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Performance evaluation of battery-operated knapsack sprayer cum fertilizer broadcaster

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Abstract
In our country more than 75% farmer belong to marginal and small category, and "mechanization" for the small farmer is a great challenge. An application of small equipment which can be operated by single person and capable of doing multi operation is the best solution for us. To improve mechanization in the field of spraying and broadcasting, battery operated knapsack sprayer cum fertilizer broadcaster has been developed and are being produced and these are now using in the country. Battery operated knapsack sprayer cum fertilizer broadcaster is used for effective spraying of chemicals and also used as effective broadcasting of granular fertilizer. The parameters like spraying pressure, spray droplets, spray volume, discharge rate, disc rpm swath width, aperture opening position etc. Thus, keeping above discussed matter in view, tests on a battery-operated knapsack sprayer cum fertilizer broadcaster was performed in the laboratory of FMP department, CAET, JAU, Junagadh. For performance evaluation of sprayer, the operating pressure was maintained between 1 to 3.5 kg/cm^2. The results were found that average discharge rate was 1658 ml/min, and triangular pattern was obtained as spray distribution pattern. For performing of broadcaster, it was found that at disc rpm 1390-1400 and aperture opening position (1), application rate of 403.25 kg/ha and swath width 5.33 m was achieved. Effective field capacity was 1.19 ha/hr for BOSF broadcaster at a speed of 3.00 km/hr and field efficiency was achieved 74%.

Keywords: battery operated knapsack sprayer cum fertilizer broadcaster, operating pressure, discharge, disc rpm, swath width, aperture opening position, application rate

Introduction
Indian agriculture is the backbone of economy. Agriculture in India has gone through immense changes in the second half of the twentieth century. Chemical pesticides have played and continue to play a major role in the rapid advancement of the agricultural production as we enter the twenty first century. Crop quality and yield have been improved and the use of chemical herbicides has greatly reduced the labour requirements for weed control. Now a day's chemical fertilizer is used to ensure the sufficient production as well as improve soil structural and fertility properties which results in advancement of agriculture.
Insects are man's chief competitors on earth as many of them feed on all kinds of plants including crop plants, forest trees, medicinal plants and weeds. The various factors affecting crop losses and their percentage are given in the following Table 1 (Anonymous (a), 1999):

Table 1: Factors affecting crop losses

Sr. No.	Factors	Losses (%)
1	Weeds	33
2	Diseases	26
3	Insects	20
4	Rodents	8
5	Birds	3
6	Other organisms	2

