater area per leaf. But the highest yielding clone had significantly less leaf area index (LAI) than the next two high yielders and was not different from the lowest yielder.

Njuguna (1987) observed that the shoot generation duration was related to yield, that is, the shorter the duration (high rate of growth of shoots) more the generations per year which in turn resulted in high yields. Also, high number of shoots, greater weight of leaf per bush, larger number of shoots per bush and bigger size of the shoots resulted in higher yields. High correlations were seen between the yields vs number of shoots (0.83), the size of the shoots and the high rate of growth of the shoots (0.92). He also observed that internal leaf water potential (which is not related to yields) when combined with the number of shoots per bush had given a better correlation (0.93) with yield than the number of shoots per bush alone.

Green (1971) did not find a useful relationship between the weights of prunings of seedlings and the yields of the clones raised from them.

Sebastiampillai and Solomon (1976) who studied the yield of 31 clones and of one seedling population of tea over 7 years in the up-country and low-country observed that the weight of prunings were not only correlated with yield preceding the pruning operation but were also related to the mean yield over seven years. Wight and Saikiah (1958) and Visser (1969) have also established similar relationships when they compared the weight of prunings and crop harvested in the preceding period. Satyanarayana and Sharma (1981) found that both the fresh and dry weights of prunings were positively associated with yield; since there was no marked difference in the per cent error between the two, fresh weight of prunings itself could be considered for yield prediction. A high correlation between the fresh weight of prunings and yield was also established previously (Anon., 1967), but because the high soil heterogeneity within a field will have an impact on growth and spread of the bush, the pruning weights alone may not be completely reliable and this may

have to be considered in conjunction with other characters such as bush area and rate of recovery from pruning as suggested by Visser (1969).

Weight of pruning as a selection criterion would considerably cut down on the labour involved in selection but would not effect a saving in time.

Shanmugarajah, Kulasegaram and Senanayake (1990) carried out studies on mature bushes of ten clones to identify selection criteria for developing high yielding clones in a shorter period. Various attributes of the tea plant recovering from pruning as well as in plucking were correlated with their proven yield of a clonal test; the clones used had already been identified as high and low yielders. They found that length of internode of tipping shoots and depth of canopy of bushes in plucking were reliable indicators of high yield potential and the correlation coefficients of these two parameters with the yield were 0.94 and 0.88 respectively.

## **2.2. Yield to yield relationship**

Tunstall (1934) who made some observations on the yield of individual bushes felt that the yield of a bush over 10 successive plucking rounds was inadequate to judge the total yield of a bush since it covers only a portion of the season.

However, Wellensiek (1938) who correlated the yields of progressively increasing number of plucking rounds with the total yields of 48 rounds of plucking of 1555 selected bushes concluded that yield determination made from 5 to 6 consecutive plucking rounds was sufficient for a selection programme.

Visser (1958) showed that a series of 10 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 judgement of the yield potential of clones. Tea is a perennial plant and yield is a vegetative product which is distributed over many years. Hence caution has to be exercised in predicting such long-term yields based on 10 consecutive plucks in the immature stage of the tea plant. Moreover, Visser's estimate of yield potential ignores the increased contribution of crop during the mature stages to the total yield. These restrictions seem to justify the caution exercised by tea breeding in the past.

Sebastiampillai and Solomon (1976) obtained a highly significant positive correlation between the yield in the immature stages and yield potential based on seven years yield. This study envisaged that such short-term assessments for yield potential would enable estates to identify the most productive clones for their locality well in time for large-scale replanting.

A practical approach to the selection of tea clones would 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 would considerably reduce the time lag between selection and release of clones to the industry.

The selection criteria developed by Venkataramani (1962) presages the relative yield potential of a marked bush from among a group selected in a field: He calculated the yield potential of a marked bush after recording the yield of the marked bush and the field in which the bush was selected, simultaneously for a period of 3 months only. Since it was realised that the yield recorded for 3 months could not reflect the real yields of marked bushes, yields of the marked bushes were recorded for a period of one year (Sharma, 1977). Though this period covered all seasons it causes a positive delay in the progress of clonal selection and expends considerable amount of man-hours and money. In view of this, Satyanarayana and Ramachandran (1981) attempted to investigate the appropriate period over which yields of the marked bushes should be recorded. They recorded the yields of 74 and 39 bushes selected in two estates over a year (52 rounds). The yields of individual bushes were totalled for periods of 3, 6 and 9 months to ascertain whether any significant correlation occurs between these and the annual yields. The study indicated the desirability of recording yields of marked bushes for a minimum period of any 6 months at weekly intervals.

