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Comparative Performance of the Developed Mini Tractor Operated Sprayer Cum Weeder with The Various Types of Existing Spraying and Weeding Methods

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Abstract— *Insects, diseases and weeds are the three main biological elements that have the greatest influence on agricultural output losses and farmer profits. The two most crucial practises in agriculture for maximum yielding are chemical application and weeding. In the past, spraying was performed using a knapsack sprayer, and weeding was carried out manually and with a bullock-drawn weeder, both of which required a lot of time and effort. For spraying and weeding in modern agriculture, farmers employ a variety of power-operated tools. However, because each task was carried out independently, it took more time and effort to finish the weeding and spraying tasks. Multioperational equipment or machinery is required to decrease operating time, cost, and the number of passes. As a result, efforts have been made to create a machine that can complete both tasks in a single pass. Considering these points, mini tractor operated sprayer cum weeder was developed. By using the developed sprayer cum weeder time saving of 95.79 %, 90.42 % and 38.71 % could be achieved as compared to existing manual methods, animal drawn machine and power operated machine and developed machine could also save 91.50 and 8.84 % operational cost as compared to existing manual methods and power operated machines in spraying and weeding operations respectively. The weeding efficiency of the developed machine for combined operations was found 84.53 % as compared to power operated weeder (86.12 %) which is more or less equal while it is only for weeding operation.*

Keywords— ***Sprayers; Weeders; Cost saving; Time saving; Weeding efficiency***

I. INTRODUCTION

The technological improvements in Indian agriculture since mid-sixties have brought about revolutionary increase in agricultural production. Total farm power availability on India farms is around 2.761 kW/ha and food grain productivity were about 2.42 t/ha around the year 2021-22. In last 50 years, farming has undergone great evolution in spraying mechanism to control various diseases on plants. Pesticides are widely used for controlling diseases, insects and weeds in the crops. They are able to save a crop from pest attack only when applied in time. Historically, pesticides were known as economic poisons. Pesticides can be categorized into insecticides, fungicides, herbicides (weedicides) and plant-growth-regulators based on their activity and target groups. In modern agriculture, the use of sprayers has become indispensable for crop protection and management. The effectiveness and efficiency of sprayers are essential to achieving optimal yields. There are various types of sprayers available, such as boom sprayers, air blast sprayers, and electrostatic sprayers, each with its own advantages and limitations (Jalu *et al.* 2023). Weeds are always associated with human endeavours and cause huge reductions in crop yields, increase cost of cultivation, reduce inputs use efficiency, act as alternate hosts for several insect pests, diseases and nematodes. Weeds

decrease crop yields from 15 to 50 % depending on the species, density and weeding time through competition with main crop for light, water and nutrition (Hasanuzzaman *et al.* 2009). The total economic losses will be immense if indirect effects of weeds on health, loss of biodiversity, nutrient depletion, grain quality, etc., are taken into consideration.

Mostly in the forming process chemical spray a taking a critical role due to poison properties of chemical. So, now there is need to make something unique and useful machine for spraying and inter cultivation. Agricultural implement and machinery program of the government has been one of selective mechanization with a view to optimize the use of human, animal and other sources of power. Earlier agriculture was more dependent on the nature and all the operations were carried out by using human and animal power. For profitable agriculture timely operations are the most important. Second important point is the cost of operation (Ambaliya *et al.* 2022). In order to reduce labour costs and working hours, a mini tractor operated sprayer and weeder was developed, and its performance compared with existing methods.

II. VARIOUS TYPES OF SPRAYERS

Spraying agricultural chemicals is a useful way to control insects, diseases and weeds and is important for growing high-yielding, quality crops and pasture. Applying the right amount of chemical at the right time is a major factor in ensuring successful control. Sprayers are the equipment used for applying liquid substances to plants or crops. These substances could be fertilisers, herbicides, or pesticides all of which are important for the maintenance of crop health during the crop growth cycle.

