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Chapter

Machinery for Plant Protection in Cotton Crop

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Abstract

Spraying is very tedious and time consuming operation. There is a need of an efficient, precise and high capacity machine for spraying. The pesticide with conventional sprayers is not so effective because non-uniform spray and of lesser width of coverage. Distribution of pesticide is not uniform especially at the underside of the leaves. The pest can be controlled effectively if pesticides are applied properly at the right rate, right time and on the target by right equipment. In field crops like cotton the pest attacks is on the lower side of the leaves during vegetative as well as reproductive stages of the cotton crop. The sprays with conventional sprayer do not enter at the bottom of the plant canopy and at lower side of the leaves. Different type of sprayers are being developed especially for the control of white fly in cotton crop. These sprayers can also be used for crops like sugarcane, potato etc. Air assisted electrostatic sprayer, Auto rotating gun type sprayer, Multipurpose high clearance sprayer and even drones are now a days used for spraying in cotton crop. Multipurpose high clearance sprayer mostly preferred by the farmers has three types of spraying arrangements namely auto rotate gun, boom type and drop up type nozzles can work at all stages of the crop and saves time, labor and cost of operation as well as it reduces drudgery of the operation. Selection of nozzle is also important for these type of sprayers. Automatic controller can be fitted on these sprayers for adjusting the discharge and to reduce missing or overlapping of spray.

Keywords: spraying, high clearance sprayer, auto rotate gun sprayer, electrostatic spraying, drone, weeding etc.

1. Introduction

Leading cotton producing countries worldwide in 2020–2021 are China with the production of 6.42 million metric tons followed by India with 6.16 million metric tons accounting for about 58% of the world cotton production [1]. Over the past several years, plantings of transgenic crops producing insecticidal proteins from the bacterium Bacillus thuringiensis (Bt) have helped to control several insect pests and reduced the need for insecticides. Broad-spectrum insecticides kill arthropod natural enemies that provide biological control of pests. The decrease in use of insecticide [2] sprays associated with Bt crops could enhance bio-control services [3]. Although, Bt. cotton provides effective protection against cotton bollworms, but sucking pests namely whitefly, jassid, aphid and mealy bug are the most serious in Bt. cotton and
they cause maximum damage. Whitefly adults and nymphs suck sap from leaves and excrete honey dew on leaves which become sticky. Affected leaves and seed cotton turns black due to development of sooty mold on the plants. Regular supervision of the crop is must for detection of whitefly incidence. If possible proper coverage of underside of leaves during the insecticidal spray may effectively reduce the whitefly population in cotton crop.

Chemical application by sprayer is a common field operation in crop production. Different types of sprayers namely; manual operated, tractor operated boom sprayer, auto-rotated gun sprayer, self-propelled high clearance boom sprayer, air assisted boom sprayer, air assisted electrostatic sprayer and unmanned aerial vehicle (UAV) based sprayer are available for spraying on cotton crop. Special devices, such as the portable knapsack sprayer, have been designed for manual operation has only one nozzle, which is fixed on a lance. Sprayers for crop protection can be divided as vehicle-mounted, trailed types and portable type sprayers. Vehicle-mounted sprayers generally use wider booms attached with nozzles for horizontal or vertical spraying. Horizontal boom sprayers are used to spray in field crops, while vertical boom sprayers are used to spray for vineyards and orchards. Both type of sprayers utilize air in which the nozzles spray into the air stream of a fan flow, which carries and distributes the droplets into the vineyards and orchards. Spray booms can also be mounted on drones, airplane or helicopter for application to spray on large fields.

Nozzle selection and efficient operation of sprayers is must for the better control of the pest on cotton crop. The success of control over insect-pest, diseases and weed depends upon use of proper spraying technologies (spray machine & spray method) [4]. Agrochemical may be applied at various crop growth stages of cotton during the entire crop seasons by different sprayers technology commercially available in the market. Sprayers may be designed as attachments to tractor or self-propelled power unit. Numerous types of sprayers are available i.e. knapsack sprayers, auto rotating gun sprayer, air assisted boom sprayer and tractor mounted boom sprayers, multipurpose high clearance sprayer, and recent new advance developed sprayer i.e. air assisted electrostatics sprayer, Drone (UAVs) sprayer etc.

