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EFFECTS OF LIQUID FLOW AND AIRFLOW RATES ON SPRAY MASS FLUX ON ORCHARD TREE CANOPIES

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Abstract
A study was conducted in the orchard research farm of the National Open University of Nigeria, to investigate the effects of sprayer liquid flow rates and airflow rate on spray mass flux of citrus tree canopies. Results showed that an increase in both the liquid airflow rates of the sprayer with a corresponding increase in spray mass flux. The maximum attained value of spray mass flux of 7.20 kg\m^{2}s was obtained at a liquid flow rate of 0.005m^3/s and an airflow rate of 0.51m^3/s at a specified distance away from the tree canopy boundaries and decreased at the lowest of spray mass flux of 1.46kg/m^{2}s at liquid and airflow rates of 0.0022m^3/s and 0.132m^3/s at a distance of 1m from the sprayer due to air entrainment at spray jet boundaries, droplet settlement and decrease in spray velocity. The regression analysis showed a high linear correlation of spray mass flux with a coefficient of determination of 0.84 and 0.99 with liquid flow rate and airflow rate, respectively. These findings will help in obtaining the effective distribution of disease and insect control agents at the target in above and below-ground applications, amongst other advantages.
Keywords: Canopies, spray velocity, droplet size, spray mass

Introduction

Modern improved techniques were discovered for pesticide and plant protection products. At the beginning, the distribution of agrochemicals was shared flawlessly in the gardens, due to the dose of each unit ground area being expressed as a dose rate and their application explains the realistically approach where pesticides are delivered to their original biological goals (e.g. pest organism, harvest, or another plant) (Shani, 2020). Shani, (2021) also reported that public concern with the use of pesticides has emphasized the requirement to make this process as effective as possible, to minimize their discharge. The most calculated solutions for improving spray control and reducing drift losses are by adjusting the air outlet of the sprayer that matches the canopy of the crop. Taking this approach to the extreme development of air-assisted sprayers, in which shield rows and recycling systems have the full edge of the target spray liquid (Shani, 2020). Air-blast sprayers have alterations in air delivery methods and the fluid which allow tailoring of the software to match a range of orchard requirements (Locke, 2013).

Pesticide applications aim at depositing the highest possible amount of the active ingredient on the target surface (e.g., the leaf), where the target pest resides and/or feeds (Mathew *et al*., (2014). Despite having state-of-the-art sprayers, a number of pesticides can drift through the air or can be lost to the ground (Balsari *et al*. (2017). Pesticide drift and losses to the ground result in environmental pollution, and tools are being developed to measure and reduce off-target losses (Cross *et al*., 2001). The management applications of pesticide are influenced by the following factors; the cost of orchard pest control and its effectiveness, the abilities of sprayer operators and supervisors to assess orchard requirements, and change operating methods and machine configurations to maximize the performance of sprayers (Shani, 2008), observed that other significant differences are the much greater distances between nozzles and targets in orchard spraying and the amount of air used to carry spray to the tree. Jadav *et al.* (2019) reported that sometimes, many researchers analysed and developed dose models for orchards, groves, and vineyards. Recent trends in air-assisted spray applications are based on the use of non-conventional sprayers to increase treatment options and reduce pollution. A poor match appeared between the conventional air blast sprayer and the plant geometry in losses of insecticide.

According to Farooq (2001), for harvest applications employing standard sprayers, spray sediment in the plant canopy is dependent upon droplet size, droplet speed, spray volume rate, wind speed, and tree construction. While Miller and Ellis (2000) stated that the droplet size is dependent upon atomizer form, nozzle pressure/atomizer rate, liquid flow rate, liquid components and atmospheric temperature and relative humidity. The broad objective of this study was to establish the effect of liquid flow rate and airflow rates from the sprayer on the spray mass flux on the canopies of the tree.

