ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor: 5.2
IJAR 2018; 4(4): 160-166
www.allresearchjournal.com
Received: 05-02-2018
Accepted: 07-03-2018

R Parthibaraj Rajendran
Upasi Tea Research Institute
Tea Research Foundation
Department of Plant Genetics and Improvement division
Nirar Dam B.P.O, Valparai – 642 127, Coimbatore district, Tamil Nadu, India

R Victor J Ilango
Upasi Tea Research Institute
Tea Research Foundation
Department of Plant Genetics and Improvement division
Nirar Dam B.P.O, Valparai – 642 127, Coimbatore district, Tamil Nadu, India

Correspondence
R Parthibaraj Rajendran
Upasi Tea Research Institute
Tea Research Foundation
Department of Plant Genetics and Improvement division
Nirar Dam B.P.O, Valparai – 642 127, Coimbatore district, Tamil Nadu, India

Studies on impact of mechanical harvesting of tea (*Camellia)* in South India

R Parthibaraj Rajendran and R Victor J Ilango

Abstract
South Indian tea industry is facing severe crisis of acute shortage of work force especially for harvesting, along with steep increase in worker wages and agro inputs. Mechanization of harvesting is compulsory to harvest the crop in time with the available workers. The recommended schedule of harvesting in South India is six months of hand plucking and six months of shear harvesting. When the existing practices are extended to nine and twelve month's period both in shear and machine harvesting schedule and it's leading the adverse impacts on yield and yield components. A significant crop loss of 2092 kg made tea/ha has observed during the study period. In seedling tea field, total crop loss was increased up to 446 kg made tea/ha under mechanical harvesting when compared to shear harvesting. Between the Clonal and 'Assam' seedlings, loss in crop was more in the clonal field due to motorized harvesting.

Keywords: labour shortage, mechanical harvesting, Camellia, productivity and dry weight

1. Introduction
Tea industry in India employs over a million people directly to carry out the various cultivation practices such as planting, pruning, harvesting, manuring, pest, and disease and weed management. Among these, harvesting alone requires 71% of work force (Radha Krishnan *et al*., 2012) [9]. For the last two decades, south Indian tea industry is facing severe crisis of acute shortage of work force especially for harvesting. A recent survey carried out by the UPASI Tea Research Institute revealed that reduction in labour strength when compared to the year 1999 ranged from 21.4 % to 56.2 % in different planting districts of South India. Like the south Indian tea industry, shortage of workforce has been reported in all over the tea growing countries like Japan (Chika Yagi *et al*., 2010) [2] and Taiwan (Huang and Chiu, 1990) [3]. Mechanization of all the operations is the only option available to the industry. UPASI Tea Research Institute had undertaken studies to mechanize the above operations such as, pitting for planting, pruning and harvesting (Sreedhar *et al*., 1997; Sreedhar and Ilango, 1997a; Ilango *et al.*, 2000) [14, 15, 16]. Most of these operations have been accepted by the industry and are being implemented routinely. Even then, the problem of non-availability of adequate workforce is acute during the two high cropping seasons, i.e. April to June and September to November. During these two high cropping seasons in a month itself, about ten to eleven percent of the total crop is harvested. (Ilango *et al*., 2001) [5] . When the duration of shear harvesting and machine harvesting are extended to overcome the worker shortage, adverse impacts like excessive 'banji' shoots formation, dwarfing of crop shoots with reduced inter nodal length and leaf area leading to reduction in the weight of crop shoots and crop loss (Nyasulu, 2006) [8].

