



## Performance evaluation of tractor mounted boom sprayer on chilly crop

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ARTICLE INFO	ABSTRACT
Received : 28 June 2022 Revised : 27 October 2022 Accepted : 06 November 2022  Available online: 09 March 2023  <b>Key Words:</b> Boom sprayer Pump tester Nozzle discharge Nozzle pressure	<b>Chilli (<i>Capsicum annuum L.</i>) is an important vegetable and spice crop belongs to Solanaceae family which grown all over the world. Dried pods contain 36 gms of carbohydrates, 18 gms of proteins, and excellent source of vitamin A and vitamin C which together provide roughly 160 calories of energy per 100 gms (Narayanan <i>et al.</i>, 1999). Area, production and productivity of Chilli in India was 7.43 Lakh ha, 19.14 Lakh Tonnes and 2576 kg/ha, respectively (Anonymous, 2018). Keeping in mind, above parameters the performance of tractor operated boom sprayer was tested on Chilly crop. Under laboratory conditions, the designed boom sprayer performed excellently at 0.90 l/min nozzle discharge and 689.5 kPa operating pressure. It was observed that droplet size, spray uniformity, and droplet density was influenced by the nozzle discharge rate and pressure of 0.45, 0.70, 0.90, and 1.35 l/min and 275.8, 413.7, 551.6, and 689.5 kPa, respectively. The Volume Median Diameter (VMD), Uniformity Coefficient (UC) and Droplet Density (DD) of the existing boom sprayer have 130.9-206.36 <math>\mu\text{m}</math>, 0.98-1.39 and 11-27 number of droplets/cm<sup>2</sup>, respectively, for nozzle 0.9 lpm and pressure 689.5 kPa. The modified sprayer has droplet sizes between 125.04 and 181.42 <math>\mu\text{m}</math>, droplet densities between 16 and 27 number of droplets/cm<sup>2</sup>, and uniformity coefficients between 0.99 and 1.25 at nozzle discharges of 0.90 l/min. With the 689.5 kPa working pressure and 0.90 l/min nozzle discharge, the designed boom sprayer offers notably higher discharge and nozzle pressure in each individual nozzle than the existing sprayer.</b>

### Introduction

Chilli (*Capsicum annuum L.*) is an essential vegetable and spice crop grown all over the world and prized for its aroma, taste, flavour, and pungency. Chilli belongs to solanaceae family with chromosome number  $2n=24$ . It is a basic ingredient in many Indian curries and chutneys, as well as in vegetables, spices, medical products, condiments, sauces, and pickles. In terms of nutrients, Chillies are high in vitamins, particularly vitamin A and C (Raju

and Luckose, 1991). For every 100 gms of dried pods, there are 36 gms of carbohydrates, 18 gms of proteins, 16 gms of lipids, 480 mgms of calcium, 3.1 mgms of phosphorous, 31 mgms of iron, 2.5 mgms of niacin, 640 I.U. of vitamin "A," and 40 mgms of vitamin "C", it gives about 160 calories of energy (Narayanan *et al.*, 1999). There are more than 400 different types of Chilli grown around the world, with the "Carolina reaper" variety from the USA

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being the spiciest (Bindu and Nayak, 2021). Nationwide, 1.776 million hectares are used to cultivate Chillies, yielding 7.182 million tonnes yearly. With a 25% and a 24% share of all global exports, respectively, India and China are the two biggest chilli exporters in the world (Anonymous, 2018). Area, production and productivity of chilli in India was 7.43 Lakh ha, 19.14 Lakh Tonnes and 2576 kg/ha, respectively (Anonymous, 2018). In India, Andhra Pradesh stands first in both production and area of Chilli which accopies 49%, followed by Orissa, Maharashtra and Madhya Pradesh 7, 6 4% of Chilli production in the India (Gade *et al.*, 2020). Pest, disease, and weed infestations are the main causes of decreased crop productivity. The most common technique used to manage most insects, weeds, and diseases is chemical control. Either spraying or dusting the chemicals on is used to apply them. One of the best and most efficient ways to apply a tiny amount of spray liquid to protect crops is through spraying. When using the traditional spraying technique, it is challenging to evenly and successfully apply the insecticide throughout the tree. Although this method effectively controls pests, it requires a lot of time and labour and consumes a lot of liquid per plant. Nowadays, agriculture is facing significant challenges, due to growing public concern over how agricultural production practices affect the environment and our ability to live in a safe and secure environment. To safeguard crops against insects and pests, a number of sprayers are available on the market. Numerous technological, technical, and environmental aspects affect how well a sprayer performs. These consist of the nozzle type, suitable spray parameters, temperature, humidity, and plant protection product directions. Ground surface deposition and off-target drift are the main obstacles to plant protection with spraying equipment. This drift commonly causes a hazard to both human and animal health as well as a source of environmental contamination (Maski and Durairaj 2010). A tractor-based spray application system can be promoted to reduce the multiple - input and achieve uniform deposition, distribution, and vertical fluid distribution (Sedlar *et al.*, 2013). As a result, it's important to encourage the usage of time-saving machinery operated by tractors (Raut *et al.*, 2013). Inadequate nozzle pressure, discharge, height, and other factors all contribute to pesticide