With advancement of agricultural science, more fields remain covered under crop for longer duration of time due to multiple cropping, intensive farming and better irrigation facilities. Consequently, there is increase in plant pest and diseases to considerable extent. So, it has become necessary now to use pesticide and fungicide for controlling the pests and diseases. The chemical applied on plants on the form of spray and dust. Uneven spreading of fertilizers affects the overall performance of crops, reduces fertilizer use efficiency and profit margins due to loss of crop yield and quality, and increases the risk of nutrients losses to the environment. The components of the application system with performance targets relating to delivery rate and uniformity of distribution include the following a. Machine design (Olieslagers *et al*. 1996), settings, calibration and maintenance (Bansal, A. S. 1998), b. Physical and chemical properties of the fertilizer material (Davis J. B. and C.E. Rice.,1973) [3], and c. Weat her conditions during fertilizer spreading, particularly, wind speed, which influences particles' trajectory, and relative air humidity, which influences the behaviour of the fertilizer material. Pesticide use is an important aspect of the modern agriculture to protect plant by insects, fungus, virus parasites and weeds which are unfavourable for agricultural plant growth. Sometime weeds can be destroyed by 10 effective cultivations but pests and diseases have to be kept under control with chemical spray and power application. Knapsack sprayer is the best selection of the farmers for chemical spraying. Knapsack sprayers are generally use for spraying low crops, vegetables and trees up to 2.5 m height. Patel (1997) [10] reported that the chemical pesticide has played and will continue to play major role in rapid advancement of agricultural production. Crop quality and yield have been improved and the use of chemical herbicides greatly reduced the labour requirement for weed control. investigated about agricultural sprayers. Practically, the experiment was required to calculate the volume of liquid or weedicide mixture required to cover a 1-ha area by using information such as the 5% of concentration of liquid which is 5 ml of liquid in a 1 litre bottle and estimation that this sprayer covers 20 km/h. Therefore, the volume of water flowing out through the nozzle was measured by using measuring cylinder for 5 s. Data obtained were then used to calculate the volume of liquid or weedicide needed. Parish R. L. (1987) [9] reported that the better biological effect will be get by small droplet, but more drift will come on. Droplet drift can be improved greatly by adjusting the factors of spray that can reduce environment pollution. The optimal droplets size is changed with different target and condition. In general, the droplets will be absorbed more easily by insect pests and leaves when droplets size is smaller than 100 µm. For spraying of water-based agricultural chemicals in high environment temperature, diameter of droplet quickly reduces with evaporation which cause more drift distance for high density fine droplets. So, drift of droplets is a serious issue. For lush plant, the bigger uniform droplets could reach to the middle zone of canopy with less drift. Ganapathy and Singh (1993)[5] developed a prototype hand held sprayer using high voltage circuit of an output of 15-20 KV DC for an input of 6 V. Preliminary testing of prototype sprayer indicated that the experimental electrodyn sprayer produced droplets 15-250 µm in size for an oil-based spray of malathion kerosene mixture at a flow rate of 10 ml/s. The droplet size decreased with an increase in flow rate. Gupta (2003) [7] designed and developed a bullock drawn sprayer at Gujarat agricultural university campus, Junagadh. They reported that at pressure of 3.5 kg/cm^2, the boom of four nozzles gave 2.47 to 2.53 lit/min discharge from the height of 400 mm. Average power requirement was 0.48 hp. The operating cost was Rs.40.86/ha with 1.44 man-h to cover one ha area. The main problem of the bullock drawn sprayer was that it has limitation of maintaining constant pressure for spraying. The bullocks reduced the speed of operation during turns and stopping of bullocks in the field. The cost of bullock drawn sprayer is also high. Griffis and Ritter (1983) [6] developed a comprehensive simulation model for single-impeller rotary distributor. They found that irregularly shaped particles and interactions among the particles introduce randomness into experimental distributions. Bernaki *et al*. (1972) [2] performed an analysis of the particle speed on disc with radial blades, forward, and backward-pitched blades. The blades on the disc were also set alternately at angles (-20 and 0) deg. in that analysis. They indicated that the increase in blade positive angle of setting reduced the swath width of spreader, while an increase in the negative angle worsened the distribution uniformity. Fulton *et al*. (2004) [4] conducted that disc type spreaders are attractive because they can cover large areas effectively; they are simple in design, reliable, inexpensive, robust and required little maintenance. They can produce a good pattern for constant application rates if properly overlapped and calibrated. An alternative, developed in recent years, is pneumatic application where the granular material is transported through air tubes and delivered to dividers.

Pesticides and fertilizer application to crop is the most important input to agriculture. The maximum effect of chemicals favourable to crops is depended on the degree of efficient deposition on the crop. Spraying having fine droplets have good biological effects but more drift losses hence, spraying should be done in such a way that it has optimum droplet size and minimum drift losses with economization. This can only be achieved by optimization of various factors like pressure, discharge, orifice meter, swirl hole size etc. It is revealed from the above review that mostly manually operated fertilizer broadcaster were evaluated for its performance in terms of application rate, swath width, field efficiency etc. The battery-operated fertilizer broadcaster is an innovation which would be beneficial to the farmer community. Hence, keeping all these aspects under consideration the study was undertaken with the following objectives to evaluate the working performance and the efficiency of battery-operated knapsack sprayer cum fertilizer broadcaster

Materials and Methods

This chapter deals with the test procedure adopted under laboratory conditions as well as filed conditions. Measurement techniques and methods for determining different parameters have also been deal with. The performance evaluation of battery-operated knapsack sprayer cum fertilizer broadcaster was conducted at the Testing and Training Centre of Farm Machinery, Department of Farm Machinery and Power, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh.

