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Assessment of Manual and Shear Harvesting in High Elevation Tea Plantations in Sri Lanka

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ABSTRACT. *Substantial variability is seen in the quantity of leaf plucked by different pluckers and a significant decline in the plantation labour force has been reported. Hence, various innovations have been aimed at improving plucker productivity. This study attempted to assess manual and shear harvesting while introducing a new backpack type plucking basket to replace the traditional and also mobile weighing. The study was conducted during July to October 2001 at the Great Western estate, Talawakele in Nuwara Eliya District. Thirty female pluckers were selected adopting the stratified random sampling method. All the pluckers were provided the backpack type plucking basket (Great Western model) as a collecting device for plucked tea leaves. Pluckers of treatment 1 were allowed to pluck manually, whereas the pluckers of treatment 2 were provided with shears. Primary data were collected by field measurements, observations and video recording. Video recording was done in order to identify and measure the plucking motions and to identify the minor activities performed by the pluckers. A sample of tea leaves was obtained in order to estimate the leaf standard. The manufactured tea was sent to professional tea tasters for quality evaluations. Nine different plucking elements were identified for both manual plucking and shear plucking with Great Western Plucking Basket (GWPB). One hundred and seventy-three shoots were cut within a minute with 82 shear cuts. It was found that the productivity of medium pluckers could be increased by 22% by using shears in the morning hours. There was no significant difference in the quality between the tea harvested manually and using shears. However, manual harvesting had 16% higher leaf standard compared to shear harvesting. Further studies are required to assess the quality of made tea with shear harvesting.*

INTRODUCTION

Plucking, which involves the removal of immature tender leaves (2-3 leaves and the bud), is the crucial revenue generating field operation in tea production. The objective of plucking tea is to harvest the maximum yield of good quality leaf per unit area, combined with maximum labour efficiency (Watson, 1986). Plucking is the most labour intensive and the most expensive field operation in tea production. It accounts for about 40% of the cost of production and 60% of the total field cost. Approximately 67% of the field work force in tea plantations is engaged in plucking (Sivaram and Herath, 1996).

Among the yardsticks available for judging the production efficiency of the

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tea industry, the most important is the plucking productivity and it represents the quantity of green leaf harvested per person per day (Sivaram, 1996). Plucking productivity in Sri Lanka is 15 kg person^{-1}day^{-1} for the state sector and 24 kg person^{-1}day^{-1} for the private/small holdings sector, whereas, in Kenya the average is 40-50 kg person^{-1}day^{-1} (Sivaram, 1996). Substantial variability can also be seen in the quantity of leaf plucked by different pluckers. Jain *et al.* (1996) have shown that the physical constitution and fitness of the pluckers, actual plucking methods and motion patterns account for the above differences. However, agronomic factors such as type of clone, plucking interval, weather, elevation and various field practices adopted by the management influence the plucking productivity (Sivaram and Herath, 1996).

A significant decline in the plantation labour force averaging 4% over the last 10 years has been reported. Further, the decline in labour force is expected to continue in the future as the workers find attractive employment opportunities outside the estates. The problem is aggravated due to the decline in the registered workers reporting for work, from about 80% in the past to 60% (Sivaram and Herath, 1996). An appropriate scientific approach is required to mitigate the adverse impacts of out migration and absenteeism of registered resident workers and to increase the productivity of the existing work force.

Some innovations have been aimed at improving plucker productivity, of which the Great Western Plucking Basket (GWPB) is recent. It was observed that the present cane basket, supported by a strap which passes over the head, creates a backward pull which necessitates a forward contracture of the neck muscles and a stooping posture to balance the weight of the bag on the back. A report published by the National Institute of Plantation Management suggests that the above problem could be overcome by devising a comfortable method for carrying the green leaf without causing strain to the head and neck; perhaps, a basket strapped to the back, similar to a knapsack (Anonymous, 1998). Consequently, the Manager of Great Western estate designed an aluminium framed backpack type-plucking basket.

In the conventional weighing system, the pluckers have to wait in a queue for long periods of time to weigh the leaves plucked. This consumes time that could otherwise be used for plucking. The pluckers also lose energy by walking long distances carrying heavy weight to weighing sheds. As a solution to these problems, concept of mobile weighing was proposed as an innovation, aimed at improving plucker productivity.