loss. Therefore, in order to minimize pesticide losses from sprayers, the optimum discharge rate and pressure must be determined (Gholap *et al.*, 2013). Keeping in mind, above parameters the performance of tractor operated boom sprayer was tested in chilly crop. In order to study the effects of nozzle discharge rate (i.e., 0.45, 0.70, 0.90, and 1.35 l/min) and nozzle pressure (i.e., 275.8, 413.7, 551.6, and 689.5 kPa) on spray uniformity, the hydraulic boom sprayer was tested for Chilli crop. Tires from tractors cause very little crop damage since they can move easily between rows (Nalavade *et al.*, 2008). The efficiency of insecticides can be improved with a good sprayer (Singh *et al.*, 2019). In developed nations, spraying enables people to enjoy high-quality products that are free of pest contamination and blemishes (Prokop and Kejklicek, 2002). In order to increase the sprayer's efficacy on the guar crop in the context of the local environment, it is necessary to evaluate and improve the performance of various spray parameters, including pressure, nozzle height, swath width, and discharge (Nuyttens *et al.*, 2007; Narang *et al.*, 2015).

**Material and Methods**

**Study area:** The present study was carried out in ASPEE Research Farm, Wada, Thane.

**Sprayer setup:** Using three point linkage, a 35 HP tractor was equipped with a 12 m boom sprayer. A universal joint was used to link the sprayer's v-belt pulley to the tractor P. T. O. unit. An experiment was conducted in a lab using a 12 m tractor mounted boom sprayer, descriptions of the sprayer is shown in Table 1. The tractor's power take-off (PTO) shaft provided the required energy for the boom sprayer to operate it.

**Table 1: Specifications of the tractor mounted boom sprayer**

Description	Boom sprayer
Tank capacity	400 litre
Operating pressure	689.5 kPa
Maximum pressure	2758 kPa
Power required	35 HP
Weight of sprayer (without liquid)	270 kg
Size of sprayer (l × w × h)	1364x1000x1212 mm
Application Rate	580-700 lit/ha
Type and number of nozzles used	Hollow cone nozzle, 25

**Instrument used:** A pump tester was used to determine the pump flow rate, and a master pressure gauge tester was used to calibrate the pressure gauge. The nozzle discharge rate of 0.45, 0.7, 0.9, and 1.35 l/min, respectively, were independent variables for spray deposition on Chilli crop, while operating pressures were 689.5 kPa. Three times the experiment was conducted on chilly crops in a lab.

**Field preparation:** To assess the spray deposition of the boom sprayer on the Chilli crop, a plot size of 100x100 m<sup>2</sup> was selected. At a distance of 25 m length and 12 m width, two poles were built.

**Nozzle discharge:** The discharge of the sprayer nozzles at the desired pressure was measured in the lab using a test bench. The discharge of the nozzles was measured and noted using a timer and graduated beaker. Spray discharge was collected in still air for a period of 60 seconds.

**Spray angle:** Another crucial nozzle performance factor, spray angle which determines the proper

nozzle spacing, application height, and overlapping. The type of nozzle, orifice size, and operating pressure all affect the spray angle. Spray angle and swath width also increase with pressure. Using a patternator, the spray angle of the nozzles was computed in the lab.