Materials and Methods

Brief Description of Experimental Site

The experiment was conducted at the Orchard Farm of the Faculty of Agricultural Sciences, National Open University of Nigeria, km 4, Zaria-Kaduna Expressway, Barkallahu, Kaduna, Kaduna State. The study area occupies part of the Central position of the Northern part of Nigeria (with Kaduna as its capital) and shares common borders with Zamfara, Katsina, Niger, Kano, Bauchi and Plateau States. To the South-West, the State shares a border with the Federal Capital Territory, Abuja. The global location of the State is between longitude of 30E2 east of the Greenwich meridian and also be-tween latitude 0900 and 11 30E2North of the equator. The State has a land area of approximately 48,473.2 square kilometres.

The research farm also is located within 6 km and 84 km distances from the Kaduna town respectively. The area altitude ranges between 2,200-1,850m above sea level and average temperature varies between 20 and 35°C. The Rainfall range is between 950 to 1,400 mm per year.

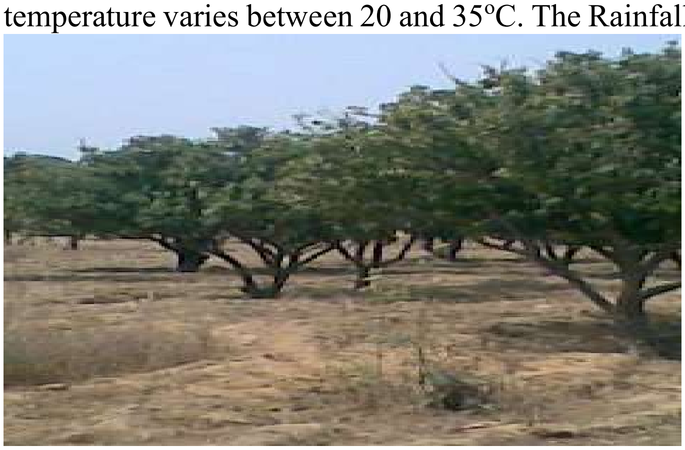

Plate 1: Picture of the tree crop used for the experiment

Experimental Materials

The materials used for the experiments were motorized mist blower, manometer, anemometer, tachometer, measuring tape, photographic papers or tracers, stopwatch, and trees of various sizes (see plate 1) the orchard farm. The sprayer was calibrated in the crop protection machinery laboratory of the Agricultural Engineering Department, Ahmadu Bello University, Zaria, Nigeria. The Sprayer used for this study was a tuber super K90 motorized knapsack mist blower (see plate 2)

Plate 2: Picture of the motorized mist blower

The machine consists basically of a pesticide and fuel tank (tank unit) of 11.81litres and 15litres capacities, respectively and tank units operated by small powered two-stroke engines. Extending from the fan casing are air discharge hoses, which extend to the gaseous energy nettles. Pesticide coming from the tank by gravity passes down through delivery tubes and restrictors to the nozzles where it is atomized by the high-velocity air from the fan.
The experimental treatments included:- low (0.0022 m^3/s, 0.132 m^3/s), medium (0.0047 m^3/s,0.33 m^3/s), and high (0.006 m^3/s ,0.56 m^3/s) liquid and air flow rates;- leaf side: upper and under side;- leaf location: outside and inside;- height range in the canopy: H1: 0.55 to 0.95 m, H2: 0.95 to 1.45 m, H3: 1.45 to 2.00 m; was added as a third subplot factor

Measurement of Sprayer Parameters
Air flow rate at outlet (Q_a)
A pitot tube manometer at 56 nodes was used to measure the airflow rate, at different speeds at the sprayer outlet of the sprayer. The recorded data are presented in table 1

Table 1: Presentation of Results of various Experimental Trial

No. of Restrictors	Amount of Spray collected	liquid Flow Rate (m^3/s)	Airflow Rate (m^3/s)	Ground Speed
1	0.0032	0.0022	0.132	0.8
2	0.0043	0.0033	0.197	1.6
3	0.0052	0.0042	0.237	2.4
4	0.0054	0.0044	0.283	3.2
5	0.0057	0.0047	0.33	4.0
6	0.006	0.005	0.35	4.8
7	0.0064	0.0053	0.44	5.6
8	0.0066	0.0056	0.49	0.8
9	0.006	0.005	0.51	1.6
10	0.007	0.006	0.56	2.4

Liquid flow rate

A laboratory test was conducted to determine the liquid flow rate of the sprayer in view as shown in table 1.