2. Materials and Methods
2.1 Experimental site and layout
A field experiment was carried out in a tea estate in Valparai, Coimbatore district, Tamilnadu, in a Clonal tea Camellia sinensis L.O.Kuntze, cultivar 'UPASI – 9' and in an old 'Assam' seedling tea field Camellia assamica (Masters) Wight, cultivar 'Assam seedlings'. The design of the experiment was split plot with six treatments (method of harvesting) with three replications. Treatments were 1) Machine harvesting for six months

(April to June and from Sep to Nov) + Hand plucking for six months (Dec. to March and July to August) 2) Machine harvesting for nine months (April – December) + Hand plucking for three months (January - March) 3) Continuous machine harvesting (January to December) 4. Shear harvesting for six months (April to June and from Sep to Nov) + Hand plucking for six months (Dec. to March and July to August) 5) Shear harvesting for nine months (April – December) + Hand plucking for three months (January - March) 6) Continuous Shear harvesting (January to December)

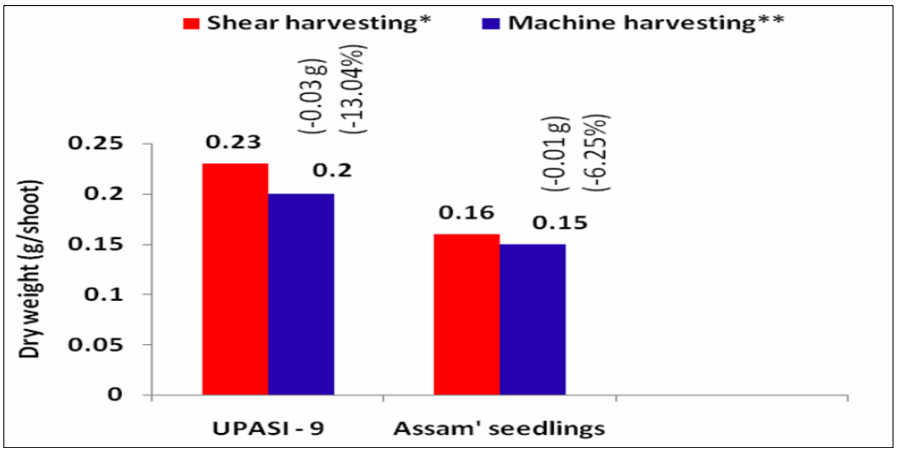
2.2 Quantification of yield and yield components

Crop (green leaves) harvested from each experimental plot was recorded during every harvesting rounds. Crop record was maintained over the entire study period. Harvested crop shoots were weighed fresh in the field and yield was expressed as made tea per hectare based on dry matter recovery at an out turn of 22.5 per cent and with a bush population of 13,340 per hectare for clonal tea field and the bush population of 6800 for seedling tea field. Crop shoots of 100g comprising three leaves and a bud were collected from the harvest (from individual plots) and brought to the laboratory. From the sample, ten shoots with three leaves and a bud (standard of shoots for south Indian tea) were taken for measuring the intermodal length and dry weight. The shoot was oven dried at 100 °C for 24 hours and dry weight recorded. The three leaves and a bud was measured for the inter nodal length (second to the third leaf from top) and the length was recorded by using a graduated ruler. Mean values of three different durations of machine harvesting (mean of MT1 to MT3) and shear harvesting (mean of MT4 to MT6) were considered. All the datas were subjected to the statistical analysis.

3. Results

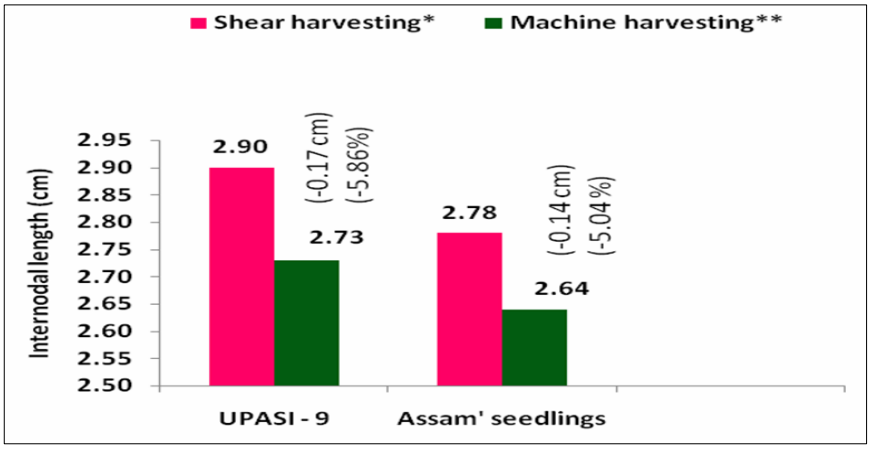
3.1 Effect of harvesting methods on yield and yield components