**Control valve assembly**

**Control panel set-up 1:**

The pressure regulator (CVA), suck-back valve, and four on/off valves make up the control panel setup. When the hydraulic agitator is operated, it makes it easier to spray from any part of the boom, and it also helps in sucking back. For every six nozzles that follow one another, four on/off valves are provided for delivery, and one is for the auto-filling assembly. Four on/off valves are provided for delivery for every six consecutive nozzles and one is provided for auto filling assembly. The conceptual sketch of control panel set-up 1 has shown in Figure 1 (a) and the original set-up 1 has shown in Figure 1 (b).

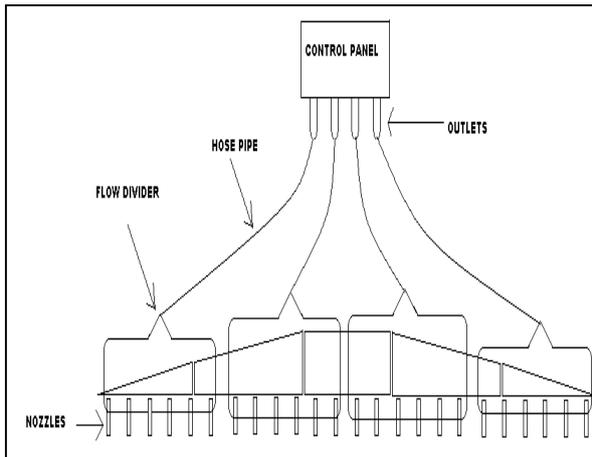


Figure 1(a): Conceptual sketch of control panel set-up 1

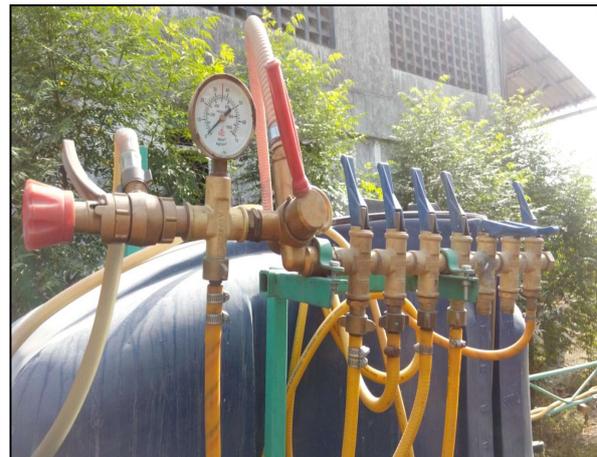


Figure 1(b): Set-up 1 Four control valve assembly

**Control panel set-up 2:**

The pressure regulator (CVA), suck back valve, and six on/off valves make up the control panel setup. For every four successive nozzles, there are six on/off valves provided for distribution, and one is also available for the auto filling assembly. There is a pressure regulator available for controlling the pressure. Reduced spray fluctuation is the primary use of pressure vessels. The primary frame of the sprayer's spraying was where the control

assembly was attached. The conceptual sketch of control panel set-up 1 has seen in Figure 2 (a) and the original set-up 1 has shown in Figure 2 (b).

**Nozzle:**

Generally hollow cone nozzle was used in the boom sprayer, this nozzle available in standard size of 0.4 to 1.35 l/min discharge rate. So, Hollow cone nozzles of 0.4, 0.7, 0.9 and 1.35 l/min were selected for the testing. The nozzle discharge rate,

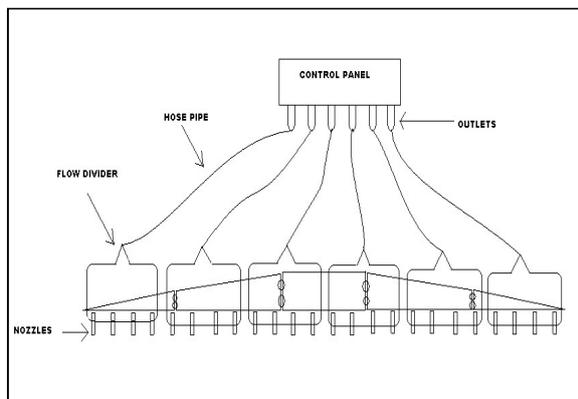


Figure 2(a): Conceptual sketch of control panel set-up 1



Figure 2(b): Set-up 2 Six control valve assembly

spray angle, droplet size distribution, and spray intensity distribution under specific standard pressure are such distinguishing characteristics. The Hollow nozzle was selected, based on type of chemical being sprayed. The recommended angle of hollow cone nozzle is  $65^\circ$  to  $110^\circ$  (Sanchavat *et al.*, 2020).

