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TESTING AND CALIBRATION OF THE AIR BLAST CITRUS ORCHARD SPRAYER FOR OPTIMUM APPLICATION

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Agriculture is back bone of Pakistan's economy and all kind of crops and fruits are grown over its fertile land. In Pakistan citrus garden area is 194.5 thousand hectares, in Punjab 184.2 thousand hectare and from this 89.7-thousand-hectare area exists under Sargodha district. The citrus is the cash crop of the Sargodha district. During last few years the quality of citrus was deteriorated due to different kind of diseases and application of pesticide/fungicide is necessary to address this issue. The conventional sprayer doesn't cover whole canopy of the plant. After micro study, AMRI introduced the air blast sprayer to abolish constraints. Air blast citrus orchard sprayer was tested and calibrated at the AMRI subdivision Sargodha. During the test field maneuverability was good and wheel slippage was 4.35%. A spray tank of 500-liter capacity has been provided and 12 hollow cone spray nozzles are arranged. Tractor (75hp) was used to test this machine, filed capacity of this machine was 7.58 acre/hr at speed 3.1 MPH and application rate of this machine was 217 lit/acre. The spray delivery rate was 19.78 L/min and per nozzle delivery rate was 1.65 L/min. A speed of 4 km/hr was recommended for optimum coverage. Full tank with a capacity of 500 liters is sufficient to cover an area of one acre.
Keywords: Citrus Orchard, Air Blast Sprayer, Hollow cone nozzles, diaphragm pump

INTRODUCTION

Citrus fruits are the world's best nutritious fruit crop which known by its special aroma. It is widely consumed directly in the form of peeled fruit as well as fresh or concentrated juice (Shie and Lay, 2013). Citrus is one of the major cash crop of Pakistan among all fruits with the production of 2.39 million tons in 2014-15 from which 97 % produced in Punjab with the production of 2.32 Mt (Agricultural Statistics of Pakistan 2014-15). It includes oranges, lemons, mandarins (Kinnow) and grapefruit, from which mandarins (Kinnow) have great importance in Pakistan due to its large 95% production rate and huge export globally (Mahmood and Sheikh, 2006). Kinnow is firstly produced by crossing fruit crop between King and Willow leaf species of Citrus Fruit. In Pakistan, Kinnow is prized 1st position in rank of all fruits due to its area and production. Pakistan ranked at 12th position internationally in terms of annual production rate. Pakistani kinnow is highly recognized due to its taste and quality in the world after Brazil and china (FAO, 2005).

In citrus garden, biochemical spray of pesticides generally practiced for protecting the plant against the bad affect of arthropod and disease pests. The density of citrus trees are greater with massive canopy than other fruit trees and even distribution of spray is very difficult so intervention of air blast sprayer meet the problem with more even distribution (Spray Drift Task Force, 1997). In this research study air blast sprayer machine is used to spray these pesticides which also known as air-carrier sprayers or mist-blowers. In this sprayer, high velocity air rather to large quantities of water is used to deliver the pesticide to the targeted area. The radial fan with high RPM that engender a large speed of air wave, which picks up the spray from the nozzles and convert it into the mist when passing through the nozzles. This citrus orchard sprayers driven with power take off shaft of the tractor (Whitney *et al.,* 1986).

The drift of spray is the most significant factor which generally dependent upon the spectrum size of droplet and predominant conditions of weather (Fox *et al.,* 2000). In commonly, the droplets with smaller size and wind with higher blast pressure tend to produce the increase potential of drift in applications. The droplet size is remarked as a variable in terms of functional parameters of equipment design and properties of mixer tank (Akesson and Gibbs, 1990). By increasing the hydraulic pressure of nozzle or rotating vaporizer speed produced smaller spectrum size of droplets (Stover, 2002).

An early stage spraying of citrus trees were generally done with hand-held Knapsac hydraulic sprayer. This method of spraying was usually stated as thin spraying. The application rate of spray changes from 160-400 gallons per acre (GPA), which depends on the size of tree and inter spacing (Reichard *et al.,* 1977). The defined amount of pesticide will be mixed in 100 gallons of water which is recommended as standard.