In China and some other countries, use of UAV spraying with low altitude and low volume is increasing for the application of chemical to control insect, pest and disease in different crops. It saves time, energy and drudgery of operation with less chance of contact chemical to operator skin also avoid soil structure damage by controlling traffic over field surface.

2. Sprayers

Sprayer is a machine dispersal of fluids chemical in the form of spray droplets by using hydraulic or gaseous or centrifugal energy are commonly known as sprayers. Specification of all purpose sprayer are:

1. High clearance for tall crops.
2. Enough wide, light, flexible boom, adjustable in height.
3. Non corrosive construction to enable the sprayer to be used for all type chemical.
4. Boom section control valve.
5. Accurate ground speed indicator.

6. Flexible connections on the nozzles from the boom.

Different types of sprayers available for the protection of cotton crop are explained below;

2.1 Knapsack sprayer

Generally, knapsack sprayers are utilized for spraying on low height crops, vegetables and plant up to 1.5 meters in height (Figure 1). Different types of knapsack sprayers produce different impacts on agriculture in terms of the plant protection. Knapsack sprayers are indispensable agricultural equipment for small and marginal farmers for pest control because of affordability and ease of operation [5]. But this device has some limitations. It causes fatigue to operating person and hence cannot be used for longer time. The hand operated knapsack sprayer needs a lot of effort to move the lever up and down to generate the pressure inside the sprayer. The machine consists of lever-operated hydraulic pump to produce the desired pressure up to 3.0 kg cm\(^{-2}\). It has hollow cone type nozzle mounted on a handheld lance of 1500 mm long with effective discharge of 1.3 l min\(^{-1}\) and having a 16-liter chemical spray tank. The field capacity of this sprayer is 0.08 hah\(^{-1}\). The droplet size and percent coverage area of knapsack sprayer is as 347.85 \(\mu\)m, and 22.29%. The bio efficacy to control whitefly in cotton crop with the knapsack sprayer is varies between 65 and 70%.

2.2 Auto rotate gun type sprayer

An auto rotate gun sprayer was developed for the control of whitefly (Bemisia tabaci) in cotton crop. An auto rotate gun type sprayer [6] with two gun type nozzle (Make: Teejet) was developed in Department of Farm Machinery and Power, PAU, Ludhiana in collaboration with the industry (Figure 2). It has tractor mounted, boom with guns,
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dc motor, hydraulic piston type pump and spray tank (600 liter). Spacing between the two guns is kept 9 m. Each gun rotates 120 degree of rotation to cover about 30 m of span or working width of sprayer at liquid pressure of 35–40 kg cm$^{-2}$. These guns can be operated independently if required. There are two rotation settings (30 and 40 RPM) for each gun. The auto rotate gun sprayer were control as 85–95% whitefly nymphs in cotton crop. The droplet of auto rotate gun type sprayer having size of 250–330 micron [7]. Auto rotate gun type sprayer was preferred by the farmer as it may be used for effective spraying at earlier stage of crop and saves time, labor and cost of operation as well as it reduces drudgery of the operation.

2.3 Multipurpose self-propelled high clearance sprayer

A high clearance self-propelled 4 wheel drive high clearances drive tractors with spraying system is developed (Figure 3) and popularized by Punjab Agricultural University (PAU), Ludhiana, India [8]. It has three types of spraying arrangements namely auto rotate gun, boom type and drop up type nozzles which is operated by a single pump. The spray machine consists of a hydraulic pump, spray tank (1000 liters), pressure gauge and hydraulic assistance for controlling the boom. The pump can be operated at 800 rpm to develop desired pressure up to 35 kg cm$^{-2}$.