2.1 Manual operated sprayers

In India, we primarily used old techniques and tools for farming. In order to rid the agricultural area of insects, pesticides and water are primarily needed after a period of time. Some manually operated sprayers are given below.

Foot sprayer/pedal pump sprayers

This foot-operated sprayer is frequently used to apply CPP. It can be equipped with one or two long delivery hoses that include lance or two to six nozzle booms. This sprayer has the benefit of covering a vast area with a high volume of spray.

Hydraulic knapsack sprayer

This manually powered sprayer features a 15-liter tank and operates by using a hand lever to maintain continuous pressure. Using this sprayer specifically for spot treatments.

Pneumatic or compressed system knapsack

It is used sparsely to spray on weeds in rice and jute, as pumping is not essential with this sprayer. The tank is pressurised when the liquid has filled it to about two-thirds of its capacity.

Motorized pneumatic sprayer

It is a low volume sprayer that works well for spraying concentrated spray liquid. Spray liquid is ejected in the blast of air that passes between the delivery hose and nozzle tube during the spraying process. Spray liquid is turned into tiny droplets by an air blast. Air serves as a carrier, and the faster it is compressed, the more atomization occurs. These sprayers can be used as blowers as well. Herbicides, pesticides, and fungicides used in crop protection products are significantly lost via mist blowers to the wind.

(a) Foot Sprayer/Pedal Pump Sprayers

(b) Lever operated Knapsack Sprayer

(c) Manual pneumatic knapsack sprayer (d) Motorized pneumatic knapsack sprayer

Fig.1 Manually operated sprayers

2.2 Animal drawn sprayers

Gupta *et al.* (2003) designed and developed a bullock drawn fraction sprayer. At a pressure of 3.5 kg/cm^2, the sprayer's performance was evaluated for various parameters in both lab and field condition. In laboratory and field circumstances, the average boom discharge was 2.47 l/min and 2.53 l/min, respectively. At 400 mm height, the spray pattern was uniform across all nozzles. At 400 mm height, the spray pattern for the central nozzles grows wider. The machine required 0.486 HP on average to operate. The sprayer's average field capacity was 0.704 ha/h, or nearly seven times as much as the backpack sprayer. For the sprayer to cover a 1 ha area, only 1.44 man hours were needed.

Anibude *et al.* (2016) developed the prototype of an animal drawn hydraulic boom sprayer considering the agronomical and functional requirement for application of chemicals on field crops. The major components include; 100 litres spray tank capacity, mainframe, operator seat, 3 Hp petrol engine, piston pump, boom, ten flat fan nozzles, wheel and axle shaft. The petrol engine was used as the power source for operating the piston pump during spraying and pair of bullocks was used for hauling purpose. Application rate of 260 l/ha was achieved, theoretical field capacity of 1.16 ha/h, effective field capacity of 1.04 ha/h and 89.6 % field efficiency. Comparing the results with what was obtained using the manually operated knapsacks sprayer represents 62 % and 37 % increase in effective field capacity and field efficiency respectively.

Fig.2 Animal drawn hydraulic boom sprayer

2.3 Power operated sprayers

Padmanathan and Kathirvel (2007) evaluated the performance of power tiller operated rear mounted boom sprayer for cotton crop. A power tiller operated rear mounted boom sprayer was developed for spraying cotton and other crops planted in rows and to produce uniform spray pattern using minimum amount of spray materials. Test was carried out on the developed sprayer both in laboratory and in the field. The spray boom has sixteen hollow cone nozzles, placed 40 cm apart. It has a swath width of 3.2 m for a forward speed of 2 km/h. The effective field capacity of the sprayer was 0.72 ha/h. The performance of the power tiller operated boom sprayer was satisfactory at a pressure of 3 kg/cm^2 and can be adopted by the farmers for spraying cotton crop and other row crops. Cost economics of power tiller operated rear mounted boom sprayer was found to be 88.25 ₹/ha and 76.45 ₹/h. The entire boom assembly fixed at the rear of the power tiller, behind the operator seat. Even in adverse wind conditions, by the time the power tiller would have moved through considerable distance, the chemical would be deposited on the canopy, thereby reducing the effect of chemical inhalation by the operator almost too nil. To facilitate for the convenience of the operator the design of the entire controls was provided near the operator seat so that very efficient spraying can be achieved without affecting the health of the operator.

