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Impact of Science on the Economics of Tea Industry

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COST REDUCTION IN FIELD AND FACTORY

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Technical Session 1
Cost Reduction in field
Chairman P. Sivepalan

Dr. P. Sivepalan was born on 26th December 1936, graduated from University of Ceylon in 1960 and earned Ph.D. in Nematology at Rutgers in 1965. In1965, he became head of Nematology and then of Plant protection in 1968 at TRI Srilanka. Following a special postdoctoral programme in Integrated Pest Management at the University of California under Ford Foundation, he was appointed Director of the tea Research Institute in 1980, a position he occupied till retirement in 1994. He was also appointed to the FAO Panel of International Experts on Integrated Pest Management during 1986-1989 and was selected as a Fellow of the National Academy of Sciences Srilanka in 1991. Presently, Dr. Sivepalan is the Managing Director of a consultancy firm Crop Optima Pvt. Ltd.

Opening Remarks by Session Chairman:
Ladies and gentlemen, it's my privilege to chair this first technical session. I thank the organizing committee for having chosen me for this particular assignment and I also wish to convey Sri Lanka's congratulatory message to the Tea Board of India in celebrating the 50th year

Chapter 7

REDUCING COST OF FIELD OPERATIONS IN TEA

F. Rahman*
Tea Advisory & Training Service, Siliguri

Dr. F. Rahman graduated from Bihar University, College of Agriculture and obtained his PhD degree from the Indian Agricultural Research Institute in 1962. He was a teacher for a short period at the Shanti Niketan Agricultural College, after which he joined the services of Tocklai Tea-Research Institute TRA's Tocklai Experimental Station, Jorhat in 1964 and held the position of Head of Agronomy until 1980. From 1980 to 1992 he joined the service of private companies Mc Lloyd and Russell and Williamson & Magor as a Manager and Advisor R&D. During1980 he also worked as an advisor in tea research at the institute of Tea and Cinchona in Indonesia for a short period. After his retirement in 1993 he was involved in training and advisory work in his own private organization Tea Advisory and Training Service. He has been a visiting faculty member of Tea Management at North Bengal University. He has visited many tea producing countries including Bangladesh, Indonesia, Kenya, Sri Lanka, Malawi, Zimbabwe. His significant contributions in tea research have been in nitrogen nutrition, bush population, chemical weed control, young tea management, plucking and harvesting and irrigation of tea.

The theme of the conference is to address the problems resulting from the current crisis facing the industry. The slump in prices has resulted in many companies selling their teas below cost of production. No company can survive if this trend continues over a long period of time. Prices

* 5/3, Akshay Tara Appartment, Sevoke Road, Siliguri 734401, India
email <f_rahman 90@hotmail.com>

reached an all time high in 1998 and have been declining thereafter. Average prices of teas sold in north and south Indian auctions in 1999-2002 are given in Rupees (Table 1).

Table 1. Average price (INR/Kg) of tea sold in North and South India

Year	North India	South India
1999	80.62	57.09
2000	70.36	44.64
2001	69.83	46.02
2002	60.67	40.35

On the other hand the cost of production has been increasing steadily. It varies considerably between estates depending on their yield per ha, labour deployed per ha and labour productivity. The unit cost of tea per kg increased from Rs.7.10 in 1970 to Rs. 52.50 in 1994. The current average cost at garden is around Rs. 66.00 and varies from Rs. 43.00 to Rs. 83.00. Head office cost per kg. varies between Rs. 10.00 to Rs. 18.00. (Table 2)

Labour cost is a major factor and productivity per worker is a major determinant of cost of production.

Yield per ha has a direct bearing on productivity. Yield per ha is determined by:

- Soil and climate
- Management
- Pruning and plucking policy
- Age and profile of tea
- Vacancy
- Manuring policy
- Planting material
- Shade status
- Proportion of young tea

Cost of production at estate is mainly determined by yield, plucking cost, pest control, weed control, cultivation and irrigation costs.

The major field operations in tea are plucking, pruning, pest, disease and weed management, and manuring and water management. Labour accounts for 57-70% of the garden cost.

LABOUR

Labour productivity has a major impact on cost of production. Man-days required per ha in a year for all operations vary from 444 to 961. An approximate

Table 2. Labour and garden costs per kg made tea

Area	Estate/Group	Labour cost			Total garden cost	Labour cost as % of garden cost
		Direct	Indirect	Total		
Dooars	Group 1	30.95	5.81	36.76	54.68	47.29
	Group 2	31.11	5.24	36.35	52.55	69.2
	Estate 1	49.46	8.46	58.95	83.53	70.6
	Estate 2	40.75	6.44	47.19	73.11	64.5
	Estate 3	23.87	3.36	27.23	48.20	56.5
	Estate 4	46.35	6.84	53.19	81.18	65.5
Terai	Estate 1	23.45	4.06	27.51	43.48	63.3
	Estate 2	31.25	4.31	35.56	55.25	64.4
	Estate 3	38.43	8.17	46.60	77.10	60.4
	Estate 4	34.19	12.13	46.32	65.01	71.2
Assam	Group 1	32.29	8.12	40.41	59.29	68.16
	Group 2	31.01	6.00	37.01	54.92	67.4
	Group 3	25.97	6.29	32.26	53.38	60.4
	Estate 1	26.85	6.11	32.96	57.95	56.9

idea of the percentage of labour deployed in different operations is given below (TRA, 1940).

Pruning	3-4.5
Plucking	46-50
Winter operations	8-12
Manufacture	8-9
Other operations	28-34

Survey results (Awasthi & Sarkar, 1983) show wide variation in the number of man-days employed pr ha between estates and between regions. The average number varied between 503 and 924 in South Bank of Assam and between 444 and 961 in the north Bank of Assam. Between 44 and 71% work force was deployed on plucking. Another survey (Kar et al., 1994) showed that between 50 and 61% of work force was deployed on plucking.

Factors affecting plucker productivity are enumerated below (Venkatakrishnan & Sen, 1981):

- Variety, spacing, height of bush, type of prune, yield
- Plucker – age, physical fitness, speed
- Standard of leaf plucking
- Deployment and time utilization pattern
- Method of plucking

Plucker productivity can be increased by:

- Increasing plucker productivity
- Increasing worker productivity and reducing man-days on unproductive work
- Training and motivation
- Introduction of labor saving devices in field and factory

Survey results showed that worker productivity was directly related but did not show consistent trend with land productivity. This indicates that other factors are involved. In a subsequent survey (Awasthi & Bordoloi, 1992) it was found that increase in land productivity from 2000 kg/ha to 2500 kg/ha improved plucker productivity by about 8 kg. It also confirmed the earlier observation that plucker productivity varied widely between estates in the same region and at the same level of yield. Kar et al. (1994) also found that labor productivity was significantly correlated with land productivity (r=0.94).

INPUTS

Inputs account for 7-12% and power and fuel 10-17% depending on machinery, manufacture and type of fuel used. From the information received from nine estates and four groups (41 estates) from Dooars, Terai and Assam valley the cost per kg of different inputs varied as under:

Fertilizers and pesticides	: Rs. 4.50–7.50
Firewood	: Rs. 1.00-1.50
Fuel for spraying and irrigation	: Rs. 1.00-2.00
Power and fuel for manufacture	: Rs. 5.77-11.76
Loss on food stuff	: Rs. 2.00-4.50

Figures for per kg cost of inputs in field and factory are given in Tables 3 and 4 (next page).

Better management of inputs can achieve reduction of cost of production. Higher yields reduce cost of inputs both directly and indirectly, and as such any strategy that increases yield will reduce cost of production. As a medium to long term strategy, planting of tea in potentially low yielding areas, or in areas which will require additional inputs like pump drainage, irrigation, high pH areas, sandy/ stony shallow soil, hard pan, steep slopes etc., should be discouraged. In past 40 years many marginal tea areas have been planted that are low yielding and cost of maintenance of these areas is high due to vacancies, infilling, higher cost of pest and weed control and higher cost of irrigation and drainage. Such areas were planted when profitability was high, but now these areas are a burden on the economy of the estate.