Boom and drop-up nozzle mechanism consists of 14 hallow cone nozzles on boom and 13 hallow cone drop-up nozzles (Make: Teejet) mounted on foldable 9.8 m wide boom with 67.5 cm nozzle spacing. Boom nozzles are used to spraying on top side of plant canopy and other drop-up nozzles which is used to spray inside the crop canopy up to 65–75 cm below from the boom and within the row or underside of leaf through adjustable drop-up arrangement of nozzle to target whitefly residing locations. The height of boom can be adjusted up in the range of 30–250 cm according to the crop height with the help of a hydraulic assistance provided.
The auto rotate gun type attachment has two guns (Make: Teejet) placed at 9.5 m apart on each end of its boom and it has coverage radius of 10 m per nozzle at limiting pressure of 35 kg cm$^{-2}$. This gun performs 120$^\circ$ rotation to cover about 20 m of swath or working width. These guns can be operated independently if required. There is a provision for adjusting vertical height of boom from target which makes it suitable to spraying for different crops at different crop growth stage.

The auto rotate gun boom type nozzles and drop up nozzles performed batter as 92–95% whitefly nymphs are killed by these spraying attachments as compared to knapsack sprayer. Auto rotate gun, drop up nozzles and boom type nozzle performed batter as 65–75% whitefly adults are killed by these type of spraying attachments as compared to knapsack sprayer as control by which only 50–65% whitefly adults are killed. Droplet size (micron) is in the range by high clearance boom type (320–380), drop up (200–320), auto rotate gun type (250–330). High clearance was preferred by the farmer as it can work at all stages of the crop and saves time, labor and cost of operation as well as it reduces drudgery of the operation.

These multipurpose high clearance sprayer can be further modified to improve self-propelled high clearance sprayer with four-wheel drive system having narrow width tires and four-wheel steering system to facilitate the operation of these sprayers in other crops like rice, wheat etc. It has two types of spraying arrangements namely boom type and drop up type nozzles which is operated by a single pump.

Safety guide lines for tractor driver to operate PAU-Multi-purpose high clearance sprayer

1. Open and close the boom smoothly without any jerks.
2. Always engage the clutch gently.
3. Before machine putting in spraying field adjust the boom height according to the crop height, it should be 30 cm above the crop height.
4. Put the appropriate gear (Low/IV) of tractor at constant engine speed (1000 rpm) during the spraying in fields.
5. Check the pressure gauge reading if found low or high adjust it should be in pressure range 18–20 bar for boom with drop-up or single boom spraying system and 30–35 bar if gun is in working.
6. Reduce speed before making a turn or applying brakes.

