Tea Q. 51 (2), 58-66, 1982. Printed in Sri Lanka

THE USE OF PLUCKING MACHINES FOR HARVESTING TEA

M. Watson, J. I. H. Bandaranayake and D. T. Wettasinghe

(*Tea Research Institute of Sri Lanka, Ratnapura, Sri Lanka*)

The results obtained with two small plucking machines are reported. Machine harvesting was done on an extended round of two weeks while hand plucking was done on a weekly round.

The knapsack machine was more efficient than the machine where power was transmitted through a cable. Outputs of 215 kg Green Leaf/day with 25 - 35% coarse material was obtained. When labour for picking out coarse material was considered the output of acceptable leaf was 28 kg/labourer which was comparable to hand plucking. Due to the labour required for sorting, the total labour utilisation per kg made tea was similar for machine and hand plucking, and the total cost/kg was higher as a result of the fuel cost for machine harvested leaf.

Machine harvesting resulted in a 30 - 40% decline in green leaf yields, decreased pruning weights and poorer recovery after pruning.

INTRODUCTION

Harvesting of tea in Sri Lanka is entirely done by hand and hence called plucking. Plucking is the most labour intensive operation on an estate. Any method of increasing the output/labourer would therefore be of great advantage. In agriculture, mechanisation has been used successfully as a means of increasing the output per labour day and it is therefore logical to consider mechanisation of the harvesting operation in tea.

Various types of plucking machines are manufactured in Japan, where harvesting is done by machine. These range from small knapsack machines to large tractor-type machines where the wheels straddle one or more rows of tea. The latter type of harvesters are in use in the U.S.S.R. Such huge machines are obviously unsuited to the terrain of tea lands in Sri Lanka.

Plucking machines differ in size of cutting width, method of cutting, source of power, mode of transmission of power and number of operators used. The following options are generally available:

(a)	Size of cutting width	—Small (30 cm); large (100 cm)
(b)	Method of cutting	—Hair clipper type (horizontally reciprocating teeth); Mower type (cylindrically arranged blades).
(c)	Source of power	—Engine; Motor, powered by either a generator or batteries.
(d)	Mode of power transmission	—Direct, from power source carried on back; transmission through a cable from power source.

In practice 2 persons are required to operate the small machine, one person being required to guide the collection bag and assist in collecting the leaf. The large machine normally requires 3 persons to harvest and collect the leaf.

As far back as 1948, mechanical harvesting of tea was tried out at Dickwella Estate, Hali Ela by the Superintendent in consultation with the TRI (Fay, 1951). The machine used was a "Tarpen Cropper" powered by a motor. These trials gave no difference in yield at one site and 10% more with hand plucking at another; lower cost per pound of leaf with the machine during a high cropping month, but higher cost in a low cropping month; and no serious differences in tasters' valuations of the made tea, except in appearance where hand plucked tea was superior. Fay also noted a marked improvement in spread of the bushes.

In the 1960's the TRI carried out trials with 2 small machines of the hair clipper and mower types. Total yields from machine harvested plots i.e. including coarse leaf, were higher than those from hand plucked plots. But the valuation of made tea was very much lower than those from hand plucked plots (de Silva, 1968). Moreover, the time involved in picking out coarse leaf was not considered economical. No information was gathered on outputs and productivity.

With the rising labour wages over the years and scarcity of labour experienced by several estates it is relevant to re-examine the feasibility of using plucking machines. The results of these investigations carried out in the low country are reported in this paper.

MATERIALS AND METHODS

The trials were started with a motor-driven hair clipper type machine (Model KM-330) powered by a portable generator (Model TAS QEG-300) with a connecting cable. This was later replaced with an engine-driven knapsack machine, the specifications of which are shown in Table 1.

TABLE 1 — *Specifications of Plucking Machine*

Engine - Model KT-15		
Type - Air cooled, 2-stroke, single cylinder petrol engine		
Bore × Stroke (mm)	—	34 × 30
Displacement (cc)	—	27.2
Real compression ratio	—	7:1
Ignition system	—	Flywheel magneto
Fuel	—	Petrol & 2-stroke oil mixture - 25:2
Fuel tank capacity (L)	—	1.0
Dimensions - L × W × H (mm)	—	204 × 196 × 220
Weight (Kg)	—	3.1
Plucking Machine - (Harvesting Section) - Models KS-330		
Type	—	Engine driven, cutting by horizontally reciprocating teeth
Dimensions - L × W × H (mm)	—	380 × 500 × 170
Weight (Kg)	—	2.7
Blade length (mm)	—	330
Blade stroke (mm)	—	25
Blade driving speed (rpm)	—	2100/7500
Capacity	—	1 arc/h.