In the clonal tea field (UPASI-9), among the two methods of harvesting, use of motorized tea harvesters reduced the weight of crop shoots (Fig.1) and inter nodal length (Fig.2) ultimately reducing the productivity up to 2092 kg made tea/ha (-15%) during the two year study period (Fig. 3). Similarly, in the seedling tea field also reduction in weight of crop shoots and inter nodal distance was noticed. Total loss of crop for the two year study period increased up to 446 kg made tea/ha (-5 %) under mechanical harvesting when compared to shear harvesting
(Fig. 4). Between the clonal and 'Assam' seedlings, loss in crop due to motorised harvesting was more in the clonal field (Figs. 3 and 4). These results were substantiating the similar findings of Sreedhar *et al*., (1997) [14, 15, 16] and Ilango *et al*., (2001) [5].



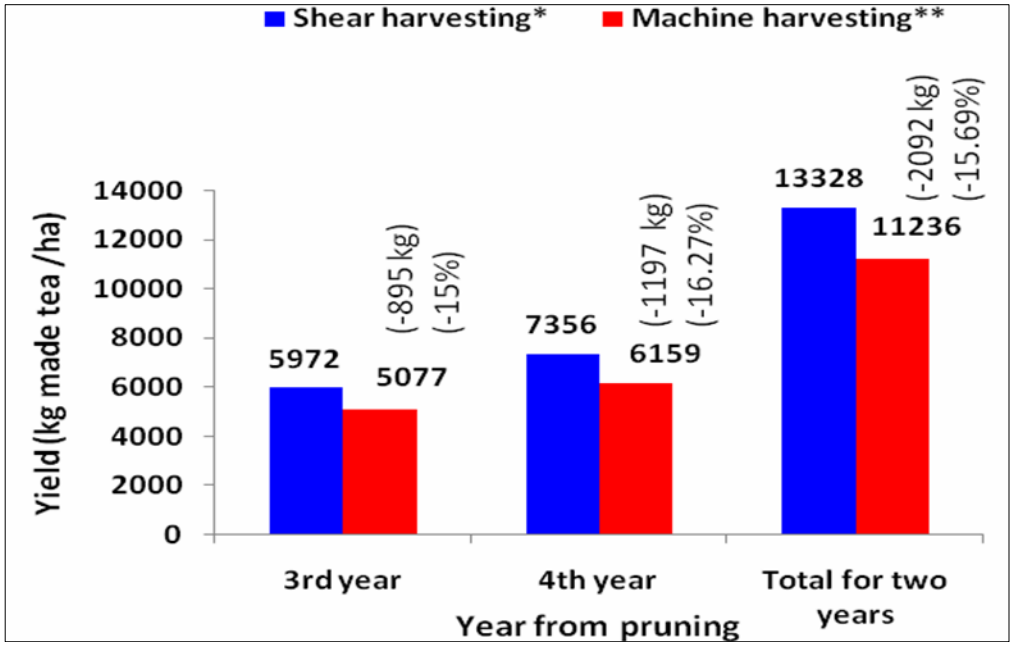
Values in parenthesis indicate reduction in weight when compared to control
* Mean of MT4 to MT6. ** Mean of MT1 to MT3

Fig 1: Effect of harvesting methods on weight of crop shoots in the clone - UPASI – 9 and 'Assam' seedlings



Values in parenthesis indicate reduction in inter nodal when compared to control
* Mean of MT4 to MT6. ** Mean of MT1 to MT3

Fig 2: Effect of harvesting methods on inter nodal length of crop shoots in the clone (UPASI– 9) and 'Assam' seedlings



Values in parenthesis indicate reduction in yield when compared to control
* Mean of MT4 to MT6. ** Mean of MT1 to MT3

Fig 3: Effect of harvesting methods on productivity in the clone - UPASI – 9

3.2 Effect of duration of different harvesting methods

3.2.1 Effect of duration of harvesting methods on yield and yield components Clonal tea (Shear harvesting and Machine harvesting)