7. Off the cut-off valve of outside boom, left and fold the boom during turning without crop damage.

8. After completion of spraying fold the boom and exit from field carefully without crop damage.

9. While driving on road it should insure that the boom supported on stand and locked properly.

10. Open the appropriate cut-off valve while refilling of spray water tank.

11. Important nuts and bolts should be checked if any of them are loose, it should be tightened.

2.4 Drop up with air-assisted boom sprayer

The sprayer machine is tractor operated and attached with three-point linkage system of tractor. Power requirement of drop-up air assisted boom sprayer (Figure 4) is 30–35 hp. and hydraulic pressure pump of sprayer is run by PTO power of tractor. The machine consists of water tank, hydraulic pressure pump, one blower fan, foldable and height adjustable boom with air assisted and drop-up type nozzles. High-density polyethylene made water tank which have enough water holding capacity of 600 liters to minimize frequent refilling of tank resulting improve field efficiency of machine. A hydraulic pump pressure in range 15–35 kg cm$^{-2}$ bar is used to archive desire pressure range for efficient operation of drop-up and air assisted nozzle. Power from tractor PTO to hydraulic pump with gear ratio:1.6 transmitted through a v-belt drive arrangement. The pump has one suction pipe diameter of 32 mm, three outlets port of
diameters 12.7 mm and one overflow pipe with a pressure control lever and a pressure gauge. Suction pipe of pump is used to suck water solution from the water tank. Two pressure pipes with individual “on” and “off” valve were used to connect the outlets of pump to inlets pipe of drop-up and air assisted nozzle. Another one pressure pipe is used to fill water tank which connected with the suction pipe of water tank. The blower has two air stream discharge pipes diameter of 110 mm connected with air assisted nozzle boom through flexible PVC pipe diameter of 110 mm. The diameters of air discharge pipe were same as the diameter of air assisted boom pipe and this air stream opening around air assisted nozzle which improves the atomization of liquid for good spray pattern. A foldable and height adjustable boom is mounted on the rear side of spray frame which are made of 40 × 40 × 4 mm angle iron bar. The total width of boom is as 9500 mm which have five sections two each side left and right with one middle fixed section. The height of boom is adjusted from 1000 mm up to 2500 mm from the ground surface.

2.5 Back pack type air assisted electrostatic sprayer

Mobile Back Pack type (MBP) air assisted Electrostatic Sprayer powered by a 5.0 HP engine with an on-board compressor and spray gun can also be used for cotton crop (Figure 5). The engine power the air compressor and the compressor produces pressurized air which passes through conducting hose and used to atomize and propel the liquid spray. The electrostatic sprayer is equipped with a 15 liters tank which is hang on the operator’s back. For charging the spray particles in the nozzle, two 9.0 V rechargeable batteries have been provided. Air and liquid enter separately at the out-most of nozzle. Just before leaving the nozzle, the air hit the liquid stream to atomize it into spray droplets that passed through the charging ring. Spray deposition on the upper side and underside of leaves by electrostatic sprayer is 80 and 85% more than knapsack sprayer respectively. Average drift loss of electrostatic sprayer is approx.
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50% lesser as compared to knapsack sprayer. Bio efficacy of the sprayer is given as percentage of insects killed by the operation of spraying [9]. Overall bio-efficacy of electrostatic sprayers i.e. 80–85% is comparatively higher than conventional sprayer.

2.6 Drone (unamend aerial vehicles)

In modern agriculture, Unmanned Aerial Vehicles (UAVs) have been used for field mapping, surveillance, farm management etc. It is also used for remote sensing, visual inspection of crop and soil conditions etc. This technology has utility in agriculture and forestry not only for taking observation and sensing but it can also be used in spraying application. Pesticides are applied in agricultural crop fields to increase output, improve quality and decrease cost of production. However, extended direct or indirect contact with these chemicals can cause various diseases to human such as cancer, complications in the respiratory system, neuro-logical diseases, asthma, allergies, hypersensitivity, and hormone disruption. According to World Health Organization (WHO) there are 3 million cases of pesticide poison every year and up to two lakhs twenty thousand deaths in developing countries. This problem may be reduced by the use of drone to carry out the task of spraying pesticides/herbicide.

The octa-copter type UAV with configuration of 8 propellers and its self-weight about 12 kg can be used for spraying as shown in Figure 6. The UAV have maximum take-off weight capacity up to 28 kg and its flying time 15–20 minutes with two lithium polymer batteries having capacity of 16,000 mAh. The UAV have two flight mode i.e. GPS and manual. A GPS receiver can locate UAV’s exact location and altitude can be maintained by barometer. The range of remote controller has 1.5 km maximum transmission distance to control the UAVs. The UAV remote control system operates at 2.4 GHz radio wave frequency. Telemetry consisted of a radio modem and one ground control station which provide real time information during the flight. The UAV sprayer system consisted of 5–10 liters capacity tank and four flat fan nozzles having spray angle 110° were used in UAV sprayer and fitted beneath propeller. Swath width of UAV sprayer is upto 3 m with four nozzles. Transparent PVC pipes with an inner diameter of 8 mm is used; while a small independently 12 volts’ electric power pump was used to develop desire pressure of 3.0 kg cm$^{-2}$. Remote control system is used to drive the pump, vary its speed and also autonomous of UAV through the electronic system and GPS. For this function, a pulse width modulation (PWM) system is used, in which the radio signal sent from the receiver adjusts the flow rate of the spraying system. Using this, the flow rate of the nozzles can be varied between 0.10–0.25 l/min at the minimum to maximum pump speed.