**Spacing:**

Consideration of appropriate nozzle spacing is important, as it affects the boom height and overlap. Generally, for  $110^\circ$  spray angle nozzle spacing is considered as 500 mm (Matthews, 1994).

**Pump flow rate Measurement:**

The flow rate of pump was measured using instrument AAMS pump tester. The pump was dismantled from the sprayer and connected to pump tester. The flow rate was measured for four pump rpm speeds as 800, 850, 900 and 950.

**Pressure gauge testing:**

The manometer of the sprayer is dismantled and attached to a quick coupling that can be fitted on the manometer tester. The gauge was calibrated for the 1, 2, 3, 4, 5, 6, and 7 kPa.

**Analysis of water sensitive paper strips:**

For determination of droplets size of each sprayer, a blue-coloured dye was mixed with water and the impression of droplets was taken on glossy paper. For the purpose of observing the droplets fall, three glossy papers were attached to each place. Before starting the experiments, the equipment was calibrated as necessary and operated for 30 minutes. The set up was started 3 meter before the canopy and the sample was gathered on sample cards made of glossy paper with measurements of 62 mm x 44 mm.

This was done to ensure that the crop was exposed to the spraying uniformly. To create a coloured spray solution, royal blue indigo dye was combined with water. Onto the sample glossy photographic paper, the coloured spray was allowed to fall. After experiment, sample cards were carefully taken out and taken to the lab for analysis. The Digital image analyzer was used to determine the size of droplets i.e. NMD, VMD, spray uniformity etc.

**Measurement of Droplet Deposition:**

The most powerful electronic imaging software, "Image Pro Plus," was used to evaluate glossy paper. The program's advanced image processing abilities are made available by Microsoft Windows, which includes a microscope which was connected to the computer software via a Graphical Interface Card, allowing us to view the image on computer screen directly, as shown in Figure 3. Following computer processing of these photos, droplet size and density were directly determined.

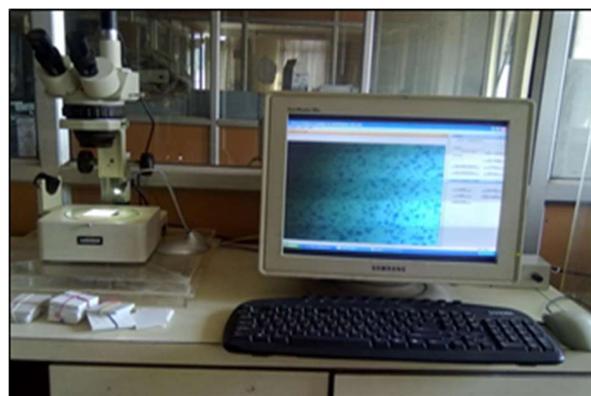


Figure 3: Electronic imaging instrument

### Data Analysis

M.S. Excel was used to store and analyze the data. The droplet spectrum recorded on the sample card at a particular place had its VMD and Mean diameter calculated using the image-pro application. Utilizing factorial CRD statistical software tools, the data were analyzed on a computer. At the 1% level, it was discovered that the data for VMD, NMD, DD, and UC was significant.



Figure 4: Modified hydraulic boom sprayer

### Plant Position:

The boom sprayer has mostly used for spraying pesticide on vegetable, pulses, catch crops etc. so for the measurement of the droplet deposition the chilly plant was selected for the study. The arrangement of the glossy paper on chilly plant has seen in Figure 5. To ease the assessment of spray penetration into the canopy of the Chilly plant, the plant was separated into six distinct portions depending upon the area where the influence of independent variable on spray deposition was to be examined.