Shoots are cut by the action of high speed reciprocating blades with teeth and the cut leaf is blown into a cloth collecting bag by a blast of air from a fan.

Experiments were carried out at 2 locations in Ratnapura viz. St. Joachim Estate and Hapugastenne State Plantation. The details are given in Table 2.

TABLE 2 — *Schedule of Experimental details*

Location	*Site*	*Clone*	*Plot size*	*Last pruned*	*Period*
St. Joachim	1	2025	Single row of 32 bushes	Mid 1978	June 1979 - May 1981
	2	2023	2 rows of 38 bushes each	Mid 1978	June 1979 - May 1981
	3	2025	Single row of 20 bushes	Mid 1978	November 1979 - May 1981
Hapugastenne	1	2026	4 plots of 100 bushes each	Sep. 1978—2 plots July 1979—2 plots	October - August 1981

At all sites comparable plots were hand plucked. Hand shears were included at 2 sites, but only the results with the plucking machine will be reported in this paper.

The weight of leaf harvested was recorded at each harvest at weekly and fortnightly intervals for hand and machine respectively. A 200 - 500 g sample of leaf was separated into various components - active, banjhi, single leaf shoots, 2-leaf shoots, 3-leaf shoots, single leaves and pieces. Coarse and unacceptable material was also separated from the sample of machine harvested leaf. The time taken to harvest the plots and fuel consumption was recorded regularly to work out the outputs and costs. Height and spread of bushes was measured periodically. The plots were pruned in June 1981 and pruning weights recorded. Recovering from pruning was assessed by measuring the new shoot growth and the tipping weight.

The results for St. Joachim are averages of the 3 sites. No clonal differences were evident in respect of the performance of the machine or type of leaf harvested.

RESULTS

1. Productivity

The outputs obtained are shown in Table 3. At St. Joachim, the cable-operated machine harvested approximately 2½ times the quantity plucked by 1 labourer in the same time, while the output of the knapsack machine was double that of the cable-operated type. Since 2 labourers were used to operate the machines, the output/labourer reduces to 35 and 69.2 kg green leaf for the cable and knapsack machines respectively.

The leaf harvested by machine included mature leaves and pieces, stalk and overgrown shoots all of which contributed to 35% of the weight of leaf harvested. Thus the output of acceptable leaf works out to 14.4 and 20.9 for the 2 machines, as against 28.4 kg for hand picking.

TABLE 3 — *Productivity of machines*

	St Joachim			*Hapugastenne*
	Hand	*Cable op. Machine*	*Knapsack machine*	*Knapsack machine*
No. of occasions timed	14	14	32	12
Output of green leaf per machine (Kg/day)	—	70.1 (1)	138.4 (1)	215.5 (1)
Output of green leaf per labourer (Kg/day)	28.4	35.0 (2)	69.2 (2)	107.8 (2)
% Acceptable leaf	100.0	65.1	65.0	73.2
Output of acceptable leaf (Kg/lab/day)	28.4	14.4 (3)	20.9 (3)	28.2 (3)

(1) 1 day = 390 mins.
(2) 2 labourers required to operate machine
(3) Labour required for picking out coarse leaf = 1 lab/60 Kg leaf.

At Hapugastenne an output of 215 kg green leaf was obtained with the knapsack machine (cf 138 kg at St. Joachim). A higher proportion of acceptable leaf was also obtained (Table 3). This is due to both the skill of the operator and more vigorous growth of tea at this location. The output of acceptable leaf per labourer was 28 kg.

Costs of harvesting were worked out based on an output of 200 kg green leaf, 75% of which is acceptable for manufacture (Table 4). It is seen that the labour cost with the machine, i.e. including labour for picking out coarse material, works out to Rs. 2.56 per kg made tea. This is of the same order as the cost of hand plucking assuming an output of 30 kg. When the cost of fuel is included however, the cost works out to Rs. 3.52 per kg made tea compared to Rs. 2.44 for hand plucking.

Out of the labour component of 0.16 per kg made tea, the labour required for sorting is almost double that for the actual harvesting operation (Table 4).