Figure 6.
UAVs sprayer in cotton crop.
The bio-efficacy of drone sprayer varying between 70 and 80% to control pest in cotton crops [10]. The water application rate also lies in range of 20–50 liter per hectare. Application of pesticides with the help of UAV has advantage of its use for any crop of any season also, in covering large areas quickly. UAV (drone) allows the farmer to take advantage of very small windows of opportunity such as weather conditions or pest growth cycle. UAVs do not cause soil compaction and crop damage. Now, many countries including India has their own regulations and guidelines for the use of drone in agriculture. Recently, Government of India has released standard operating procedures (SOP) for use of drone with pesticides for the crop protection and for spraying soil and crop nutrients in agriculture, forestry, non-cropped areas etc [11].

2.7 Cost on spraying

Actual field capacity of high clearance sprayer was found as 1.78 ha/h as compared to 0.80 ha/h for gun type sprayer and 0.08 for knapsack sprayer. Similarly cost, labour and time saving by using high clearance sprayer was 66, 95 and 95% respectively as compared to knapsack sprayer. Breakeven point for the multi-purpose high clearance sprayer was calculated 300 ha/year.

3. Selection of nozzles for various application

Most of the nozzle manufactures give discharge of nozzles at various operating pressures and on the basis of the purpose of use. However, nozzles should be selected on the basis of the type of spray job, i.e. spraying of insecticide, weedicide, fungicide.
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eq{x}. Uniform distribution of chemical depends on the constant speed and proper nozzle selection and efficient operation of sprayers is must for the better control of the insect and pest on cotton crop. The success of control over insect-pest, diseases and weed may depends upon selection of appropriate spraying machinery (spray machine and spray method).

Flat fan nozzle is used for uniform coverage application such as for weed spraying (Figure 7). Hollow cone nozzles give a fine mist for complete coverage of plants being sprayed for insect control. Solid cone nozzles are used when a high pressure penetrating spray is required as for the control of whitefly in cotton. Use hallow cone nozzle which deliver 600 ml of spray material per minute for efficient pest control. Nozzle performance changes as spray materials erode the nozzle tip. Brass tips show wear about one third as fast as aluminum tip; stainless steel and some of the new plastic tips show wear only one-quarter as fast as brass. Nozzle wear is more significant in first 50 hours of use, depending on the abrasiveness of the spray material. Hence, nozzle performance should be periodically tested for changes in flow rate and spraying pressures used and for changes in spray pattern owing to nozzle tip wear.

4. Calibration of sprayers

Societal and environmental distresses as well as economics require precision application of only enough chemical to accomplish pest control. Conventional spraying technology depending on gravity force and spray droplet inertial forces often achieves less than 50 per cent deposit of the total spray volume on the plant targets and actual quantity reaching the insect or disease pest can be as low as 0.01% of the total spray volume. Hence, Air-assisted with electrostatic technology is better to achieve more penetration of spray and more uniform distribution on the plant canopies, particularly on the lower side of leaves. Calibration of the sprayer is very important to determine the effectiveness of spraying and elimination of the over-spraying. Sprayer requires too much care in calibration as various parameters affect the eventual spray concentration per acre are:

1. Pressure and delivery of pump
2. Speed of forward travel
3. Height of boom
4. Nozzle spacing
5. Concentration of spray materials

