

Ergonomic Analysis of Harvesting in High Elevation Tea in Sri Lanka

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ABSTRACT. *Harvesting efficiency is one of the most critical factors affecting productivity in tea plantations. Substantial differences in the quantity and quality of leaf plucked by different pluckers are reported. Therefore, time spent on the actual plucking was estimated and the motions involved in plucking were studied to identify methods to increase the worker productivity.*

Fifteen female pluckers were selected adopting the stratified random sampling method. During the study period, July to October 2001, the pluckers were closely observed from the commencement of work in the morning till the last weighing of tea leaves in the evening in order to estimate the time spent on different activities performed in the field. The movement of three pluckers were video recorded and the recorded tapes were also analysed.

Fifteen specific elements of plucking motions were identified. The ratio of left to right hand movement is 0.8, which indicates the lesser movements of the left hand. The effective plucking time is four hours and 22 min per day. This is only 54.6% of a normal working day of eight hours. If the morning effective plucking time is increased by 15 min, the day's worker productivity could be increased by 5.7%. Fast pluckers pluck nearly 159 shoots per minute. Compared to an average plucker, a fast plucker plucked 27% more shoots per minute.

Introduction of mobile weighing, proper deployment of pluckers in the field and better supervision are recommended to increase the worker productivity. Supervisors should also be trained on plucking motions, deployment of pluckers and on how to reduce the wastage of productive time.

INTRODUCTION

Plantation agriculture is a vital part of Sri Lankan economy. Contribution of the tea sector to GDP is 2.2% and earned US \$ 621 million in 1999 as export earnings (Central Bank of Sri Lanka, 2001). In 2000, tea production reached a record level of 306 million kg from 180,000 ha (Central Bank of Sri Lanka, 2001). Plucking, which involves the

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removal of 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 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 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 also influence the plucking productivity (Sivaram and Herath, 1996).

Plucking productivity depends on the actual time that pluckers spend for plucking, known as effective plucking time (EPT), and the speed of plucking. According to a time utilisation study in India, the effective plucking time ranged from 3.8-5.7 h day⁻¹ (Venkatakrishnan and Sarkar, 1996). Routine activities such as weighing, walking to and from fields, extended tea and lunch breaks reduce the effective working time of a plucker. The effective plucking time has been estimated as 4 h and 37 min in vegetatively propagated (VP) tea fields in an upcountry estate in Sri Lanka (Shankar, 1997).

A significant decline in the plantation labour force averaging 4% over the last 10 years has been reported (Sivaram and Herath, 1996). The decline in labour force is expected to continue in the future as the workers find attractive employment opportunities outside the estates (Sivaram and Herath, 1996). It is reported that the worker outturn *i.e.*, percentage of registered workers reporting for work, has fallen from about 80% in the past to 60% (Sivaram and Herath, 1996). A suitable scientific approach will have to be developed to mitigate the adverse impacts of the out migration and absenteeism of registered resident workers and to increase the productivity with the existing work force. Therefore, the objective of this study is to identify the plucking motions and the time spent for different operations and activities to estimate the effective plucking time as a way to increase the plucking productivity.

METHOD

The study was conducted at Great Western estate situated in Nuwara Eliya district in the up-country tea from July-October 2001. The mean elevation of the estate is 1,463 m above mean sea level. Lists of names of the registered pluckers and their monthly plucking intake for the past six months were obtained from office records. Pluckers were classified to three groups based on plucking efficiency as fast, medium and slow based on previous records on amount of green leaves harvested per day by a plucker. Finally, five pluckers

from each group were randomly selected, making the total number of respondents to 15. Tea fields were grouped to three categories based on age of tea namely, early, medium and late fields.

Primary data were collected by field observations and by video recording of tea harvesting. Observations were made on the pluckers from the commencement of work in the morning till the last weighing of tea leaves in the evening. The time spent on various activities such as weighing, walking and other personal activities such as chewing betel and wearing raincoat were also measured. Furthermore, using a stop watch observations were made of workers for 1/2 h thrice a day (morning, noon and evening) to estimate the time spent on activities while plucking such as bush-to-bush walking, weeding and talking. The observations and time measurements during the first week of the study period has not been considered for estimation purposes to avoid the Hawthorne effect (Babbie, 1995).