Different types of mechanical harvesters have also been innovated in order to increase the productivity and to solve the problem of shortage of workers. A light weight shear without long handles has been designed and fabricated by the Tea Research Institute (TRI) low-country station to suit the Sri Lankan terrain and pluckers (Wijeratne, 1997). According to a recent study with conventional bags and conventional weighing carried out in upcountry estates, worker productivity has been increased with the use of shears from 17.2 kg day^{-1} worker^{-1} to 18.6 kg day^{-1} worker^{-1} (Wanigasundera *et al.*, 2001).

In the past, time and motion studies and studies on shear harvesting were carried out with conventional basket and conventional weighing method. Therefore, this study was conducted with the objective of assessing the manual and shear harvesting combined with GWPB and mobile weighing. Especially this study attempted to identify the plucking motions and time used for different activities in

order to estimate the effective plucking time and evaluated the quality of made tea obtained from the different harvesting and weighing systems.

METHODOLOGY

The study was conducted from July to October 2001 at Great Western Estate located in Nuwara Eliya district where most of the high elevation tea plantations are concentrated. Thirty female pluckers were selected adopting the stratified random sampling method. Name list of pluckers and their monthly plucking intake for the past six months were obtained from office records. Based on previous records, according to the daily output, pluckers were stratified into fast, medium, and slow for sampling purposes. The pluckers' average daily intake (harvest) ranged from 10 to 19.8 kg. Pluckers whose intake fell in between 14 to 16 were classified as medium pluckers, whose intake were below 14 were classified as slow pluckers and above 16 were classified as fast pluckers. Finally, five pluckers were randomly selected in order to optimise the resource utility from each category for both treatment 1 and treatment 2.

Since the age of the crop (year after pruning) and type of tea (seedling tea or vegetatively propagated tea) affects the productivity, blocking was adopted to eliminate this effect. Three different fields *i.e.* early (first year after pruning), medium (second year after pruning), and late (third year after pruning) were selected. Therefore, the experiment was carried out in the fields with different growth levels. The study was carried out on vegetatively propagated tea fields.

All the pluckers were given GWPB to collect the tea leaves. It is an aluminium framed backpack type-plucking basket, with two main parts. One is the aluminium frame and the other is the net, for collecting of tea leaves (Figure 1). The height of the basket is 50 cm and it has a wide opening, which is 50 x 40 cm. This basket weighs about 1.6 kg. On either side of the belt, there are two pockets to keep a water bottle and the daily record card. When the net is full with plucked leaves, it can be removed for weighing and another one can be placed.

Pluckers of treatment 1 were allowed to pluck manually, whereas the pluckers of treatment 2 were provided with a TRI Selective Tea Harvester (TSTH) for plucking. The TSTH consists basically of two sharp blades held together at one end by a nut and a screw (Figure 2). A handle fixed to the upper blade is used to move it over the lower blade bends the tea shoots in between the blades for an easy, clean cut. The edges then guide the cut shoots to a collective tray fixed to the lower blade. The blades are fixed to a step 2.5 cm above the bottom of the leaf -collecting tray. This raised position protects small shoots being cut and removed while plucking (Wijeratne, 1997).

Initially, pluckers were given an orientation to the different treatments. Pluckers of both T1 and T2 were given training on how to use the GWPB. The pluckers of T2 were given training on the use of the TSTH. All the pluckers were informed about the mobile weighing such as place of weighing, leaf collecting staff, etc.

