Harvesting policies of tea (*Camellia sinensis* L.) for higher productivity and quality

M.A.Wijeratne
Tea Research Institute, Low Country Station, Ratnapura, Sri Lanka

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ABSTRACT

Sustainability of tea lands greatly depends on the harvesting policies, because they have a great influence on the cost of production, quality of the end product and growth of the bush. Therefore, adoption of proper harvesting policies has become a vital component in tea cultivation. In this strategy, maximizing yield components through selection of proper standards, severity and frequency of plucking and maintenance of source : sink relationship and the bush health are of paramount importance. However, adoption of good harvesting policies has been limited by shortage of workers in tea plantations, especially during heavy cropping months (rush crop). Hence, possibilities of using different management tools for minimizing the crop losses during the rush crop without affecting quality of the end product need be explored. This paper discusses some important issues and suggestions pertaining to harvesting for enhancing productivity of tea lands and quality of made tea.

Key words: Tea, harvesting, rush crop, quality, mechanization

INTRODUCTION

The marketable product of tea (made tea) is manufactured from tender shoots harvested at varying intervals depending on their growth. The method of harvesting tea shoots is termed plucking. Unlike in many other perennial cash crops, harvesting policies of tea *viz.* standard, severity and frequency adopted in a field have a profound influence on the sustainability of tea plantations due to their impact on cost of production, Quality of the end product and growth of the tea bush.

Cost of harvesting accounts for a greater share of the COP. Although, this proportion varies from region to region and from estate to estate depending on their plucking policies, harvesting usually accounts for about 35 percent of the COP in Sri Lanka which is the highest single component of the COP. This high proportion is a result of the involvement of labour for manual plucking which is about 70 percent of the labour force employed on an estate. Hence it is considered to be the most labour intensive field operation in tea cultivation. Under average field conditions in Sri Lanka, the labour requirement for manual harvesting is about 10-12 workers per ha, which can be considerably reduced by mechanical harvesting.

The quality of made tea is greatly determined by the chemical constituents of the tea leaf and its fibrous content that varies with the growth and maturity of shoots. When these quality parameters are considered, the best quality tea can be produced from tender shoots having 2-3 leaves. Moreover, the physical condition of shoots is determined by leaf handling *i.e.*; collection and transport of shoots, also affects the quality of made tea. Therefore, proper plucking policies should be exercised so that tender shoots having 2-3 leaves are harvested and transported to the factory with minimum damage and delay.

Harvesting removes the photosynthetically active green tissues. Frequent removal of young shoots encourages the bush to produce more shoots which a large amount of food material is utilised. Accordingly, production, partitioning and utilisation of assimilate, which determine the growth and vigour of the tea bush are largely influenced by the plucking policies.

Appropriate plucking policies should, therefore, be adopted to generate a higher yield with enhanced labour productivity, while ensuring the quality of end product and productivity of the tea bush.

Maximization of yield components

Yield components are the parameters which determine the potential yield of a crop. When considering a tea field, total yield is greatly determined by the bush density, which is decided at the time of planting and rate of casualties in the fields. Thereafter, shoot density of a bush and mean shoot weight govern the yield. These constitute the yield components of a tea bush. Of these two yield components, more than 80 per cent of the variation in tea yield are accounted for by the shoot density (Wijeratne, 1994). Hence, these two yield components mainly the density of shoots need to be increased for obtaining a higher yield. However, increase in shoot weight is a limiting factor as the degree of maturity of shoots influences the quality of the end product. Hence, plucking policies should be selected to maximize these two components without affecting the quality of the end product. The density and weight of shoots at harvesting are greatly determined by the rate of growth. Thus, the rate of growth of shoots is fast, the shoots reach the harvestable size within a short period of time and they also secure more weight. The above two yield components are, therefore, affected by the rate of shoot growth.