These types of air blast sprayer machine primarily used for spraying single trees or minor clusters of trees. It is rarely applied in big, salable orchards. Sometimes, air-blast sprayers are known as focus sprayers, because air and water distributed the spray exact ally to the required target. This confirms that equal distribution is gained by using less amount of water. Application rates per acres of insecticide are generally stated in a specific amount of insecticide to be applied. Insecticide concentration ratio varies which depends upon the type of sprayer used. Air-carrier sprayer generally utilizes small amount of water per acre than watery sprayers. Though the water amount is reduced but the quantity of pesticide remains the same as applied per acre, or per tree.

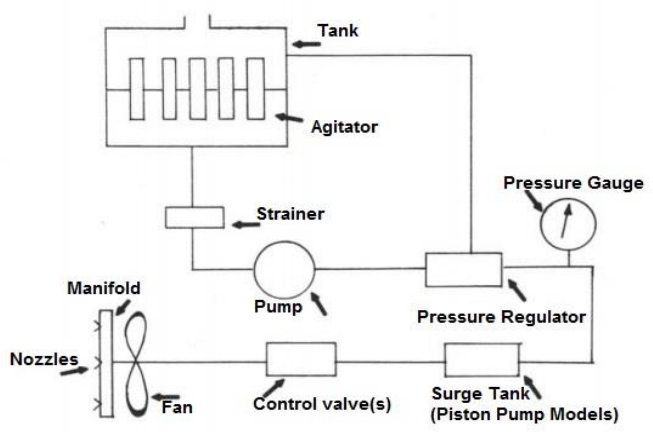

Figure 1. Schematic diagram of air blast sprayer with all components

Figure 2. Air blast sprayer in citrus garden under working condition

***Nozzles*:** Nozzles are the utmost significant component of any spray machine. Hollow cone nozzles are generally used in the citrus orchard air blast sprayers which produces droplets in small size. The nozzles which produced bigger droplets are arranged/set at the top and the nozzles which produced tiny droplets are fixed at the bottom for maximum coverage. This type of format is planned to distribute the 70% amount of the spray to upper third portion of the targeted citrus tree (Clark and McGuckin, 1996). Set the position of nozzles in the air blast sprayer machine so that spray droplets/mist cover the whole canopy of tree from top edge to bottom edge. Nozzles angles sets according to the plant canopy, turn off that nozzles which waste the spray in the air or on to the ground (Stover and Salvatore, 2002a). Nozzles checks regularly because it wears out so quickly and replace at least once a year.

MATERIALS AND METHODS

Numerous factors were considered and selected in this research study to test the functioning of air-blast sprayer on citrus trees. These factors were discharge volume, forward speed of tractor, field capacity, field maneuverability, wheel slippage, tree spacing, tree height and liters of spray applied per acre.

Main specification of sprayer:

Dimension Length * Width * Height (in)	52 * 44 * 46
Tank capacity.	500 lit.
Tank material.	Fiber glass.
No. of nozzles.	12
Nozzle type.	Hollow cone
Pump type.	Diaphragm
Blower dia.	700 mm.
No. of blower wings.	10
Blower RPM.	1600
No. of belts.	3

Field layout:

Tree to tree distance (ft)	20 x 20
Avg. plant height (ft).	13
Effective Width (ft).	20

Others:

Tractor used.	Fiat-640
Type of spray	Fungicides.
Total spray of the years.	Depends on disease.
Labor used.	2 people.

Figure 3. Pre-inspection and maintenance of Air blast sprayer machine

***Testing of air blast sprayers*:** Systematic test on the machine was conducted keeping in view the following points and variable.

***Field capacity*:** To get the optimum field capacity of the sprayer the idle time were minimized by implementation of all possible efforts through proper planning and selecting the length wise row. Less turning also increases the field capacity of the machine.

The parameter recording data as under:-

Field capacity = S = $\frac{A}{(T_p + T_1) * (12.1)}$ (i)

Where;

S = Field capacity effective ($\frac{\text{acre}}{hr}$) .

A = Covered area (acre).

T_p = Total productive time (sec).

T_1 = Non-productive time (loss of time during turning, loading and adjusting excluding trouble shooting and refueling).

Note: 12.1 is used as a conversing factor to covert (sq. feet per second) $\frac{ft^2}{sec}$ into acre/hr.