Shear harvesting and machine harvesting for a period of six months (during the two high cropping seasons as per MT4 and MT1) followed by hand plucking during the remaining part of the year produced the highest yield of 15771 and 12984 kg made tea/ha during the study period. (Table 1). When shear and machine harvesting was extended for a period of nine months (April to December as per MT2 and MT5) significant reduction in cumulative productivity was observed when compared to shear and machine harvesting for a period of six months. Under nine months of shear and machine harvesting schedule, reduction in yield was 18 % and 16 % respectively. When shear and machine harvesting was carried out throughout the year, (MT3 and MT6) cumulative productivity reduced significantly when compared to six months as well as nine months of harvesting schedules. Loss in crop under 12 months of shear and machine harvesting system was 29 % and 24 % during the entire study period. (Table 1).

Table 1: Effect of duration of harvesting methods on total productivity in the clonal tea (UPASI – 9) (Total of two years)

Yield, (kg made tea /ha)						
Treatments	**6 months**		**9 months**		**12 months**	
	SH	**MH**	**SH**	**MH**	**SH**	**MH**
	MT4	**MT1**	**MT5**	**MT2**	**MT6**	**MT3**
ST1	13439	11095	10784	9371	9594	8834
ST2	14474	12131	12016	10015	10565	9330
ST3	16099	13116	13416	11068	11548	9882
ST4	16528	13669	13680	11382	11863	10091
ST5	15597	12469	12397	10546	10608	9607
ST6	18489	15429	15548	12696	13276	11529
Mean	15771	12984	12974	10846	11242	9879
Reduction in kg made tea /ha (-2797) When compare to MT4 and MT1				(-2138)	(-4529)	(-3106)
Reduction in percentage (-17.74%) When compare to MT4 and MT1				(-16.46%)	(-28.72%)	(-23.92%)
Critical difference at P = 0.05 Main treatment 103.29						
Sub treatment 103.29						
Interaction (MT X ST) 253.01						

3.2.2 Seedling tea (Shear harvesting and Machine harvesting)

Shear harvesting and machine harvesting for a period of six months (during the two high cropping seasons as per MT4 and MT1) followed by hand plucking during the remaining part of the year produced the highest yield of 9479 and 8963 kg made tea/ha during the study period. (Table 2). When shear and machine harvesting was extended for a period of nine months (April to November as per MT2 and MT5) significant reduction in cumulative productivity was observed when compared to shear and machine harvesting for a period of six months. Under nine months of shear and machine harvesting schedule, reduction in yield was 15 % and 13 % respectively. When shear and machine harvesting was carried out throughout the year, (MT3 and MT6) cumulative productivity reduced significantly when compared to six months as well as nine months of harvesting schedules. Loss in crop under 12 months of shear

and machine harvesting system was 22 % and 26 % during the entire study period (Table 2). The same results were obtained by the Ilango *et al*., (2001) [5].

Table 2: Effect of duration of harvesting methods on total productivity in 'Assam' seedlings (Total of two years)

Yield, (kg made tea /ha)						
Treatments	**6 months**		**9 months**		**12 months**	
	SH	**MH**	**SH**	**MH**	**SH**	**MH**
	MT4	**MT1**	**MT5**	**MT2**	**MT6**	**MT3**
ST1	8571	7749	7032	6962	6357	5918
ST2	8960	8448	7534	7397	6774	6239
ST3	9712	9173	8227	8018	7277	6687
ST4	9650	9199	8151	7854	7330	6767
ST5	9129	8679	7753	7464	6980	6314
ST6	10851	10527	9554	9073	8315	7668
Mean	9479	8963	8042	7795	7172	6599
Reduction in kg made tea /ha (-1437) When compare to MT4 and MT1				(-1168)	(-2307)	(-2364)
Reduction in percentage (-15.16%) When compare to MT4 and MT1				(-13.03%)	(-22.34%)	(-26.38%)
Critical difference at P = 0.05 Main treatment 67.82						
Sub treatment 67.82						
Interaction (MT X ST) 166.13						

