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Mechanization in Indian Coffee Plantations: Evaluation of Different Machineries to Improve Labor Use Efficiency and to Reduce Drudgery

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A B S T R A C T

Field evaluation of different machineries was carried at Central Coffee Research Institute (CCRI) and Coffee Research Sub Station (CRSS), Chettalli during the year 2012-16. Results of field evaluation on different spaying system indicated that significantly higher field efficiency was observed with Multi Utility Track Vehicle spraying with 4 spray lance (0.557 ha per hour) and it was on par with Centralized Spraying System with 14 spray lance (0.510 ha per hour). Lower field efficiency was observed with power tiller spray system (0.410 ha per hour) with 8 lance. Similarly, the labor requirement for Multi Utility Track Vehicle system was less (9 labors per day) as compared to Centralized Spraying System (28 labor per day) and PT (16 labor per day), which resulted in labor cost savings to the extent of 211% as compared to Centralized Spraying System. Mechanical weed cutter was found to be more efficient and economic in terms of cost (Rs. 829 per acre) over manual weeding (Rs. 2800 per acre) and chemical weeding (Rs. 1075). Man days utilized for mechanical weed cutter was also much lesser (1.5 per acre) than manual weeding (10 per/acre) and chemical weeding (3.3 per/acre) respectively. Under the same trial, regeneration of weeds was more in manual weeding compared to mechanically weeding. Significantly higher number of pits (150 pits/man/day) with mechanical pit digger was observed as compared to manually (75 pits/man/day). Therefore use of small machineries in existing coffee plantations of India it would greatly improve the efficiency of field operations and reduce the labour requirement.

Introduction

In India mechanization is relatively new concept in coffee cultivation and still remains primarily as hand crop. As coffee cultivation in developed countries like Brazil, USA (Hawaii) and Australia, is grown in almost flat and gentle sloping lands under open conditions, mechanization has been already introduced to a great extent to bring down dependency on human labour which is very expensive. But in developing countries including India, coffee is to be essentially grown in hilly and undulating terrain under the shade trees and the operations have to be carried out mainly by human labour. Hence, adoption of mechanization in coffee cultivation is virtually difficult under these conditions.

Coffee cultivation in India is more labour demanding crop. The number of labour

required for maintaining one acre of coffee is about 0.70 and 0.40 Labour / day throughout the year in arabica and robusta coffee field respectively. Cost of labour alone constitutes about 70 per cent and 59 to 65 per cent of the total cost of cultivation in arabica and robusta coffee respectively (Coffee Guide, 2014). In recent years, labour shortage in plantation areas has become severe due to migration of workers to urban areas for searching easy and better living. The permanently employed workers in the coffee farms are also getting aged and retiring and shortage of young successor leads the labour shortage for critical operations coupled with high wages demanded by the labour contractors. The increase of the world agricultural output in the future will depend on various factors such as input and labor management (WDR, 2008 and Alston *et al.,* 2010). The productivity of coffee farms depends largely on the availability and judicious use of farm facilities and infrastructure by the coffee growers. Thus, there is an imperative need to improve the efficiency of input use, increase the productivity of labour and land, to reduce the cost of production and increase overall income from the holdings. This can be achieved only by introduction of mechanization in coffee cultivation. Mechanization also enables effective utilization of available land and inputs such as plant materials, agro inputs, spray solutions, fertilizers and irrigation water. Keeping these factors in view the coffee board of India research department initiated a filed evaluation of different machineries for partial mechanization of coffee cultivation in hilly tracts in agro forestry ecosystem.

Materials and Methods

Field evaluation of different machineries was carried at Central Coffee Research Institute (CCRI) and Coffee Research Sub Station (CRSS), Chettalli during the year 2012-16. Evaluation of three different spraying systems namely, centralized spray system (CSS), power tiller (PT) Multi Utility Track Vehicle (MUTV) was carried out at CRSS, Chettalli and evaluation of hand operated small weed cutting machines and pit digger was carried out at CCRI. The data on system use efficiency, area coverage, and weed re growth input use and statistical data were analyzed as suggested by Gomez and Gomez (1984). The data pertaining to the specifications of the different systems and labour requirements for major operations in coffee plantations are illustrated in table 1, 1A and 2, respectively.

