Research Article

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Mechanical harvesting in tea: A case study of Pasuparai estate

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Abstract

Tea cultivation is a highly labour intensive and more than 2.0 lakh people are directly or indirectly involved in south India. Normally, women workers are deployed to harvest the crop manually at an interval of 10-12 days. By the turn of the century, usage of hand held shears became inevitable to increase the labour productivity. An interval of 14-16 days is mandatory to obtain good quality and regular crop production when hand held shears are used. Employing more labour is not practically and economically viable and hence adoption of mechanical harvesting is the only option to achieve the sustainability of the crop. The case study deals with continuous mechanization over a period of 6 years and its impact on crop productivity besides the adoption of improved agronomic practices. Significant improvement in plucking average was recorded after the introduction of machines. Timely harvesting of the crop improved the quality parameters of made tea and reduced the cost of harvesting. Deliberate addition of a new tier of maintenance foliage was followed during January-March, every year after the machine harvesting. Furthermore, foliar application of micronutrients, plant growth regulators and potassium nitrate also given to minimize the ill effects of mechanization. Mechanization enabled to achieve sustained crop productivity, and the case study narrates the impact of mechanization and the importance of adopting good agronomic practices to sustain the productivity in south Indian tea plantations.

Keywords: Harvesting, mechanization, plucking, plucking average, shear, yield

Introduction

Cultivated tea (*Camellia* spp.), the most popular and cheapest source of beverage in any part of the world is one of the Indian's major export commodities, contributes over 7 per cent of gross foreign exchange earnings (Siby Mathew, 2010). In India, tea industry employs over a million people directly in routine agronomic practices of which 50 per cent are women force (Bora and Deka, 1999). Crop distribution pattern in Central Travancore is exhibiting two distinct peak cropping seasons (Siby Mathew, 2006). It is estimated that 60-70 per cent of total crop is harvested during the peak periods of April to June and September to November and remaining crop during lean season. Being a labour intensive crop, scarcity in work force is a major limiting factor in tea plantations. Due to labour shortage during the peak growing season, efficient harvesting is not possible there by affecting the crop productivity (Ilango *et al*., 2001). Generally, two workers are required per ha per day to maintain tea plantation. However, majority of tea gardens are operating at present with ~0.8 man days ha^{-1}.

Mechanization in agricultural operations has gained considerable importance and *in toto* mechanization is achieved in pruning. Traditionally, manual plucking is adopted in harvesting. After introduction of hand held shears, usage of shears became unavoidable tool in harvesting. In fact, shears improved the labour productivity and sustained the crop productivity as well. As a result, UPASI Scientific Department issued a recommendation on integrated shear harvesting to protect the bush health (Satyanarayana *et al.*, 1990). Of late, estate management looked into the alternatives to cope with the prevailing situation.

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In this context, mechanical harvesters came in to the existence in tea sector.

Mechanization is being attempted since last one decade to improve labour productivity and complete harvesting of fields. Mechanical harvesting not only improved the labour productivity, it also reduced the cost of production (Ilango *et al*., 2012). Significant reduction in yield was reported earlier when single and two men operated machines used for regular harvesting the crop (Ilango *et al*., 2001). Consequently, usage of machines were restricted only to manage rush crop. However, labour shortage forced many estates to adopt extensive mechanical harvesting (Ajaikumar, 2009). Present study deals with the impact of continuous mechanization, agronomic practices to be adopted to overcome the ill effects and the cost economics.

Materials and methods

Pasuparai Estate, belongs to M/s. A. V. Thomas Group Companies, is located in Vagamon village of Idukki district. The total tea area of the estate is 187.76 ha and the mean daily employment of pluckers was 350 during 2000-2011. At present the estate employs around 150 pluckers every day. Initially the estate was planted with seedling material in 1940's and new planting was commenced during 1990's with high yielding clonal material, predominantly UPASI-9. New planting was done in contour double hedge method (0.75 m x 0.75 m x 1.35 m). The total area of clonal tea is 30 ha comprising of four fields where the field numbers 13 to 16 comprised of 5.0, 6.0, 6.5 and 7.4 ha, respectively. Mean yield of the field (made tea kg ha^{-1}) was around 3000 kg prior to the commencement of mechanization.

Mechanization of clonal area was commenced during the year 2005 using imported single man operated Ochiai harvesters. Single man operated machine was selected for the easy operation due to steep terrain in some of the fields. Mechanization was continued up to nine months a year (April to December). Even though adverse impacts on maintenance foliage load and creep of the bushes was noticed due to mechanization, the negative impacts could be minimized with suitable amendment in the agro techniques (Table 6). Deliberate mother leaf addition (a new tier of maintenance foliage) was done during January to March every year using hand held shears or manual plucking. Furthermore, recommended micronutrients, plant growth regulators and potassium nitrate were foliar applied to minimize the ill effects, besides the regular cultural operations (Muraleedharan *et al*., 2007; Muraleedharan and Hudson, 2007). Crop harvested from each plucking round was weighed and converted to made tea per hectare at an out turn of 23 per cent. Plucking average (kg) was computed with harvested green leaf per unit area and the number of labour deployed for harvesting. Pluckers utilized per hectare were also computed during every round and the average for the year is presented in the study.