TABLE 4 — *Costs of Harvesting (per kg MT)*

	Hand Plucking (1)	*Machine Harvesting* (2)		
	Harvesting	*Harvesting*	*Sorting*	*Total*
Labour — Units	0.150	0.060	0.100	0.160
Rs.	2.44	0.96	1.60	2.56
Fuel — Gallons	—	0.023	—	0.023
Rs.	—	0.96	—	0.96
Total Cost (Rs.)	2.44	1.92	1.60	3.52

(1) Output = 30 Kg green leaf/day; Norm = 17 Kg; Wage = Rs. 13/-; Overpounds rate = -/25 cts. per kg; outturn of MT to Green Leaf = 1:4.5.

(2) Output/Machine = 200 Kg/day with 2 labs; % acceptable leaf = 75% Requirement for sorting = 1 lab/60 kg leaf;
Wage = Rs. 16/-; Petrol consumption = 0.75 galls/day at Rs. 42/50 per gall; Outturn of MT to acceptable leaf = 1:4.5.

2. Shoot characteristics

Machine harvesting resulted in production of smaller shoots as shown by the lower shoot weights of both 2-leaf and 3-leaf shoots (Table 5). There was no difference in the proportion of active shoots between machine and hand plucked bushes.

TABLE 5 — *Shoot characteristics (St. Joachim) - average over 1 year from July 1979 to June 1980.*

	Hand	*Machine*
Active shoots (% by weight)	63.3	61.1
Weight of 2-leaf shoots (g FW/shoot)	0.61	0.40
Weight of 3-leaf shoots (g FW/shoots)	0.99	0.76

3. Yield

The results obtained at the 2 locations are presented in Tables 6 & 7. Lower yields of made tea were obtained with machine harvesting when compared with hand plucking. Even when total green leaf was considered, machine harvesting resulted in 30-40% lower crop. It is interesting to note that differences of the same order were obtained at both locations with respect to weight of green leaf as well as yield of made tea.

TABLE 6 — *Green leaf harvested - St. Joachim (July 1979 to May 1981)*

	Green tea (Kg) per 100 bushes			*Made tea* (All sites)*
	Site 1 (23 mths.)	*Site 2 (23 mths.)*	*Site 3 (19 mths.)*	*Kg/ha/yr*
Hand	308.9 (100)	198.9 (100)	230.2 (100)	3633 (100)
Machine	184.4 (60)	125.5 (63)	161.8 (70)	1509 (42)

*65% acceptable leaf for machine.

TABLE 7 — *Green leaf harvested over 8 months (January - August 1981) at Hapugastenne*

	Pre-treatment wt. of Green Leaf Jan. - Aug. 1980 (Kg/plot)	*Green Leaf (Kg/plot)*	*Made tea* Kg/ha/yr*
Hand	123.7 (100)	101.8 (100)	4651 (100)
Machine	125.0 (101)	63.3 (62)	2113 (45)

*73% acceptable leaf for machine.

4. Height and spread of bushes

The increase in height was much lower in machine harvested bushes resulting in a height of 83.0 cm. after 2 years, compared with 106.5 cm for hand plucked bushes at St. Joachim (Table 8). A similar trend was observed at Hapugastenne.

TABLE 8 — *Height of plucking Table (cm)*

St. Joachim	*August 1979*	*June 1980*	*July 1981*
Hand	79.0	91.0	106.5
Machine	74.5	79.5	83.0
Hapugastenne	*August 1981*		
	2nd year	*3rd year*	*Mean*
Hand	85.8	102.0	93.9
Machine	80.4	94.4	87.4

The spread of bushes was also restricted as a result of machine harvesting (Table 9).

TABLE 9 — *Spread of bushes (cm)*

	St. Joachim (July 1981)	*Hapugastenne (August 1981)*
Hand	137.0	101.7
Machine	117.3	89.5

5. Pruning weights

The plots at St. Joachim were pruned after 2 years of treatments and the weights recorded (Table 10). Lower total, stem and leaf weights were obtained in machine harvested bushes.

TABLE 10 — *Weight of prunings (kg/bush)*

	Total Prunings (F. W.)	*Stem (Air dry weight)*	*Leaf (Air dry weight)*
Hand	3.095 (100)	0.885 (100)	0.365 (100)
Machine	2.215 (72)	0.655 (74)	0.265 (73)

6. Recovery from pruning

Hand plucked plots produced more shoots which were of greater length and diameter at Hapugastenne (Table 11). The poorer recovery of machine harvested plots compared with hand plucked plots is clearly seen in lower "Diam² x length x No." which is an index of total growth, as well as lower tipping weights. The assessments at St. Joachim also show lower shoot diameter, "Diam² x length x No." and tipping weight as a result of machine harvesting (Table 11).