***Forward Speed of Tractor*:** Tractor forward speed is a key factor to get superlative results. It was observed that growers operate the air blast sprayer at variable forward speed rather than optimum speed. Tractor operator generally travel in high speed to cover the more area in acres as quick as possible. Travelling at fast speed gave scarce coverage, on the other hand travelling at slow speed, resulting in too much spray being applied (Salyani and Wei, 2005). Generally, travel speed of 4 km/hr is recommended ideal speed for spraying in citrus orchard with this sprayer machine. Tractor forward speed during operation depending upon the different factors viz; trees size, density of trees and type of sprayer used. In the early stages of newly planted citrus garden the size of trees are small so spray could be applied faster because air penetration inside trees are less critical. The thrust of air parting the sprayer is greatly reduced while tractor moving more than 6 km/hr (Ghate and Perry, 1994), which caused the upper part of tree canopy uncovered (dry), while the amount of spray applied on each tree remained same. Air thrust velocity reduces hastily as the distance between fan outlet and tree increases. Take heed on this, because for spray to reach the outermost portion of the plant canopy time is required. Distance between plant to plant should be factor of determining for selection of optimum tractor operating speed. Mark two points and measured the distance between them, operate the machine and note the time consumed from start point to end marked point. This reflects the conditions under which spraying is applied. Tractor forward speed can be calculated by using the (ii) & (iii) formulas.

The formulas used to compute travel speed:

Speed (MPH) = $\frac{Total\ distance\ travel\ (Ft) * (.682)}{Total\ time\ required\ (Sec)}$ (ii)

Speed (km/h) = $\frac{Total\ distance\ travel\ (m) * (3.6)}{Total\ time\ required\ (Sec)}$ (iii)

Note: 0.682 is constant which used as conversion factor to convert $\frac{ft}{sec}$ to MPH.

3.6 is a constant factor which is used to convert $\frac{m}{sec}$ to km/h.

***Wheel slippage*:** During the operation the unevenness of the field and due to the load there is somewhat slippage that reduces the field capacity and causes the wastage of some amount of spray.

The wheel slippage is calculated

% of the wheel slippage = $\{\frac{A-B}{A}\}$ x 100 (iv)

Where,

A = No. of turns of tractor rear wheel with load

B = No. of turns of tractor rear wheel without load

***Application rate of spray (L/ha)*:** Firstly, measure the distance between rows (row width). When spraying both sides during forward travelling in every row then the row width is the space between the two consecutive rows. When spray is applied only one side during forward travelling in every row then the row width is measured from the center of the row to the tree line. Spray application rate was calculated using the (v) & (vi) formula:

Application rate (L/ha) = $\frac{600 * total\ sprayer\ output\ (\frac{L}{\min})}{row\ width\ (m) * travel\ speed\ (\frac{km}{h})}$ (v)

Application rate (L/ac) = $\frac{498 * total\ sprayer\ output\ (\frac{L}{\min})}{row\ width\ (ft) * travel\ speed\ (MPH)}$ (vi)

Note: 600 is conversion factor for calculation of application rate in liter per hectares.

Note: 498 is conversion factor for calculation of application rate in liter per acre.

***Field maneuverability*:** The field maneuverability is the term that means how easily the machine during the operation turns in the field by losing less time.

RESULTS THE DISCUSSION

The different parameters viz. field capacity, wheel slippage, travel speed, fuel consumption and application rate were calculated. The real volume of spray applied on per acre will fluctuate if forward velocity of tractor or interrow space varies. When nozzle flow rate changes then errors will also be occurred due to nozzle wearied or blockage instigated by contamination in the pesticide mixture or pressure changes.

Field capacity	7.58 acre/hr
Application rate	217 lit/acre
Wheel slippage	4.35 %
Travel speed	3.1 MPH (4.96 Km/h)
Field maneuverability	good
Plant coverage	Full plant

***Field capacity*:**

Area covered = 15600 ft²

Time (T_p+T_1) = 170 sec

S = $\frac{A}{T_p + T_1}$ = $\frac{15600\ ft^2}{170\ sec}$ = 91.76 x $\frac{3600"}{43560}$ = 7.58 acre/hr

Wheel slippage: A (No. of rear wheel turns with load) = 23
B (No. of rear wheel turns without load) = 22
% of the wheel slippage = $\{\frac{A-B}{A}\}$ x 100
% of the wheel slippage = $\{\frac{23-22}{23}\}$ x 100 = 4.35 %