After bud break, the tea shoot grows very slowly until it opens rudimentary leaves such as scale and fish leaves, and thereafter passes through a period of rapid extension. At the end of the growing cycle or soon before dormancy, the rate of shoot extension again reduces with a less weight gain. A tea shoot with an active terminal bud weighs 10-18 per cent more than that with a dormant bud having the same number of leaves. Hence, a marginal reduction in yield can occur due to the abundance of dormant shoots (Wijeratne, 1994). It is, therefore, important to harvest a shoot at the phase of rapid extension and before it become dormant. Moreover, abundance of dormant shoots reduces the quality of end product. These disadvantages can be minimized by adopting proper plucking policies (eg. Shorter plucking rounds) either to harvest shoots before attaining dormancy or remove dormant buds at their first appearance in the plucking table.

Maintenance of source and sink relationship

The "source" of dry matter production is the mature foliage. When there are a large number of growing buds in the canopy, the majority of carbohydrates produced by leaves are diverted to the top growth of these buds. In contrast, they are stored in roots if the shoot growth is hindered. Hence, roots and growing buds are called the "sink". Of them , growing buds and *arimbus* (small shoots) are the major sinks for assimilated carbohydrates. The sink capacity is greater in the elongating buds compared to expanding leaves and immature shoots. Manivel and Hussain (1986) found that the sink capacity of an unopened growing bud declined to about 30 per cent when it unfolds its first leaf. Barua (1987) indicated that the sink capacity of the first, second and third leaf from the apical bud, declined in the order 70, 40 and 30 per cent, respectively of that of the apical bud. It is, therefore, clear that the elongating buds and immature shoots (*arimbu*) on the plucking table are the strong sinks for assimilates. If the sink capacity of a tea bush reduces, the production of carbohydrates by the foliage (source) may reduce due to affected partitioning or removal of carbohydrates. In contrast, if there is no efficient source, the growth of shoot and root (sink) is affected due to inadequate supply of food. It has been reported that the tea bush is sink limited (Tanton, 1979, 1992). Frequent removal of immature tea shoots (*arimbus*) by plucking has been identified as the major limiting factor for increasing the productivity of the tea bush. However, selective harvesting *i.e.* removal of standard shoots leaving *arimbus*, can minimize the deterioration of the sink capacity of the tea bush. Further, removal of *arimbus* exposes immature axillary buds for re-growth delaying bud break. Plucking policies, therefore, affect the balance growth of shoots and roots of the tea bush, which determine its productivity and survival.

Selection of proper harvesting policies

In order to maximize yield components by maintaining source and sink relationship and health of the bush, selection of proper harvesting policies is necessary. These plucking policies include methods, standard, severity and frequency of harvesting. These policies can vary from field to field depending on age and clone or jat. They also differ from one estate to the other depending on the management practices and the type of tea produced. Furthermore, these variations occur from one region to the other depending on weather and climatic conditions. Nevertheless, the best plucking policy is one that gives the highest productivity at a low cost while ensuring the quality of the end product and vigour of the tea bush.

Selective harvesting

When plucking is selective, a few generations of shoots having 2-3 leaves are removed, leaving a true leaf (mother leaf) or a fish leaf. However, a few more generations of immature shoots (*arimbus*) are left unplucked to enhance the "sink" capacity of the bush and also to pluck them as heavier units in the subsequent rounds. Selective plucking not only gives a higher and a sustainable yield, but also ensures a maximum utilization of shoot growth and production of good quality made tea. Under non-selective plucking system, as many generations of shoots as possible are harvested without any selection. This practice not only adversely affect the source: sink balance of the bush, but also extends the time taken for shoot regeneration due to release of immature buds for re-growth. Although non selective harvesting can give a higher yield at the beginning for few months, there will be a marked reduction at the latter part of a pruning cycle due to affected shoot production and assimilation. Moreover, it deteriorates the health and vigour of the tea bush thereby reducing its life span. The mean weight of a harvested shoot is also less under the system of non selective harvesting due to removal of *arimbus*. Some other adverse consequences of non selective harvesting are the production of smaller shoots and formation of "*mudichchies*" (Crow's feet condition). *Mudichchi*, which is a clump of shoots and stalks originating from one base or a stem , is formed due to multiple shoot production on a single shoot butt and inadequate distance (space) among shoots that originate from the single shoot butt particularly when they are developed below the fish leaf. The harvested crop with no selectivity consists of shoots with various degrees of maturity. Hence, non selective harvesting may create problems in tea processing and lead to the production of poor quality tea (Wijeratne 2001).