3.3 Effect of duration of harvesting methods on dry weight and intermodal length of crop shoots

Harvesting using either shears or mechanical tea harvesters for a period of six months (during the two high cropping seasons MT1 and MT4) gave the highest weight of crop shoots. When shear harvesting as well as machine harvesting was extended for a period of nine months (April to November MT5), dry weight of crop shoots reduced when compared to six months of shear harvesting as well as machine harvesting schedules. Reduction in weight of crop shoots percentage was 8% both in shear and machine harvesting (Nine months schedule). When shear harvesting and machine harvesting was carried out throughout the year (12 months MT3 and MT6) dry weight of crop shoots further reduced when compared to six
months and nine months of shear harvesting and machine harvesting. The dry weight of crop shoots under 12 months of shear harvesting and machine harvesting was 16% respectively (Table 3). The same trends were observed in the 'Assam seedlings tea field also (table 4). Between the clonal and 'Assam seedlings, dry weigh of crop shoots was higher on side of clonal tea field (tables 3 and 4). These results were coinciding with the findings of Barman *et al*., 1992 [1].

Table 3: Effect of duration of harvesting methods on weight of crop shoots in the clonal tea (UPASI – 9)

Dry weight (g/shoot)						
Treatments	**6 months**		**9 months**		**12 months**	
	SH	**MH**	**SH**	**MH**	**SH**	**MH**
	MT4	**MT1**	**MT5**	**MT2**	**MT6**	**MT3**
ST1	0.18±0.01	0.17±0.02	0.17±0.02	0.14±0.03	0.15±0.02	0.13±0.02
ST2	0.20±0.04	0.18±0.03	0.19±0.02	0.16±0.03	0.17±0.02	0.15±0.03
ST3	0.26±0.03	0.23±0.02	0.25±0.02	0.21±0.03	0.22±0.03	0.19±0.02
ST4	0.29±0.01	0.26±0.02	0.26±0.03	0.24±0.04	0.24±0.01	0.21±0.02
ST5	0.24±0.02	0.21±0.01	0.22±0.02	0.19±0.03	0.20±0.02	0.17±0.01
ST6	0.32±0.02	0.28±0.03	0.29±0.02	0.26±0.04	0.26±0.04	0.23±0.02
Mean	0.25	0.22	0.23	0.20	0.21	0.18
Reduction in percentage when compared to MT4 and MT1			(-7.98%)	(-8.0%)	(-15.97%)	(-16.0%)

Table 4: Effect of duration of harvesting methods on weight of crop shoots in 'Assam' seedlings

Dry weight (g/shoot)						
Treatments	**Treatments**		**9 months**		**12 months**	
	SH	**MH**	**SH**	**MH**	**SH**	**MH**
	MT4	**MT1**	**MT5**	**MT2**	**MT6**	**MT3**
ST1	0.14±0.01	0.13±0.02	0.13±0.01	0.12±0.01	0.11±0.01	0.11±0.01
ST2	0.16±0.02	0.15±0.01	0.15±0.02	0.14±0.01	0.13±0.02	0.12±0.01
ST3	0.18±0.02	0.16±0.01	0.16±0.02	0.15±0.02	0.16±0.03	0.15±0.02
ST4	0.20±0.02	0.19±0.03	0.18±0.02	0.17±0.04	0.17±0.03	0.17±0.03
ST5	0.16±0.02	0.16±0.03	0.15±0.02	0.15±0.02	0.15±0.03	0.14±0.01
ST6	0.22±0.02	0.21±0.03	0.21±0.02	0.20±0.04	0.20±0.03	0.19±0.01
Mean	0.18	0.17	0.16	0.16	0.15	0.15
Reduction in percentage when compared to MT4 and MT1			(-8.0%)	(-3.95%)	(-4.0%)	(-7.96%)