In order to keep the tea industry competitive internationally the Government & Industry policy should be such that the tea growing is confined to areas that are ideally suited for tea so that high

Table 3. Cost of field inputs per kg made tea

Area	Estate/Group	Field inputs	Total garden cost	Field inputs as % of garden cost
Dooars	Group 1	5.27	54.68	9.6
	Group 2	3.45	52.55	6.6
	Estate 1	4.65	83.53	5.6
	Estate 2	6.21	73.11	8.5
	Estate 3	5.94	48.20	12.3
	Estate 4	11.20	81.18	13.8
Terai	Estate 1	4.96	43.48	11.4
	Estate 2	7.04	55.25	12.7
	Estate 3	15.57	77.10	20.2
	Estate 4	4.05	65.01	6.2
Assam	Group 1	6.40	59.29	10.8
	Group 2	3.71	54.92	6.8
	Group 3	5.55	53.38	10.4
	Estate 1	7.91	57.95	13.6

Table 4. Cost of inputs for manufacturing per kg made tea

Area	Estate/Group	Manufacturing cost			Total garden cost	Manufacturing cost as % of garden cost
Dooars	Group 1	7.74	1.57	9.31	54.68	17.0
	Group 2	6.70	0.40	7.10	52.55	13.5
	Estate 1	11.76	1.24	13.02	83.53	15.6
	Estate 2	10.62	3.40	14.02	73.11	19.2
	Estate 3	8.21	1.42	9.63	48.20	20.0
	Estate 4	9.45	0.60	10.05	81.18	12.4
Terai	Estate 1	7.03	1.59	8.62	43.48	19.8
	Estate 2	9.04	0.86	9.90	55.25	17.9
	Estate 3	6.84	0.84	7.68	77.10	10.0
	Estate 4	7.07	0.80	7.87	65.01	12.1
Assam	Group 1	6.16	1.28	7.44	59.29	12.5
	Group 2	5.77	0.59	6.36	54.92	11.6
	Group 3	7.98	2.38	10.36	53.38	19.4
	Estate 4	7.07	0.80	7.87	65.01	12.1
Assam	Group 1	6.16	1.28	7.44	59.29	12.5
	Group 2	5.77	0.59	6.36	54.92	11.6
	Group 3	7.98	2.38	10.36	53.38	19.4
	Estate 1	11.24	1.05	12.29	57.95	21.4

yields are obtained and additional cost of irrigation and drainage are minimal. Government & Industry Policy should be such that low yielding estates become high yielding estates by accelerated uprooting and replanting and abandoning marginal areas. A very good example is Sri Lanka (Vijayraghavan, 2001) where the area under tea has been brought down by deliberate decision of the Government for peasant settlement and village expansion programme. There has been a trend of gradual growth in small holding sector and decline in the large and older estate sector more particularly in the mid and high elevation areas. In the process of rehabilitation, restructuring of the areas under high and mid grown and low grown has taken place. Whereas high and mid grown have lost 80000 ha,

low grown area has increased by 30000 ha. Over all area of tea has gone down to 1.9 lac ha from 2.4 lac ha and yield of tea has gone up to 1600 kg/ha from 800 kg/ha in 1960. The productivity of low growth areas is comparable to the best in the world.

The Government of Sri Lanka sought aid from International Finance Institutions like World Bank, ADB and others and undertook a massive programme of rehabilitation in State owned estates (62% of total area) and modernization of factories. Similar programme was undertaken for the private sector lands (38% of the area) but contributed less than 20% of the crop. The small holder development authority launched new programme. It is estimated that in the late eighties something like 500 crores was spent in a mere five years on improving the estates and the factories (Broca, 2001).

CONCLUSIONS

1. Increasing worker productivity is the most important single factor for affecting cost reduction.
2. In the medium and long term increasing land productivity and maintaining good quality is essential. It will include:
   - Good field management
   - Good planting/replanting
   - Abandoning and not planting in marginal areas that are potentially low yielding or demand higher inputs.

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Chapter 8

INTEGRATION OF AGRO-TECHNIQUES FOR HIGHER PLUCKER PRODUCTIVITY AND LOWER HARVESTING COSTS

V.S. Sharma*
Formerly Director, UPASI, T.R.I., Valparai - 642127, India

Dr.V.S. Sharma has been associated with the tea industry for over three decades in different capacities. After retirement as the Director at the UPASI Tea Research Institute in 1995 he has been with the Bombay Burmah Trading Corporation as a Technical Advisor. He has a large number of publications exceeding 80. To summarize his major contributions, Dr. Sharma has devised technique to graft fresh tea cuttings to raise composite plants, which is widely adopted now by the south India tea industry. He developed a rooting hormonal formulation specific to tea cloud cuttings. He has developed and released three tea clones and five bi-clonal seed stocks for commercial cultivation and several more are in the pipeline. He has developed and established the concept of no-tillage replanting and progressive replanting for which the Tea Board is currently giving a subsidy. He identified new additives to enhance fficacy of glyphosate.

His major achievement is the production of a video program on harvesting for which he won an award from the Fertilizer Association of India, as the best educational presentation in 1989. He had received awards for good original scientific publications and presentations from the Indian Society of Plantation Crop and Fertilizer Association of India.

Dr. Sharma is a member of Research Board of Advisors, American Bibliography Institute Incorporated, member of several scientific societies and a permanent trustee of C.S.Venkatram Memorial Trust. He has served on a number of Boards and Committees including Board *of* Examinations of several *universities.*

ABSTRACT

Plucking average, thereby, cost of harvesting of tea cannot be viewed in isolation as they are a product of multiple factors such as 'jat', age from pruning, height of bush and plucker, harvesting intervals and nutritional and health status of the bush. Use of mechanical implements, either hand-operated or motorized, if motorized, either held by one or two-men or self-propelled, contribute significantly to cost reduction in harvesting. However, choice of an appropriate implement to suit to the prevailing conditions in a region should be made carefully, lest the mechanization result in crop depression.

Hand operated shears are currently in wide use without detriment to quality.

The results with motorized, one or two-men held machines are varying, often leading to depression in quality and yield. They are in use in Japan, Russia, Argentina, Australia, Indonesia and Taiwan, but, in the importing countries they are proving uneconomic because of their high price and cost of maintenance; there is, thus, a need to develop machine(s) indigenously.

The mounted, self-propelled machines are of limited application because of constraints in their manoeuvrability on gradients over 5°.

INTRODUCTION

Productivity of plantation workers gains prominence and priority in the context of spiralling labour-wages leading to ever-increasing cost of production. The main focus in tea now is on plucker-productivity in view of the fact that about 70 per cent of the total

*Technical Adviser, The Bombay Burmah Trading Corporation Ltd. Mudis - 642117 Coimbatore Dist, T.N.
E Mail; <bbtc@vsnl.com>

labour used in tea cultivation is deployed for plucking, making it the most expensive operation accounting for about 20 per cent of the cost of production (Sharma et al.1981).

Harvesting in tea is a delicate operation involving movement of worker between rows of tea bushes, often on steep slopes, scanning bush surface, spotting ready shoots, separating them from the bush and putting them in collecting baskets or bags, hung on his/her back; it implies that each shoot is plucked individually. Enormity of the operation is revealed further by the fact that, depending upon jat and age from pruning, 4000 to 7500 shoots are required to make a kilogram of black tea (Satyanarayana and Sharma, 1994).

Against this backdrop it becomes evident that plucking average (amount of green leaf harvested per man-day) plays a crucial role in the economy of harvesting tea. A Tanzanian worker, Mr. Bernard Mng'ong'o Domiani, was reported (Muthanna, 1983) to have plucked 172 kg on a single day (effective operational time: 6 1/2 hours). A south Indian woman worker plucked 152 kg of green leaf during the same period, with the only difference that she fell sick the next day, while the Tanzanian worker was claimed to have continued plucking at the same pace throughout the year. The plucking averages (Table 1) achieved by hand in different tea growing regions broadly indicate the cost and effort involved in harvesting tea (Arifin and Samangun, 1999; Nakano, 1999; Sivaram, 2003).

Table 1. Plucking averages with hand in different tea regions

Country / Region	Green leaf per man-day(Kg)
Bangladesh	20
North-east India	20
South India	25
Sri Lanka (private sector)	24
Indonesia	16 to 35
Japan	20
Kenya	40 to 50
Zimbabwe	68

It may be added that high averages in the last two countries, perhaps, are possible because of the assistance extended by family members to the plucker, besides the latter's stature.

Crop in tea, particularly in south India, comes in peaks and troughs through a year; naturally, plucking average varies with the crop shoots available on bushes. In the conditions prevailing in south India an overall plucking average of about 35 kg over a year could be considered economically acceptable at the present juncture. That means a plucker should harvest 37,785 to 56,683 shoots during the effective operational time of six and a half hours in a day and on all days of a year; these figures resolve into 1.6 to 2.4 shoots per second! Such a task should be made ergonomically feasible by creating physical conditions favourable to the pluckers.

FACTORS GOVERNING PLUCKING AVERAGE

The terrain on which the tea is cultivated, 'jat', stature of plucker, height of tea bush, age from pruning, length of plucking rounds, nutritional and general health status of the bushes are some of the important factors that influence the plucking average. The first three factors are beyond the control of the current management(s), while the latter could be manipulated favourably by the management(s).