Plucking standards

The plucking standard gives the proportion of different sizes of shoots in the harvest. The quality of the end product, and the cost of manufacture are greatly influenced by the standard of plucking. There are three plucking standards identified in Sri Lanka *viz*., fine, medium and coarse. Accordingly, when the majority of plucked shoots comprise 2 leaves and a bud, it is called fine plucking. If the harvested crop consists of equal proportions of shoots with 2 and 3 leaves, it is considered as medium plucking. Coarse plucking implies the presence of a higher proportion of shoots with more than 2 leaves together with the other mature dormant shoots.

Yield of tea is low under very fine plucking systems due to harvesting of smaller shoots and the extension of shoot replacement cycle. It is also costly to maintain a fine plucking standard, as intake per plucker (weight of shoots harvested by a worker per day) is also less than the other two standards. Hence, adoption of a medium plucking standard enhance profitability of tea cultivation. However, the 3rd leaf and its stem immediately below the 3rd leaf are more fibrous (coarse) in slow growing seedling tea and during dry weather. Hence, it is necessary to collect a higher proportion of shoots with 2 leaves from such fields and during dry months.

Although it is difficult to harvest and supply 100 per cent acceptable shoots as a result of varying field conditions and other constraints such as labour, leaf standard (% of acceptable leaf) should not be less than 75 per cent for ensuring the production of better quality teas.

Change of Severity of plucking for higher productivity

Under light plucking systems such as single leaf plucking, a fair amount of dry mass is added to the canopy at every round of harvesting. Part of them is leaves. When shoots are plucked to the fish leaf, adequate leaves are not added to the canopy. However, as a result of harvesting a greater proportion of the shoot dry mass, fish leaf plucking gives a higher yield at early stages of its introduction. The inter-nodal length of tea shoots is very short near the base of the shoot *i.e.* below the fish leaf. Hence, fish leaf plucking can induce bud break at axil of fish leaf and scale leaves simultaneously, leading to the production of several shoots thus increasing ratio of shoot replacement to more than 1:1 (Herd and Squire, 1976; Odhiambo *et al*., 1993, Wijeratne, 1994; Stephens and Carr, 1994). Nevertheless, at the latter stages of continuous fish leaf plucking, productivity of tea bushes declines due to lack of maintenance foliage and production of *mudichchies* known as "crow's feet" condition. With the presence of *mudichchies*, bushes tend to produce less shoots and also smaller shoots which become dormant early. Therefore, continuous hard plucking reduces the productivity of tea bushes.

The rate of assimilation of tea leaves increases with leaf expansion. The assimilation rate reaches maximum when the leaves are fully expanded and it reduces with further ageing of leaves. Moreover, older leaves at the bottom of the canopy leaves are covered by newly added leaves on the top. As a result, older leaves always receive less sunlight. This further reduces their photosynthetic efficiency. Generally, adequate assimilates for export are available until tea leaves are about 6-8 month old (Rajkumar *et al*, 1998). Hence, addition of a fresh layer of canopy leaves at every 6-8 months by adopting mother leaf plucking is a must to sustain the productivity of bushes. However, continuous addition of new leaves throughout the year is not necessary. This is not only a waste of harvestable shoot dry mass but also a cause of unmanageable rise in the plucking table. Moreover, addition of many leaves can reduce bud break as a result of shading the axillary buds exposed for re-growth.