In a series of studies Amma (1974) attempted to find a correlation between plant characters and yield that could be employed as a basis for selection. In studies on the yield of mature tea at the time of selection and that of the clones derived from them at maturity, the correlation coefficient was 0.70. From this result it was found that the yield of the clone can almost be presumed from the yield of mature tea in the individual selection.

Studies on yields of seedling and of clones indicated that the weight of new shoot, number of new shoots, spread of plant and length of new shoot showed high correlations to the yield of mature tea garden of a clone. It was felt that the length of new shoot was a predominant factor being more related to yield; thus if some character of the immature period which is closely related to the length of new shoot of mature tea is found, the early selection of high yielding varieties could be easily achieved.

### **3. Relationship between mother bushes and their clonal derivatives**

Clonal selection for a character can be reliable only if the relative performance of the mother bushes remain the same through the years and if a strong relation exists between the mother bushes and their clonal derivatives.

But Green (1965) reported poor correlations between the yield of mother bushes and that of derived clones; subsequently, he reported no useful relation

between mother bushes and their clonal derivatives for bush area but a close relation between mother bushes and young clonal plants for yield, although at maturity this relation existed only during active growth periods (Green, 1971). Positive correlations between the yields of selected seedling bushes and that of young clonal plants derived from them have been reported (Njuguna, 1981).

The relation between mother bushes and their clonal derivatives for bush area, shoot number and yield was investigated by Nyirenda and Ridpath (1984). By employing simple correlations they found that these attributes were all strongly and positively correlated. Clones derived from the bushes exhibited characteristics that correlated with those of mother bushes and they concluded that these observations are useful in the selection of clones for improved performance.

#### **4. Dry matter partitioning as an index to selection**

In order to understand the constraints or limiting factors restricting tea yields, it is important to understand the production efficiency of the tea bush and how it partitions its photosynthetic products.

The co-ordination of growth in the whole plant, whereby a proper balance is maintained between shoot and root, between extension growth and radial growth and between vegetative growth and reproductive growth must involve control mechanisms (Wareing, 1970).

Work on other crops show that plants under certain conditions maintain a particular balance between their various parts. When disturbed, the plant tends to react and restore the balance as a natural function.

A tea bush is in an unnatural state in that it is constantly being plucked which means that the balance between various parts of the bush are probably in a continuous state of trying to adjust themselves back to natural conditions. The development and growth of the plucked shoots on a tea bush involves the conversion and availability of the products of photosynthesis to the development and growth of those shoots.

Considerable work on dry matter partitioning in the tea bush has been carried out in Kenya. Magambo and Othieno (1977) attempted to find out whether or not a tea bush in plucking maintains a constant balance between its parts by way of two simple trials. In one study, they found that regardless of the differences in dry weights of prunings of the 3 clones rested for 12 months from last prune compared to similar clonal bushes, the amount of photosynthetic product allocated to shoot development and growth in terms of plucking was proportionally constant, being about 22 % of the pruning dry weights in the 3 clones.

In the second trial they attempted to see whether the manipulation of the environment will influence the bush so that more of the photosynthetic products are diverted to the development and growth of harvestable shoot. From the data that was not statistically analysed, they found that interplanting with oats gave a 10 % higher yield/total annual dry matter production for the clone studied. They are of the view that the remaining 90 % of the annual dry matter production goes into branch and root formation.

Magambo (1978a) determined the overall dry matter production of plucked and unplucked bushes of clone 6/8 by uprooting these bushes at regular intervals over a 12 month period. He found that the plucked bushes produced  $17.9 \text{ t ha}^{-1}$  of dry matter during the year in contrast to  $26.2 \text{ t ha}^{-1}$  for unplucked bushes, indicating that plucking reduces yearly overall dry matter production by about a third. In the same study it was evident that old branches of plucked bushes contributed 25.8 % of the overall increment while the pluckings contributed 10.7 %.