Harvesting of crop shoots by using shears and mechanical tea harvesters for a period of six months (during the two high cropping seasons MT1 and MT4) produced the longest inter nodal length of crop shoots. When shear harvesting as well as machine harvesting was extended for a period of nine months (April to November MT5), length of crop shoots reduced when compared to six months of shear harvesting as well as machine harvesting schedules. Under nine months of shear harvesting and machine harvesting, length of crop shoot was 8 % and 7 % respectively. When shear harvesting and machine harvesting was carried out throughout the year (12 months MT3 and MT6) intermodal length of crop shoots was reduced marginally when compared to six months and nine months of shear harvesting and machine harvesting. The marginal reduction of internodal length was 14 and 15 respectively (Table 5). The same trends were observed in the 'Assam seedlings tea field also (table 6). Crop loss in machine harvested fields also can be attributed to reduced inter nodal length of crop shoots. Between the clonal and 'Assam seedlings, length of crop shoots was highest in clonal tea field (tables 5 and 6). These results were coinciding with the findings of Marimuthu *et al*., 2001 [7, 5].

Table 5: Effect of duration of harvesting methods on internodal length of crop shoots in the clonal tea (UPASI – 9)

Inter nodal length (cm)						
Treatments	**6 months**		**9 months**		**12 months**	
	SH	**MH**	**SH**	**MH**	**SH**	**MH**
	MT4	**MT1**	**MT5**	**MT2**	**MT6**	**MT3**
ST1	2.64±0.01	2.52±0.02	2.48±0.03	2.26±0.02	2.31±0.04	1.99±0.02
ST2	2.80±0.01	2.71±0.02	2.65±0.01	2.51±0.04	2.38±0.03	2.21±0.03
ST3	3.27±0.02	3.07±0.04	2.97±0.02	2.87±0.08	2.76±0.04	2.67±0.02
ST4	3.28±0.05	3.12±0.05	3.02±0.04	2.87±0.04	2.83±0.03	2.69±0.03
ST5	2.95±0.02	2.72±0.03	2.69±0.03	2.59±0.03	2.55±0.04	2.43±0.03
ST6	3.83±0.06	3.58±0.02	3.45±0.04	3.31±0.03	3.28±0.05	3.03±0.01
Mean	3.13	2.95	2.88	2.74	2.68	2.50
Reduction in percentage when compared to MT4 and MT1			(-7.98%)	(-7.12%)	(-14.3%)	(-15.3%)

Table 6: Effect of duration of harvesting methods on internodal length of crop shoots in "Assam' seedlings

Inter nodal length (cm)						
Treatments	**6 months**		**9 months**		**12 months**	
	SH	**MH**	**SH**	**MH**	**SH**	**MH**
	MT4	**MT1**	**MT5**	**MT2**	**MT6**	**MT3**
ST1	2.51±0.02	2.40±0.03	2.37±0.02	2.23±0.01	2.16±0.04	1.97±0.02
ST2	2.69±0.04	2.56±0.04	2.52±0.03	2.41±0.01	2.39±0.04	2.22±0.02
ST3	3.09±0.03	2.87±0.05	2.83±0.01	2.77±0.01	2.73±0.02	2.53±0.03
ST4	3.11±0.01	2.96±0.03	2.88±0.02	2.84±0.05	2.82±0.01	2.66±0.02
ST5	2.72±0.02	2.63±0.01	2.63±0.05	2.54±0.04	2.57±0.01	2.43±0.02
ST6	3.52±0.01	3.32±0.03	3.27±0.04	3.19±0.02	3.18±0.03	2.98±0.03
Mean	2.94	2.79	2.75	2.67	2.64	2.47
Reduction in percentage when compared to MT4 and MT1			(-6.46%)	(-10.2%)	(-4.30%)	(-11.5%)

4. Discussion

4.1 Effect of harvesting methods on yield and yield components

High yields with the deployment of less number of workers for harvesting only can reduce the cost of harvesting / cost of production (Ilango *et al*., 2001) [5]. Between shear harvesting and machine harvesting, machine harvesting depressed the productivity significantly both in the clonal and 'Assam' seedling tea field (Figs. 3 and 4). Such reports are available in other tea growing regions like Malawi (Nyasulu, 2006) [8]. Crop loss due to machine harvesting schedule could be attributed to the damage caused to the maintenance foliage because of the heavy weight of the harvesters (up to 12 to 16 kg) and high speed of the reciprocating blade (Ilango *et al*., 2001) [5]. Whereas, hand operated shears due to less weight did not depress the crop significantly when compared to mechanical harvesting. However, all over the tea growing regions in the world, different types of harvesters are preferred because of their speed, more area coverage and high worker productivity (Ilango *et al*., 2012) [5]