TABLE 11 — *Recovery from pruning**

	St. Joachim		*Hapugastenne*	
	Hand	*Machine*	*Hand*	*Machine*
No. of shoots/bush	10.82	11.70	16.58	11.56
Mean length/shoot (cm)	43.90	43.19	47.67	36.90
Mean diameter/shoot (cm)	0.4146	0.3872	0.4526	0.4022
Diam² x length x No. (cm^3)	81.65	75.75	161.90	69.00
Weight of tippings (g/bush)	96.4	62.3	166.3	76.00

*Shoot measurements were done on 50 individual bushes. Tipping weight taken per plot at St. Joachim and per bush at Hapugastenne.

DISCUSSION

1. Productivity and Labour Use

The results clearly show the superiority of the knapsack machine over the cable-operated type in outputs obtained (Table 3). The poor performance of the cable-operated machine is due to the difficulty in manipulating the cable especially shifting from one row to another. During operation it sometimes gets disconnected if pulled by getting entangled in a branch or trampled.

There is a marked difference in outputs obtained with the knapsack machine at the 2 locations. This could be attributed to the skill of the operator and the more vigorous growth of tea at Hapugastenne. At this location the operator was able to harvest one row in 3 direct runs. The width of bushes at St. Joachim was larger and the operator had to go over the bush several times to completely cover the row. This would obviously result in a reduced speed of harvesting. An output of 28.2 kg of acceptable leaf was obtained with the machine at Hapugastenne, which compares favourably with outputs obtained by hand plucking.

The labour use and costs were computed assuming an output of 200 kg green leaf and 75% acceptable leaf which is equivalent to 33.33 kg made tea. For comparison an output of 30 kg (6.67 kg made tea) was used for hand plucking. It is seen that the labour used for the actual harvesting operation is only 0.06 units/kg for machine harvesting compared to 0.15 units/kg for hand plucking (Table 4).

When sorting is taken into account the labour requirements per kg made tea is 0.160. This is comparable to hand plucking. The total cost inclusive of fuel is Rs. 3/52, i.e. Rs. 1/08 more than the cost of hand plucking for every kg of made tea. It is important to note that depreciation and maintenance/repair costs have not been taken into account. These would further increase the cost of machine harvesting.

Due to the harvesting of immature shoots, machine plucked plots were harvested on an extended round of 2 weeks while hand plucking continued at weekly intervals.

This halving of the frequency of harvesting would not however lead to any saving in labour requirement since the total labour utilisation per kg made tea is similar for machine and hand plucking.

2. Yields and Quality

At St. Joachim machine harvesting resulted in a decline in yield of 36% over a period of 2 years. When acceptable leaf was considered machine harvested plots gave less than half the production of hand plucked plots (Table 6). A reduction in yield was also observed at Hapugastenne, where 8 months of pre-treatment and hand plucking confirm that there were no inherent differences in the machine and hand plucked plots (Table 7). Pruning weights were also lower in machine harvested plots. Decreased pruning weights after 18-20 months of mechanical harvesting has been reported in Indonesia though they obtained higher yields (Kartawijaya & Tarlan, 1980). The low pruning weights could in part be due to decrease in height and spread of mechanically harvested bushes (Tables 8 & 9).

Not only did machine harvesting result in low pruning weights but also poor recovery and re-growth of bushes after pruning (Table 11).

It was observed at both locations that machine harvested bushes generally had a poorer appearance, the differences being quite conspicuous during the drought. This could be attributed to the very hard "plucking" done with the plucking machine as shown by counts of cut points on the plucking table (Table 12). Only 24% of the shoots were cut to a single leaf or big fish leaf and as much as 45% were cut below the janum or small fish-leaf in machine harvested plots. In the hand plucked plots on the other hand only 5% were plucked below the janum or small fish-leaf and over 50% plucked to big fish or single leaf. The drastic effects of hard plucking are known (Wettasinghe *et al*, 1976).

TABLE 12—*Assessment of plucked/cut points at St. Joachim - average of 3 occasions*

	(*% of shoots*)	
	Hand	*Machine*
Plucked to Big fish or single leaf	54.8	24.3
Plucked to Janum or small fish leaf	40.5	31.1
Plucked to below Janum	4.8	44.7
	100.1	100.1

Thus, the results show that continuous machine harvesting would lead to reduced vigour, lower yield and pruning weights and poor recovery from pruning.

In tea production in Sri Lanka quality considerations are of paramount importance. Manufacturing tests could not be carried out in these trials. Experiments done at St. Coombs gave a marked reduction in valuation of machine harvested tea in both seedling and VP (de Silva, 1968). This was presumably without picking out the coarse leaf.

