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RESEARCH ARTICLE

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1. INTRODUCTION

The challenge of providing enough food is and will remain one of the most pressing and urgent problems in Ethiopia. This is an alarming situation calling for an integrated approach towards increasing food production, productivity and protection both in the field and after harvest. Grains may be lost in the pre-harvest, harvest and post-harvest stages. Pre-harvest losses occur before the process of harvesting begins, and may be due to insects, weeds and diseases. According to Tadesse and Asferachew,(2008) Crop diseases caused by fungi, bacteria, viruses, and plant parasitic nematodes inflict a significant amount of losses on field crops ranged between 32-52%. Similarly the average loss on industrial crops ranged between 22 and 44%, and on horticultural crops ranged between 35 and 62%. Losses caused by weeds in selected crops have been reported to be as high as 100%. The average loss for field crops ranged between 49 to 65% and for industrial crops it ranges between 45 and 83%. The overall average loss on crop yield estimated to reach between 52-76%. However, it should be noted that the above crop loss data provide general indications on the importance of pests and weeds in the reduction of food production. So application of plant protection chemicals through the equipment for controlling pests, disease, insects and weeds plays an important role. As the chemicals are very costly, the uniform application and effective rate is the main requirement. Sprayers are the most common pesticide application equipment. They are standard equipment for nearly every pesticide applicator and are used in every type of pest control operation. Sprayers range in size and complexity from simple, hand-held models to intricate machines weighing several tons. Different types of sprayers have been developed. The lever operated knapsack sprayer is probably the most commonly used manual sprayer in Ethiopia. The sprayer is carried on a person's back and therefore be easily transported around the farm and used in different terrains. The tank makes up the largest part of the sprayer and can contain between 10 and 15 liters of liquid when full. A hand lever on the side of the tank, which is moved up and down, is used to create the required pressure .The pressurized liquid is released through a nozzle at the end of a hand lance and broken down into small droplets forming the spray. This activity is tiresome and time taking to cover relatively larger farm because as the size of field increases the effectiveness of manually operated spraying decreases.

2. Literature review

In crop protection, anything that interferes with the growth, development and yield of a crop is called “pest”. Pest can be a range of species including mammals, insects, viruses, fungi and weeds. These pests may affect the crop plant so severely that, unless they are controlled the quantity or quality of the crop or the ease of harvest may be seriously reduced (Pathak, 2004)

Rapid urbanization, improved living standards, increased educational opportunities, and changes in employment opportunities and social values and attitudes in advancing countries, have all resulted in changes in labour availability, such that it is frequently impossible to find the labour to carry out timely hand weeding (Abayneh, 2006). Herbicides and pesticide have been shown to increase agricultural production and improve rural welfare (Young et al, 1978). The incorporation of herbicides into small-scale farmer production systems can minimize labour requirements and increase profitability. In many small-scale farming areas, especially where labour is scarce or relatively expensive, the option of a cheap ground-wheel operated and reasonably accurate animal-drawn herbicide applicator is good than manual sprayer. In 2002 the FAO Panel on Agricultural Mechanizations recommended giving further attention to animal-drawn sprayers (*Wegayehu*, 2002). Animal drawn small motorized sprayers have all the components of larger field sprayers but usually are not self-propelled. They may be mounted on wheels so they can be pulled mounted on a small trailer for pulling behind an animal or skid-mounted for carrying on truck.

3. Material and Methods

3.1. Machine parts

The main parts of the animal drawn spray were: - Diesel Engine pump 3KW for power source, 150lt solution container tank (plastic), Different size pressurized hoses for transmission of solution from tanker to engine pump and then to nozzles, Plastic fitting nozzle to pressurize the solution into boom, Different size sheet metals and angle iron for supporting the parts, Tires/wheel for transportation, Steel shaft for connecting the two tires/wheels, and Wood beam (Figure 1).