Results and Discussion

Evaluation of spray systems

Results of field evaluation on different spaying system indicated that significantly higher field efficiency was observed with MUTV spraying with 4 spray lance (0.557 ha per hour) and was on par with centralized spraying system (CSS) with 14 spray lance (0.510 ha per hour). Whereas, lower field efficiency was observed with power tiller spray system (0.410 ha per hour) with 8 lance. MUTV consumed less spray volume (1018 L ha^{-1}) as compared to CSS (2371 L ha^{-1}), which was about 132 % less as compared to CSS. Similarly, the labor requirement for MUTV system was less (9 labors per day) as compared to CSS (28 labor per day) and PT (16 labor per day), which resulted in saving of labor cost to the extent of 211% as compared to CSS. It clearly showed that spraying through MUTV reduced spray volume or chemical, cost of production and increased the labor use efficiency without drudgery (Table 3). MUTV also useful for load carrier (input/out), heaping, spreading and raking activities during coffee processing time and watering for better establishment of young plants (Plate 1). These results are the tune of Mazoyer (2001) who reported that

Mechanization is a key factor for agricultural development and farmers' wellbeing. Not only it helped improving labor productivity up to 500 times in comparison to agriculture without motorization and without chemical application, mechanization provides also the power to ensure that agricultural operations for the soil, the plants and the animals are done precisely in time and with the highest efficiency. Thereby the quality of agricultural products specified by their ingredients, freshness, maturity and shelf life are improved, leading to higher prices at the market. Field evaluation results clearly indicated that spraying operation with MUTV could able to save spray volume or chemical along with saving the cost of labor and inputs, it helped in reducing the cost of production and increasing the labor use efficiency apart from reduction in environmental pollution. Mahantesh Kapasi *et al.,* (2013) also reported that performance high pressure with high volume sprayer like Taiwan sprayer and tractor mounted sprayer were superior to other sprayers in terms of time taken to cover unit area, suppression of larval population, reduction in pod damage and harnessing higher yield.

Evaluation of weed / brush cutter

The results of the evaluation studies conducted at regional stations shown that weed control by the use of mechanical weed cutter /brush cutter are economic and improve the labour efficiency (Table 4). The cost incurred for weeding unit area by mechanical weed cutter was around 60 per cent less than the cost of manual weeding (Rs.2280/ acre versus Rs.829 / acre). In terms of savings of man days, mechanical weeding ensured a savings of 8.5 man days /acre. Use of chemicals was costlier by about Rs.246/ acre over and above the cost of mechanical weeding and it incurred 1.8 more man days over the mechanical weeding. Kamala Bai *et al.,* (201l) also reported similar results on weed control methods. The bio- mass exhibit in each treatment was taken at every month interval to study the efficiency of different control methods. Significantly lesser regeneration of weed bio mass noticed in chemical weed management followed by mechanical weeding and manual weeding in all three months (Table 5).

Table.1 The specifications of the different spray system evaluated

Specifications	CSS	Power tiller	MUTV
Power source (hp)	3-5	12-14	5
Discharge (L/min}	33	36	20-36
Speed (rpm)	3600	950	3600
Pressure (kg/cm2)	30-40	30-35	40
Drive	Fixed	Clutch pulley	Clutch
Tank capacity (L)	500-1000 (varying size)	200	250
Number of nozzles /spray	16	6	4

Table.1A The specification of the weed cutter evaluated

Parameters		Observation/Declaration
Engine – Type	:	Horizontal, Air cooled, Single Cylinder, 2 stroke, Spark Ignition
Power, (kW) (apa)	:	1.4
Power Transmission system		
Type of drive gear	:	Gear drive
Starting method	:	Manual, Recoil starting system
Overall Dimensions (mm)		
Length (with triangular blade assembly), (mm)	:	1883
Length (with circular disc assembly),	:	1880
Height, (mm)	:	500
Width, (mm)	:	625
Mass, (kg)		
With circular disc and crop deflector	:	8.5
With triangular blade and grass deflector	:	8.2

Table.2 Labor requirements for major operations in coffee production

Operation	Arabica- Nos. required per acre	Percent to total	Robusta – Nos. required per acre	Percent to total
Fertilisation	8	4.3	8	6.1
Liming	3	1.6	3	2.3
Shade regulation	20	10.8	10	7.6
Weeding	15	8.1	12	9.1
Pruning	22	11.9	11	8.3
Soil mgmt.	19	10.3	11	8.3
Plant protection	43	23.2	10	7.6
Harvesting	42	22.7	55	41.7
Processing	14	7.6	6	4.6
Others	0	0	6 (irrigation)	4.6
Total	**185**	**100%**	**132**	**100%**

(Source: Coffee Guide, 2014)

Table.3 Field efficacy of spraying systems in coffee ecosystem during post monsoon (Mean of 2 seasons)