Babasaheb and Omkar (2015) conducted experiment, on comparative performance of tractor operated boom type field sprayers on cotton crop. Two 12 m tractor operated boom type field sprayers of ASPEE make, one of the existing designs and other of new design (developed) having similar specifications, were selected for the study. Comparative performance showed that the liquid distribution of developed boom sprayer improved. Discharge and pressure of the developed boom sprayer was nearly uniform for all nozzles, droplet size, droplet density and uniformity coefficient of the existing sprayer ranged from 130.9 to 206.39 µm, 11 to 27 drops/cm^2 and 1.18 to 1.31, respectively, whereas for developed sprayer it was ranged from 155.44 to 181.55 µm, 17 to 29 drops/cm^2 and 0.99 to 1.23, respectively.

Udaybhaskar *et al.* (2018) developed and evaluated low HP tractor operated wiper sprayer. Among all the crop protection methods, chemical protection usage growing effectively as of its immediate action, low cost and reduces human drudgery. To spray pesticides on crop, low hp tractor operated wiper sprayer was developed instead of using conventional equipment to reduce operating cost, time and drudgery. In laboratory condition, uniformity coefficient of developed wiper sprayer was found to be 89.9 %. The average effective field capacity, field efficiency, fuel consumption and application rate of developed wiper sprayer in the field of groundnut was found to be 0.9072, 1.4899, 2.0618 ha/h , 80, 78.83, 77.92 %, 1.513, 1.018, 0.815 l/ha and 423, 253, 181 l/ha at forward speeds of 1.5, 2.5 and 3.5 km/h . Cost economics of developed wiper sprayer was found to be 310.2, 197.61 and 150 ₹/ha at forward speeds of 1.5, 2.5 and 3.5 km/h. Saving of labour cost (%) and time (%) over conventional method of spraying found to be 101.5, 216.27, 316.67 % and 1714, 2880, 4023 % at forward speeds of 1.5, 2.5 and 3.5 km/h. Operating speed of 3.5 km/h was given best performance.

Fig.3 Developed low HP tractor operated wiper sprayer

Basavaraj *et al.* (2020) developed and evaluated solar operated sprayer. The performance evaluation of the sprayer was carried out for spraying in sugarcane and paddy. The walking speed of the operator is about 2.5 km/h and which corresponds to a theoretical field capacity of about 0.6 ha/h. The effective field capacity of the

sprayer was observed to be 0.5 ha/h and field efficiency was 83.33 % was observed. The maximum flow rate obtained for four hole adjustable nozzles with a flow rate of 2.1 l/min and minimum flow rate was obtained for hallow cone nozzle with a flow rate of 1.021 l/min . The discharge rates for sugarcane and paddy were 110.81 and 101.26 l/h respectively. The application rates for sugarcane and paddy were 195.25 and 154.75 l/ha respectively. This equipment does not use any other external source of power for spraying and is operated by the user only; it reduces drudgery, economical and eco-friendly as it uses the solar energy which can be easily affordable by the farmers.

III. VARIOUS TYPES OF WEEDERS

Weeding is the removal of weeds from the field. It is an effective pre-harvesting method of crop protection and crop production management. Weeds act as competitors of the crop for various resources required for growth like nutrients, light, water, etc. so they have to be removed as they may cause interference and decrease the yield. Weeds can be controlled in many ways. Weed management includes land preparation, water management, hand weeding, hand hoeing, crop rotation, and herbicides. Land preparation helps in the removal of seeds and uprooting of weeds before sowing seeds of the main crop. Hand weeding is done manually which is very tiresome and time-consuming.