On an average about 60 per cent of dry mass of a harvestable shoot are removed by mother leaf plucking. However, this can be as high as 80 per cent when fish leaf plucking is adopted (Wijeratne, 2001; Wijeratne, 1994). This emphasizes the importance of adopting a mixture of fish leaf and single leaf plucking to sustain the growth and productivity of the tea bush. Change of plucking system can be coupled with the changes of weather conditions. Usually, the cropping pattern of tea goes in parallel with rainfall. The peak cropping months fall in wet weather while the trough (drop) in production sets in with the commencement of dry season. Accordingly, a higher proportion of fish leaf plucking (by removing 3 leaves and a bud) can be advocated during wet weather when bushes are in full production while resorting to a higher proportion of single leaf plucking (by removing 2 leaves and a bud) during non cropping months *i.e.* during dry weather. Adoption of such a mixture of plucking will not only maximize the dry matter partitioned to shoots but also regulates the rise in plucking table to a manageable height and preserves the quality of the end product.

Frequency of harvesting (Plucking round)

This refers to the number of days between successive harvests. A plucking round had earlier been defined as the time taken by the majority of shoots remained after the previous round to become ready for harvesting (harvestable). Usually, the round is determined by the field supervision. Scientifically defined, an ideal plucking round is the number of days between successive opening of leaves which is known as leaf period or phyllochron. Plucking rounds are generally shorter during wet weather and are extended during dry weather. The frequency and standard of plucking are, to a greater extent, independent variables. However, extended plucking rounds, which increase the weight of harvested shoots, reduce yield due to the harvesting of a lesser number of shoots for a given period. Moreover, it will adversely affect the quality of the end product due to the presence of more fibrous tissues in the harvest. Hence, in a proper plucking policy, there should be a logical balance between plucking round and plucking standard in order to secure a higher yield and good quality of the end product.

Plucking after tipping and bringing into bearing

The importance of the depth of maintenance foliage has been discussed in the previous section. The tea bush soon after bringing into bearing and tipping does not have sufficient maintenance foliage. Moreover, ground cover is very poor under such conditions. Hence, it is necessary to build up a healthy canopy by adopting a light plucking system (mother leaf plucking) during early stages of bringing into bearing and tipping. The period of light plucking depends on the condition of the canopy. Under normal growing conditions in Sri Lanka, light plucking for a period of about 6 months after tipping and one year after bringing into bearing is preferred. Moreover, spread of such tea bushes can be enhanced by leaving the horizontally growing branches or side shoots unplucked if they are actively growing.

Management of rush crop

Tea yield varies with the changes of weather conditions. Rainfall is the most influential factor in the tropics. In our tea plantations, the rush crop is formed during monsoon periods due to synchronization of bud break and subsequent growth of shoots after a dry spell. Favourable climatic conditions during monsoons enhance shoot growth thus making more shoots harvestable within a short period of time. During the peak cropping months, labour requirement for harvesting is comparatively high mainly due to the adoption of shorter plucking rounds and availability of more harvestable shoots in the bush. As a result many tea estates face problems of labour distribution for plucking fields. However, the majority of the annual crop comes from the rush crop periods and hence, proper planning of available resources is essential to ensure maximum benefit of the rush crop.

As the shoots should be harvested before they are over-matured or become coarse for manufacture, it is very necessary to adjust harvesting policies to match the availability of workers taking into consideration harvestable extent, plucking round and plucker intake. In this strategy, some pruning policies such as, resting of fields before pruning, pruning before the rush crop and commencement of plucking after tipping are useful management tools for reducing pluckable fields. Extension of plucking rounds during peak cropping months is also possible by adopting partial removal of *arimbus*. However, this should not be continued after the rush crop or as a routine practice, because it deteriorates the source:sink relationship and debilitate the health of the tea bush. Labour requirement for harvesting can be reduced by increasing the output of workers. Suitable shears such as TRISTH or motorized machines can be effectively used during rush crop periods depending on the degree of labour shortage. In addition, payment of incentives to workers (attractive over killo rates, incentives for attendance etc), cash plucking (plucking tea outside normal working hours) will increase daily coverage of pluckable fileds and worker output reducing absenteeism of workers. Postponement of sundry works such as road repairs, building work, fencing etc to non cropping months will also ease the problem of rush crop management (Wijeratne, 1998).