The harvest index (HI) of tea is low and values of 10 % have been reported by various workers (Othieno, 1976; Jain, 1977; Magambo and Othieno, 1977; Tanton, 1977; Laycock and Othieno, 1978). Magambo (1979) found that seasonal harvest index varied tremendously being 8 % during the cool months and 22 % with ample rainfall, for bushes with complete canopy cover. He concluded that the HI of tea bushes could probably be greatly increased if ways of reducing the development of much wood could be found.

Othieno (1979) investigated the relationship between the shoot/root ratios and yields of five clones which were five years of age. He found a strong positive linear relationship ( $r = 0.840$  and  $0.837$  respectively) between the ratios and yields of these clones; clones with higher shoot/root ratios persistently gave higher yields. He also observed that, in general, the clones which showed higher ratios in the four-year and five-year-old field plants also showed higher ratios in the one-year-old nursery plants.

Using 15-year-old tea bushes pruned at 60, 30 or 15 cm or at ground level Magambo (1980) assessed the percentages of total dry matter in various parts in the prunings and that left on the bush after pruning. He observed that, of the total dry matter of the whole bush the leaves contributed 9 %, the frame 66 % and the roots 25 %.

It has generally been assumed that tea like many other vegetative crops is source-limited and investigators have consequently studied characters known to be associated with photosynthesis (Barua, 1964; Hadfield, 1974; Magambo, 1977). On the other hand Huxley (1975) argued that tea productivity could be severely sink-limited because of repeated plucking. Tanton (1979) claimed supporting evidence for the sink-limited concept on the grounds that tea yields in Malawi were 38 % less when plucked every 7 days

rather than every 14 days. In any case extreme views have been stated towards the question of whether tea productivity is source or sink limited. It is known that sources and sinks are functionally related; plucking removes both. Magambo and Cannel (1981) felt that it was difficult to judge what limits tea yields without information on these combined effects on plucking in terms of total bush dry matter production and distribution. They found that plucked tea produced 36 % less biomass and 64 % less wood per hectare per year than the unplucked tea. Besides restricting the height of the crop and hence the development of woody stems, plucking had significantly decreased the proportion of total dry matter increment partitioned to stems and correspondingly increased the proportions partitioned to leaves and roots. They found that only 8.3 % of the total annual biomass increment was harvested and suggested that this proportion might be increased by plucking older leaves, increasing the shoot/root ratio and by lowering the plucking table so that less wood is produced.

Magambo and Waithaka (1983) investigated clonal differences in dry matter production and partitioning in young tea plants employing five different clones and found that the clones which normally give high economic yields produced larger amounts of dry matter than the low yielding clones. The latter had the highest per cent dry matter partitioned in the roots. They also observed clonal differences in dry matter ratios of plant parts. The highest yielding clone produced the highest total dry matter and had significantly larger shoot/root and leaf/root dry matter ratios than the others. Positive relationships were also obtained between the plant dry matter ratios and total dry matter production. In their study the high yielding tea clone (31/8) which produced the highest total dry matter also produced the highest plant parts dry matter ratios. If these findings could be extended to other tea clones then these plant parts dry matter ratios could be utilised as selection criteria. In the same way the establishment of the relationship between clonal plant part dry matter ratios of nursery plants and yields of similar clonal plants in the field would greatly reduce the period taken to select the best tea clones.

Work on tea canopy structure in clonal tea has been conducted in an attempt to find out why various clones differ in yielding capacity. The heterogenous nature of tea shows many leaf types ranging from the small erect leaves of the pure China through intermediates (hybrids) to the large horizontal Assam types and the droopy types.

In a thicker canopy the self shading effect of top layers on the lower layers become important. Shading of lower leaves by upper leaves is likely to make the former photosynthetically less efficient. Studies on light penetration and leaf pose (leaf angle) by Barua (1967) has shown that a horizontal leaf type causes heavy self shading on the foliage below the top hamper resulting in a large fraction of the maintenance foliage below the top layer receiving insufficient light for maximum photosynthesis; erect leaf types reflect more

radiant energy than the horizontal leaves and this results in more light being reflected to lower leaves. Barua (1969) also determined the quality and quantity of light reaching the lowest leaves in both leaf type bushes and found that in spite of a greater leaf area in the semi-erect type, the lowest leaves received more light than the horizontal type, and although the values of the infra red part of the spectrum were almost equal, there was twice as much visible, photosynthetically useful radiation (mainly diffuse light) in the semi-erect canopy. This result provides powerful support to the idea that leaf angle plays a more important role in light penetration than leaf area.