Treatment	No of Labors & lances used	Filed efficiency (Ha. per hour) *	Spray volume (Liters per ha.)	% Increase in spray volume / chemical	Fuel used (Lt/hr)	Cost of labors # (Rs per hour)	% Increase in labor cost (Rs./hr)
T_1- MUTV spray system***	9 labor & 4 lance	0.557	1018	-	0.75	256.5	-
T_2-Power tiller spray system**	16 labor & 8 lance	0.410	1625	60	1.00	456.0	78 (199)
T_3-Centralised spray system (CSS)*	28 labor& 14 lance	0.510	2371	132	1.17	798.0	211(541)
SEM+/-		0.0316					
CD (P=0.05)		0.066					

Note: Bulk trail and the data were analyzed with completely randomized design; * Average of 5 replication, ** Average of 4 replication, *** Average of 16 replication (Days as replication), # Cost of labors @ 228 per working day of 8 hours (Rs. 28.50 per hour).

Table.4 Economics (cost /acre) of different weed control

Treatments	Man days required *	Cost of man days (Rs.)	Cost of input **	Total cost	Per cent cost reduction over manual weeding
T_1- Manual weeding-slashing	10	2280	---	2280	--
T_2- Chemical Weeding (as per recommendation Glycel, Paraquat dichloride + Urea in case of mixed weeds)	3.3	752	323	1075	52.85
T_3-Mechanical weeding - weed cutter /brush cutter +	1.5	342	487	829	63.64
Note *: Rs.228 / man day ****** Herbicide, petrol and rope / blade cost					

Table.5 Regeneration of weeds at different intervals as influenced by various weed control methods

Treatments	Weed dry matter (g/0.25m^2) months after imposition of treatments		
	I	II	III
T_1- Manual weeding	103.14	125.11	125.97
T_2- Chemical weeding	1.49	5.09	36.83
T_3- Mechanical weeding	62.03	82.93	117.60
SEm±	1.95	0.78	0.84
CD (0.05)	6.01	2.42	2.58

Table.6 Mechanical pit digger Vs manual pit digging in different land situations

Situations	No of pits opened	Time taken	Man days
1. In areas with gravelly soil with small to medium stones and presence of large number of shade tree roots	210	8 hours	3 man days
	2.2 liter petrol and 100 ml 2T oil used. (70 pits/man-day with digger and Manually 40-50 pits/man-day)		
2. Under normal conditions (deep soil without gravel or stones)	300	8 hours	2 man days
	2.2 liter petrol and 100 ml 2T oil used. **(150 pits/man-day with digger and Manually 75 pits/man-day)**		

Plate.1 Multiple uses of Multi Utility Track Vehicle (MUTV) – Spraying, Spreading, Heaping and Load carry.

Evaluation of pit diggers in coffee estates

Pit digger was evaluated under different soil conditions at CCRI and neighboring private estate. In areas with gravelly soil with small to medium stones and presence of large number of shade tree roots, the efficiency of pit digger was found to be marginally superior to pitting over manual labor. A batch of 3 labours using pit digger were able to takeout 210 pits in an 8 hours shift averaging 70 pits per man-day. In addition, about one liter of petrol was required for the machine every 100 pits. When pitting was taken up manually each worker was able takeout only 40-50pits/day. Under normal conditions (deep soil without gravel or stones), the efficiency of the pit digger was found to be significant when compared to pitting by manual workers. A batch of 2 workers was able to takeout 300 pits in an 8 hour shift averaging 150 pits per man-day. There was no major difference in petrol consumption. When pitting was taken up manually each worker was able to digg 75 pits/ day (Table 6).

In conclusion, the performance results of three different spraying systems in coffee estate showed that the MUTV sprayer was better than CSS and power tiller sprayer system for coffee and its associated crops not only due to the higher reach of spray, more field efficiency and adequate application rate but also for lower man-power requirement. Multi Utility Track Vehicle was also evaluated for various farm operations like transporting of input/output, heaping, spreading and racking activities during processing and watering for better establishment of young plants. Controlling weeds in coffee plantation through mechanical weed cutter was found to be more efficient with respect to man days used and cost incurred over manual weeding and higher no pits per man days is possible with mechanical pit digging.

By use of small machineries in existing coffee plantations of India, it would greatly improve the efficiency of field operations such as spraying, fertilizer/manure application, weeding, pit digging for planting etc., and thereby mitigating the labour constraint. It will also help in implementation of farm operations in a timely manner as well as improve the labour efficiency by reducing their drudgery. Ultimately, by improving the efficiency of farm operations, the cost of cultivation can be reduced substantially.

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