Plucking Lanes

Tea in south India has been planted on hill slopes up to a gradient of 33 per cent and beyond in certain cases. Movement of workers on plateaus and gentle slopes, say up to 16 per cent gradient, would be faster leading to coverage of a larger number of bushes per man-day resulting in higher plucking averages. Steep slopes militate plucker's movement in the field resulting in low averages. The management could at best trim lateral branches in alternate rows to make "plucking lanes" of about 22.5 cm width to facilitate easier and faster

movement of pluckers, attending to a row on either side. Provision of such lanes was reported to enhance plucking average by 3.9 kg and yield by 2.4 percent; it also led to a saving of about 65 pluckers per hectare per year (Joseph, 1979). Such lanes could also be used for movement of workers attending to other cultural operations.

Jat

Plucking average, being the result of the number of shoots harvested per man-day multiplied by weight of each shoot, is naturally influenced by the "jat" and tends to be lower in small-leaved chinary jat. Achieving economic plucking average in such jats will be dealt under different heads in the course of this presentation.

Height of Plucker vis-à-vis Bush Height

The average height of tea plantation workers in India is about 150 cm (60") and less; it gives a clearance of 100 to 105 cm (40" to 42") from ground to elbow (Sharma, 1983). A plucker can, hence, operate efficiently on bushes with a height of 100 to 105 cm (Sharma, 1983; Venkatakrishnan *et al.*, 1999) with least strain on forearms and biceps; this, in turn, results in higher averages. It, thus, becomes essential to contain the bush height, which is regulated by height of pruning, tipping height and annual creep of a bush in long pruning cycles.

Bush Height

The routine maintenance pruning is generally imposed at a height of not more than 70 cm (28"), usually between 60 (24") and 70 cm (28") from ground; such bushes should be tipped leaving behind two tiers of mature leaves above the pruning cut, giving an allowance of about 10 cm (4") above the pruning cut resulting in a bush height of 70 to 80 cm following tipping. The annual bush creep depends on the altitude, height of pruning and jat. It should be so regulated as to contain the bush height to not more than 105 cm (42") by the end of pruning cycle, the length of which should be determined with this aim in mind (Sharma, 1987; Sharma, unpublished; Table 2)

Table 2. Height of bushes at the end of each year from prune

Height of prune/skiff (cm)	Height of tipping (cm)	Bush height (cm) at the end of				
		I yr	II yr	III yr	III yr & 9 mths	IV yr
60	70 - 72.5	80 - 82.5	90	97.5	-	105
65	75	85	92.5	100	-	107.5
70	80	87.5	95	102.5	107.5	-
75	82.5	90	97.5	105	110	-

Shoot Size

Additionally, it should be born in mind that shoot size declines with increasing height of pruning and advancing age from pruning, though number of shoots per unit area may increase (Table 3); increased shoot numbers do not compensate for the decreased shoot size beyond a particular stage necessitating a balance to be struck between the two parameters so as to sustain higher productivity of both the bush and plucker (Sharma, unpublished). Decline of shoot size with the increasing height of pruning and advancing age from pruning, is faster and more pronounced in chinary jat compelling to adopt shorter pruning cycles and lower pruning heights.

Table 3. Shoot weight and number of shoots per kg green leaf in relation to age from pruning

Jat	Year from pruning							
	I year		II year		III year		IV year	
	No*	Wt**(g)	No	Wt (g)	No	Wt (g)	No	Wt (g)
Assam	545	1.84	750	1.42	1076	0.93	1200	0.83
China	813	1.23	1020	0.98	1235	0.81	1275	0.76

** Number of shoots/kg of green leaf*

*** Weight (g) of each shoot*

Plucking Intervals

The influence of harvesting intervals on plucking average does not seem to have been fully appreciated. Optimised length of plucking rounds, formulated on the basis of "Leaf Expansion

Concept" evolved by computing accumulated day degrees (Murty and Sharma, 1989), was reported to have increased the plucking average by 1.50 kg (Murthy *et al.*, 1991), without altering the quality adversely.

MECHANIZATION

Harvesting in tea is a perennial operation carried out at short, regular intervals. In a majority of tea growing areas high crops come during short periods because of the over-riding influence of climatic factors on growth and physiology of the bush. About 65 per cent of the annual crop in south India is produced during April to mid-June and mid-September to mid-December (Satyanarayana and Sharma, 1994); often, up to 1.50 per cent of the annual crop is harvested on a single day (Barua, 1989).

Sheer physical limitations lower the efficiency of hand-plucking during peak seasons resulting in a number of ready shoots being left behind on the bushes. It is estimated to lead to a crop loss of about 10 per cent annually in south India (Satyanarayana and Sharma, 1994); crop loss of such magnitude cannot be ignored. Hand plucking with low plucking average requiring a large number of pluckers is not economically viable anymore.

All the important field operations such as planting, pruning, spraying nutrients and plant protection chemicals, weeding, manuring and shade regulation, requiring considerable labour force, are also to be carried out during those high cropping seasons. The large labour force required to harvest huge crop(s) in short bursts and to attend to the other important cultural operations cannot be maintained permanently by estates. Such multiplicity of problems encountered in containing the cost of production could be surmounted to a great extent by mechanization of harvesting tea.

Options of Mechanization of Harvesting

I. Hand operated topiarist's shears with leaf collecting tray
II. Motorized mechanical harvesters
   a) One man-operated machine
   b) Two men-operated machine
III. Mounted motorized harvesters
   a) Self-propelled riding machines
   b) Self-rail-tracking system
   c) Magic carpet

Different methods of harvesting have been compared with hand plucking as recorded in Table 4.

Table 4. Plucking average in different methods of harvesting

Country	Plucking average* in different methods of harvesting				
	Hand shear	Portable/Motorised/ Mechanical type		Self propelled	Self rail tracking
		One person	Two persons		
Japan	100 -200	300 - 450	700 – 1000	2000-3000	3000-5000
South India	40 -60	360-400	900-1000	-	-
Central & South Africa	72-84	350	900-1500		
Indonesia	55-60	-	-	-	-
Russia	-	-	650-750	-	-

* Plucking average (kg green leaf / day) for a season / machine.

Hand-Operated Shears

Harvesting tea with hand-held shears was tried in different regions at various times with varying results (Ananda Rau, 1951; De Jong, 1953; Wright, 1953; Fay, 1954; Anon.,1959; Swaminathan, 1975; Haridas, 1976; Sharma *et al*, 1981; Mwakha and Anyuka, 1982; Satyanarayana *et al*, 1991; Sharma and Satyanarayana, 1993; 1994; Sreedhar *et al.*, 1996). Many of the studies were carried out over short durations leading to inconclusive results. First ever guidelines on shear-harvesting were formulated in 1981 (Sharma, *et al.*, 1981) based on a long term experiment substantiated by multi-locational field trials carried out on different jats over

one or more pruning cycles (Satyanarayana, *et al.*, 1991). Further evaluation of the continuing field experiments mentioned above and an industry-wide survey carried out in south India confirmed the utility of shear-harvesting in enhancing plucker productivity and reducing the plucker requirement effecting considerable economy in cost of harvesting (Table 5; Satyanarayana and Sharma, 1994).

Table 5. Effect of shear harvesting on yield, plucking average and plucker requirement at different yield levels

Parameters compared to hand plucking	Yield level		
	2000 to 2500	2500 to 3000	3000 to 3500
Difference in yield (kg/ha/year)	+110	+200	+250
Reduction in the requirement of pluckers (No./ha/year)	60 to 95	110 to 150	130 to 180
Increase in plucking average (kg/plucker)	2 to 6	5 to 7	5 to 9

The following interesting points arise out of the several investigations and the survey carried out.

1. Shears were recommended for use on bushes 15 and 18 months old from pruning in "China" and "Assam" jats respectively, the idea being that a firm plucking table is formed by then. However, prolonged field experience indicates a possibility of introducing shears by the end of nine to 12 months depending upon the formation of plucking table on which shears could be glided smoothly.

2. Shear harvesting should be integrated with hand plucking, the former being resorted to in high cropping seasons for over a period of six months. A possibility, however, exists to extend the period of shearing to nine months (Satyanarayana and Sharma, 1994) without detriment to crop or bush health in long run, by ensuring a let up by resorting to mother leaf/single leaf plucking over lean dry period so as to retain adequate maintenance foliage on the bush.

3. It is a fallacy to consider that "China" bushes can withstand the onslaught of continual shearing throughout the pruning cycle. "China" bushes too need maintenance foliage to sustain their health and productivity and hence the need of periodic let up and addition of maintenance foliage.

4. Step-shears, whatever is the size of the step, depress yield (Table 6; Barbora *et al.*, 1993; Satyanarayana and Sharma, 1994; Sreedhar *et al.*, 1996).

5. There is no detriment to quality of made tea because of shear harvesting (Ramaswamy, 1983). Adverse reports on the quality of made tea from shear-harvested leaf, if any, are obviously because of enhanced coarse leaf content resulting from unduly extended rounds of harvesting (Owuor, 1989; Sharma and Satyanarayana, 1993, 1994).