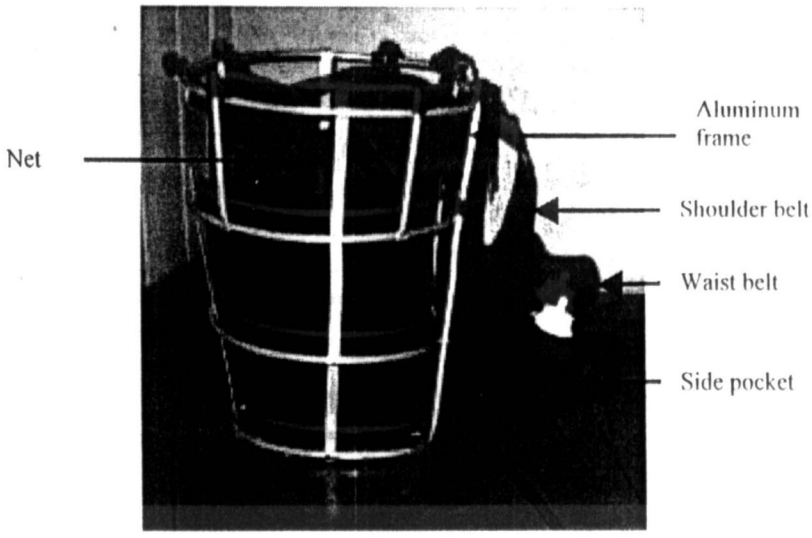

Fig. 1. Great Western Plucking Basket

This basket can hold only 5-7 kg of tea leaves. Once the net is full with plucked tea leaves, it is removed from the basket, weighed in the field itself and a new one is replaced. This process is known as mobile weighing. Therefore the pluckers do not want to walk to the weighing shed and return to the field again and again. Therefore, mobile weighing was practiced with all pluckers in the study.

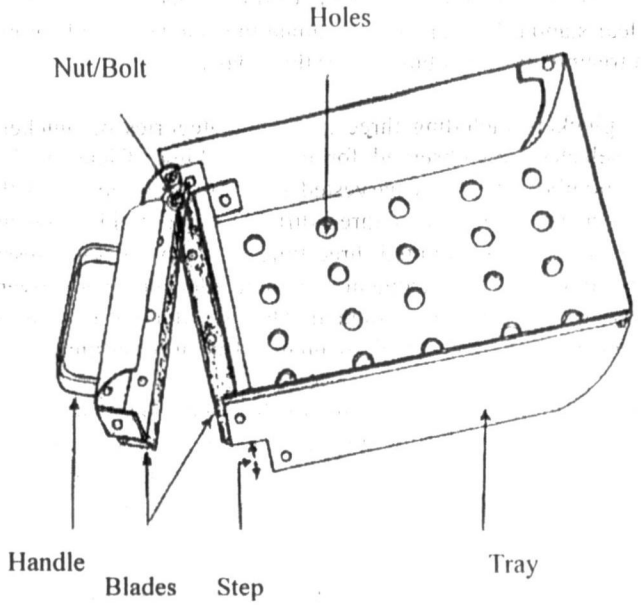

Fig. 2. TRI Selective Tea Harvester.

Primary data were collected by field measurements, observations and by video recording. Using a recording sheet, time spent on different activities by the pluckers

was recorded. The pluckers were observed from the commencement of work in the morning till the last weighing of tea leaves in the evening and time spent on various activities such as weighing, walking and other personal activities were estimated. Timing was not done during the first week of the study period to avoid the Hawthorne effect.

Video recording was done in the field in order to identify and measure the plucking motions and to identify the minor activities performed by the pluckers. Three pluckers, one from each category (fast, medium and slow) were selected for video recording. Prior to this, all the pluckers were video recorded in order to make them comfortable with this intrusion and to minimize the Hawthorne effect. The recorded tapes were studied in an audio-visual laboratory. The video recordings were analysed to identify all types of motions and time spent for each motion.

Productivity was measured in terms of number of kg harvested day^{-1} by workers. Efficiency of plucking was measured by the number of shoots plucked per minute. Effective Plucking Time (EPT) is the actual time spent for the physical motion of plucking which involves the removal of a bud and two leaves. Pluckers perform different activities other than actual plucking in the field. However, some of these activities such as transferring leaves to the basket and walking along the rows of tea bushes were related to plucking. Others were personal activities, which include chewing betel and wearing raincoat. The other activities were related to the field such as walking to new fields and weeding. Time taken for all these activities was subtracted from the total working hours in order to estimate the effective plucking time.

The leaf standard refers to the proportion of the acceptable leaf components in the harvested flush (Ekanayake, 1995). Careful selective harvesting could give an acceptable leaf standard. In order to estimate the standard of plucking a sample of tea leaves from treatments were obtained for three days.