Figure 5: Chilly plant with glossy paper

**Actual field capacity:** Real work time and time lost to other operations like turning and tank filling were both taken into account when determining the actual field capacity. The field capacity was given by (Sanchavat *et al.*, 2017)

$$\text{Actual field capacity (ha/h)} = \frac{\text{Width (m)} \times \text{Speed (km/h)}}{10} \times \text{Efficiency (\%)}$$

**Theoretical field capacity:** Theoretical field capacity was calculated by (Sanchavat *et al.*, 2017)

$$\text{Theoretical field capacity (ha/h)} = \frac{\text{Width (m)} \times \text{Speed (km/h)}}{10}$$

**Field efficiency:** Field efficiency is calculated by (Sanchavat *et al.*, 2017)

$$\text{Field Efficiency (\%)} = \frac{\text{Theoretical field capacity}}{\text{Actual field capacity}}$$

### Results and Discussion

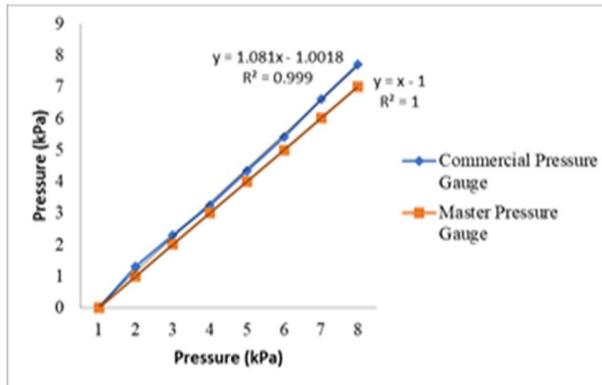
To evaluate the performance of the developed tractor mounted boom sprayer, various tests were carried out in laboratory.

#### Pump flow rate measurement

In a laboratory, the discharge of the sprayer pump at each of its four rpm settings was measured. The pump's rpm could be adjusted by using pulleys of various diameters. For each pressure of 275.8 kPa, 423.7 kPa, 551.6 kPa, and 689.5 kPa, the pump's rotational speed was selected as 800, 850, 900, and 950. Pump discharge was found to be 36 l/min at 689.5 kPa pressure. The results showed that for increase in pressure flow rate increases (Hofman, 2004). It was found that the minimum values of flow rate were 32.40 l/min for 850 pump rpm and maximum value 35.94 l/min for 950 pump rpm. The pump was able to maintain appropriate flow rate but failed to maintain sufficient pressure in the nozzles. The test results are shown in Figure 6.

#### Pressure gauge testing

The AAMS master gauge was used to test the sprayer's pressure gauge. The gauge was calibrated for the 0, 10, 20, 30, 40, 50, 60 and 70 kPa pressures. The commercial pressure gauge of the existing boom sprayer showed linear relationship when calibrated with AAMS master gauge.



**Figure 6: Pressure curve for commercial pressure gauge and master gauge**

**Effect of nozzle discharge rates and pressures on droplet density (DD), uniformity co-efficient (UC), and droplet size (VMD) of existing boom sprayer**

**Effect on droplet size (VMD)**

With nozzle discharge rates of 0.45, 0.7, 0.9, and 1.35 l/min and a nozzle pressure of 689.5 kPa, the boom sprayer's VMD ranged from 130.9  $\mu\text{m}$  to 288.33  $\mu\text{m}$ . The droplet sizes (VMD) with 0.9 l/min nozzle discharge and 689.5 kPa pressure were extremely near to the practical range of 150  $\mu\text{m}$  to 250  $\mu\text{m}$ . The droplet sizes at a 0.9 l/min nozzle discharge were found to be 206.36  $\mu\text{m}$  and 199.5  $\mu\text{m}$  for the top upper and bottom lower plant positions, 178.67  $\mu\text{m}$  and 160.5  $\mu\text{m}$  for the middle higher and lower plant positions, and 145.3  $\mu\text{m}$  and 130.9  $\mu\text{m}$  for the bottom upper and lower plant positions. The droplet size reduced as a result of rising operating pressure, which also caused an increase in the number of droplets (Kumar *et al.*, 2021).

**Effect on uniformity coefficient (UC):**

At nozzle discharge rate of 0.45, 0.7, 0.9, and 1.35 l/min, the sprayer's uniformity coefficient was found to be in the range of 0.82 to 1.84. 0.9 l/min nozzle discharge and 689.5 kPa pressure resulted in a uniformity coefficient (UC) that was extremely near to one. The middle upper and middle lower plant positions had uniformity coefficients of 1.35 and 1.25, the top upper and top lower plant positions had uniformity coefficients of 1.39 and 1.29, and the bottom upper and bottom lower plant positions had uniformity coefficients of 1.18 and 0.98 at 0.9 l/min discharge.