6. If the harvesting schedule is formulated on the basis of 'phyllochron' mentioned earlier, shear-harvested leaf will be acceptable to make good quality tea (Murty and Sharma, 1989; Sharma and Satyanarayana, 1994)

Commercial Implications of Shear Harvesting

1. Hand-held shears are gaining wider acceptance in major tea growing regions in recent years; the shears have come to stay for harvesting tea in all terrains.
2. Shear-harvesting during high cropping seasons out-yielded hand plucking by 110 to 250 kg/ha at different yield levels ranging from 2000 to 3500 kg/ha (Tables 5 and 6; Satyanarayana and Sharma, 1994).

3. Shear–harvesting led to an increase in plucking average by two to nine kg per worker at different yield levels mentioned earlier (Tables 5 and 6).
4. Integrated shear harvesting led to a reduction in plucker requirement by 60 to 180 workers per hectare per year at different yield levels (Tables 5 and 6).
5. Continual shear harvesting depressed yield at different levels, though there is a significant increase in plucking average and considerable saving in plucker requirement (Satyanarayana and Sharma, 1994).

Table 6. Effect of shear harvesting on yield and plucking average (after Sreedhar et al., 1996)

Type and duration of harvesting	Yield (kg made tea/ha) and plucking average (kg green leaf /plucker/day)						Total Yield
	II Year		III Year		IV Year		
	Yield	PA	Yield	PA	Yield	PA	
Continuous hand plucking	2890 f	26	3920 e	24	4440 f	22	11250 e
Shear harvesting in Apr-Jun & Sep-Nov using flat shears; hand plucking in remaining seasons	2840 ef	31	3869 e	30	4355 f	29	11064 e
Shear harvesting in Apr-Jun & Sep-Nov using step shears; hand plucking in remaining seasons	2800 d	-	3665 d	-	3880 d	-	10345 c
Shear harvesting in Apr-Nov using flat shears; hand plucking in remaining season	2804de	36	3708 d	34	4065 e	32	10577d
Shear harvesting in Apr-Nov using step shears; hand plucking in remaining season	2537 b	-	3524 c	-	3638 c	-	9699 b
Continuous shear harvesting using flat shears	2661 c	39	3399 b	36	3453 b	33	9513 b
Continuous shear harvesting using step shears	2392 a	-	3107 a	-	3341 a	-	8840 a

PA: Plucking average for the year (kg green leaf/day/worker).

Values followed by the same alphabets in a column are not significantly different at P = 0.05.

Motorized Mechanical Harvesters

Motorized mechanical harvesters have two types of cutting blades, reciprocating and rotary. Portable machines are two types, carried either by one person or two and the latter requires a third person to adjust/carry the leaf collecting bag. The portable machines are widely used in Japan, achieving an average of 300 to 450 kg by one-man machine and 700 to 1000 kg by two-men type; they are still being extensively experimented in other tea areas (Table 7).

A crop depression of two and five per cent over a pruning cycle was reported in south India following the use of one-man operated and two-men operated machines respectively in integrated schedule (Ilango *et al.*, 2001). The plucking averages reported were 47, 183 and 308 kg green leaf per man-day for hand-held shears, one man operated and two men operated machines in that order during their use in the peak cropping periods; the overall plucking averages over a year turned out to be 34, 52 and 63 kg per man-day (Table 7). Plucker requirement for harvesting has progressively come down from 495 per ha under integrated shear harvesting to 315 and 255 with one-man operated and two-men operated machines; the drastic reduction of pluckers is chiefly because of the significant reduction of the number of plucking rounds. A significant reduction in the cost of harvesting following the use of both the motorized machine harvesters was claimed (Ilango *et al.*2001); but in their scheme of things importing of spare parts and maintenance of the machines were not taken into consideration. Harvesting average, though high per machine *per se*, per man-day could be depressed considerably because of the need to use extra workers to adjust leaf carries (Martin, 2000)

Table 7. Effect of motorized mechanical harvesting on yield, plucking average and plucker requirement (after Ilango et al., 2001)

Schedule requirement	Yield+ (kg made `tea/ha)	Plucking average* (kg green leaf/worker)	Plucker (No. of pluckers / ha/year)
Integrated schedule** of harvesting - hand shears	9484 e	34	495
Integrated schedule of harvesting – hand held one person operated	9290 d	52	315
Integrated schedule of harvesting – hand held two persons operated	9042 c	63	255
Continuous harvesting- hand held one person operated	8059 b	92	152
Continuous harvesting- hand held two persons operated	7533 a	247	56

* *For the year; values followed by the same alphabets in a column are not significantly different at P = 0.05.*

** *Involves mechanical harvesting in high cropping months and hand plucking during the very wet and dry months.*

\+ *Total Yield of III and IV year.*

A large tea plantation company in south India used two-men operated machines for over two years on a large scale but gave up in view of the high cost of maintenance of the machines, which turned out to be economically unviable. It is gathered that two-men operated machines are currently being tried out in some estates in northeast India; a plucking average of about 200 kg per man-day is being achieved during the machine's operation in high cropping season (Maheshwari, 2003). It is yet to be seen whether they prove economic over a long term there. Various other tea growing regions such as Sri Lanka, Indonesia and Kenya are obtaining varying results with the motorized harvesters, but with the uniform experience of the need to sort out coarse leaf from the leaf-collector (Modder and Wijeratne, 2002; Arifin and Semangun, 1999; Ndamugoba, 1997).

Several reports indicate the unsuitability of the motorized mechanical harvesters currently available in the market; not only are they priced high, but also the spare parts are to be imported and are too expensive leading to high maintenance cost. There is, thus, a need to modify them or develop situation-specific machines indigenously so that their price and maintenance are economically viable.

Mounted Motorized Harvesters

Different tea growing regions in Georgia, Japan, Australia, Papua New Guinea, Uganda and Assam experimented with mounted machines developed in countries like Japan, Australia and USSR (Wilson, 1992). Some machines were developed that could operate on slopes up to 25°. USSR was an early starter amongst those who developed self-propelled harvesters (Wilson, 1992). Self-propelled harvesting machines developed and used in Australia have a cutting width from 1.8 to 5.0 meters. Each machine, depending upon the design, is capable of handling 20 to 200 ha per day. Various harvesting machines were developed in Australia, some of which reached a high level of performance; some machines have been exported for use in countries like Uganda and Papua New Guinea.

Riding machines developed and used in Japan have changed from wheel type driving mechanism to crawler type to avoid soil compaction; these machines operate on gradients of less than 5° (Nakano, 1999). The

machine movement in slopes and undulated terrains was stabilized by the development of "Self Rail Tracking System" with an electric motor.

These mounted machines are reported to have a capacity of harvesting anywhere between 2000 to 5000 kg of green leaf per day. The quality of leaf and teas made from leaf harvested by these machines are reported to be of low quality in view of their non-selectivity (Wilson, 1992; Nakano, 1999).

Williams Hi-Tech International developed a harvesting machine called "Magic Carpet" which runs on top of tea bushes. The machine, 'T 1000', is run by one operator and is reported to harvest up to one hectare per hour (Williams Hi-Tech International Pvt. Ltd., 1999, 2000). It has a floating head for even and accurate cutting resulting in improved quality of harvesting. It is gathered that two of these machines are being field-tested by a large plantation company in Assam and hope the results are favourable.

Mounted motorized machine harvesters can be used only in plains or gentle slopes in tea planted in straight rows or very gentle contours and, as such, are situation specific to areas such as Argentina, Assam, Australia, Japan, Georgia, Papua New Guinea and Uganda.

The blades of the harvesting implement, whether hand-operated, motorized or mounted, should be sharp so as to minimize bruising of the leaf. The time lag between harvesting and its arrival at the factory should be minimal. Teas of superior quality could be made if these two precautions are observed.

Careful integration of different aspects of bush management, such as height of pruning and tipping, annual creep of the bush height, rational length of pruning cycle, optimized nutrient management, good bush health, appropriate methods and implements of harvesting and optimal harvesting intervals will together contribute to increased plucking average and reduced plucker requirement, resulting in a significant reduction in cost of production.

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Chapter 9

REDUCING THE COST OF TEA PLUCKING WITHOUT LOSS OF QUALITY

Salwa Lubnan Dalimoenthe

Ms. Salva Lubnan Delimonthe has worked as a scientist since 1985 at the Research Institute for Tea and Cinchona in Indonesia. She graduated in 1981 from the Bogor University of Agriculture in the field of Agronomy and earned the postgraduate degree in weed science from the University of Padjadjaran in Bandung. Her research specialties are in the field of Agronomy and Plant Physiology. She had followed an international applied Plant Breeding course in Netherlands in 1988.

In 1996 she was the counter-part scientist at the tea tissue- culture project in New Queens land in Australia. In 1990-2000 she had involved herself on the aspect of research in mechanization in tea harvesting and she now continues as research scientist in tea agronomy at the Research Institute of Tea and Cinchona in Indonesia.