Six pluckers including three different categories of pluckers (fast, medium, slow) were selected and observed for their plucking efficiency. For T1 treatment, initially, the number of shoots harvested manually was observed three times a day (morning, noon and evening) in three different aged fields. The number of shoots harvested per minute was counted three times in each plucking session *i.e.* morning, noon and evening. For T2 treatment the same pluckers were given shears and the number of shoots harvested was counted. This was done at the later part of the study when the pluckers were used to both manual and shear harvesting.

To assess the quality of the tea of different treatments, the manufactured tea was sent to three professional tasters in duplicate for quality evaluations for the characteristics such as infused leaf, colour, strength, quality and flavour. Scores were given to the above characteristics and the total score was calculated. The quality, difference of the treatments were analysed by using 'Fried Mann Test'.

The percentages, means and ranges were used to summarize the data. The Duncan Mean Separation procedure was adopted to test the significance of the differences among the treatments. Using the linear regression analysis, models were developed for different types of treatments.

RESULTS AND DISCUSSION

The age of the pluckers varied from 21 to 53 years. The experience of pluckers ranged from 2 to 30 years and the mean was 19 years. Nearly 77% of the respondents had up to primary level of education. Mean weight of the pluckers of T1 and T2 were 42.7 kg and 46 kg while mean height was 145.5 cm and 151.6 cm respectively.

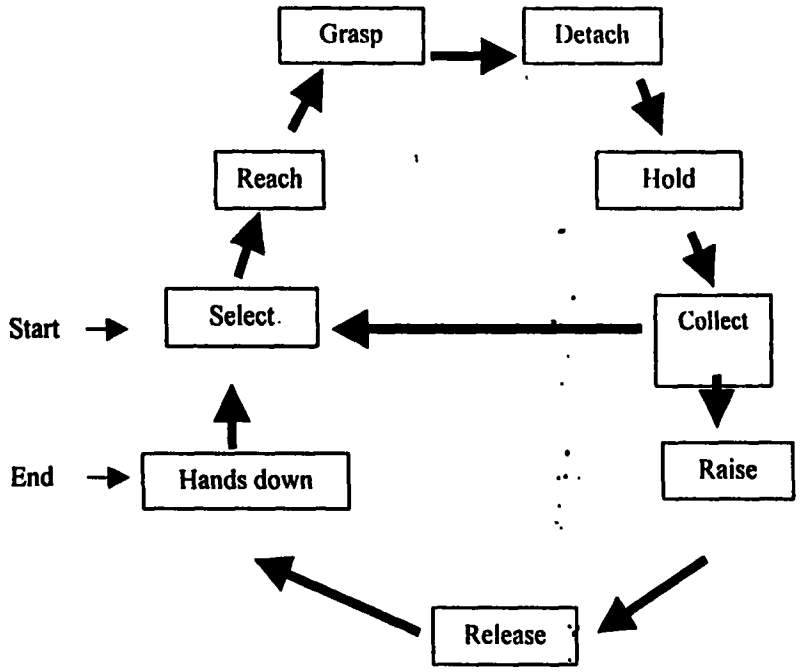

Fig. 3. Plucking Motion Cycle for Treatment 1.

Analysis of tea plucking motions

Based on the video tape analysis, nine basic elements of plucking motions were identified in the treatment 1 where GWPB was used for plucking (Figure 3). This is 40% reduction when compared to the number of motions where the poly sack is used for plucking (Shankar *et al.*, 2002). Reduction of the number of elements would influence the plucker productivity. For instance, use of GWPB eliminated the motions such as grabbing and opening of the poly sacks. The number of motions for T1 and T2 were same (Figure 4).