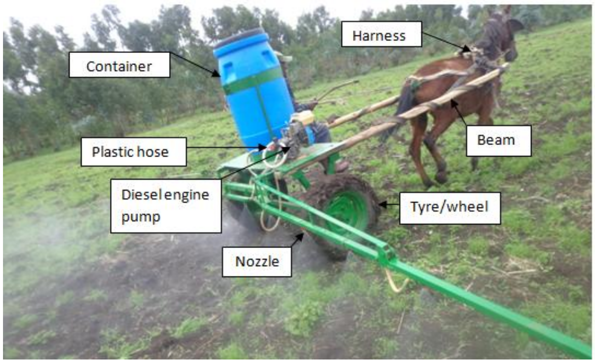

Figure 1. Developed sprayer being tested on the field and its major parts

3.2. Working principles

The effective application of pesticide and herbicide for pest control using spraying equipment play an important role. The chemical distribution in the field by the sprayer is regulated by nozzle spray discharge rate and walking speed of animal. The chemical sprayer is operated by a single equine animal. And spray tank and diesel engine is mounted on the sheet metal plat form, which is operated by draft power of the animal/s. The spray swath width of 7.5 m length is provided with fourteen numbers of hollow cone nozzles which are adjustable according to row spacing of crop. The wheel /tires sprayer are also adjustable according to row spacing of different crops and the unit is provided with a plastic tank of 150 liters capacity. During the field trials, the wheel tread of cart was adjusted in such a way that the unit could move in between two rows of crops.

The suitable beam length and harness were also selected and the animal freely walked in field. The boom height was also adjusted in accordance with crop height for effective spraying. During field trials, single equine animal was used for pulling the wooden beam with support of harness. A suitable size platform of length 600 mm and width 1300 mm was fabricated and fitted in above portion of the wheel for the sitting of the tanker and pump engine. An equine animal was used for pulling the cart and the engine was used as power source for carrying out spraying operation. The inlet hose of the pump is connected to spray solution tank and outlet pipes were connected to two spray lines mounted on spray boom and care was taken in such a way that there was no leakage of spray solution while carrying out the spraying work.

3.3. Performance evaluation method of animal drawn sprayer

Both laboratory and field method were carried out on the prototype animal drawn sprayer to evaluate its performance.

3.3.1. Laboratory method

The laboratory evaluation was carried out to determine the flow rate, application rate and discharge rate from each nozzles of sprayer. Discharges of each nozzle were recorded for three minute with three replications. Flow rate for each and overall or total flow rate were determined for the nozzles. This flow rate was determined using the expression given below (Shani etal, 2006,)

$$v \quad \frac{Q_{av}}{T_{av}} \qquad (1)$$

Where V = flow rate (l/min), Q_{av} = Average discharge in litres and T_{av} = average time for discharge in minutes.

The application rate in litres per hectare was determined for the prototype sprayer. Using also, the expression as given below (Shani etal, 2006,):

$$A \quad \frac{V}{30WS} \qquad (2)$$

Where: A = Application rate (lit/m^2), V = Amount of liquid from the fourteen nozzles in three minutes (l/min), S = traveling speed (m/min) and W = swath width (m).

The total swath width of the fourteen nozzles of the sprayer was determined in three replicates as shown in Table 4.

3.3.2. Field method

The field evaluation was carried out in order to determine the following parameters under field conditions:

a. Slippage of the ground wheel;
b. Theoretical and effective field capacities;
c. Field efficiency;

The experimental field was 3 hectares located in Arsi zone of Oromia region. The test was carried out on the flat surface. The prototype sprayer was set and hitched to a single horse for operation.

$$A_p \quad \frac{V_t}{A_t} \qquad (3)$$

Where: Ap = field application rate, Vt = total volume of effective spray (litres), A_t = total area sprayed or treated (hectares).