Video recording was done in the field in order to identify and measure of the plucking motions and to identify the minor activities performed by the pluckers. Three pluckers, one from each category 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 the types of motions and time spent for each of the activities.

Time was estimated for the motions involved in plucking. The movements of the right and left hands of pluckers were observed.

Productivity was measured in terms of amount (kg) green leaves harvested per day by each worker. The number of shoots plucked per minute was used to measure the plucking efficiency. Effective plucking time (EPT) was calculated using the following equation.

$$EPT (h) = [Total\ time\ spent\ within\ the\ field\ (h)] - [Time\ spent\ on\ activities\ other\ than\ plucking\ (h)]$$

Percentages, means and ranges were used to summarize the data. Based on the models developed by linear regression analysis, the possible increase of intake by increasing the effective plucking time was estimated.

RESULTS AND DISCUSSION

The 15 women pluckers in the sample showed variations in terms of age, weight, height and plucking experience. The age of the pluckers ranged from 21-55 years (Mean = 37.1). The average plucking experience of the sample is 18.4 years, with a minimum of five and maximum of 30 years. Mean weight of the respondents is 46.2 kg, which ranged from 38-67 kg. The height of the respondents ranged from 1.32-1.58 m (Mean 1.49 m).

Analysis of tea plucking motions

Based on the video analysis, 15 basic elements of plucking motion were identified as shown in Fig. 1. Sometimes, pluckers raise only their right hands and perform both opening the mouth of the bag and releasing the tea leaves. Out of 15 plucking elements, eight elements (1-7, 10) are common for both left and right hands.

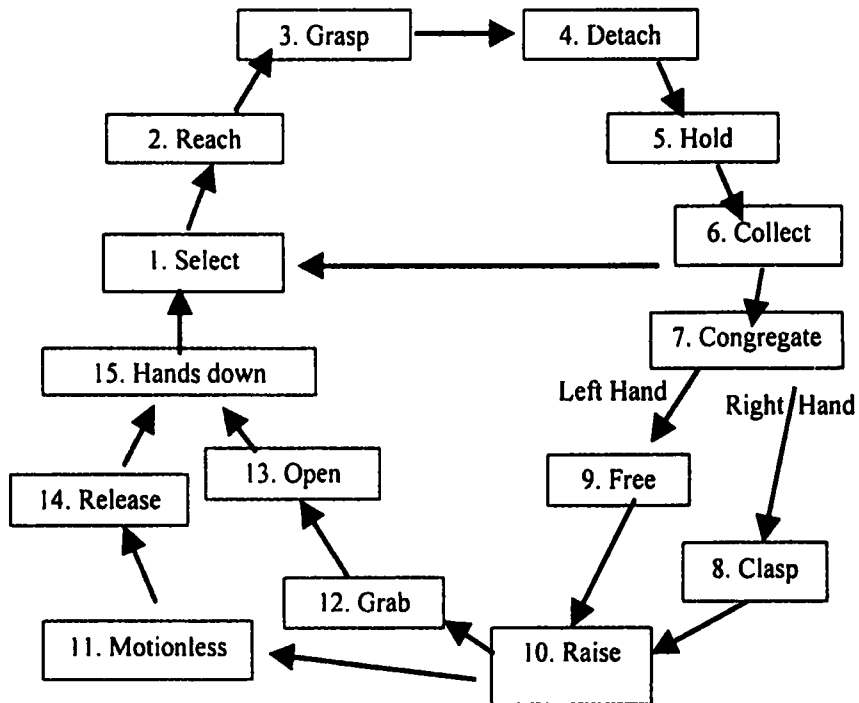


Fig. 1. Tea plucking motion cycle.

Total time taken on the average for the completion of one cycle of plucking motions *i.e.*, for the 15 elements is 48 seconds. However, this varies from plucker to plucker even if the field condition is same generally due to the holding capacity of the pluckers. Holding capacity is the amount of plucked tea leaves a plucker can hold in her hand with her fingers. Pluckers who have longer middle fingers and palm tend to hold more tea shoots in their hands. Hence, the time taken to complete one cycle of plucking motion may increase.