Results and discussion

Irrespective of the mode of harvesting/ agronomic practices followed, total production of the estate fluctuated between 500 and 700 tonnes during 2004-05 to 2011-12 (Table 1). Productivity per unit area ranges from 2663 to 3750 kg made tea ha^{-1} during the same period. When the 2004-05 agricultural year was considered as baseline data for crop production, moderate decline in total production was observed after the implementation of mechanization. However, on adoption of recommended agro-techniques, the crop productivity per unit area enhanced considerably. Fluctuation in crop production and productivity per unit area are primarily influenced by the climatic

Table 1. Brief account of economic and cultural aspects of Pasuparai estate

Parameter	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Total production (in lakh kg)	5.42	5.32	5.0	5.82	6.59	7.04	6.40	6.55
Productivity (made tea kg ha^{-1})	2884	2845	2663	3111	3525	3750	3440	3443
Plucking average (kg $worker^{-1}$)	29	33	39	46	63	72	79	83
Pluckers strength of the estates (Nos.)	280	220	180	165	150	130	110	97
Average price at Cochin auction Centre (₹ kg^{-1})	74.37	76.45	72.72	77.12	82.06	103.99	97.93	101.77

Table 2. Planting details of the fields adopted for mechanization

Parameters	Field 13	Field 14	Field 15	Field 16
Year of planting	1987	1988	1999	2000
Total area (ha)	6.0	6.5	5.0	6.74
Clone	B6/61	TRI 2025, B/6/61	B/6/61, BSS-I	B/6/61, BSS-I
Spacing	135 × 75 × 75 cm	135 × 75 × 75 cm	135 × 75 × 75 cm	135 × 75 × 75 cm
Terrain	Steep	Moderate	Steep	Moderate
Shade pattern	20 × 40'	20 × 40'	20 × 40'	20 × 40'
Present age	III	II	IV	III
Width of plucking table (cm)	150	140	160	150
Mechanized from	2005	2005	2006	2006

variables, pest and disease incidence besides the agricultural operation like pruning. Over the years after mechanization, pluckers productivity, rather plucking average was increased substantially (Table 4). On the other hand, strength of the workforce declined from 280 to less than 100 within the period 2004-2012. There was a myth that mechanization result in coarser leaf/maintenance foliage in the harvest which in turn affect the quality of made tea. Though there was a rise and fall in the price realization at Kochi auction centre, overall quality sustained even after mechanization (Table 1).

As mentioned earlier, the planting was done at varying intervals (Table 2) between 1987 and 2000. New clearings were planted predominantly with UPASI-9 followed by TRI 2025 and BSS-1 seedlings. Field 13 and 15 located at steep terrain. Irrespective of the planting year, mechanization was implemented during 2005-2006 in the newly planted areas.

During the agricultural year 2004-2005, the fields selected for the study were of different age from planting/pruning (Table 3). As on date, Field 13 completed two pruning cycles after adoption of mechanization in harvesting. Treating the 2004-05 productivity of the field, yield increased substantially in the second and third year and a gradual decline was noticed in the fourth year. A similar trend was observed in other tea fields. In the second cycle, there was a tremendous jump in yield of the field, especially in the third year. In Field 14, almost two fold increase in the yield was observed during 2010-2011 when compared to pruned year (2008-2009). Similar trends were observed in the other two fields as well but the degree of productivity in response to mechanization varied due to plant age and age from pruning. When the crop recorded among the four fields were compared, Field 13 and 15 showed moderately higher crop productivity after the implementation of agro techniques while Field 14 and 16 exhibited almost two fold increase in crop. This may be due to steep terrain and age of the plants from planting. Bushes grown on steep terrain had limited the canopy spread as the age advances the canopy area increases. Since formative pruning of the Field 15 carried out during 2005, the canopy spread was confined due to its age. Moreover, the field was partially planted with BSS-1 seedlings.

Table 3. Yield recorded over the period after mechanization

Field	Yield (kg made tea per hectare during each agricultural year)							
No.	2004-05#	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
13	3162	4994	4568	4053 *	6504	6870	6577	6594
14	2657 *	5597	5876	5655	3846 *	7010	7513	7031
15	1750 **	4051	4213	4469	5283	3448 *	5220	5031
16	Young tea	2101 **	3924	4752	6156	6202	3722 *	5809

Base data; *pruned year; ** formative pruned

Unlike UPASI-9, BSS-1 seedlings were not amenable to mechanization. This may also be a variable that influenced the crop productivity.