SUMMARY

The enormity of labor involvement in harvesting makes tea a labor-intensive crop. The wages of tea production cost up to 50–55%, and almost 75% of the workers are used in harvesting. Escalating cost of the inputs has contributed to the urgency of generating basic information for judicious management of tea for sustained high productivity, besides maintaining the bush health and quality.

In these days labor shortage is so severe and level of wages so high that it is almost impossible for the tea industry to employ labor on such an irregular basis as required intermittently throughout the year. This situation has become a serious constraint to harvest the tea crop completely. Mechanical harvesting either by shears or machine is one of the ways to solve the problem of tea harvesting.

Shear or machine can increase the plucking potential and also maintain the production and health of tea bushes. Shears-plucker's potential is 1.70 times and machine-plucker's potential is 5.73 times, compared to hand plucking. Shears or machine plucking does not damage the leaf quality, bush health or even the quality of made tea. Our goal is to reduce the cost of tea plucking through the implementation of mechanization, without loss of quality.

Plucking with shears could replace 6.25 persons/ha/plucking, while plucking by machine could replace 20 persons/ha/plucking and 360 persons/ha/year. This would mean mechanization of tea harvesting can reduce not only cost of plucking, but it can also increase the welfare of pluckers, give higher productivity per labour, decrease investment on labour housing, increase the efficiency in field activity and also solve the problem of availability of pluckers.

INTRODUCTION

As we realize, tea plantation is one of the labor-intensive industries. Today, the tea industry worldwide is experiencing reduced profits due to high costs of production and low prices. Escalating cost of the inputs has contributed to the urgency of generating basic information for judicious management of tea for sustained high productivity, besides maintaining the bush health and quality.

Research Institute for Tea and Cinchona, P.O. Box 1013 – Bandung 40010, Indonesia
Email: gambung@bdg.centrin.id

To overcome this situation, the most obvious approach would be to reduce cost of production and increase productivity, simultaneously. This is easier said than done. But to survive, this is to be achieved. The efficiency of the production system has to be increased; and for this to happen, the essential ingredient is an effective management system of tea plantation business.

The changing scenario in several sectors (industries, tourism etc.) and improvement of the education system make the young generation reluctant to become the unskilled labor particularly for agricultural subject. Besides that most of the tea plantations are located on isolated places and far from the city. So, most of the young workers decided to work in the city or in the factory rather than in tea plantation.

Plucking in tea plantation is the most labour intensive and also the most expensive item of tea harvested accounting for as much as 29–37% of the total cost of production and up to 70% of all labour employed on an estate (Sivapalan, 1983; Rosyadi et al, 2002); for harvesting, there could be used almost 75% from the workers in tea plantation.

The objective in plucking tea is to manage harvesting in a way so as to have maximum yield of good quality leaf per unit area, combined with maximum labor efficiency. In other words we should look for the possibility of bringing down the plucking cost.

In these days, labor shortage is so severe and level of wages so high that it is almost impossible for the tea industry to employ labor on such an irregular basis as required intermittently throughout the year. This situation has become serious constraint to harvest the tea crop completely. Mechanical harvesting could be the way to solve this problem, either from the simple way to pluck by shears or by use of plucking machine.

Actually, mechanization of tea plucking is not the new regulation. Since 1950, some people have done it. But the increasing cost of production and the development in other sectors bring us to the condition that we should reduce the cost of plucking without loss of quality. The main advantage of mechanization of plucking is reducing the number of pluckers especially while pluckers are becoming a constraint. Plucking by shears could replace 6,25 pluckers per ha, meanwhile machine 20 pluckers on each plucking and 360 pluckers per year.

LEAF PRODUCTION

The process of harvesting tea by selective hand picking of the tender shoots is called plucking. The shoots are plucked at regular intervals throughout the year. The plucking cycle depends on climatic conditions, type of tea and rate of growth. The plucked shoot consists of the terminal bud, the internodes (stalks) and 1, 2 or 3 leaves immediately below the bud.

Shear harvesting during two high cropping seasons and hand plucking in the intervening low cropping seasons gave the same level of yield as that under continuous hand plucking, without adverse effects on health of the bush. Mechanizing the harvesting operation enhances the plucking average, and also the combination between hand and shears plucking leads to considerable economy in plucking by way of fewer plucking rounds and higher plucking average (Tables 1 and 2). Reducing plucking rounds and enhancing plucking average could reduce cost of production without losing the quality. But continuous shear harvesting was found to depress the yield and adversely affect health of the bush in terms of quantum of maintenance foliage left on the bush.

Shears and plucking machine are only the tools for tea harvesting. The important thing is to maintain the standard of plucking. Good supervision is very important to maintain quality of plucked leaves.

Plucking of coarse leaf is not desired. Quality of made tea depends on the inherent quality of the leaf, size and types of shoot plucked, leaf handling and standard of manufacture. Fine plucking enhances quality of tea. As far as the leaf quality is concerned, we could always maintain the standard by plucking with shears or machine and could produce good quality tea.

Table 1. Effects of shears-harvesting on yield

Treatments	Yield in kg green leaf/plot in years from pruning					Total
	1	2	3	4	5	
Hand plucking	142	495a	722	606	443cd	2408 abc
Continuous level plucking	156	576b	802	644	432bcd	2610 d
Shearing during high cropping season in each year	150	484a	719	622	399a	2374 ab
Shearing during first high cropping season in each year	149	515a	733	665	429bcd	2491 abcd
Shearing during second high cropping season in each year	140	473a	740	596	419abc	2368 a
Shearing during high cropping season of 1st, 3rd, 5th years	151	505a	794	641	414ab	2505 bcd
Shearing during high cropping season of 2nd and 4th years	160	504a	784	630	454d	2531 cd

Source: Satyanarayana et al, 1990

Table 2. Leaf production (kg/plot)

Treatments	Estate A	Estate B	Estate C
Shears A	137,59 b	183,00 b	159,02 b
Shears B	133,73 b	187,77 b	141,09 b
Machine	364,81 c	486,57 c	322,00 c
Hand	127,64 a	170,69 a	130,98 a

Source: Johan et al, 2002

Estate A: shears + hand plucking 26 times; machine 13 times

Estate B: shears + hand plucking 24 times; machine 17 times

Estate C: shears + hand plucking 25 times; machine 12 times

The best time to operate plucking machine was found to be during high cropping seasons to get better leaf production compared to by hand plucking. The shoot density during high cropping season was very high, when it was just not possible for the hand pluckers to remove all shoots individually in a short period of time. Consequently several ready shoots were often left unplucked on the bush. Generally 5000-7000 shoots are required to manufacture one kilogram of made tea (Sreedhar et al,1996). But, by integrating hand plucking with shears or machine plucking, all the ready shoots could be removed in time.

Yield data indicated significant differences among different treatments (Table 3). The integrated schedule of harvesting using one man and two men operated machines resulted in significant depression in yield when compared to shear harvesting. When one man-operated machine was used continuously, the depression in yield was smaller comparing when two men operated machine was used. The one-man operated machine could be efficiently used in fields situated on gentle slopes. Similarly, the two men operated machine was found efficient in fields located on flat lands and gentle slopes (Ilango et al, 2001).

Table 3. Effect of machine harvesting on yield

Treatments	Total cycle yield (kg made tea/ha)
Integrated harvesting using hand shears	9484
Integrated harvesting using one man operated	9290
Integrated harvesting using two men operated machine	9042
Continual harvesting using one man operated machine	8059
Continual harvesting using two man operated machine	7533

Source: Ilango et al, 2001

PLUCKING ROUND

Total number of plucking rounds with hand plucking was the highest among the treatments, mainly

because of shorter rounds of plucking (Tables 4 and 5). There were required 2079 people in hand plucking, as compared to 1822 people required in hand plucking combined with shears plucking during first high seasons.

Table 4. Influence of hand and shear harvesting on plucking round

Field	Treatment	Total number of plucking round /pruning cycle*		
		Hand plucking	Shear plucking	Total
A	Hand plucking	114		114
	Shear harvesting during the 2 high cropping seasons	51	34	85
B	Hand plucking	124		124
	Shear harvesting during the 2 high cropping seasons	96	16	112

** Pruning cycle four years in A and five years in B.*
Source: Satyanarayana et al, 1991

Duration of plucking round depended on rate pf bud growth and what was left on the bush surface after plucking. Hand plucking was selective, while plucking by shears or machine removed every thing from over the plucking table. That is why usually the plucking round for shears or machine plucking was longer than for hand plucking. However, the shorter plucking rounds made shoot growth more active, increasing thereby the total number of shoots plucked. But then we should realize that plucking by shears could reduce 6,25 person/ha/ plucking, while plucking by machine could reduce 20 person/ha/plucking or 360 persons/ha/year.

The main objectives of using shears and machine for plucking were to reduce the number of plucking rounds and the total number of pluckers. As we could see, by managing the round of plucking and the way of plucking, we could reduce the cost of plucking without loss of quality of tea leaves. Mechanized harvesting of tea reduced the cost of production through reduction in number of plucking rounds.