**Effect on droplet density (DD):**

At nozzle discharge rates of 0.45, 0.7, 0.9, and 1.35 l/min, the boom sprayer's droplet density ranged from 10-29 number of droplets/cm<sup>2</sup>. The effective range of 16 to 30 number of droplets/cm<sup>2</sup> was very nearly achieved by the droplet density (DD) at 0.9 l/min nozzle discharge and 689.5 kPa pressure. At 0.9 l/min nozzle discharge, the droplet density of the top upper and top lower leaves varied between 27 and 19 number of droplets/cm<sup>2</sup>, while that of the middle upper and middle lower leaves was 17 and 14 number of droplets/cm<sup>2</sup>, and the bottom upper and bottom lower leaves had a droplet density between 12 and 11 number of droplets/cm<sup>2</sup>. The droplet quantity may have increased due to a decrease in the mean droplet size (Kumar *et al.*, 2021).

**Measurements of Pressure and discharge of nozzles:**

The boom sprayer was run at 689.5 kPa working pressure for laboratory testing. For each individual nozzle, the tractor mounted boom sprayer pressure and discharge were measured from left to right in front of the driver seat (Nalavade, 2008). The modified set-up 2 boom sprayer's nozzle discharge with an operating pressure of 689.5 kPa is depicted in Figure 7(a). The discharge rate of the nozzle varied from 0.87 to 0.92 l/min when the boom is shifted from left to right. The variation was found to be 4.5% as compared to 29.8% in the boom sprayer that was already in use. The nozzle pressure of a modified set-up 2 boom sprayer with an operating pressure of 689.5 kPa is shown in Figure 7(b). From 490 to 525 kPa, the nozzle pressure varies. The modified set-up 2 boom sprayer's nozzle discharge with an operating pressure of 689.5 kPa is depicted in Figure 7(a). The discharge rate of the nozzle varied from 0.87 to 0.92 l/min when the boom is changed from left to right. The variation was found to be 4.5 % as compared to 29.8 % in the boom sprayer that was already in use. The nozzle pressure of a modified set-up 2 boom sprayer with an operating pressure of 689.5 kPa is shown in Figure 7(b). The nozzle pressure ranges from 490 to 525 kPa. Figure 8(a) illustrates the mean nozzle discharge performance of the original and modified (set-up 1 and set-up 2) boom sprayers.

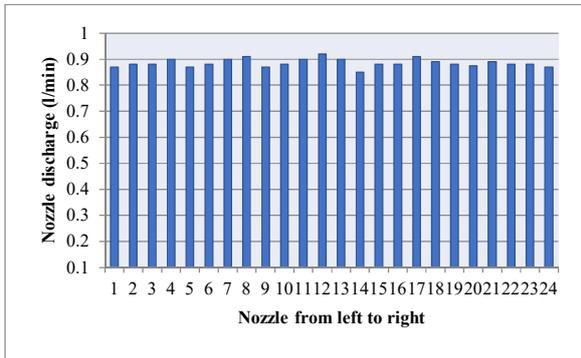


Figure 7 (a): Nozzle discharge of modified set-up 1 boom sprayer for 689.5 kPa working pressure

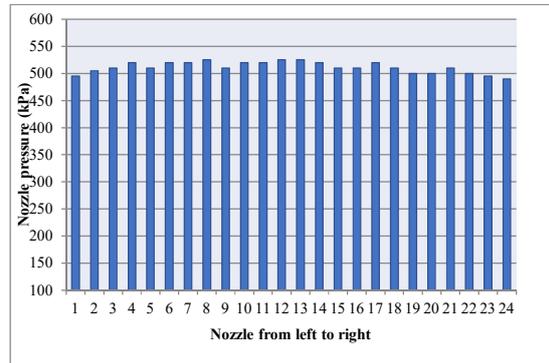


Figure 7 (b): Nozzle pressure of modified set-up 1 boom sprayer for 689.5 kPa working pressure