Discharge test

The nozzle, under test, should be connected to supply of clean water or spray materials which are equal in density, surface tension and viscosity of water. The water or spray material should be under a controlled pressure being indicated by a pressure gauge. The pressure gauge should be positioned immediately before the nozzle and should have full scale reading of pressure from 0 to not exceeding 2.5 times or not less than 1 time, that is to be read. The fluctuation of the pressure during the test should not be more than 10% from the controlled pressure. Turn on the supply and adjust the pressure and direct the spray, for a period timed by stopwatch, into a receiving vessel so designed as to collect the whole of the spray from the nozzle. The period should not be less than 60 seconds or not less than the time required to discharge 500 ml, whichever is higher. Direct the spray away from the vessel and turn off the supply and measure the volume of the water or spray material collected and calculate the discharge rate per minute. Repeat the above test for at least four times and calculate average rate of discharge per minute. The test should be done by direct spray at standard rate of discharge and standard pressure, from the nozzle on to a patternator. Tolerance on each division is ± 20 ml, decrement of nominal value outline is 11.1 ml per tube. The discharge rate of the nozzle should be declared by the manufacturer. In case of adjustable nozzle, the declared value should be for extreme adjustments for cone and jet spray patterns at a pressure of 300 kPa, as per IS: 3652-1995.

Spray angle
The spray angle of the nozzle should be declared by the manufacture. The angle when tested at a place protected from draughts. Connect the nozzle to a supply of clean water. A pressure gauge having full scale reading of pressure not exceeding 2.5 times or not less than 1.5 times of the pressure to be read, should be connected immediately before the nozzle. Commence the spray at a controlled pressure of 75 or 300 or 600 kPa within a fluctuation of ± 10%. The spray angle is read directly on the protractor and is round it off in whole degree.

Setup of spray patternator
The spray pattern of nozzle is evaluated with the help of spray patternator. The main components of spray patternator are spray table or main frame having dimension 200 X 90 X 178 cm and made of an angle iron (40 X 45 X 2 mm and 40 X 20 X 2 mm). Spray channels are 50 ± 2.5 mm wide and 60 cm long made of GI sheet. They are straight columns, which have V- type shape at the lower end and are 40 in number. Test tubes of 40 mm rim diameter and 490 mm in length are fixed on wooden support. Waste water trough is made of GI sheet with dimension of 1680 X 360 X 600 mm to collect the water from test tubes. Arrangement is made to mount single nozzle over it to study their pattern at certain pressure as shown in Fig.2. The effective swath width and discharge rate are determined for the single nozzle spray lance at different pressure settings as explained in section.

Fig 1: View of Spray Patternator

Performance Evaluation of Fertilizer Broadcaster
Discharge Rate: The broadcaster was operated as constant spreading disc rpm and at particular feeding control levers. The fertilizer discharged for one minute was collected in the plastic sheet. Each trial was repeated for three times and average discharge rate was worked out in kg per minute. The same procedure was repeated at the other spreading disc rpm to get the discharge rate at different spreading disc rpm. The procedure was repeated at another aperture opening position to get the discharge rate at different aperture opening position.

Fig 2: Measurement of swath width

Speed of Operation: To calculate speed of operator distance of 30m in the selected test plot was marked. The time required to cover the distance of 30m was noted at the optimum speed of disc and aperture opening position. Thus, the speed of operator was worked out in term of km/hr.

Results and Discussion
The BOSF broadcaster is available in the Department of Farm Machinery and Power, College of Agricultural Engineering and Technology, JAU, Junagadh. The BOSF broadcaster was evaluated under laboratory conditions. The observations of different parameters like spray distribution pattern, discharge rate, height of operation and battery performance for sprayer and discharge rate, swath width and spreading disc rpm for fertilizer broadcaster are presented and discussed in this study.