3.1 Manual operated weeders

Controlling weeds by hand-pulling them may be all that is necessary if you practice regular and proper maintenance procedures. Hand-weeding is particularly important to prevent infestations of the some weeds because they are difficult to manage once they have invaded. Tools and implements for weed control can be machine operated, manual operated or animal operated. Though manually operated weeders are slow in operation but they are the most effective methods among all methods. Some of the tools and implements which are suitable for manual weeding and interculture operations are shown in Fig.4.

Manjunatha *et al.* (2014) developed and evaluated the manually operated sprocket weeder. The sprocket weeder can be easily fabricated by farmers themselves with low cost by using inexpensive bicycle materials. The weeding efficiency of the sprocket weeder was found to be 94.5 %. The sprocket weeder could work up to 4 cm depth. No plant damage was occurred during weeding operation with the sprocket weeder. The field capacity of the sprocket weeder was found to be 0.032 ha/h. The operational cost was found 375 ₹/ha. The saving in time and cost was 84 % and 79.16%, respectively. It can be operated easily by farmers or unskilled labours. It is most economical and effective for marginal farmers who are affordable to maintain bullocks.

(a) V-Blade Hand Hoe

(b) Three Tined Hand Hoe

(c) Wheel Hoe

(d) Cono weeder

Fig.4 Manual operated weeding tools

Fig.5 Manually operated sprocket weeder

3.2 Animal drawn weeders

Sims, B. G. (2000) evaluated the performance of the animal drawn weeder. Performance of weeder was depended on the categories of information required for a particular purpose and include both technical and socio-economic parameters. The maximum field efficiency of 75 % was obtained at 2.8 km/h speed. The mean effective field capacity was found 0.11 ha/h.

Biweta and Endeblhatu (2008) tested and evaluated animal drawn weeder. Weeding with pair of oxen using traditional plough at weeding tine is much faster and saves labour and time by about 79 % compared with this hand hoe method. If weeding is performed at early stage, about two weeks after emergence, the plough throws enough soil on the crop rows which was burry and suppress small weeds without harming the crop. Weeding efficiency was found as 81 %. During weeding or cultivating using a pair of oxen, one of them was probably pass on the free space between rows of plant while the other was ride on planted rows, causing breakage on germinated crop. Besides, cultivating depth, which is about 12 cm, is greater than the required depth.

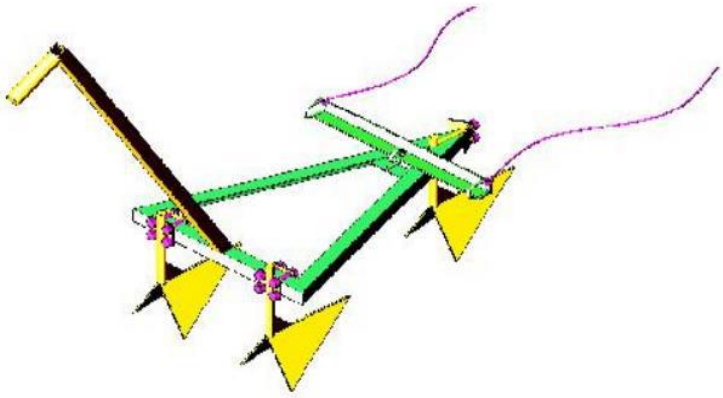

Fig.6 Triangular tool bar animal drawn weeder

3.3 Power operated weeder

Rathod *et al.* (2010) developed a tractor drawn inter-row rotary weeder keeping in view the crop, soil and machine parameters and made a performance evaluation. They conducted field tests with inter row rotary weeder at three forward speeds i.e., 1.1, 1.2 and 1.5 km/h. The developed weeder was evaluated at different test fields for different crops. The maximum weeding efficiency of 81.39 was obtained at 1.1 km/h speed and at 13.00 % moisture content. The mean effective field capacity was 1.43 ha/day. The average field efficiency was found to be 92.50 %. The field efficiency decreased with increase in speed of operation. While the minimum weeding efficiency of 69.04 was obtained at 1.5 km/h of speed and at 13.75 % moisture content hence the weeding efficiency decreased with increase in speed of operation, weeding efficiency increased with increase in depth of operation.