The insecticides recommended for control of sucking pests like whitefly, jassid etc., should be sprayed using 300–375 liters spray solution per hectare a with the manually operated knapsack sprayer. For calibration of a sprayer to control whitefly, let us suppose that dose of insecticides is recommended as 1500 ml/ha. Measure the nozzle discharge by collecting the liquid coming out from each nozzle in ml/min. Calculate total volume collected from 18 nozzles, let it was10 l/min. The sprayer travels at a forward speed of 4 kmh$^{-1}$. When the sprayer nozzles are spaced 67.5 cm apart on the boom and carried 50 cm above the crop canopy, the application will be uniform. Field efficiency of the sprayer is to be assumed as 50% (using Eq. (1)).
Where, \( A \) = Application rate (l/ha) of spray, \( D \) = Pump Discharge (l/min), \( F \) = Forward Speed (m/min), \( S \) = Spacing between Nozzles (m), \( N \) = No. of Nozzles, \( E \) = Field efficiency.

To find the quantity of water required for spraying, fill the spray machine tank with measured quantity of water and spray in field. After spraying, measure the area sprayed and record amount of water consumed in that area. Calculate the amount of water required per hectare by the following equation (Eq. (2)):

\[
Q = \frac{V \times 10000}{A}
\]

Where, \( Q \) = Amount of water required (l/ha), \( V \) = Volume of water consumed (liter), \( A \) = Sprayed area (m\(^2\)).

5. Automatic spray control system

Various commercial spray controllers use section control technology to auto-turn boom-section valves to ON/OFF. This technology has a potential to reduce overlapping application resulting in savings on inputs. There are two type of spray control technology available first is Automatic Section Control (ASC) and second is Boom Section Control (BSC). The ASC technology has reduced over-application of pesticides to a large extent as compared to manual control system. Applying pesticides below a desired rate may lead to yield loss. Owing to its potential to save farm inputs, its ease of usage, and improved efficacy, the ASC technology has become increasingly popular. At this rate, this technology will gradually become a part of sprayer control systems. Based on this background, it is imperative to integrate factors such as speed and flow rate with the functioning of self-propelled sprayer in order to prevent the hazards of non-uniform spraying. Varios system and part of the technology are explained below.

5.1 Spray controller

The spray controller system consists of a manifold, electronic control unit (console), proximity sensor, pressure sensor, and water hose pipes (Figure 8). Manifold is composed of several components including flow meter, liquid strainer, electric regulating valve with bypass mode, and pressure relief valve (Figure 2a). These components ultimately control the spray application rate by adjusting the liquid flow rate. Flow meter is used to measure the actual rate of flow in a system and the value of system's real time flow rate is displayed on electronic control unit in a digital readout form. A liquid strainer is fitted to filter or separate out unwanted solid matter from the liquid stream. Regulating motor rated 3 rpm which is the most accepted motor used to regulate the liquid flow rate in automated systems was used. Motor opens the valve to the maximum flow in about 6 seconds and pressure relief valves in about 10 seconds. The pressure relief valve (PRV) is designed to open at a predetermined set pressure used to control or limit the pressure which otherwise may results in process upset or system failure. The pressure is relieved by allowing the pressurized liquid to flow from an auxiliary passage out of the system.
The function of the electronic control unit (ECU) was to control the spray boom sections during real-time applications and to switch on/off the spray. The selected ECU had a provision to control five boom sections in real-time. The number of active boom sections was set to three in ECU as only 3 boom sections were used. A small display provided on ECU delivered all real-time information regarding sprayer. This system had a provision to run in auto and manual modes. The parameters like on-target application rate, number of tips on each boom sections, tip spacing, nozzle used were calibrated on ECU before the field operation.

A proximity transducer was fixed on rear tyre of high clearance boom sprayer to measure the forward speed. It works by sensing a metal object mounted in front of sensor face. The control system monitors the traveling speed and adjusts the amount of pesticide sprayed for a unit area accordingly for precise spraying applications. The analogue pressure transducer is mounted at valve manifold to monitor the overall liquid pressure. A pressure transducer generates an electrical signal which is displayed on electronic control unit (ECU) indicating the pressure imposed in the system. Pressure transducer used in this study is able to measure pressure up to 10 bar.