Total number of plucking rounds under integrated schedule of harvesting using hands and shears was the highest among the treatments (Table 6); the plucking intervals were shorter due to retention of sufficient number of immature buds. The one-man operated machine, because of its lightweight, removed mostly two leaves and a bud; it left a large number of shoots with one leaf and a bud unplucked. The two men operated machines, due to their heavy weight, harvested majority of shoots with one and two leaves; consequently, the plucking intervals were extended (Ilango *et al*, 2001).

Table 5. Plucking economy in relation to shear harvesting.

Treatments	Plucking rounds/cycles		Total	Total pluckers used/ha/cycle	Plucking average per mayday (kg green leaf)
	Shear	Hand			
Hand plucking	-	124	124	2079	26
Continuous level plucking	-	124	124	2160	27
Shearing during high cropping season in each year	16	96	112	1822	29
Shearing during first high cropping season in each year	8	110	118	1969	28
Shearing during second high cropping season in each year	8	110	118	1880	28
Shearing during high cropping season of 1st, 3rd, 5th years	8	109	117	1954	28
Shearing during high cropping season of 2nd and 4th years	8	111	119	1925	29

Source: Satyanarayana et al, 1990

Table 6. Influence of mechanized harvesting on plucking rounds

Treatments	No. of rounds/year		
	Hand plucking	Shearing /mechanical harvesting	Total
Integrated schedule of shear harvesting	14	10	24
Integrated schedule of harvesting using one man operated machine	10	7	17
Integrated schedule of harvesting using two men operated machine	10	6	16
Continual harvesting using one man operated machine	-	14	14
Continual harvesting using two men operated machine	-	12	12

Source: Ilango et al, 2001.

ACCEPTABLE LEAF QUALITY

Plucking in tea comprises harvesting tender shoots containing two/three leaves and a bud. In general, 5000 to 7000 such shoots are required to manufacture one kg of made tea. Plucking has been thought to be one of those agronomic aspects, which affect tea quality most. Nevertheless, quality of made tea depends on the inherent quality in the leaf, size and type of shoot plucked, leaf handling and standard of manufacture (Basu, 1989). Of course emphasis is always put on plucking standards, other plucking attributes such as plucking interval and mode of plucking affect chemical composition and hence quality of made tea.

Compared to hand plucking (Table 7), shears or machine plucked leaves had acceptable fine leaf percentage and quality. Fine plucking enhances quality of made tea. Very coarse plucking reduced the tip content, and proportion of bud, first leaf and second leaf came down from nearby 83% to 43%. This brings down the chemical components, which contribute to liquor characters (Basu, 1989). But there was no significant difference between shear, machine and hand on producing good quality of leaves. This parameter was very important, because reducing plucking cost had no meaning if there was inferior quality of leaf and made tea.

Table 7. Plucking averages and leaves acceptable quality

Treatments	Estate A		Estate B		Estate C	
	Plucking capacity (kg/ person)	Fine leaves (%)	Plucking capacity (kg/ person)	Fine leaves (%)	Plucking capacity (kg/ person)	Fine leaves (%)
Shears A	95.12	63.52	103.51	60.02	89.95	63.36
Shears B	79.25	64.43	91.04	60.09	68.41	63.93
Machine	243.21	59.00	324.71	61.59	322.00	61.55
Hand	52.94	63.66	57.93	62.83	44.45	69.99

Source: Johan, 2002

PLUCKING CAPACITY

Mechanization of harvesting in tea is expected not only to contain the spiraling wage bill, but also ease the demand on plucker requirement by way of increased worker productivity.

The plucking averages under the integrated schedule of shear or machine harvesting (Table 8) or plucking in separate ways using plucking tool (Table 7) could increase the plucking average comparing with hand plucking. Plucking average with shears was 1.70 times while by using machine the plucking average was 5.73 times comparing with hand plucking (Table 7). If the plucking was done on integrated schedule (Table 8), the plucking average by shears was the lowest among all treatments. It increased four fold under integrated schedule using one man-operated machine and almost six fold when two men operated harvesters were used. Under continuous motorized harvesting the plucking average was the highest among all the treatments for the whole year (Ilango et al, 2001).

Table 8. Plucking average under different harvesting schedule

Season	Plucking average (kg green/worker)				
	Integrated hand shear	Integrated schedule		Continuous harvesting	
		One man	Two men	One man	Two men
Low cropping season	22	21	20	158	267
High cropping season	47	183	308	198	316
For the year	34	52	63	92	247

Source: Ilango et al, 2001

PLUCKING ABILITY

Plucking ability is the ability of people to pluck tea leaves for certain time. This parameter becomes important because by knowing the plucking ability of the pluckers we can know how many people we need for plucking in the field. Table 9 shows data on plucking ability of a person for working seven hours a day. For plucking 3 ha using shears we needed 24 people, spending between 4.50 to 5.25 hours. For plucking with machine we needed only 3 persons taking 4.50 hours, compared with 24 persons taking 7.50 hours. Plucking for seven working hours by using shears, machine and hand they could pluck 4.00 to 4.67 plots, 19.44 and 2.80 respectively. These data showed that plucking by shears or machine gave some probability for the pluckers to pick more leaves in the same time. We could see that mechanization of plucking increased the plucker's ability and reduced the time required for plucking. This gave advantage both to the company and the pluckers.

Table 9. Plucking ability on Estate B

Treatments	Pluckers (persons)	Time (hour)	Plucking ability (person/7hr) (1 plot = 400 m^2
Shears A	24	4.50	4.67
Shears B	24	5.25	4.00
Machine	3	4.50	19.44
Hand	24	7.50	2.80

Source: Johan, 2002

PLANTS HEALTH

In machine harvesting the photosynthetic rate, C-14 retention and partitioning, root carbohydrate reserves and levels of GA_3, GA_3: ABA ratio were reduced (Table 10). However, there was an increase in photorespiration, dark respiration and levels of ABA. Besides these there were no significant changes in the other biochemical constituents in machine harvesting. There was a significant positive linear relationship between maintenance leaf load and yield. Enhanced level of maintenance foliage sustained the metabolic activities, thereby influencing the partitioning of assimilates towards the sinks. Photosynthetic rate had a positive relationship with yield and certain yield components, like leaf load, phytomass and carbohydrate reserve (Ilango et al, 2001).

Table 10. Influence of machine harvesting on physiological activities and biochemical constituents of green leaves

Parameters	Hand shear	One man operated machine	Two men operated machine
Physiological parameters			
Pn rate (mmole $CO^2/m^2/S$)	9,40	8,23	6,07
C-14 retention (%)	66,40	64,60	65,60
C-14 portioning (%)	21,66	14,28	17,49
Photorespiration	8,53	14,32	12,57
Dark respiration	3,41	6,78	4,30
Endogenous growth substances			
GA_3 (mmole/g fr.wt.)	37,20	26,50	11,80
ABA (mmole/g fr.wt.)	3,10	9,58	7,21
GA_3: ABA	12,00	2,77	1,64
Biochemical constituents			
Proline (mmole/g fr.wt.)	0,48	0,49	6,17
Amino acids (%)	1,89	1,79	1,74
Polyphenols (%)	30,90	30,50	30,50
Catechines (%)	23,30	22,70	22,80
Chlorophyll-a (mg/g fr.wt.)	0,80	0,72	0,64
Chlorophyll-b (mg/g fr.wt.)	0,36	0,33	0,25
Carotenoids (mg/g fr.wt.)	0,31	0,26	0,25
Chlorophyll a/b	22,60	2,40	2,76
Root carbohydrates (%)	15,00	13,30	12,20

In order to know the effect of mechanization of plucking on tea bush health, we studied the effect on the leaf area index (LAI) and root carbohydrate reserve (Table 11), and no adverse effect was observed. Tea plant was considered to be in good condition if the LAI was between 3-4 and root carbohydrate was more than 12 %.

Table 11. Leaf area index (LAI) and root carbohydrate

Treatments	Estate A		Estate B		Estate C	
	LAI	Root carbo-hydrate (%)	LAI	Root carbo-hydrate (%)	LAI	Root carbo-hydrate (%)
Shears A	3.2	12.87	3.2	14.24	2.9	16.30
Shears B	3.2	13.13	3.2	14.03	3.1	20.81
Machine	3.1	12.17	3.1	13.15	3.0	17.88
Hand	3.2	14.67	3.2	13.08	3.0	15.98

Source: Johan et al, 2002

BUD GROWTH

The plucking intervals were short in shear harvesting due to retention of sufficient number of immature buds (Table 12). The one-man operated machine, due to its lightweight, retained large number of shoots with one leaf and a bud but harvested majority of shoots with two leaves and bud. Therefore, the number of plucking rounds was less when one man-operated machines were used. The two men operated machines, due to their heavy weight, harvested majority of shoots with one and two leaves. Consequently, the plucking intervals were extended (Ilango et al, 2001). There was a reduction in total leaf area (LAI) of bushes under machine harvesting (Table 13). Of course we didn't expected this situation. Although mechanization is only a tool, it is very important to keep tea plants in good health as otherwise all good points of mechanization of harvesting would be negated.