Effective field capacity (EFC) as defined by Culpin (1986);

$$EFC = \frac{Area\ treated}{Total\ time\ taken} \qquad (4)$$

Theoretical field capacity (TFC) This is defined as the rate of performance obtained if a machine were performing at 100% of the time at the rated operating speed and 100% of rated width (Hunt,1994).

$$TFC \quad \frac{SW}{10}(ha/hr) \qquad (5)$$

Field efficiency (E)-: is the ratio of effective field capacity to theoretical field capacities and it is expressed as percentage (Hunt, 1994).

$$E = \frac{Effective\ field\ capacity}{Theorethical\ field\ capacity} \qquad (6)/$$

Wheel slip (S) is defined as (Culpin, 1986):

$$S = \frac{Speed\ without\ load - speed\ with\ load}{speed\ without\ load} \qquad (7)$$

$$S = 1 - \frac{Speed\ with\ load}{speed\ without\ load} \qquad (8)$$

It is usually expressed as a percentage. If t_1 and t_2 are the times taken to cover a known distance (100m), with and without loads respectively, then:

$$Speed\ without\ load = \frac{100m}{t1} \qquad (8)$$

$$Speed\ with\ load = \frac{100m}{t2} \qquad (9)$$

Substituting equn. 8 and 9 in into slip equation

$$Slip\ \% = 1 - \frac{t1}{t2} \qquad (10)$$

4. EXPERIMENTAL RESULT AND DISCUSSION

3.1. Laboratory result

The spray pattern distribution was carefully studied in the laboratory in order to determine the flow rate, application rate and discharge rate from each nozzles of sprayer. The discharge values from each nozzle were recorded as shown in Table 1.

Table 1: Average Discharge Rate for each Nozzle using chemical ratio; (Palace) 1: (Water) 625

Nozzle	Nozzle discharge rate(lit/min)
1	4.26
2	4.74

slippage respectively. The time recorded to complete one hectare in three trials are given in Table 3

Table 3. Field test result data

Trial No	Time (min)	Fuel consumed (ml)
1	14.03	200.10
2	15.32	207.30
3	13.17	198.23
Mean (X)	14.17	201.88
Standard Deviation	1.08	4.79
Coefficient of Var .	0.08%	0.02%

The performance results of horse drawn engine operated sprayer for spraying on tef crop is presented in Table 3, 4, and 5. The average time of 14.17 min was obtained to complete one hectare in Table 3.

The operating pressure was maintained constant by locking the throttle lever. The theoretical field capacity, effective field capacity; field efficiency and wheel slippage was observed 4.65ha/hr, 4.23ha/hr, 90.96% and 1.01% respectively as shown in Table 5. The fuel consumption was observed as 201.88 ml/ha as observed in Table 3. During field trials, it was observed that uniformity in spraying was achieved as the animal was trained before field operation.

Table 4. Time for covering 100m distance with 100 lit and its respective swath width

Trial no	with load(sec)	without load(sec)	Swath width (m)
1	58.20	58.11	7.56
2	57.21	56.55	7.12
2	59.58	58.56	7.82
Mean(x)	58.33	57.74	7.5
Standard Deviation	1.19	1.05	0.35
Coefficient of variation	2.04 %	1.82 %	4.6 7%

Table 5. Slippage, theoretical and effective field capacities and efficiency of the sprayer

Parameters	Result
Theoretical field capacity	4.65ha/hr
Effective field capacity	4.23ha/hr
Efficiency	90.96%
Slippage	1.01%

4. Conclusion

For the agricultural crop pest protection Multi-nozzle booms are suitable for relatively medium outdoor areas. The recoded advantages of these chemical sprayers are: Larger capacity than hand sprayers, Low- and high-pressure capability, and Built-in hydraulic agitation. The horse drawn traction sprayer is capable to cover 7.5 m at one pass with an average field capacity of 4.23 ha/h. The field efficiency of horse drawn engine sprayer is 91 % with slippage of 1.01% and the quantity of chemical solution sprayed was 285 l/ha for tef. The average fuel consumption was 201.88 ml/ha.

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