5.2 Installation and calibration of the automatic spray control system

A frame casing was fabricated using the angle-irons and G.I. sheet to house the manifold and sensors of the automatic spray control system. This complete unit was mounted on the high clearance sprayer such that the delicate parts were protected from the harsh operating conditions. The block diagram of the setup used to configure the automatic sprayer control system is shown in Figure 9.

Once the system was successfully installed, calibration was necessary to ensure its effective operation. To this end, different sensors and other electronic parts of the system were optimally calibrated. The proximity/speed sensor installed near the rear wheel of high clearance sprayer counts the number of wheel rotations (Figure 10a). It is calibrated by the spray controller (ECU) to provide the exact speed and spray area readings. For calibration, the tractor was made to run over a 100-meter distance i.e., point A to point B in the field after activating the calibration step of the automatic spray control system.
and pulses generated by the speed sensor were counted. Once the desired distance was covered, the speed calibration number was displayed on the screen (Figure 10b). It was saved in console memory and calibration procedure was completed.

The pressure transducer was calibrated by adjusting the pressure displayed by the ECU to the actual pressure value. To this end, an accurate manual pressure gauge was placed in the spray line close to the spray nozzles to measure the actual pressure in the system. Then, in-auto mode calibration step was activated to calibrate the installed pressure transducer and the displayed pressure was adjusted. Once the actual pressure matched the displayed pressure, calibration was initiated. The newly recorded value of maximum rating of pressure transducer, which lies between “0–10”, was displayed and saved in memory after calibration.

The calibration of flow meter sensor was performed by setting the console in auto mode and activating calibration step wherein the flow meter pulses are calculated on
the basis of a known volume of fluid passing through the flow meter. To achieve this, calibration step was activated and the sprayer pump was started. During calibration, a known volume of fluid (360 liters) was sprayed and monitored. Once the entire volume had been sprayed, the ECU was instructed to stop counting pulses. Based on the pulse count obtained, the flow meter was calibrated.

6. Spraying tips with safety precautions

Agro-chemicals are toxic to both humans and animals. However, the harm to humans and non-target animal species can be reduced, if necessary precautions are taken. Insecticides will cause maximum harm, if inhaled or ingested or if they are in direct contact with the skin. Pesticide particles can also be inhaled with the air, while they are being sprayed. Another risk is the contamination of drinking-water, food or soil with insecticide particles. Precautions should also be taken during transport, storage and handling of pesticides and spray equipment. Spray equipment should be regularly cleaned and maintained to prevent leaks. People who work with pesticides should receive proper training in their safe use. Some spraying tips along with safety precautions before, during and after spraying are mentioned below;

Before spraying:

1. Ascertain the insect, pest attack level and ascertain the damage done

2. Usage insecticide only if it has exceeded the Economical Injury threshhold Level.

3. Use only the recommended insecticide which is the less toxic.

4. Read guidelines booklet of the pesticide and equipment.

5. Check the spraying machine and fittings which are to be used.

6. Ascertain that all components are clean, especially filling and suction strainer, sprayer tank, cut off device and nozzle.

7. Replace worn out parts such as ‘O’ ring, seal, gasket, worn out nozzle tip, hose clamps and valves.

8. Test the sprayer and ascertain whether it pumps the required output at rated pressure.

9. Check the nozzle spray pattern and discharge rate. Make sure that appropriate protective clothing is available and is used.

10. Train all concerned with the application and also understand the recommendations.

11. Confirm that soap, towel and plenty of water is available at the spray site.

12. DO NOT transfer pesticides from original container and packing into another container.
13. Do not spray when high velocity of wind, high temperature and rain.