The clone UPASI – 9 produced very high yield throughout the experimental period when compared to the field planted with 'Assam' seedlings. This could be attributed to the genetic character of the clone UPASI – 9 which is a proven high yielding cultivar (Venkataramani and Sharma, 1975; 1976) followed by the high bush population without any stem diseases. Whereas the old 'Assam' seedlings (planted in 1910), due its low bush population of around 6800/ha and stem diseases such as bole canker and branch canker produced lower yields (Figs. 1 and 2).

Yield in tea is the product of number of shoots/unit area multiplied by the weight of each shoot (Sharma, 1983). Crop loss recorded in the machine harvesting schedule can be attributed to the reduced weight of crop shoots (Fig 1). Maintenance foliage with reduced leaf area could not support the growth of the dependent crop shoots as reported in several studies (Sharma, 1987; Tanton, 1992 and Satyanarayana, 1994) [1, 12, 10]. Dry weight of crop shoots collected from the field planted with the clone UPASI – 9 was always higher than the 'Assam' seedlings (Fig. 1) due to the superiority of the clone over the old 'Assam' seedlings as explained earlier. Dwarfing of crop shoots with

short inter nodes due to mechanical harvesting (Fig. 2) also contributed to the crop loss. As reported by Sharma (1987), Tanton (1992) [12] and Satyanarayana (1994) [10] growth of a crop shoot is directly related to the maintenance foliage maintained on the plucking surface. Damaged maintenance foliage under mechanical harvesting schedule could not support the elongation of the inter nodes of the crop shoots (Fig. 2). Crop shoots collected from the clonal tea fields had longer inter nodes than the 'Assam; seedlings (Fig. 2) due to the superiority of the clone UPASI - 9 over the old 'Assam' seedlings.

4.2 Effect of duration of harvesting methods

4.2.1 Effect of duration of harvesting methods on yield and yield components

Both in the clonal and 'Assam' seedling tea as the duration of shear harvesting and machine harvesting schedule increased from six months to nine and 12 months, significant drop in productivity was noticed (Tables 1 and 2). Earlier studies carried out in south India also proved that extending the duration of shear harvesting and machine harvesting resulted in crop loss and detoriation of bush health. (Sharma *et al*., 1981, Ilango *et al*., 2001; Ilango *et al*., 2012) [1, 14].

Crop loss under extended duration of machine harvesting and shear harvesting schedule was on the lower side in the clonal tea field UPASI – 9 when compared to the old 'Assam' seedlings (Tables 1 and 2). The clonal tea field due to its young age and closer planting with dense plant population withstood the impact of the mechanical damage under machine harvesting schedule as reported by earlier researchers (Ilango *et al*., 2012) [5].

Due to frequent harvesting for an extended period of nine months and twelve months, shear harvesting as well as machine harvesting damaged the maintenance foliage on the plucking surface. As discussed earlier, canopy with a reduced leaf area could not support the normal growth of crops shoots resulting in the production of crop shoots with reduced weight (Sharma, 1987; Tanton, 1992 and Satyanarayana, 1994) [1, 12, 10] As reported by several researchers, damage to the maintenance foliage is detrimental to tea bushes and adversely affects the physiological activities of the plant system (Barman *et al*., 1992) [1]. A significant reduction was observed on metabolic activities and photosynthetic rate due to continuous shear harvesting. As a result, water use efficiency (a ratio between photosynthetic and evaporation rate) declined sharply in the mechanical harvested fields due to mechanical injury (Marimuthu *et al*., 2001) [7, 5].

5. Conclusion

Among the two methods of harvesting, machine harvesting reduced the yield significantly. Mechanical harvesting is crucial to harvest the crop during the two high cropping seasons (April to June and September to November) without any abandon the crop while concern the non availability of the workers. Another line of work is going on the minimize of the adverse impacts of mechanical habvesting by the foliar application of combination of various macro and micro nutrients.