Prior to implementation of mechanization, the plucking average ranged from 27 to 30 kg worker^{-1} day^{-1} (2004-05). After implementation of machines, pluckers productivity increased several folds over the period and attained about 150 kg day^{-1} worker^{-1} during 2011-12 (Table 4). According to age from pruning and terrain of the fields, the plucking average varied differently.

During the period before introduction of machines, workers deployed for harvesting the crop per unit area varied from 10 to 18 (Table 5). After introduction of machines for harvesting, the pluckers utility reduced drastically except the pruned years. In other words, it was possible to execute other field operations with the workers saved with mechanization.

As reported earlier (Raj Kumar *et al*., 2010; Siby Mathew *et al*., 2013), continuous shear harvesting and implementation of mechanization altered the bush physiology and thereby affected the crop productivity. Detailed account on the study pertaining to shear harvesting elucidated the morpho-physiological aspect of tea besides the bush health (Marimuthu *et al*., 2001). Ajayakumar and Haridas (2002) discussed about the after effect of tea bush health after the mechanical harvesting. In contrast to earlier reports (Ilango *et al*., 2001), no major decline in crop production was observed when extensive mechanization was adopted in large sections. Initially, the fields under continuous mechanization exhibited shallow canopy, inadequate mother leaf load, nutrient deficiency and higher level for banji formation. In order to overcome these ill effects, the estate management followed the UPASI recommendations (Muraleedharan *et al*., 2007) with minor modification. Deliberate addition of mother leaf during the dry weather season (December to March) was followed which helped the bushes to recoup health and thereby sustained productivity.

N and K (1:1) fertilizers were applied as per UPASI recommendations to all the fields under mechanization except the pruned year where N and K at 2:3 ratio was applied. Over and above, additional soil inputs were applied to these fields in accordance to the manure audit and field performance (estate practice). Accordingly 400:40:400 kg NPK was applied per hectare in six splits. Apart from the soil application, foliar application of nutrients, micronutrients and plant growth regulators (22 rounds *in toto*) were also executed. Instead of micronutrients (Venkata Ram, 1968 and 1976) commercially available 'Multiplex' was applied five rounds as per recommendations coinciding the crop periods. During May and October, protein hydrolysate formulation (Biozyme) was foliar applied (Marimuthu and Raj Kumar, 1997) and two rounds of potassium nitrate were applied during November and January to reduce the leaf leatheryness (Jibu Thomas *et al*., 2008). Immediately after summer showers one prophylactic round of Carbendazim was applied to protect the plants from die back due to pathogens.

Table 4. Plucking average (kg) after the introduction of mechanical harvesting

Year	Field No			
	Field 13	Field 14	Field 15	Field 16
2004-05				
(Base year)	27	29	30	28
2005-06	53	85	97	33
2006-07	104	165	135	148
2007-08	98	178	143	151
2008-09	109	75	132	164
2009-10	138	149	102	142
2010-11	148	171	135	142
2011-12	152	176	149	148

Table 5. Pluckers utilized per hectare after the introduction of mechanical harvesters

Year	Field No			
	Field 13	Field 14	Field 15	Field 16
2004-05				
(Base year)	18	12 *	10 *	18
2005-06	11	10	9	8 *
2006-07	8	10	8	9
2007-08	12 *	9	9	10
2008-09	10	13 *	10	9
2009-10	9	9	9	10
2010-11	9	8	9	10
2011-12	9	9	8	9

*Pruned year

During summer season/onset of summer diammonium phosphate (DAP) (3 rounds) N and K as urea and muriate of potash (MOP) (four rounds) were applied to impart drought tolerance (Manivel *et al*., 1995). Coinciding with peak crop periods (April, May, September and October) cocktail of 'Multiplex' tea special, potassium nitrate (Jibu Thomas *et al*., 2013) and 'Kadostim' were applied to enhance the crop (Raj Kumar *et al*., 2011). Over and above, all other plant protection measures were followed accordingly, wherever necessary. Soil nutrient management and foliar feeding have resulted higher crop productivity and sustained the crop even during fourth year after pruning. Timely and complete harvesting would have resulted in the mobilization of reserves into crop shoots. Further, adoption of agronomic practices with more emphasis on foliar application also would have helped to achieve high productivity. UPASI TRF has released new recommendation on special foliar for mechanized fields based on the long-term experiments (Ilango *et al*., 2012). At present, the estate management aim to sustain crop productivity with an integrated approach of drip irrigation and fertigation.