Discharge test: The nozzle discharge was measured by collecting the liquid in measuring cylinder for unit time. The minimum and maximum discharge at 1kg/cm^2 was 1100ml/min and at 3.5 kg/cm2 was 2304 ml/min, respectively.

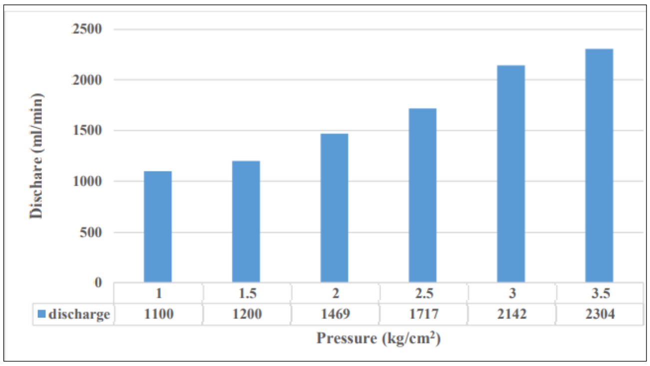

Fig 3: Discharge rate of single nozzle at different pressures

Test for spray distribution pattern: This test was carried out on the Patternator to obtain the distribution pattern at different operating pressures. The particulars regarding the test were as follow

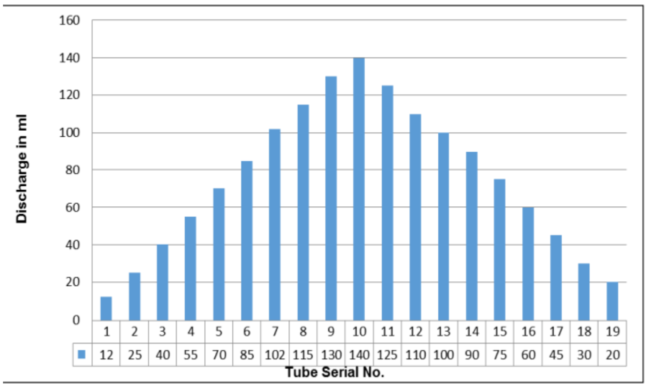

Fig 4: Spray Distribution Pattern of the nozzle (1- hole) knapsack sprayer based on approx. 1.0 litre discharge

Laboratory Performance of the Battery-Operated Fertilizer Broadcaster

a. **Discharge rate:** The fertilizer discharge was measured by collecting the fertilizer in plastic sheet for unit time. The discharge rate increases with speed of disc as discharge rate is directly proportional to speed of disc.
b. **Spreading disc rpm:** Spreading disc rpm is one of the important factors affecting on performance of BOSF broadcaster. Three speeds are considered for performance evaluation 1440-1450(max.), 800-810(medium), 260-270(min).
c. **Aperture opening position:** The aperture opening position is one of the important factors affecting performance of BOSF broadcaster. Performance evaluation at the aperture opening position 1-3-5 level. Opening position is increasing discharge rate is increasing but swath width is decreasing.
d. **Broadcaster height:** The broadcaster height is the major factor affecting on area coverage it was 90 cm from the ground

The stationary calibration of fertilizer broadcaster was carried out for DAP fertilizer at different speed of disc at three various aperture positions in the laboratory. The details of the tests are given in table 2 and table 3

Table 2: Laboratory Performance of the Battery-Operated Fertilizer Broadcaster at Different Speeds of Disc and Different Aperture Opening Positions

Sr. No.	Speed of disc/ Aperture opening position (1-5) (Min-Max)	Av. Effective width of spread (m)	Fertilizer rate observed (kg/ha) at av. forward speed 3.0 km/h
1	**1390-1400 (Max.)**		
i)	Position-1.0	5.33	403.25
ii)	Position-3.0	4.69	833.03
iii)	Position-5.0	4.23	1760.14
2	**1120-1125 (Medium)**		
i)	Position-1.0	4.49	389.74
ii)	Position-3.0	3.31	1113.96
iii)	Position-5.0	2.74	2510.95
3	**840-850 (Min.)**		
i)	Position-1.0	3.90	406.67
ii)	Position-3.0	3.01	1189.37
iii)	Position-5.0	2.30	2937.39