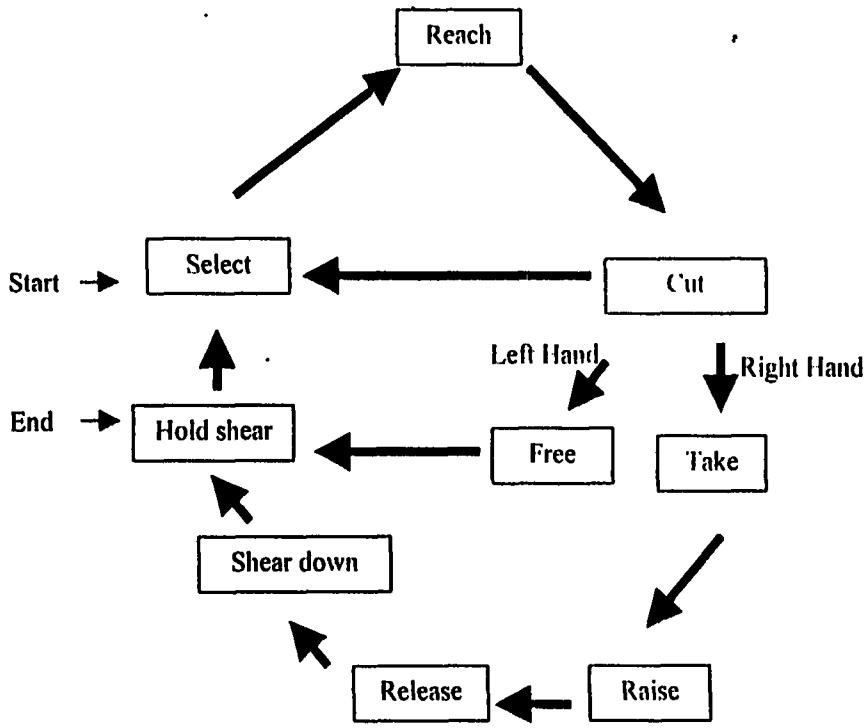

Fig. 4. Plucking Motion Cycle for Treatment 2.

The number of cuts made by the shear varied from plucker to plucker. An average pluckers cut 82 times per minute using the shears. The number of cuts and the number of shoots plucked are given in Table 1.

Table 1. The variation of manual and shear harvesting of the respondents.

Category of plucker	Number of shear cuts min^{-1}	Number of shoots plucked min^{-1}	Number of shoots per shear cut	Number of shoots plucked manually min^{-1}
Fast	103	205	2.0	159
Medium	74	170	2.3	120
Slow	69	143	2.1	95
Average	82	173	2.1	125

On the average, 173 shoots were cut within a minute with 82 shear cuts. Number of shoots per shear cut was 2.1 and highest for the medium plucker. When using shears, 173 shoots have been harvested minute, whereas only 125 shoots were harvested manually. Hence, harvesting was enhanced by 38% by using shears. However, statistical analysis was not carried out to test significance of differences due to insufficient numbers of pluckers observed. Hence, further studies are necessary to find out exactly what factors affect shear harvesting.

Influence of manual and shear harvesting on effective plucking time

Pluckers perform several activities other than actual plucking in the field. Time taken for these activities (Table 2) was subtracted from the total working hours in the field to estimate the Effective Plucking Time (EPT). The EPT of T1 and T2 are 265.6 and 275 minutes respectively. Even though, the EPT is higher for the treatment 2, it is not statistically significant for different category of pluckers (Table 3).

Table 2. Activities affecting the Effective Plucking Time.

Activity	Average time (minutes)	
	T1	T2
Tea break	46.4	43.7
Lunch break	132.1	122.2
Weighing the tea leaves	7.0	8.3
Walking to weigh the leaves/new rows/other field	20.7	22.1
Personal activities (chewing betel, wearing rain coat etc.)	15.4	16.3
Maintain the plucking table	5.3	4.6
Other minor activities (adjustment to scarf/GWPB/shears)	11.9	16.0

Table 3. Effective plucking time by category of pluckers.

Treatment	Category	Effective plucking time (minutes)		
		Morning*	Noon**	Evening***
1	Slow	69.0 (a)	76.2 (a)	115.1 (a)
	Medium	71.5 (a)	75.4 (a)	122.0 (a)
	Fast	73.2 (a)	80.1 (a)	111.4 (a)
2	Slow	70.1 (a)	77.6 (a)	126.4 (a)
	Medium	65.9 (a)	81.2 (a)	130.8 (a)
	Fast	63.5 (a)	79.3 (a)	125.3 (a)

* Up to morning weighing, which is followed by tea break

** After tea break till noon weighing, which is followed by lunch break

*** After lunch break till last weighing of the day

Letters in parentheses indicate Duncan group of means. The means with same letters are not significantly different

Worker productivity per minute was calculated by dividing the intake by the EPT. A slow plucker in T1 plucked 740 g of green leaves per minute in the morning whereas, in T2, a slow plucker plucked 780 g. This is nearly 5% higher than the T1. However, the difference is not significant. However, for the medium pluckers of T1 this is significant compared to the other treatment at 0.15 reference level of error (α). Table 4 shows worker productivity in terms of kg of leaves harvested per minute by different categories of pluckers and treatments.