Hadfield (1974) and Magambo (1977) investigated the canopy characteristics of tea plants and found that tea bushes with semi-erect leaves maintained a higher leaf area index and deep canopy with more light penetration through the canopy.

Othieno (1987) who made measurements of canopy characteristics, photosynthetically active radiation (PAR) and CO<sub>2</sub> uptake in high and low yielding clones found that high yielding clones had a deeper canopy than low yielders. He also found clonal differences in PAR penetration.

In studies involving penetration of light through tea canopies Wadasinghe (1988) estimates that the topmost 5 cm layer of the canopy intercepts about 38 % of the PAR, leaves within first 15 cm layer intercepts 86 % of PAR while leaves below 25 cm of canopy intercepts less than 2 % of PAR.

Squire (1985) is of the view that the low productivity of tea could be traced not to inefficient interception of solar radiation by foliage but inefficient conversion of intercepted radiation to dry matter. Notwithstanding this inefficiency of the canopy, the main constraint to yield was shown to be the very small fraction of dry matter diverted to shoots. Magambo (1978b) and Magambo and Cannel (1981) showed that about half the dry matter was partitioned to frame, one quarter to the extractable root system and only one-tenth to the harvestable shoots.

## **5. Yield prediction**

Various biometric parameters were considered by Satyanarayana and Sharma (1981) to formulate new indices for yield prediction of mother bushes so that a simplified procedure could be evolved for tea clonal selection. They observed a direct relationship between the number of serrations on the leaves and yield in four clones while the other two clones of contrasting yield levels had the same number of serrations. Direct association of the leaf area at the plucking surface and at depths of 15 and 22 cm below the surface with yield was obtained in their study and they also noted a positive association between the shoots per unit area and the yield. The pruning weights (both fresh and dry) also had direct association with yield.

The yield of a crop can be analysed in terms of the product of (a) solar energy received,  $s$ , (b) that fraction of this energy intercepted by the foliage,  $f$ , (c) conversion efficiency,  $e$  and (d) the harvest index,  $i$ . Squire (1985) is of the opinion that yield increases are likely to arise through increases in the size of the sinks, which may be associated with a change in either  $e$  or  $i$  or in both.

However, it is difficult to predict the potential maximum values of  $e$  and  $i$  for tea, mainly because its cultural system is unique. Kulasegaram and Wadasinghe (1988) have collated several suggestions made by crop physiologists to increase the productivity of tea.

Some of the mature bush as well as 8-12-month-old nursery plant attributes which showed high correlation with the proven yields (of high and low yielders) were fitted into linear models by Shanmugarajah et al (1990, 1991) to predict yield in the higher elevation (up-country) of Sri Lanka. The contribution made by length of internode of tipping shoots, bush width and depth of canopy in explaining the variation in yield were 88, 74 and 78 % respectively. But when length of internode of tipping shoots and bush width between rows of plucking bushes were combined, they could explain 93 % of the total variation in yield. The contribution made individually by the height and girth of plant and by the dry weight of shoot of the nursery plants in explaining the variation in yield is 85 % . As the dry weight of shoot involves destructive sampling which cannot be afforded to at this stage, the height and girth of plants could be used to predict yield.

### ACKNOWLEDGEMENTS

I wish to thank Dr A.Kathiravetpillai for his suggestions and for critically reading the manuscript.

### REFERENCES

- AMMA, S. (1973). Relationship between the characters of young tea seedlings in the nursery period and the yield at maturity of the same seedlings. *Study of Tea*, No. 45, 6-10.
- AMMA, S. (1974). selection of high - yielding clones of tea plant. *JARQ*, 8 (4), 214-218.
- ANONYMOUS, (1967). Report of the Botany Division. *Ann. Sci. Rep., Tocklai Exp. Stn.* 1966 33-44.
- BARUA, D.N. (1964). Selection of vegetative clones. *Two and a Bud*. 11, 32-38.
- BARUA, D.N. (1967). Report of the Botany Department. *Tocklai Exp. Stn.* 1966, 33-44.
- BARUA, D.N. (1969). Report of the Botany Department. *Tocklai Exp. Stn.* 1968, 69, 50-63.
- BARUA, D.N. and SARMA, P.C. (1982). Effect of leaf pose and shade on yield of cultivated tea. *Ind. J. Agri. Sci.*, 52 (10), 653 - 656.