The leaf obtained with the plucking machine contained 25-35% of coarse material consisting of cut mature leaves and stalk and coarse portions of overgrown shoots. This is somewhat higher than the values of 22.2% (Kartawijaya & Tarlan, 1980), and 15% (Anon, 1976), reported from Indonesia and East Africa respectively. Although coarse leaf % as low as 15% have been obtained in individual harvests, it seems virtually impossible to achieve this consistently over a period of time.

In addition to coarse leaf, machine harvested leaf also contained 15-25% of soft leaves and pieces compared to 10% or less for hand plucking.

With the type of leaf harvested by machine sorting or picking out coarse material will have to be done and this has been accounted for in the computation of costs discussed above. If sorting out of coarse material is properly done it is unlikely that the manufactured product would be affected adversely particularly in the low country where factors other than quality per se are considered important.

3. Feasibility

The tea landscape itself imposes a limitation on the mechanisation of plucking in Sri Lanka, as plucking machines are not feasible on steep slopes. We estimate that not more than 25% of the acreage of tea is on terrain suitable for convenient use of plucking machines.

Several problems were encountered with the machines during the period of the trials. The problem of a long connecting cable from the power source to the machine has already been discussed. In the engine driven machine the flexible shaft was found to get heated up at the bend and resulted in melting of the tubing at that point. The flexible tube often got caught in the tea bushes and this slowed down the operator. Even with the limited use of the machines on an experimental scale the fan had to be replaced twice, the flexible shaft was replaced, and other minor repairs became necessary in addition to the general maintenance of the machine.

In our experiments the productivity per labourer and the labour use per kg made tea were similar for hand and machine harvesting. Due to the dimensions of the machine at least 3 runs had to be made with the machine to completely harvest a row. A larger machine which could cover a single row in one pass would give a much higher output and increased productivity per labourer. The so-called 2-persons machine has a cutting width of 1 m and could probably cover one row in a single pass. The transmission of power is also such that there is no flexible tube which could give rise to difficulties. This should therefore give a much better performance than the machine tested.

In the machine tested, fuel accounted for 50% of the cost of harvesting. This could be reduced substantially if a cheaper source of power, such as batteries, is used. The batteries should be able to store sufficient power for at least 4 hours continuous operation. If batteries are used to power a motor-driven machine however, they should be in a handy pack to be carried knapsack fashion so that there is no long connecting cable from power source to machine.

With regard to the nature of leaf harvested by machine, we cannot foresee getting leaf that could be manufactured without picking out coarse material. The machines used were of the hair clipper type. In preliminary results with a mower type machine as much as 30-40% cut pieces were obtained in the acceptable leaf fraction of the harvested leaf. It appears that with this type of cutting action shoots are cut more than once resulting in a lot of pieces which is definitely unsuited to the present methods of manufacture.

Mechanisation of any agricultural operation should increase output per labour day, be economically worthwhile and be practically feasible. Our results indicate that an increased output with the attendant benefit of ensuring timeliness is possible, and it is likely that the use of machines will be economically and practically feasible on the gently sloping and flat lands. The major drawback to the use of plucking

machines however, is the loss of crop. In our experiments continuous machine harvesting lead to reduction in maintenance foliage, weakening of the bush and reduction in yield. Investigations are currently being done to work out a system with limited use of plucking machines so that there is no loss of crop or debilitation of the bushes.

ACKNOWLEDGEMENTS

The co-operation of the Superintendents and staff of Hapugastenne State Plantation and St. Joachim Estate is gratefully acknowledged.

REFERENCES

ANONYMOUS (1976). Agronomical Investigations. Tea Research Institute of East Africa, *Ann. Rep. for* 1976: 58-103.

DE SILVA, R. L. (1968). Report of the Plant Pathology & Nematology Div. Tea Research Institute of Ceylon. Ann. Rep. for 1967, Part II: 67-77.

FAY, B. D. (1951). The Mechanical Plucking of Tea. *Tea Q.* **21**, (II & III): 38-44.

KARTAWIJAYA, W. S. & TARLAN, S. (1980). Plucking machine experiment at Pasir Sarongge, II. Paper presented at the Tea Symposium III at Surabaya, 14-17th Oct. 1980.

WETTASINGHE, D. T., NATHANIEL, R. K. & KROON. D. D. (1976). Effect of severity of plucking on the growth and yield of low grown tea. Warta BPTK 2 (1/2): 123-132.