### Comparative Performance of Modified set-up 1 and set-up 2 Boom Sprayer with Existing Boom Sprayer

The figure demonstrates that, compared to the existing boom sprayer, the mean nozzle discharge of the modified set-up 1 and set-up 2 boom sprayers improved by 29.5 and 44.2%, respectively. Figure 8 (b) compares the performance of existing and modified (set-up 1 and set-up 2) boom sprayers. The Figure illustrates that the mean nozzle pressure of the modified setups 1 and 2 boom sprayers increased by 70 and 160% of the baseline boom

sprayer, respectively. It was observed that the top position of the plant, which was followed by the middle location and the bottom location, achieved the largest droplet size (VMD). The results also showed that the droplet size at the plant's upper and lower leaf surfaces was within the acceptable range. The top location of the plant yielded the maximum droplet density (DD), which was followed by the middle and bottom locations. The results also showed that the droplet density at the plant's upper and lower leaf surfaces was within acceptable limits at the top, middle, and bottom locations.

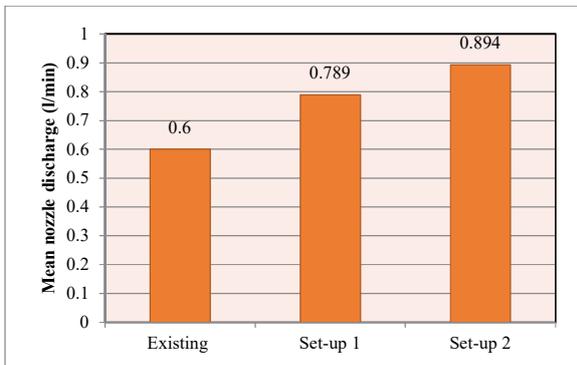


Figure 8 (a): Comparative performance of nozzle discharge for existing and modified (set-up 1 and set-up 2) boom sprayer.

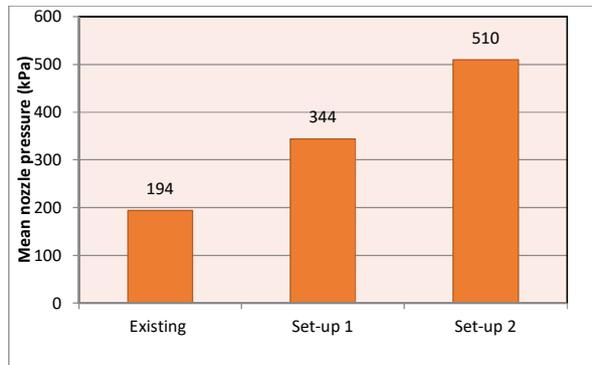


Figure 8 (b): Comparative performance of nozzle pressure for existing and modified (set-up 1 and set-up 2) boom sprayer.

### Economical parameter:

The developed tractor mounted boom sprayer was tested in chilly crop. The theoretical field capacity and field efficiency of tractor mounted boom sprayer was 3.5 ha/h and 72.4%, respectively. An average of

three trials showed that the theoretical field capacity was 3.3 ha/h and field efficiency of 63.03% (Sanchavat *et al.*, 2020). The cost of operation of tractor operated booms sprayer was Rs.208.12/ha for

Chilli crop. For the cotton crop, the cost of running a tractor-operated boom sprayer was Rs. 220.79/ha (Sanchavat *et al.*, 2020).

## Conclusion

The performance evaluation of tractor mounted boom sprayer was found satisfactorily for Chilly crop. The nozzle discharge of 0.9 l/m and pressure of 689.5 kPa the values of VMD, UC and DD of the existing boom sprayer were 130.9-206.36  $\mu\text{m}$ , 0.98-1.39 and 11-27 number of droplets/cm<sup>2</sup>, respectively. It has been found that using a tractor-mounted sprayer operating at 600 kPa results in more evenly dispersing insecticides across the cotton crop's field. Modified sprayer has the droplet size in the range 125.04 to 181.42  $\mu\text{m}$ , droplet density 16 to 27 Number of droplets/cm<sup>2</sup> and uniformity coefficient 0.99 to 1.25 at 0.90 l/min nozzle discharge. Therefore, it can be concluded that the modified boom sprayer gives the desired spray

deposition and highly efficient as compared to existing boom sprayer and its performance was found up to mark. The pressure and discharge of each individual nozzle was significantly increased and was able to maintain uniform pressure and discharge in each section of boom.

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## Conflict of interest

The authors declare that they have no conflict of interest.

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