Fig.7 Tractor drawn inter-row rotary weeder

Chandel *et al.* (2014) investigated performance of rotary power weeder in vegetable crop. The self-propelled rotary power weeder was used in wide row line sown vegetable crops tomato, yard long bean and okra. At forward speed of 2.3 km/h, 2.0 km/h and 2.4 km/h the effective field capacities were 0.092, 0.08, and 0.096 ha/h in tomato, yard long bean and okra, respectively. With the average effective working width of 400 mm, the depth of weeding was observed as 53, 46, and 50 mm for tomato, yard long bean and okra, respectively. Weeding efficiency in tomato, yard long bean and okra was found as 97, 96 and 97 %, respectively. Plant damage was found as 1.6, 2.8 and 1.9 % in tomato, yard long bean and okra, respectively.

Manjunatha *et al.* (2016) developed and evaluated the performance of the tractor operated rotary weeder in redgram crop. The weeder was designed using computer aided design (CAD) software and prototype was fabricated. The operational parameters selected for the study were, three forward speeds (2.0, 2.5 and 3.0 km/ha), two rotary speeds (210 and 240 rpm) and three types of blades (L-type, C-type and J-type). The field performance of weeder was found to be better at 2.5 km/ha with rotary speed of 210 rpm for L-type blade compared to other types. The maximum weeding efficiency of 92.5 % with a field capacity of 0.42 ha/h and fuel consumption of 5.2 l/ha was recorded with minimum plant damage (3.15 %). The cost of weeding with tractor operated rotary weeder in redgram crop was found to be 1469 ₹/ha, which was 41.25 % less as compared to manual weeding (2500 ₹/ha).

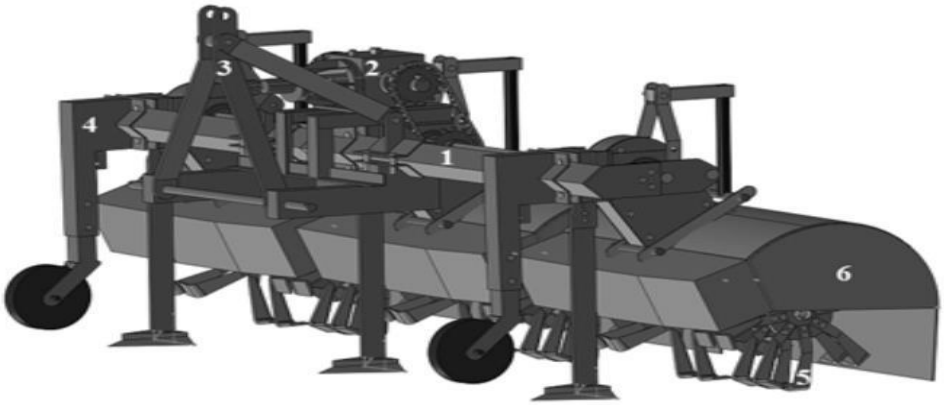

Fig.8 Isometric view of tractor operated rotary weeder.

IV. DEVELOPED SPRAYER CUM WEEDER

To perform spraying and weeding simultaneously by a mini tractor a machine was developed considering the required agronomical crop parameters (like crop type , variety, row to row distance, height of crop, weeding stages, spraying interval, spraying rate etc.). Also considered that the machine should be simple in design and made of locally available materials. The developed machine was mainly consisted of battery powered sprayer and mechanical weeder, run by a mini tractor. To run the spraying unit a tractor battery, diaphragm pumps, water

pipe, nozzles, tanks to store the spraying liquid for spraying were used. For weeding T-type blades were used. The developed machine with different parts is shown in Fig.9 and specifications of the machine are shown in Table 1.