14. Never eat, drink or smoke when mixing or applying pesticides.

15. NOT EVER blow out blocked nozzles or hoses with your mouth.

16. Never allow children to be nearby during mixing.

17. NEVER leave chemicals unattended in the field.

18. Never spray if the wind is blowing towards grazing cattle or meadowlands regularly used or habitat.

During spraying:

1. Clean the spray tank and nozzles with clean water before and after the spray by running for 2–3 minutes.

2. Wear hand gloves for preparation of spray mix, full cover, full sleeve shirt and trousers during spraying.

3. Spray should be done on calm days in straight bands/stripes. Avoid spraying in heavy wind, dry (low humid) and hot environment condition as possible.

4. Always use clean water for spraying to avoid clogging in the nozzles.

5. If rate of discharge of nozzle go above by 10–15% from the initial ejection rate, the nozzle is reflected as worn out. Change the worn out nozzle.

6. Only 15 liters of water volume per acre is needed for spraying with electrostatic sprayer.

7. In case of backpack type electrostatic sprayer, electrostatic nozzle should not be lifted above shoulder height.

8. Do not touches the nozzle tip while operating the backpack type air assisted electrostatic sprayer.

9. Keep the gap of the electrostatic nozzle tip about 1 to 1.5 feet above/away from the crop canopy.

10. Take only required pesticide for the day’s application.

11. Make sure insecticides are mixed in the correct amounts.

12. Liquid formulation should be poured carefully to avoid splashing.

13. Selecting right track of spraying to avoid drift.

14. Fix nozzle and boom at a suitable height to avoid drift loss of spray.
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15. Wear full and appropriate clothing to cover yourself.

16. Avoid infection of the skin mainly eyes and mouth.

17. Follow correct spray procedure.

18. Run sprayer at accurate speed and correct pressure.

After spraying:
1. Remaining pesticides left in the tank after spraying should be emptied and disposed off in pits dug on wasteland.

2. Store the tractor in a dry, well protected place.

3. Under no circumstances empty the tank into irrigation channels or pools.

4. Never leave unused pesticides in sprayers tank. Always wash sprayer machine properly. After use, oil it and then keep always in store room.

5. Do not use blank insecticide bottles for any other purpose.

6. Damage and bury the containers in the ground preferably in a land filled dump.

7. Clean various item used to prepare spray solution like buckets, sticks, measuring jars, etc.

8. Wash yourself, protective clothing and footwear after the operation.

9. Always keep the record of pesticide usage for each crop.

10. Stop peoples to enter spray treated areas

11. Mark the sprayed fields with an appropriate flag to identify.

7. Conclusions

The following conclusions have been drawn regarding the plant protection equipment used for cotton crop;

• Bt (bacterium B. thuringiensis) cotton provides effective protection against cotton bollworms, but sucking pests namely whitefly, jassid, aphid and mealy bug are the most serious in Bt cotton and they cause maximum damage

• Major specifications of all-purpose sprayer are that it should have high clearance for tall crops, boom adjustable in height, have boom section control valve, Accurate ground speed indicator and flexible connections on the nozzles from the boom.
Multi-purpose high clearance sprayer has two types of spraying arrangements namely auto rotate gun, boom type with drop up type nozzles which is operated by a single pump.

High clearance sprayer is preferred by the farmer as it can work at all stages of the crop and saves time, labor and cost of operation as well as it reduces drudgery of the operation.

Bio-efficacy of electrostatic sprayers i.e. 80–85% is comparatively higher than conventional sprayers.

Recently, Government of India has released standard operating procedures (SOP) for use of drone with pesticides for the crop protection and for spraying soil and crop nutrients in agriculture, forestry, non-cropped areas etc.

Uniform distribution of chemical depends on the constant speed, proper nozzle selection and efficient operation of sprayers, must for the better control of the insect and pest on cotton crop.

Calibration of the sprayer is very important to determine the effectiveness of spraying and elimination of the over-spraying.

There are two type of spray control technologies available first is Automatic Section Control (ASC) and second is Boom Section Control (BSC). The ASC technology has reduced over-application of pesticides to a large extent as compared to manual control system.

Special precautions must be taken during transport, storage and handling of pesticides and equipment. Spray equipment should be regularly cleaned and maintained to prevent leaks.
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