On the average for a right hand plucker, right hand moves 69 times min^{-1} whereas the left hand moves only 54 times. Table 1 shows the number of right and left hand movements by different categories of pluckers and the number of shoots plucked by them.

Table 1. The variation of motions of right and left hands of the respondents.

Category of plucker	Number of movements min ⁻¹			Number of shoots plucked min ⁻¹		
	Right hand	Left hand	Total	Right hand	Left hand	Total
Fast	82	66	148	89	70	159
Medium	68	51	119	72	48	120
Slow	56	46	102	54	41	95
Average	69	54	123	72	53	125

Generally the right hand of the plucker moves more than the left hand during plucking. The ratio of number of movements left to right hand is 0.8. This shows the frequent use of right hand in plucking by the respondents who are right-handed pluckers. Pluckers pluck nearly 125 shoots min⁻¹ with 123 hand movements. Hence, the number of shoots hand⁻¹ movement is 1.02. Compared to an average plucker, a fast plucker plucks 27% more shoots min⁻¹. The number of shoots plucked is more than the number of hand movements for the fast and medium pluckers. Hence, effectiveness of hand movements of fast pluckers and medium pluckers is better than the slow pluckers. Therefore, slow pluckers should be trained to improve the effectiveness of plucking. However, further studies have to be carried out to identify the reasons for the slowness and methods to maximise it.

Influence of effective plucking time on worker productivity

On the average, time taken from the commencement of work in the morning to stopping of work in the evening is eight hours and 31 min (511 min) including tea and lunch breaks. Pluckers perform different activities during this time other than actual plucking in the field. However, some of these activities are plucking related such as transferring leaves to the basket and walking to new rows of tea bushes. Others are personal activities, which include chewing betel and wearing raincoat and the rest are related to field such as walking to new field and removing the creepers on the plucking table.

Pluckers have their tea and sometimes breakfast in the field at about 10:00 a.m. Time taken for tea break ranges from 27-55 min. On the average it was 37 min (Table 2). However, only 20 min is permitted by the management for the tea break. Similarly, time taken for lunch is also longer than the given time. One hour is given for lunch break. Since pluckers have to go back to their line rooms, which are far away from the field and attend to household chores, they generally get late to work after the lunch break. These are the major activities reducing the effective plucking time.

Pluckers are entitled for over-kilo-payment other than the fixed daily wage when they pluck more than the norm. Thus, the pluckers' daily wage depends on the weight of the tea leaves plucked. Normally the plucked leaves are weighed thrice a day. In the study

area, the morning weighing was done closer to the field and noon and evening weighing were done at the weighing shed. As pluckers have to walk, wait in the queue and weigh their tea leaves, they lose some of their productive time.

Table 2. Time taken for tea and lunch breaks (min).

Activity	Minimum	Maximum	Average	% of total work time
Tea	27	55	37.2	7.3
Lunch	81	139	113.9	22.3

Total weighing time ranges from 11-35 min. On the average, weighing time, including morning, noon and evening weighing is 23.7 min. In addition to this, some pluckers who assist the weighing session lose more of their productive time. On the average they spend nearly 29 min at the weighing spot helping in weighing, packing the tea leaves in poly sacks to be transported to the factory and cleaning the weighing shed. In order to save this time and to increase the effective plucking time, the weighing could be done by some other workers or else mobile weighing could be introduced where the tea leaves are weighed in the field whenever the basket of that particular plucker is filled. In addition, batch by batch weighing system, *i.e.*, calling the pluckers by batch rather than calling them all could be adopted. Hence, wastage of time due to waiting in the queue for the turn to weigh the leaves could be minimised.

Pluckers walk in the field for various needs. They walk thrice a day to weigh the leaves from the field to the weighing shed. Once a plucker finishes plucking in one row of tea bushes she seeks new rows from the *Kangani* (supervisor for a group of pluckers) and walk to pluck the new rows. Sometimes they also walk to other fields after finishing one on the same day. Pluckers use poly sack bags to pluck tea leaves and cane baskets to store these leaves whenever the poly sack bags are filled with tea leaves. Therefore, pluckers take time to transfer the leaves from poly sack bag to collecting basket when their bags are filled, and again they go back to their rows and continue plucking until their bags are filled again. On the average, time taken for all these daily walking activities is approximately 40 min (Table 3).