Use of harvesting shears and machines

Manual harvesting ensures removal of shoots of required maturity (standard) for production of better quality tea and to preserve the health and vegetative vigour of the tea bush. However, manual harvesting requires a large number of workers daily. Generally, manual harvesting is considered to be a fatigue field job, which keeps younger generations away. Lower wages in plantations has also attributed to the situation of lack of labour for field work. Some are going out for higher wages. Consequently, the availability of manual workers for field operations such as plucking has drastically declined in the recent past. Therefore, tea growers are compelled to look for alternatives of manual harvesting in order to ensure the entire plucking fields are timely harvested (Modder & Wijeratne, 2002).

Harvesting shears

There are varying types of plucking shears used in different tea growing countries. Most of them are modified garden shears with long handles and a leaf collecting tray or bag. Some have varying heights of steps above which the shoots are sheared to the collecting tray or bag. In Sri Lanka, the Tea Research Institute has designed a prototype shear without long and prominent handles (TRI Selective Tea Harvester-TRISTH). It weighs less than the shears used in other countries. A raise bottom (2.5cm) leaf collecting tray with perforations and a handle are made of plastic. Small handle has a protruding edge about 2.5 cm above the blade to guide and push shoots towards the leaf collecting tray.

Output of mechanical devices used for plucking depends on the yield potential of the field. When growth of shoots are synchronized (less generations) by pruning and weather (drought, temperature variation etc), the entire crop for the year is harvested at few rounds (e.g. Japan). Under such conditions the output of shears are very high. *i.e.* 50-100kg/day. However, it can be as low as 20 kg/day when the crop is less. Use of these shears in our plantations can improve the worker productivity (plucker intake) from about 20-30 kg/day (manual plucking) to about 40-60 kg/day, which is doubling the output of workers. This also reduces the labour requirement for plucking.

Yield reduction of 25-35% under continuous shear harvesting has become a limiting factor for use of imported shears. This is mainly due to the non selective harvesting and affected shoot growth. However, there is no significant drop in yield when TRISTH is used due to selective harvesting of shoots. Although, ordinary shears give about 10-15% more coarse leaves than manual harvesting, TRI shears harvest more or less similar shoots as in manual harvesting. Unlike in manual harvesting, damage to shoots while harvesting (e.g. bruising or crushing by hand) is minimum with the shears which is an added advantage of shear harvesting.

Motorized machines

Harvesting machines range from hand held portable harvesters to tractor mounted types. Depending on their size, the weight of machine may vary from about 10 kg to about several tones. These machines are manufactured to fit the varying field conditions and pattern of shoot growth. Although, there are many types of motorized harvesters, their common feature is non selectivity in harvesting of tea shoots. These harvesting machines require good ground conditions and evenly growing shoots (less number of generations) and trained canopies for better performance. Therefore, the use of motorized machines is greatly limited by field conditions and pattern of shoot growth. Most of the tea growing countries where mechanical harvesting is done, have their tea lands planted and trained to facilitate the movement machines and workers, and synchronized growth of tea shoots. Further, shoot production of some temperate countries like Japan is limited only to few months, thus performing an even growth of shoots with a few generations. This pattern of growth, is attributable to the temperature and rainfall distribution.

Under tropical climatic conditions such as in Sri Lanka, shoot growth occurs throughout the year and forms about 6 to 7 shoot generations in the plucking table. As the standard shoots having 2-3 leaves are used for producing better quality tea, motorized machines need to be modified for selective harvesting or bushes need to be stimulated to have synchronized growth of shoots with a fewer number of generations to maintain a better plucking standard. Moreover, bushes should be especially trained for motorized harvesters. This has to be done, originally at the time of planting (double hedgerows) giving more space between two hedges to facilitate the movement of workers and machines. Moreover, the hedgerows can have a dome shape plucking surface to increase the area of plucking table and facilitate the movement of machine. In order to undertake mechanical harvesting successfully, bushes can be trained repeatedly at every pruning and recovering shoots need to be cut at several occasions depending on their rate of growth after pruning. Accordingly, a plucking table with many plucking points can be formed before plucking machines are used.