Fig.9 Developed sprayer cum weeder

Table 1: Specifications of the developed sprayer cum weeder

Sr. No.	Particulars	Specifications
1	**Overall Dimensions**	
	(L × B × H), mm	2000 × 820 × 690
2	**Main frame**	
	Material of fabrication	MS pipe (75 mm dia.)
	Dimension (length × width)	2000 mm × 510 mm
3	**Blade**	
	Material of fabrication	Carbon steel
	Type	Straight (T-Blade)
	No. of blades	5 (Full size blade 3, Half size blade 2)
4	**Boom**	
	Material of fabrication	GI square pipe (20 mm×20 mm)
	Length	2000 mm
5	**Tractor Battery**	
	Voltage	12V
	Capacity	75 AH
6	**Diaphragm pump**	
	Voltage	12 V
	AMPS	3.5 A
	Flow	5.0 LPM

	Pressure	100 psi
7	**Nozzle**	
	Type	Hollow cone plastic nozzle
	Number of nozzles	4
8	**Flexible plastic hose pipe**	
	Diameter	8 mm
9	**Spraying tank**	
	Capacity of each tank	50 lit
	No. of tanks	2

Performance of the developed sprayer cum weeder was evaluated in laboratory as well as in the field. The machine was evaluated for filed capacity, field efficiency, weeding efficiency, fuel consumption, plant damage, spray angle, spray volume, spray application rate, swath width, and cost economics. Observations of all parameters are shown in Table 2.

Table 2: Observations of the developed sprayer cum weeder

Sr. No.	Particular	Observation
1	Field capacity (ha/h)	0.33
2	Field efficiency (%)	85.7
3	Fuel consumption (l/h)	1.69
4	Time required (h/ha)	2.39
5	Spray angle (°)	71
6	Spray volume (l/min)	2.76
7	Spray application rate (l/ha)	360
8	Swath width (mm)	2000
9	Weeding efficiency (%)	84.53
10	Plant damage (%)	4.58
11	Cost (₹ /ha)	584.90
12	Cost (₹/h)	244.73
13	Payback period (Year)	2.71
14	Energy consumption (MJ/h)	54.95

Comparison of the developed sprayer cum weeder with the existing spraying and weeding methods

Developed machine performs spraying and weeding operations simultaneously, in a single pass. While in the existing methods, spraying and weeding operations are completed by performing each operation separately in a separate pass. The existing spraying methods as stated above are manually lever operated spraying, animal drawn spraying and power operated spraying and existing methods of weeding are manual weeding, bullock drawn weeding and power operated weeding. The results related to the existing methods are collected/borrowed from some farm and literatures are used to compare with the results of the developed sprayer cum weeder as shown in Table 3.

Table: 3 Comparison of the developed spraying cum weeding machine with the existing methods

Parameter	Existing methods of Spraying			Existing methods of Weeding			Developed Sprayer cum Weeder
	ManuallyLever Operated knapsack Sprayer	Animal Drawn Sprayer	Power Operated Sprayer	Manual Weeding (Hand Weeding)	Animal Drawn Weeder	Power Operated Weeder	
Source of data	Borrowed from farm	Desal *et al.* (2013)	Padmanathan and Kathirvel (2007)	Borrowed from farm	Karale *et al.* (2015)	Ambaliya (2022)	
Time required to cover a hectare, h	6.88	9.51	1.55	50	15.45	2.35	2.39
Cost of operation, ₹/ha	319.17	575.83	88.25	6562.50	-	553.42	584.90
Cost of operation, ₹/h	46.28	60.55	76.45	131.25	-	235.50	244.73
Effective field capacity (ha/h)	0.145	0.66	0.72	0.02	0.064	0.34	0.33
Spray application rate (l/ha)	250	441.80	380	-	-	-	360
Plant damage, %	-	-	-	1.40	-	3.30	4.58
Weeding efficiency, %	-	-	-	96.20	82.37	86.12	84.53