In the field, once in a while, pluckers stop plucking and prepare betel to chew. Depending on the habit the number of times of chewing betel differs from plucker to plucker. When it starts raining in the field, instead of a raincoat pluckers take a polythene sheet and cover their head and the body. As a whole, nearly 17 min is spent on personal activities (Table 4). Some of these activities cannot be controlled easily. However, providing a uniform may eliminate some of these activities such as wearing raincoat during the wet season.

Table 3. Time taken for walking by the respondents (min).

Walking activities	Minimum	Maximum	Average	% of total work time
To weigh leaves	9	38	16.3	3.2
To new rows	1	19	8.4	1.6
To transfer leaves	2	18	5.4	1.0
To other field	4	22	9.7	1.9
Total	11	62	39.8	7.8

Table 4. Time taken for personal activities (min).

Activity	Minimum	Maximum	Average	% of total work time
Chewing betel	1	4	2.0	0.4
Wearing rain coat	1	6	4.3	0.8
Talking	1	12	4.1	0.8
Listening / resting	1	28	6.8	1.3
Total	1	40	17.2	3.4

In Great Western estate, pluckers are given their own rows of tea bushes. Therefore, it is their responsibility to keep the bushes clean. Hence, while plucking they remove the weeds and the creepers, which appear over the bush. This activity on the average takes nearly 5 min day⁻¹. To avoid this time loss, fields should be free of weeds.

Pluckers perform some minor activities such as putting the tea leaves into the bag and adjustment to scarf. According to the field observation and video analysis, a total of nearly 2.8 min h⁻¹ is spent on these activities. The minor activities identified and the times taken are given in Table 5. Even though time spent on these activities seems to be short, when estimated for a day, it comes to about 12 min. Hence, these activities cannot be neglected.

Table 5. Average time taken for minor activities.

Activity	Time (seconds h ⁻¹)
Weeding / cleaning the plucking table	35
Wandering / listening	37
Adjustment to the scarf / cloth	40
Moving to 'varichchu'*	12
Movement in the field	28
Ramming the leaves in the bag	16
Total	168

* Varichchu is a stick, 1.5 m in length, used to maintain the plucking table. Most of the time pluckers move this by one hand while the other hand plucks.

On the average, effective plucking time is 262 min (Table 6). If a normal working day is considered as eight hours, the EPT is only 54.6%.

Table 6. Effective plucking time.

Category of plucker	Effective plucking time (min)			
	Morning*	Noon**	Evening***	Total
Slow	75.8	81.3	132.9	290.0
Medium	67.2	75.4	112.4	255.0
Fast	66.9	76.8	115.2	258.9
Average	69.4	77.5	115.4	262.3

* 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

Increasing the effective plucking time (EPT) will increase the worker productivity. Based on the linear regression analysis, models were developed for different types of pluckers. The model for a slow plucker is as follows.

$$\text{Morning intake} = 0.0644 \times \text{Morning EPT}$$

According to this coefficient, if the EPT is increased by one minute in the morning, the slow plucker could pluck nearly 64 g of green leaves. Thus, for one hour, nearly 3.8 kg could be plucked. This is significant at 0.00 level and explained 94.6% of the variability. Since, EPT was calculated for different periods of the day when weighing was done, similar models were developed and the coefficients are presented in Table 7.

Table 7. Coefficients of variability for different pluckers at different time intervals.

Type of plucker	Morning	Noon	Evening
Slow	0.0644	0.0653	**
Medium	0.0735	0.0726	0.0737
Fast	0.0803	0.0696	0.0728
Average	0.0730	0.0690	0.0715

**Model for slow plucker in the evening was not developed due to lack of data.

According to coefficients of the models, worker productivity could be significantly increased for the pluckers especially for medium and fast pluckers if the EPT is increased. In general, the pluckers pluck 19.06 kg of tea leaves day⁻¹ in 262.3 min. If the morning EPT is increased by at least 15 min these pluckers could pluck 1.09 kg more. Accordingly, worker productivity could be increased by 5.7%. Hence, the EPT could be increased proportionately in the total working hours by reducing the unproductive motions or by reorganizing the work pattern. For instance, fast plucker can start the plucking half an hour early.