Besides the crop management in relation to continuous mechanization, cost economics of mechanization was worked out. To harvest a field yielding 20,900 kg green leaf ha^{-1} $year^{-1}$ (equivalent to 4800 kg made tea ha^{-1} $year^{-1}$ at an out turn of 23%), 105 man days are required with 3.0 harvesters ha^{-1}. Maximum output of the machine day^{-1} is 600 kg which accounts 200 kg man-day^{-1} and hence to harvest complete crop in a hectare require 9 man-days per round. Since the machines are used for harvesting, crop regeneration period extended and in a month 1.2 rounds which may vary accordingly to the crop/lean seasons. Standard out put of the machine was fixed at 450 kg day^{-1} (150 kg $worker^{-1}$) and the worker was paid ₹ 183.55. The crop harvested over and above 450 kg was given incentive of ₹ 1.50 per kg green leaf which accounts ₹ 585. Using the machine, crop harvesting cost was around ₹ 2.0 per kg green leaf (Table 6).

Comparative analysis on cost involved in different systems of harvesting per month is presented in Table 7. As a field yielding 4800 kg made tea (equivalent of ~20900 kg green leaf ha^{-1} $year^{-1}$) require varying levels of labour force. Field under manual plucking requires 50 pluckers to harvest the crop on an average of 2.5 plucking rounds. Since the manual plucking is selective and first generation shoots are left behind on the plucking table, tea plants are ready for harvesting at a shorter interval. Even under shear harvesting system, shoots are ready for plucking at fortnightly interval.

Table 6. Economics of plucking with machine

Total Green leaf	1740 kg ha^{-1} per round
No. of machine	3.0 per ha
Minimum crop per machine at fixed wages (₹183.55/worker)	450 kg
No of workers per machine	3
Total no. man days required per round at 3 machines and 3 workers per machine	9
Minimum crop harvested as per wages	1350
Extra crop harvested (1740-1350)	390 kg
Incentive for extra crop	₹ 1.5 per kg
Incentive for 390 kg @ ₹ 1.5	₹ 585
Minimum wages for 9 man days(9 x ₹ 183.55)	₹ 1651.95
*Fuel at ₹ 75 L^{-1}	₹ 1102.5
Machine maintenance.3.0 x ₹ 50	₹ 150
Total cost	₹ 3489.45 ha^{-1} $round^{-1}$
Cost of harvesting per kg green leaf	3489.45/1740 = ₹ 2.00

Parameters used for computation

Petrol consumption: 700 mL hr^{-1}; Fuel cost workings: 7 hr x 3 machines x 700 mL x 75; Machine maintenance cost: ₹ 50 day^{-1} $machine^{-1}$; Depreciation : 20% per year (not included in the cost workings) Cost of petrol: ₹ 75 L^{-1}

Table 7. Comparative economic analysis on different systems of harvesting in tea

Particulars	Hand plucking	Shear harvesting	Mechanization
Area (ha)	1	1	1
Green leaf per month (kg)	1740	1740	1740
Pluckers requirement (per month)	50	26	9
Plucking average	35	67	200
No. of rounds month^{-1}	2.5	2	1.2
Crop harvested round^{-1} (kg)	696	870	1450
Wages with incentives (₹)	192	224	249
Plucking cost month^{-1} (₹)	9598	5815	2237
Fuel + maintenance (₹)	NA	NA	1253
Cost of plucking ha^{-1} (₹)	9597	5815	3490
Cost of plucking per kg green leaf (₹)	5.51	3.34	2.00

Parameters used for computation
Labour wage: ₹183.55
Incentives for shearing and hand plucking over the standard output; First 14 kg: ₹ 0.60 kg^{-1}; Second 14 kg: ₹ 0.85 kg^{-1} and above that : ₹ 1.10 kg^{-1}

Field under mechanical harvesting enable complete harvest and the bushes are ready for next harvest almost lesser than a month. Considering the cost economics, manual plucking of crop shoots are uneconomical as far as the prevailing situations are concerned. Next to manual plucking, shear harvesting has to be considered where the plucking cost reduced by 40 per cent. Even though the initial investment of machine cost was high (₹ 75,000/- per machine), the plucking cost including the fuel comes around ₹ 2.0 per kg green leaf, which is economical too. Field under manual plucking required 20 workers to harvest the crop per unit area. The same work force can cover an area of 1.54 ha when they are using shears. On the other hand, the same level of work force can cover 2.22 ha in a day provided with mechanical harvesters.

In short, substantial increase in productivity was observed after the implementation of regular mechanization. Some of the fields even touched 7000 kg ha^{-1} after the regular adoption of mechanization besides the post-mechanization attention. Significant improvement in plucking average was noticed and timely harvesting resulted in improvement of made tea quality. Mechanization has helped to achieve reduction in cost of harvesting and cope with the prevailing labour shortage and improved overall performance of the estate. Mechanization of harvesting helped to achieve sustainability in productivity and quality of the estates.

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