From the above data it is clear that one hectare of land requires only 2.39 hours by using the developed machine which performs both the operations spraying and weeding simultaneously. In existing methods to cover one hectare of field requires 2.35 h, 15.45 h and 50 h by power operated weeder, animal drawn weeder and by manual weeding respectively. Thus, the developed sprayer cum weeder saves 84.53 % and 95 % of time as compared to animal drawn weeder and manually weeding method. As shown in the Table 3 time required (2.35h/ha) by the power weeder is more or less equal to the developed machine (2.39 h/ha) but in the existing method of power weeder only weeding operation is performed. For a spraying one hectare of field requires 6.88 h, 9.51 h and 1.5 h by manually lever operated knapsack sprayer, animal drawn sprayer and by power operated sprayer respectively. Thus, the developed sprayer cum weeder saves 74.86 % and 65.26 % of time as compared to animal drawn sprayer and lever operated sprayer. As shown in the Table 3 time required (1.55 h/ha) by the power operated sprayer is more or less equal to the developed machine (2.39 h/ha) but in the existing method of mini tractor operated sprayer only spraying operation is performed. Thus, the developed sprayer cum weeder saves 95.79 %, 90.42 % and 38.71 % of time as compared to existing manual methods, animal drawn machine and power operated machines in spraying and weeding operations respectively.

Further, from the above Table 3 it is clear that the operational cost by the developed machine (for combined spraying & weeding) for one hectare of land came ₹ 584.90 and by existing methods it costs ₹ 553.42 and ₹ 6562.5 by power operated weeder and by manual weeding respectively. Thus, the developed sprayer cum weeder saves 91.08 % of cost as compared to manually weeding

method. But the weeding costs ₹ 553.42 per hectare by the power weeder which is more or less equal to the operational cost of developed machine (₹ 584.90 /ha) but in the existing method of power weeder only weeding operation is performed. Spraying of one hectare of field costs ₹ 319.17, 575.83 and 88.25 by manually lever operated knapsack sprayer, animal drawn sprayer and by power operated sprayer respectively. Thus, the developed sprayer cum weeder saves 91.50 and 8.84 % operational cost as compared to existing manual methods and power operated machines in spraying and weeding operations respectively.

The weeding efficiency of the developed sprayer cum weeder for combined operations was found 84.53 % as compared to power operated weeder (86.12 %) which is more or less equal while it is only for weeding operation. However, manually weeding efficiency is always found highest due to inter-row and intra-row weeding.

V. CONCLUSION

Application of chemical and weeding are the most important operations in farming for high yielding. Present different category of sprayers and weeders available in the market that are tractor mounted, power operated, manual and self-propelled are available. Use of these machines in the Indian Agricultural scenario is difficult as most of the Indian farmers are small and medium and their economic conditions are not sound to adopt advanced machines and increasing the operating cost of labours and bullock power, along with very low efficiency, needs replacement. Therefore, by the matching size of tractor with the equipment not only reduces the operating cost but also maintains the quality of work. Hence, mini tractor operated sprayer cum weeder was found the most suitable for not only the small land holding farmers but also for the light operations like spraying and weeding operations. For profitable agriculture timely operations are the most important. Second point is the cost of operation. Considering these points, the mini tractor operated sprayer cum weeder is well suitable for farmers as compared to the existing methods. By using the developed machine time saving of 95.79 %, 90.42 % and 38.71 % could be achieved as compared to existing manual methods, animal drawn machine and power operated machine of spraying and weeding operations respectively. The developed machine could save 91.50 and 8.84 % operational cost as compared to existing manual methods and power operated machines in spraying and weeding operations respectively. The weeding efficiency of the developed sprayer cum weeder for combined operations was found 84.53 % as compared to power operated weeder (86.12 %) which is more or less equal while it is only for weeding operation. However, manually weeding efficiency is always found highest due to inter-row and intra-row weeding.

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