- EDEN, T. (1941). The selection of high yielding tea bushes for vegetative propagation. *Tea Q.* 14, 98-102.
- GREEN, M.J. (1965). *Rep. Tea Res. Inst. E. Afr.*, 58-59.
- GREEN, M.J. (1971). An evaluation of some criteria used in selecting large - yielding tea clones. *J. Agric. Sci. Camb.* 76, 143-156.
- HADFIELD, W. (1974). Shade in North - East Indian tea plantation. II. Foliar illumination and canopy characteristics. *J. Appl. Ecol.*, 62, 179-198.
- HARADA, S., WATANABE, A., and MITSUI, M. (1961). Studies on the method of early selection in tea breeding. Bulletin of the tea division Tokai - Kinki Agricultural Experiment Station, No. 8, 1-29.
- HUXLEY, P.A. (1975). Tea Growing. *Tea in East Africa*, 15 (2), 13-16.
- JAIN, N.K. (1977). Perspective: Technological gaps in tea research. *Two and a Bud*, 24, 1-5.
- KEHL, F.H. (1950). Mimeographed Pamphlet, *Tea Res. Inst. Cey.*, pp 14.
- KULASEGARAM, S. (1969). Report of the *Plant Physiology Division for 1968. Rep. Tea Res. Inst. Ceylon*, 2, 39-57.
- KULASEGARAM, S. and WADASINGHE.G. (1988). Productivity of tea (*Camellia sinensis* L.) in relation to other tropical perennial crops. *Proc. 1st Int. Conf. Assoc. of Plant Physiologists of SAARC countries held in Kathmandu, Nepal J. Nat. Inst. Plant. Mgmt.* 8, 1 & 2, 73-88.
- LAYCOCK, D.H. and OTHIENO, C.O. (1978). Thoughts on annual dry matter production by tea. *Tea in East Africa*, 18, 2-4.
- MAGAMBO, M.J.S. (1977). Canopy characteristics of seven clones of tea (*Camellia sinensis* L.) estimated by use of inclined point quadrat. *Trop. Agric. (Trinidad)*, 54, 205-211.
- MAGAMBO, M.J.S. (1978a). Dry matter production of plucked and unplucked bushes. *Tea in East Africa*, 18 (2), 5-7.
- MAGAMBO, M.J.S. (1978b). Crop Physiology. *Tea in East Africa*, 18 (1), 8-10.
- MAGAMBO, M.J.S. (1980). Total net dry matter allocated to various parts of tea bushes pruned at different levels. *Tea*. 1 (1), 1-4.
- MAGAMBO, M.J.S. and OTHIENO, C.O. (1977). Dry matter partitioning in tea bushes. *Tea in East Africa*, 17, 15-17.
- MAGAMBO, M.J.S. and CANNELL, M.G.R. (1981). Dry matter production and partitioning in relation to yields of tea. *Expl. Agric.* 17, 33-38.
- MAGAMBO, M.J.S. and WAITHAKA, K. (1983). Clonal differences in dry matter production and partitioning in young tea (*Camellia sinensis* L.) plants. *E. Afr. agric. For. J.* 49 (2), 57-61.
- NJUGUNA, C.K. (1981). Interplant competition study. *Ann, Rep. Tea Res. Found. Kenya*, 37.
- NJUGUNA, C.K. (1987). Report of the Botanist for 1986. *Tea Res. Found. Kenya*, 61-64.
- NYIRENDA, H.E. and RIDPATH, V.E.T. (1984). Criteria for clonal selection in tea (*Camellia sinensis*). 1. The relation between mother bushes and their clonal derivatives for bush area, shoot number and yield. *Expl. Agric.* 20, 339-343.