Travel Speed: Distance covered = 200 ft
Time = 44 sec
Speed (MPH) = (Feet / Second) x .682
= (200/44) x 0.682
= 3.1 MPH or = 4.96 km/hr

Spray Application rate:
Row width = 20 ft
Spray consumed = 500 lit
Area covered = 2.3 Acre
Application rate = 500/2.3 = 217 lit/acre

Application rate (L/ac) = $\frac{498 * total\ sprayer\ output\ (\frac{L}{min})}{row\ width\ (ft) * travel\ speed\ (MPH)}$
Delivery rate = 19.78 L/min

Table 1. At different tractor forward speeds the following parameters i.e. un-covered area%, field capacity (acre/hr), fuel consumption (Lit/acre) were calculated

Sr. No.	Tractor Forward Speed (Km/hr)	Un-covered Area (%)	Field Capacity (acre/hr)	Fuel Consumption (Lit/acre)
1	3	4.25	4.50	2.5
2	4	6.40	6.00	3.2
3	5	8.20	7.58	4.0

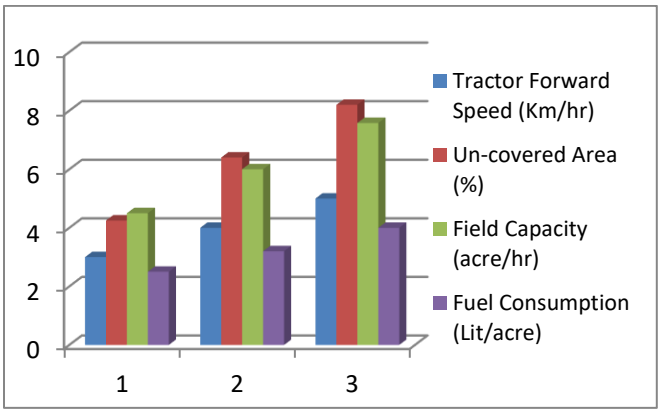

Figure 3. Graphically representation of calculated data of air blast sprayer.

The air blast sprayer was operated at three different forward speeds i.e. S1= 3 Km/hr, S2= 4 Km/hr and S3= 5 Km/hr. Effects of forward speed of tractor was studied on un-covered area, field capacity and fuel consumption. Higher wheel slippage (4.35%) was observed at forward speed of 4.96 km/hr and un-covered area (8.2%) that was probably due to relatively high tractor forward speed, field capacity (7.58%) and fuel consumption rate was 4 Lit/acre. This research study based on field calculated results showed (table 1) that at S2= 4 Km/hr was considered ideal forward speed of tractor for optimum coverage, under un-covered area (6.4%), field capacity (6 acre/hr) and fuel consumption (3.2 Lit/acre).

Actual amount of spray applied per acre will be changed and affect the machine distribution efficiency in turning during the start and end of the each rows. When rows interspacing changes and trees are not planted in a symmetry then precisely calibrate of sprayer is very difficult. Travel speed should be selected uniform for the optimum coverage. Check all the nozzles before spraying and replace out the defected one for effecting spraying. An agitator system should also be investigated to ensure that the system is working properly and homogeneous mixture of spray is applied.

***Benefits of calibration*:** Actual spray application rate 217lit/acre was calculated by calibrating the machine. This data is essentially required to calculate the specific amount of pesticide, time, fuel, and tractor forward speed are required on per acre. By having these information, it also be calculated that how much pesticide tanks are required for the specific work.

The application rate of spray changes for different type of orchards e.g. different tree spacing's and stages, elevation and thickness of orchards. Thus, standardization is necessary for every fruit garden or crop. In the long run, it will save more money and time will give more effective and precise results.

Conclusion: The delivery rate of sprayer was 19.8 L/mint, now it is concluded that for optimum application tractor would be operated at speed of 4 Km/hr at this limit 500 litre tank will empty after covering the 2.5 Acre in 25 mints needs refill, with low fuel consumption rate 3.2 L/ac. It is also concluded that blower with greater speed (1600 rpm) produced larger blast of air drift to quake the tree for inside application of spray to destroy the internal colonies of pests and fruit flies.

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