Test Procedure

The flow rate test was carried out on the machine using various restrictors and water as a test fluid. The tank was filled with water and flow rates of high volume nozzle were determined at different restrictors' settings

Determination of Spray Mass Flux

The spray mass flux upon entrance to the canopy was determined using the following procedure. The sprayer was run at a selected speed of 0.8km/hr. then spraying was done initially on the ground to obtain the swath width at that speed then at the same speed, spraying was done for 20s while the spray was collected in a container and spray was collected and measured to from (0.0032 to 0.007m^3/s (see table1)

Table 2: Results for Determination of Spray Mass Flux

S/N	Weight (kg)	Area (m^2)	Time(s)	Ground speed (m/s)	Spray mass flux (Kg/m^2)
1	0.1	1.01	5	0.8	1.02
2	0.2	1.15	10	1.6	4.00
3	0.3	0.96	15	2.4	4.78
4	0.4	0.90	20	3.2	5.05
5	0.5	0.96	25	4.0	5.10
6	0.6	0.94	30	4.8	5.15
7	0.7	0.87	35	5.6	5.39
8	0.8	0.94	40	6.4	5.20
9	0.9	1.01	45	7.2	4.99
10	1.0	0.96	50	8.0	5.26

The test was repeated for various readings of speed and as presented in Table 2 above. Subsequently, the spray mass flux was determined by calculation using the simple formula as stated by Farooq (2001) given as; Spray Mass Flux = weight (Kg) over the area (m^2) covered over a certain time (s), after the area of spray was determined also using simple mathematical express of (L x W x H), where L = length, W = width and H= height and taking into consideration that spray mass flux is a function of the amount of spray in kilogram over the area at a given time.

Results

The results from table 1, figures 1 and 2 showed that the increase in both the liquid and airflow rates of the sprayer showed an increase in spray mass flux. The maximum attained value of spray mass flux of 7.20 kg/m^2s was obtained at a liquid flow rate of 0.005m^3/s and air flow rate of 0.51m^3/s at a specified distance away from the tree canopy boundaries and decreased at the lowest of spray mass flux of 1.46kg/m^2s at liquid and airflow rates of 0.0022m^3/s and 0.132m^3/s at a distance of 1m from the sprayer due to air entrainment at spray jet boundaries, droplet settlement and decrease in spray velocity. The interactions of the main factor Spray Mass flux with all other sub factors (liquid and air flow rates) were not significant. However, all other secondary effects, related to the canopy structure, were statistically significant, indicating that spray deposits were not uniformly distributed over the canopy.