Table 3: Laboratory Performance of the Battery-Operated Fertilizer Broadcaster at Different Hopper Capacity and Different Aperture Opening Positions

Sr. No.	Hopper capacity/ Aperture opening position (1-5) (Min- Max) at 1120-1125 rpm	Av. Effective width of spread (m)	Fertilizer rate observed (kg/ha) at av. forward speed 3.0 km/h
1	**Full capacity**		
i)	Position-1.0	4.09	415.65
ii)	Position-3.0	3.15	1139.05
iii)	Position-5.0	2.78	2201.44
2	**3/4th capacity**		
i)	Position-1.0	3.94	401.52
ii)	Position-3.0	2.97	1111.11
iii)	Position-5.0	2.26	2615.04
3	**½ capacity**		
i)	Position-1.0	3.66	432.79
ii)	Position-3.0	2.78	1105.04
iii)	Position-5.0	2.13	2602.82
4	**1/4th capacity**		
i)	Position-1.0	3.64	421.98
ii)	Position-3.0	2.76	1289.13
iii)	Position-5.0	2.12	2122.64

Operational Parameters

a) **Speed of operation:** Speed of operation was calculated by observing the time required to travel a particular length of row while broadcasting.

b) **Time loss:** The time lost in turning, cleaning, adjustment and refilling of fertilizer was observed as 30% of total time consumed in broadcasting operation.

c) **Theoretical field capacity:** Theoretical field capacity of BOSF broadcaster was determined using the following equation

$$\text{Theoretical F.C. (ha/hr)} = \frac{Width\ (m) \times Speed\ (km/hr)}{10}$$

$$= \frac{5.33 \times 3.0}{10}$$

= 1.59 ha/hr

d) Effective Field capacity

Effective field capacity of BOF broadcaster was determined by the using the following equation

$$\text{Effective F.C. (ha/hr)} = \frac{Area\ covered}{Total\ time}$$

$$= \frac{Width \times Length\ of\ row}{Total\ time}$$

$$= \frac{5.33 \times 30}{36 \times 1.3} = 1.19\ \text{ha/hr}$$

e) Field efficiency

F. E. (%) = ($Effective\ field\ capacity$*100)/ ($Theortical\ field\ capaciy$)
= (1.19*100)/ (1.59)
=74%

f) Application rate

$$\text{A.R. (kg/ha)} = \frac{Discharge\ rate\ (kg/hr)}{Area\ covered\ (ha/hr)}$$

Conclusions

A new battery-operated device is expected to improve the lives of financially challenged farmers of India. So far, the farmers were forced to carry around a heavy sack that had to be constantly filled with water and pesticides. However, things are about to change as the system has improved. The new device used to apply pesticides and fertilizers to crops depends on a battery that can be charged with AC current representing a greener alternative to the fuel engines powering its predecessors.

In battery operated knapsack sprayer cum fertilizer broadcaster, uniform application of pesticide and fertilizer throughout the operation due to uniformity, uniform distribution can be achieved. Women can also use BOSF broadcaster for required operation due to less physical fatigue better field efficiency. In sprayer at the operating pressure of 1, 1.5, 2, 2.5, 3 and 3.5 kg/cm^2, acceptable rate of discharge 1100, 1220, 1469, 1717, 2142 and 2304 ml/min, respectively were found. A uniform triangular spray distribution pattern was achieved at different pressure for 1 lit. discharge. At the disc rpm 840-1400 and aperture opening positions 1, 3 and 5. The application rate of 403.25 to 2937.39 kg/ha was achieved. Swath width for broadcaster was observed 4.69 m at disc rpm 1390-1400 and aperture opening (3), swath width is inversely proportional to aperture opening position. Effective field capacity was 1.19 ha/hr for broadcaster for a speed of 3.0 km/hr and the average field efficiency was achieved 74%.

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