6. Acknowledgements

The authors are thankful to National Tea Research foundation (NTRF), Kolkata for the financial support to complete the project. We acknowledge the M/s. Wood briar Group for extended the help during the study period.

7. References

1. Barman TS, Baruah U, Sharma AK. In*:* Proceedings of 31st Tocklai Conference. Tea Experimental Station, Jorhat, Assam. 199; 242-49.
2. Chika Yagi, Namiko Ikeda, Dwight Sato. Characteristics of eight Japanese Tea Cultivars. University of Hawaii, College of Tropical Agriculture and Human Resources, Fruits and Nuts. 2010; (15):1-6.
3. Huang TF, Chiu TF. Conversion of hand plucking to manual plucking in high grade tea areas in Taiwan. ISHS Acta Horticulturae 275, International Symposium on the culture of Subtropical and tropical Fruits and Crops, Nelspruit, South Africa. 1990
4. Ilango RVJ, Mohan kumar P, Parthibaraj R, Suresh kumar B, Mareeswaran J, Govindaraj R *et al*. Saravanan, M. and Gunasundari, R. 2012**.** Development of package on foliar feeding for the tea fields under extensive shear and machine harvesting. Planters Chronicle 108; 22-23.
5. Ilango RVJR, Ajayakumar K, Muraleedharan N, Raj Kumar R, Marimuthu S, Senthil Kumar RS. Field evaluation of motorized harvesters in tea. Bulletin of UPASI Tea Research Foundation 2001; (54):1-13.
6. Ilango RVJ, Pagalavan B, Ramasubramanian B, Ajayakumar K. Evaluation of STIHL BT 120 C earth auger for making pits. Planters Chronicle. 2000; 96(11):521-523.
7. Marimuthu S, Rajkumar R, Muraleedharan N, Jayakumar D, Radhakrishnan KN. Physiological responses of tea plants to shear harvesting. Journal of plantation crops. 2001; 29(2):16-21.
8. Nyasulu SK. Mechanical harvesting of tea in Malawi: A research review. Trfca News. No. 2006, 146.
9. Radhakrishnan B, Durairaj J, Siby Mathew, Mohan Kumar M, Udayabanu KG, Sankaranarayanan PVJ. Performance of South Indian Tea Industry during last one decade and challenges ahead. Planter's Chronicle. 2012; 108(6):5-19.
10. Satyanarayana N. Source-sink relationship and production and partitioning of dry matter in tea. Planters Chronicle. 1994; 89(11):485-487.
11. Sharma VS. Plucking styles. UPASI Tea Scientific Department Bull. 1983; (38):33-48.
12. Sharma VS. Harvesting in tea. Planter's Chronicle. 1987; (81):261-266.
13. Sharma VS, Haridas P, Venkata Ram CS. Mechanization of harvesting in tea. UPASI Tea Scientific Department Bull. 1981; (37):106-110.
14. Sreedhar Ch, Ilango RVJ. (a). Evaluation of Agromatica pneumatic multipurpose gadget. Newsletter of UPASI Tea Research Institute. 1997; 7(2):1-3.
15. Sreedhar Ch, Ilango RVJ, Sasidhar R. Mechanization of field operations in tea culture harvesting. Bulletin of UPASI Tea Research Institute. 1997; (50):8-19.
16. Sreedhar Ch, Ilango RVJ, Sasidhar R.. Mechanization of field operations in tea culture harvesting. Bulletin of UPASI Tea Research Institute. 1997; (50):8-19.
17. Tanton TW. Tea crop physiology. *In*: Tea: Cultivation to Consumption. Eds. 1992.
18. Willson KC, Clifford MN. Chapman & Hall, London, 173-199.

19. Venkataramani KS, Sharma VS. Notes on the UPASI Tea clones approved by Tea Board and released for commercial planting. Planters Chronicle. 1975; 70(5):119-121.
20. Venkataramani KS, Sharma VS. The tea complex-2. Nomenclature and description of some tea clones. South Indian Horticulture. 1976; (24):155-163.