- OTHIENO, C.O. (1976). Annual total dry matter production in young clonal tea. *Tea in East Africa*, 16: 10-12.
- OTHIENO, C.O. (1979). Shoot/root ratios and yields of clonal tea. *Tea in East Africa*, 19 (1), 6-7.
- OTHIENO, C.O. (1987). Report of the Botanist for 1986. *Tea Res. Found. Kenya*, 226-227.
- RICHARDS, A.V. (1966). Vegetative propagation of tea. Advisory Pamphlet No. 8/66, *Tea Res. Inst. Cey.*, 17 pp.
- SAKAI, S. and NAKAYAMA, A. (1973). Varietal difference of tea production. Breeding of arbor crop: Development and utilization of early selection method, ed. by the research group for tree crops, Breeding of tree crops, Tokyo. The Government Forest Experiment Station, 229-251.
- SATYANARAYANA, N and RAMACHANDRAN, K. (1981). Criteria for tea clonal selection – yield prediction. *J. Plant. Crops*. 9 (1), 62- 65.
- SATYANARAYANA, N and SHARMA, V.S. (1981). Biometric basis for yield prediction in tea clonal selection. Paper presented at PLACROSYM IV (Mysore), 237-243.
- SEBASTIAMPILLAI, A.R. and SOLOMON, H.R. (1976). Short - term yield in the immature stage as an indicator of the yield potential of tea clones (*Camellia sinensis* (L.) O.Kuntze). *Tea Q.* 46, 16-25.
- SHANMUGARAJAH, V., KULASEGARAM, S. and SENANAYAKE, Y.D.A. (1990). Growth characters as criteria for selection of new tea clones (*Camellia sinensis* (L.) O.Kuntze). *Trop. Agric.*, 2, 36-44.
- SHANMUGARAJAH, V., KULASEGARAM, S. and SENANAYAKE, Y.D.A. (1991). Nursery plant attributes as criteria for selection of new tea clones. *S.L.J. Tea Sci.* 61, 76- 86.
- SQUIRE, G.R. (1985). Ten years of tea physiology. *Tea*, 6 (2), 43-48.
- TANTON, T.W. (1977). Why tea yields are so low? *Quarterly Newsletter*. The Tea Research Foundation of Central Africa, No. 48, 4-6.
- TANTON, T.W. (1979). Some factors limiting yields of tea (*Camellia sinensis*). *Expl. Agric.* 15, 187-191.
- TOYAO, T. (1965). Correlation and genetical analyses of the several characteristics at the stage of individual selection in the tea plant. II. On the correlations among yield, number of leaves per plant and characters of leaf in the clonal varieties for Green Tea. *Study of Tea*. No. 30, 1-4.
- TUBBS, F.R. (1938). Nursery selection. *Tea Q.* 11, 8-21.
- TUBBS, F.R. (1939). Selection for high yields. *Tea Q.* 12, 48-49.
- TUNSTALL, A.C. (1934). Observations on the yield of individual bushes. *Ann. Rep. Ind. Tea Assoc. for 1933*, 103-112.
- VENKATARAMANI, K.S. (1962). First progress report on tea selection. *Ann. Rep. UPASI Sci. Dep. Tea Sect. for 1961 - 62*, i-vii.
- VENKATARAMANI, K.S. (1966). Practical utilization of plant variability in tea. *UPASI – Proc. 13th Ann. Conf. Bull.* 25, 3-7.

- VENKATARAMANI, K.S. (1970). Clonal selection, a method of improvement of tea planting material. *UPASI Sci. Dep. Bull.* 28, 65-74.
- VISSER, T. (1958). The validity of assessing tea yields on a basis of intermittent plucking and test plucking. *Tea Q.* 29, 21-29.
- VISSER, T. (1969). Tea (*Camellia sinensis* (L) O.Kuntze). pp. 459 - 493. In *Outlines of perennial crop breeding in the tropics*, eds. Ferwerda and Wit, 511 pp. H.Veenman and Zenens.
- WADASINGHE, G. (1988). Physiology of growth and development of clonal tea (*Camellia sinensis* (L) O.Kuntze) at low elevations in Sri Lanka. Ph.D. thesis, 1-351.
- WAREING, P.F. (1970). Growth and its co-ordination in trees. pp 1 - 21. In *Physiology of tree crops*, eds. Luckwill, L.C. and Cutting, C.V., Acad. Press, Lond.
- WELLENSIEK, S.J. (1938). Researches on quantitative tea selection. IV. Mother tree selection. (Dutch with Eng. summ.). *Arch. Thee Cult.*, 12, 2-70.
- WIGHT, W. (1958). The agrotype concept in tea taxonomy. *Nature* 181, 893-895.
- WIGHT, W. and SAIKIAH, L.R. (1958). *Ann. Rep. Ind. Tea Asso. Sci. Dep.*, for 1957, 42-57.