Table 12. Effect of harvesting machines on retention of immature buds

Treatments	Buds retained on bush (No./30 cm²)		
	Bud	1 L + B	2 L + B
Hand shears	10,3	12,3	10,6
One man operated	22,0	12,3	2,3
Two men operated	21,0	4,6	1,5

Source: Ilango et al, 2001

Table 13. Effect of motorized harvesters on the type of leaves retained on the bush

Treatment	Leaf area (cm²) on the top 10 cm profile					
	Full Leaves	Half cut leaves	>Half cut leaves	Total leaf area	Leaf area index	No. of shoots tipped
Hand shear	4488	1253	1025	6766	2.71	79
One man operated machine	3192	1512	525	5229	2.09	52
Two men operated machine	1853	1256	681	3790	1.52	47

Source: Ilango et al, 2001

Compared to hand plucking, none of the other treatments of mechanized harvesting suppressed bud growth in anyway (Table 14).

Table 14. Growing bud rate after pruning

Treatments	Estate A	Estate B
Shears A	71.19	72.88
Shears B	69.74	69.90
Machine	66.52	68.95
Hand	66.81	67.00

Source: Johan et al, 2002

BIOMETRIC PARAMETERS

The biometric parameter measurement was to know the ratio between leaf and stem in top 20 cm profile of the bush, which is very important for the tea bush growth. Such a measurement did not show any difference (Table 15) under integrated schedule compared to hand plucking, indicating the treatment did not adversely affect the health of the bush. But 12 months of continuous shear plucking

adversely affected the ratio between leaf and stem (Table 16), and this also suppressed the yield.

Table 15. Effect of shearing on biometric parameter

Treatment	Top 20 cm profile of the bush Fresh weight (g/bush)		Ratio leaf: stem
	Leaf	Stem	
Hand plucking	561 b	445 a	1.26 b
Integrated schedule	570 b	436 a	1.30 b
Continual shearing	460 a	462 b	0.99 a

Source: Satyanarayana and Sharma, 1996

Table 16. Effect of shearing on leaf: stem ratio

Treatment	Top 20 cm profile of the bush Leaf: Stem ratio
Hand plucking	1:1.05 c
Six month shearing	1: 0.98 bc
Nine month shearing	1: 0.91 b
Twelve month shearing	1 : 0.80 a

Source: Sreedhar et al, 1996.

Continuous machine harvesting led to a significant reduction in the quantum of the maintenance foliage and the leaf/stem ratio (Table 17) and suppressed the yield.

Table 17. Effect of motorized harvesters on leaf/ stem ratio at the end of pruning cycle.

Treatments	Top 20 cm profile		
	Leaf (g/bush)	Stem (g/bush)	Leaf/Stem Ratio
Integrated harvesting using hand shears	875	891	0.98
Integrated harvesting one man operator machine	700	790	0.89
Integrated harvesting using two men operated machine	675	780	0.87
Continual harvesting using one man operated machine	600	740	0.81
Continual harvesting using two men operated machine	550	690	0.80

PLUCKERS (WORKERS)

The total number of pluckers required was the highest under integrated schedule of shear harvesting (Table 18). This number was drastically reduced when two men operated machines were continuously used; as a result of this the total leaf area was also low. Total number of pluckers on integrated schedule of harvesting using hand shears was 495 while continuous harvesting using two men operated machine needed 56 pluckers only.

Table 18. Requirements of pluckers

Treatments	No. of pluckers/ha		
	Lean season	High season	Total
Integrated schedule of harvesting using hand shears	333	162	495
Integrated schedule of harvesting using one man operated machine	222	93	315
Integrated schedule of harvesting using two men operated machine	222	33	255
Continual harvesting using one man operated machine	59	93	152
Continual harvesting using two men operated machine	23	33	56

Source: Ilango et al, 2001

If we look to the continuous shearing situation (Table 19), after 12 months treatments, we could see reduction in requirement of pluckers. The percent reduction in the requirement of pluckers was 22% in six months shearing and 37% under nine months shearing.

Table 19. Plucker requirement

Treatment	Pluckers/hectare/year			Mean
	II year	III year	IV year	
Hand plucking	483	710	877	690
Six months shears	398	560	652	536
Nine months shears	339	474	552	455
Twelve months shears	296	410	454	387

Source: Sreedhar et al, 1996.

MADE TEA QUALITY

Both black and green made teas need good quality fine leaf (Table 20). Integrated hand and shear

plucking produced more fine leaf and better quality of made tea.

Table 20. The relation between leaf quality and green tea grade percentage

Treatments	Fine leaves (%)	Green tea grade (%)			
		Peco	Jikeng	Stem	Dust
I*	41.22	52.5	25.7	2.9	19.0
II**	45.52	54.7	21.7	4.9	18.6

* *Continuous shear plucking.*
** *Integrated hand and shear plucking*
Source: Rosyadi et al, 2002

Shoots harvested using two men operated machine resulted in a significant decrease in the optimum fermentation time and an increase in high-polymerized substance (Table 21). Both these could be due to the excessive physical damage of shoots because of heavy weight of the machine.

Table 21. Effect of motorized on the quality of made tea

Treatments	Hand shears	One man operated machine	Two men operated machine
OFT (mins.)	55,00	52,67	47,67**
Theaflavin (%)	1,14	1,14	1,03
Thearubigin (%)	10,31	9,51	9,83
High polymerized substances (%)	8,49	8,65	9,75
Total liquor color	3,59	4,05	3,87
Water extract (%)	39,73	39,19	38,86
Crudefibre (%)	16,66	15,85	16,76
Caffeine (%)	2,95	3,02	2,71
Briskness index	27,76	27,40	27,52
Colour index	6,01	7,41	5,32

Source: Ilango et al, 2001

ECONOMICAL ASPECTS

The total cost per hectare per year was the highest in integrated schedule of shear harvesting due to deployment of more number of pluckers (Table 22-23). This cost could be brought down by the adoption of integrated schedule of harvesting with one man and two men operated machines. There was further reduction in the total cost of harvesting when continuous harvesting was resorted to.

There was considerable saving in the cost of production of black tea when harvesting machines were used in an integrated manner. The cost of production was the lowest when two men operated machines were continuously used. Continuous use of one-man operated machine was the least economical due to large volume of fuel used (Ilango et al, 2001).

Based on this study it is recommended that integrated schedule of harvesting using both, the one man and two men operated machines, may be implemented in fields when they are more than 18 months from pruning. However, continuous use of these machines, though it may be economical, may have limitations due to the adverse impact on bush physiology and crop production.

Table 22. Cost economics of different treatments

Treatments	Yield kgMPTH	Expenditure on harvesting (labour+fuel +depreciation)		Cultivation, manufacture and others	Total (Rs./kg)
		(Rs./ha)	(Rs./kg)		
Integrated schedule of harvesting using					
Shears	3745	61875	16.52	35.99	52.51
One man operated machine	3685	49333	13.39	36.19	49.58
		(12542)	(3.13)		(2.93)
Two men operated machine	3622	36848	10.17	36.42	46.59
		(25027)	(6.35)		(5.92)
Continuous harvesting using					
One man operatedmachine	3159	38925	12.32	37.53	49.85
		(22950)	(4.20)		(2.66)
Two men operated machine	3112	16947	5.45	38.33	43.78
		(44928)	(11.07)		(8.72)

- *Rs./kg, excluding harvesting; Figures in parenthesis indicate*

reduction in cost when compared to integrated schedule of harvesting using hand shears.
- Source: Ilango et al, 2001.

Table 23. Cost economics of different types of harvesting

Particulars	Treatments	
	Hand plucking	Mechanical plucking
a. Leaf production (kg)	1.043.632	342.843
b. Plot size (ha)	190	38
c. Round plucking (days)	12	25
d. Made tea (kg/ha)	1.208	1.982
e. Selling price (Rp)	8.000	8.000
f. Selling value (Rp)	2.689.600	15.856.000
g. Plucking capacity (kg/person)	47	308
h. Pluckers per day per ha	117	30
i. Labor cost per day	20.000	20.000
j. Fuel 2,5 lt/ha	-	543.750
k. Maintenance cost machine	-	1.500.000
l. Plucking cost (Rp)	2.689.600	6.199.300
PROFIT	**6.947.400**	**9.656.700**

Source: Jenie, 2001

SELLING PRICE

Although mechanical harvesting is only one of the ways to solve the problems of plucking, the last goal is still the selling price of made tea. Reducing the cost of harvesting would carry no meaning if we cannot sell the made tea at high prices (Table 24). Highest selling price comes from good quality of made tea, and that in turn comes from good quality leaf.