Output of machines largely depends on the length of blades (harvesting section) *i.e.* the longer blades give a higher output than shorter ones. Further, the output also vary with the yield potential and the topography (mainly slope) of the tea land. Under average field conditions in Sri Lanka, smaller machines having about 30 cm blades give an output of about 150 kg/day. This is as high as 350 kg/day for a larger machine with a 100 cm blades. The harvested crop contains about 15-20% more coarse leaves than the manually harvested crop that need to be manually removed.

The labour requirement for operating the machine may vary with the style of planting, topography of the field and presence of other obstacles such as drains, bunds and shade trees etc. Generally, a smaller machine requires one operator and a larger one (100 cm) requires two operators. However, one extra worker is required to hold and guide the leaf collecting bag on sloping terrain where tea is originally planted for manual harvesting and plucking table is formed flat. Under such conditions, the output per worker is comparatively low. The extent of tea field harvested by a machine varies with field conditions. It is usually less than a hectare under most of our filed conditions.

Generally, use of machines gives less yield than manual plucking. In our tea fields, continuous mechanical harvesting has declined tea yield remarkably (more than 50%). If harvesting machines are used only during peak cropping months (monsoon periods only), yield loss can be minimized to about 20-30%. Inclusion of coarse leaves also reduces the yield of standard shoots. Low yield is mainly due to non-selective harvesting of shoots and damage to the maintenance foliage leading to extended plucking round (Wijeratne *et. al*, 2000).

Usually machine harvesting gives poor quality crops compared to manual harvesting. Crop harvested by machines consists of sub standard shoots such as over mature (coarse) leaves and stems, and immature shoots or *arimbus*. Due to the presence of shoots of varying degrees of maturity and a wider range of moisture, the process of orthodox tea manufacture is affected and consequently they produce poor quality teas. When unsorted leaves are processed, the amount of refuse tea and the off-grade tea increases, while good quality main grade tea reduces. This could be minimized if unwanted materials are sorted out or if the number of shoot generations in the bush is reduced. Therefore, motorized machines could be used during rush crop periods when shoot growth is faster and plucking fields are to be abandoned due to lack of labour. However, it is very necessary to remove coarse leaves and other extraneous materials from the harvest before supplying to the factory.

This shows that mechanical harvesting cannot simply replace manual plucking. If that is to be used as an effective alternative to manual plucking, plucking policies and the processing need to be adjusted. Moreover, workers and tea bushes should be trained to suit the requirement of mechanical harvesting, if disadvantages to be minimized.

Maintenance of quality of harvested shoots and the end product

It has been highlighted that the maturity of harvested shoots greatly influences the quality of the end product. A good leaf standard can be maintained by manipulating the frequency and standard of harvesting. The quality of made tea can nevertheless be affected by the physical condition of shoots reaching the factory. Hence, it is necessary to minimize the physical damages to tea shoots while harvesting and transportation. Shoots can be damaged (crushed or bruised) when too much of shoots are retained in the plucker's hand during manual harvesting. Frequent charging of the leaf collecting basket not only minimized the physical damage to shoots but also improves selectivity of shoots by free movement of fingers. The use if machines and shears minimizes the leaf handling by hand. There is also a greater chance of damaging shoots at the time of bulking them into baskets or bags and during transportation. Too much of crop should not be rammed and pressed into a basket or a bag when bulking. In addition, several bags should not be stacked on top of each bag in the vehicle because poor aeration and heat breakdown the chlorophyll and, subsequently, the shoots become brown in colour. Such shoots are unsuitable for manufacture. Harvested shoots can be spread on a clean floor under a shade if bulking or transportation is delayed.

Harvested crop should not be contaminated with any extraneous material such as sand/grit or agro-chemicals because residues of such chemicals and extraneous materials retained in the made tea are hazardous to human health. When agro-chemical are used in tea fields, it is utmost important to either to bulk shoots from chemically treated fields adequately with those from untreated fields or withhold harvesting for a stipulated period of time, as recommended by the research institutes or chemical manufacturers.

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