Table 4. Worker productivity by categories of pluckers and treatments.

Trt	Morning			Noon			Evening		
	Slow	Medium	Fast	Slow	Medium	Fast	Slow	Medium	Fast
T1	0.074 (a)	0.059 (b)	0.068(a)	0.070 (a)	0.081 (a)	0.074(a)	0.063 (a)	0.065 (a)	0.064(a)
T2	0.078 (a)	0.072 (a)	0.075(a)	0.073 (a)	0.080 (a)	0.076(a)	0.076 (a)	0.063 (a)	0.068(a)

Letters in parentheses indicate Duncan group of means. The means with same letters are not significantly different

Based on the linear regression analysis, models were developed for different types of treatments. The model for the medium plucker of T1 is as follows;

Morning intake = 0.059 x Morning EPT $(R^2 = 0.93)$.

According to the above coefficient, if the EPT is increased by one minute for a medium plucker of T1 in the morning, pluckers could pluck nearly 59 g more of green leaves. Thus, for one hour, nearly 3.5 kg could be plucked. This is significant at 0.001 level and explain 93% of the variability. Similarly, medium pluckers of T2 could pluck 72 g of green leaves during morning session, thus 4.3 kg of green leaves could be plucked within an hour. Thus, worker productivity of medium pluckers could be increased by 22% if they are given shears in the morning hours to harvest tea leaves.

Analysis of quality of the made tea

There was no significant difference between the treatments in the analysis of leaf standard (Table 5). However, manual harvesting (T1) had 16% higher leaf standard, compared to shear harvesting in T2. This may be due to the inadequate training on the use of shear and cutting of mature leaves into the harvest. However, the Field Officer of Great Western Estate was of the view that the first few rounds of plucking in a field will be affected with shearing and when the tea bushes are used to shears, a better leaf standard could be maintained. He also mentioned that the matured leaves would be harvested by shears during the first few rounds and later, only the immature leaves will appear above the bush level, hence, only the immature shoots could be harvested in order to maintain the leaf standard. Further long-term studies should be undertaken to assess whether the shear harvesting affects the quality of tea.

Table 5. Leaf standard and quality score by treatments.

Treatments	Leaf Standard(%)	Quality Score
T1	65 (a)	14.4 (a)
T2	56 (a)	12.9 (a)

* Letters in parentheses indicate Duncan group of means. The means with same letters are not significantly different

Similar to the leaf standard, the quality of the made tea is also not statistically significant among treatments (Table 5). There were no significant differences among treatments in overall score for infusion, colour, strength and quality. Treatment 2 had the lowest score mainly due to lower leaf standard (Table 5).

CONCLUSIONS

Nine different plucking motions were identified for both manual and shear plucking manually or using shears with GWPB. The number of motions involved by using GWPB for plucking was found to be substantially lower compared to that of poly sack bags. This reduction might influence the plucker productivity and hence a further in-depth study is recommended to test this relationship.

On the average, 173 shoots were plucked within a minute with TSTH whereas only 125 shoots were plucked manually. Therefore, harvesting could be enhanced by 38% by using shears.

The EPT of manual harvesting was four hours and twenty-six minutes whereas it was four hours and thirty-five minutes for shear harvesting. There were no statistically significant differences among the EPT of different categories of pluckers. However, the productivity of medium pluckers was found to be 22% higher when they were given shears in the morning hours to harvest tea leaves. Therefore, it could be concluded that shear harvesting by the medium pluckers in the morning is economically feasible.

Manual harvesting had 16% higher leaf standard compared to shear harvesting. However, there was no significant difference in the quality of made tea produced by both plucking methods. Further studies are required to assess the quality parameters of made tea with shear harvesting.

Before these innovations are widely used by the pluckers, an ergonomic assessment of GWPB and TSTH in relation to safety, health and comfort is recommended and make necessary modifications.

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