Introducing mobile weighing in the field will save nearly 40 min by avoiding walking to weigh the leaves (16.3 min) and weighing the leaves (23.7 min). Proper deployment of pluckers in the field will minimise the wastage of time due to walking to other field, walking to transfer the leaves and walking to new rows. Keeping the field free of weeds or creepers is another strategy to increase the effective plucking time. Thus, pluckers will not spend time on removing the creepers while plucking. In addition, the supervisors also should be trained specially on plucking motions, better deployment of pluckers and know-how of minimising the wastage of time by the pluckers.

The elements of plucking motion should be carefully analysed to make proper recommendations. Further studies have to be undertaken to find out whether the number of elements should be increased or reduced by introducing innovations or changing the existing system to increase the productivity. If a ring is fixed to the opening of the existing poly sack bag, it could have a wide opening, which may eliminate motions such as grabbing and opening. However, these changes should also be assessed ergonomically.

The worker productivity could be improved by increasing the EPT by reducing the time spent on unproductive activities. However, there is a possibility of the pluckers getting

more tired if they spend more time on actual plucking. Hence, changes in the work pattern like frequent shorter resting periods for the pluckers could be considered.

CONCLUSIONS

Fifteen different elements of plucking motions were identified. The ratio of left to right hand movement is 0.8, which shows lesser movements of the left hand. Pluckers pluck nearly 125 shoots min^{-1} with 123 hand movements. Compared to an average plucker, a fast plucker plucks 27% more shoots min^{-1} . Therefore, slow pluckers should be trained and motivated to become better workers to improve the efficiency of plucking. However, further studies have to be carried out to identify the reasons for the slowness and methods to maximise it.

The effective plucking time is four hours and 22 min day^{-1} . This is only 54.6% of an eight hour-long normal working day. Some of the activities, which reduce the EPT, are weighing the tea leaves, walking to weigh the leaves, walking to new rows and fields and extended tea and lunch breaks. If the morning effective plucking time is increased by 15 min, the worker productivity could be increased by 5.7%.

Based on the findings, increasing the effective plucking time is one way of increasing the worker productivity. Hence, introducing mobile weighing, proper deployment of pluckers in the field and better supervision are recommended to increase the productivity. For the effective use of plucking motions, proper training to the pluckers is also recommended. In addition, supervisors should also be trained on plucking motions, deployment of pluckers and how to reduce the wastage of productive time. Further ergonomic studies are required to increase the worker productivity.

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REFERENCES

- Babbie, E. (1995). *The Practice of Social Research*, Wadsworth Publishing Company, USA.
- Central Bank of Sri Lanka. (2001). *Annual Report 2000*, Colombo.
- Jain, N.K., Venkatakrishnan, N.S., Bezbarua, R., Sarkar, A. and Sen, R.N. (1996). Ergonomic and work studies in relation to tea plucker productivity. 2nd Int. Symp., Ergonomics, Occupational Health, Safety and Environment, Nov. 25-28, 1996, New Delhi, India.
- Shankar, R.R. (1997). *Selected human factors affecting worker productivity and ergonomics of plucking*. Unpublished report, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.

Ravi Shankar, Jayatilaka & Wanigasundera

- Sivaram, B. (1996). Productivity improvements and labour relations in the tea industry in South Asia. Unpublished report, Tea Research Institute, Talawakele, Sri Lanka.
- Sivaram, B. and Herath, D.P.B. (1996). Labour economics in tea. Tea Research Institute, Talawakele, Sri Lanka.
- Venkatakrishnan, N.S. and Sarkar, A. (1996). Time and motion studies on the plucking in North East India. Int. Workshop, Global Advances in Tea Science, Oct. 10-12, 1996, New Delhi, India.
- Watson, M. (1986). Plucking. pp. 78-80. *In*: Sivapalan, P., Kulasegaram, S. and Kathirvetpillair, A. (Eds). Hand Book on Tea, Tea Research Institute, Talawakele, Sri Lanka.