Table 24. Selling price for green tea grades

Selling price (Rp/kg)	Green tea grade percentage			
	Peco	Jikeng	Stem	Dust
a. I	6.037,9	1.154,7	28,8	663,5
b. II	6.295,5	976,9	49,4	651,2

Source: Rosyadi, 2002
I: Continuous shearing
II: Integrated hand and shears

CONCLUSIONS

1. Mechanization of plucking could increase the plucking potential and also maintain the production and health of tea bushes.
2. It is recommended to follow mechanized plucking during high cropping seasons, intervening with hand plucking during low cropping seasons.
3. Shears-pluckers' potential is 1.70 times and machine-pluckers' is 5.73 times compared with hand plucking. Shears could replace 6.25 person/ha/plucking while machine could replace 20 person/ha/plucking or 360 person/ha/year.
4. Mechanizing the harvesting operation enhances the plucking average, and the combination between hand and shears plucking leads to considerable economy in plucking by way of fewer plucking rounds and higher plucking average.
5. With mechanized plucking it is important o maintain good standard of plucking and make good teas. We can reduce the cost of plucking but can not afford to lose quality.

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Concluding Remarks Session Chairman Dr. P. Sivepalan

Ladies and gentlemen, in a brief summary I would like to point out that the presentations made this morning centered on labor utilization particularly when it comes to harvesting. We are still carrying the legacy of a huge labor force on our plantations, beginning at the time when labor cost was very-very low. We are carrying that burden even today when wages have increased. A marginal increase in wage implies tremendous erosion into the cost of production, because we are carrying such a huge load of Social costs also. The question is whether should we carry this load any further? Or can we not do anything to reduce the dependence on human resource. The speakers emphasized on the three components of the labor requirements, which accounts for 55-70 percent of the total cost whereas the input cost are only marginal comparatively. The other area to be concerned and reckoned is manufacture where our energy in general including liquid fuel cost is increasing. Now coming back to labor, the single most demanding area is plucking and that is where, the speakers have touched upon the need for mechanization without compromising on the quality. This is an area greater effort needs to go in because the available machines will not be at all suitable for the terrain in countries like India and Sri Lanka where we need to use smaller versions of more effective, efficient plucking machines.

When the wage increases come, of course the labor unions are very demanding and politicized, where the government has not much latitude except to compromise. A marginal increase means tremendous erosion into the cost of production. It is time that we look into these areas where mechanization can be brought in. We do some mechanized pruning, which is another area where labor demands are not so high as compared to plucking. There are no other areas where mechanizations can come in. Some have thought of even fertilizer application by mechanized means but what is needed is something that will help reduce the plucker demand. In Sri Lanka the plucking cost averages between 35-40 percent of the total C.O.P., which should be brought down to 20 percent for a healthy state. Because of the lack of time questions can be asked of the speakers during lunch A special Panel discussion on cost reduction is also proposed later during the Conference. Thank you very much for your patient hearing.

Chapter 10

IMPACT OF MACHINE PRUNING ON THE ECONOMICS OF TEA

Subhash C. Barua and P. Jha

INTRODUCTION

Pruning is the art of cutting or the removal of unwanted plant parts to make the plant grow or behave the way it is desired. Tea is cultivated for its succulent vegetative shoots that gradually lose their vigour in absence of regular pruning. Pruning helps in sustaining a vigorous flushing activity in the bush (Chakravartee and Barbora, 1998) by maintaining continuous vegetative stage of growth with a flat plucking surface (Eden, 1965). Pruning requires huge amount of labour within a relatively short period of time and is becoming increasingly expensive due to continual escalation of labour wages. Mechanisation of pruning operation might help in overcoming the labour shortage and related problems. Barua (1989) suggested that mechanical pruning would appear to have better prospect than mechanical plucking since pruning does not have to be selective. Machine pruning was tried in tea plantations of Assam with a view to study its effects in respect of productivity of the workers and the cost of pruning.

MATERIALS AND METHODS

The experiment was laid out in a 17 year old clone T_3E_3 plot planted at a spacing of 120cm x 90cm x 60cm in tea garden of Tocklai Experimental Station, Jorhat. The six different types of pruning experimented with were rejuvenation prune (RP) at 45cm from ground level (g.l.), medium prune (MP) at 55 cm from g.l., light prune (LP) at 4-5 cm above last prune mark, deep skiff (DS) at 10-12 cm from last prune mark, medium skiff (MS) at about15 cm from last prune mark and light skiff (LS) at 1cm above last tipping mark. Total 18 treatments were replicated thrice in plots comprising of 72 bushes each under a stand of *Albizzia odoratissima* shade trees.

Tea bushes were pruned manually using standard knives, and also using Kawasaki and Kaaz pruning machines. Kawasaki PST 55R is a single man operated machine and is fitted with reciprocating type of blade. It is 74 cm long, weighs 5.5 kg and consumes about 900 ml of petrol and 20 ml of mobil oil per hour if run continuously at full throttle. Compared to this the Kaaz Java tea cutter (Model JT 430) is shoulder mounted, double handled machine with a shaft length of 1.54 m. It is fitted with a chip saw blade mounted on a spinning disc. This machine also is single man operated, weighs 7.2 kg and has fuel consumption equal to that of Kawasaki.

The tea bushes were pruned and skiffed using knives, reciprocating type of machine (Rc) and revolving type of machine (Rv) during winter. Observations were made on the requirement of labour, time and fuel for each treatment. The comparative productivity of the manual as well as the mechanical methods was also calculated.

RESULTS AND DISCUSSION

The results established the advantage of machines over the manual cuts. However, the machine having reciprocating type of blades (Rc) was not suitable for harder cuts like RP and MP, whereas the machine with revolving type of blade (Rv) was suitable for all types of pruning cuts.

The time required for manual pruning was observed to be significantly higher compared to that in

Department of Tea Husbandry & Technology, Assam Agricultural University, Jorhat 785013, India. E-mail : < subhash@aau.ac.in >

machine pruning (Table 1). The time difference between manual and machine pruning was higher in lighter cuts than the harder cuts. The number of bushes pruned per unit time was naturally higher with the machines compared to that in manual pruning (Table 2). The results showed that the productivity of the machines had an increasing trend with the increase in height of the pruning cuts. In other words, deeper the pruning cut, lower was the productivity of the machine. While the heavy prunes could be effectively done by the revolving type machine, the reciprocating type of machine was more suited to higher cuts.

Table 1. Time required (min) for pruning each plot

Pruning type	Manual (knife)	Machine	
		Rc	Rv
RP	191.00	NA	72.67
MP	182.00	NA	69.33
LP	78.33	12.67	12.33
DS	94.67	10.00	13.33
MS	101.00	9.67	10.67
LS	63.67	5.33	7.00

CD at 5% = 20.34

Table 2. Number of bushes pruned per hour

Pruning type	Manual	Rv type machine	Rc type machine
RP	22.61	59.44	-
MP	23.73	62.31	-
LP	55.15	350.36	340.96
DS	45.63	324.08	432.00
MS	42.77	404.87	446.74
LS	65.85	617.14	810.50

The per cent increase in the number of bushes pruned for LS per hour was about 810 with the Rv type machine and 1095 with the Rc type machine (Table 3). Although the Rc type machine could not perform well with the harder cuts like RP and MP, it showed better performance than the Rv type in respect of the skiffs (DS, MS, LS). The consumption of fuel by the two types of machine is presented in Table 4. Heavier cuts like RP and MP required higher quantity of fuel (about 15 ml per bush) for the Rv type of machine which was found to be suitable for these two cuts. The lighter cuts, including the skiffs, by both the machines consumed very little quantity of fuel that roughly varied from 1-3 ml per bush. The present findings are almost in line with those of Sreedhar et al. (1991).

Table 3. Increase in productivity due to machine

Pruning type	Machine over manual (%)		Machine over machine (%)	
	Rv over knife	Rc over knife	Rv over Rc	Rc over Rv
RP	162.89	-	100.00	-
MP	162.57	-	100.00	-
LP	535.28	518.24	2.75	-
DS	610.23	846.74	-	33.30
MS	846.62	944.51	-	10.34
LS	809.56	1094.54	-	31.33

Table 4. Fuel consumption (lit) for pruning 72 bushes by machine

Type of pruning	Rv type	Rc type
RP	1.240	N.A.
MP	1.330	N.A.
LP	0.190	0.195
DS	0.202	0.155
MS	0.165	0.150
LS	0.102	0.081

The pruning cost of per hectare decreased by 142-282 per cent with the Rv type and by 130-372 per cent with the Rc type machine. The productivity of the workers enhanced by 800 and 1100 per cent with the Rv type and Rc type machines respectively. It may be concluded that the use of machine for pruning tea could prove beneficial for the industry as far as working man-days and overall costs are concerned.

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