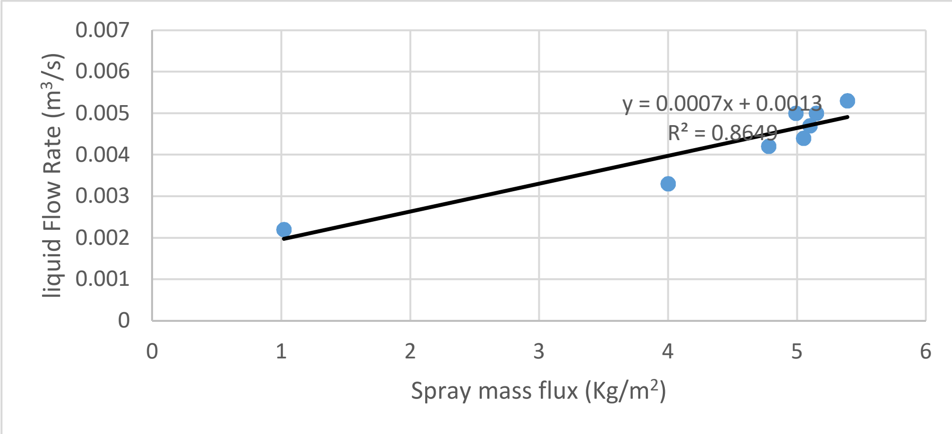

Figure 1: Effect of liquid flow rate on spray mass flux

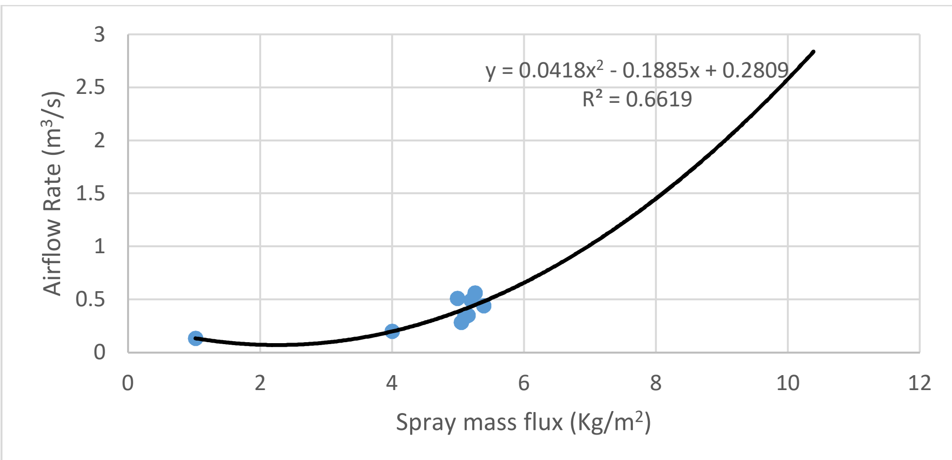

Figure 2: Effect of airflow rate on spray mass flux

Discussion

Based on the present data, it was not possible to determine whether the observed effects were entirely owing to the different air volumes, or to some extent to the different air velocities at different canopy levels. The regression analysis showed a good correlation of spray mass flux with a coefficient of determination of 0.87 and 0.67 with liquid flow rate and airflow rate, respectively. In fact, both quantities were closely associated in this type of sprayer, as in most commercial air blast sprayers, and could not be adjusted independently. Anyway, excessive energy in the air current might have reduced the ability of the foliage to retain or to collect the droplets, e.g. by deflecting the leaves so as to reduce their section, normal to the direction of the spray flux as suggested by Pergher (2005). The reasons for this relationship might be because of the higher velocities impact of spray that is sufficient enough to cover that distance with enough spray deposits on the canopy. Farooq and Salyani (2002) found similar results in the lower part of the canopy with the light foliage of the citrus tree.

The results from the experiments indicated that air-assistance was necessary to improve deposition on leaf undersides, which may be important in order to ensure sufficient control of those fungal diseases, such as downy mildew, that preferably infect through the stomata (generally much more abundant on the lower epidermis of leaves). A higher Liquid and air flow rates ($0.006m^3/s$, $0.56m^3/s$) might be preferable in this case, because of reduced deposit variability. On the other hand, a lower liquid and airflow rate ($0.00022m^3/s$, $0.132m^3/s$) would give similar deposition of maximum of $5.2kg/m^2$ on the leaf undersides, while improving the coverage of the upper sides, thus ensuring better control of pests or diseases that preferably attack there (such as powdery mildew). More importantly, a reduced air flow rate would decrease the potential for spray drift, particularly because of the higher proportion of spray volume that is deposited on the canopy. The effects of the airflow rate treatments on spray mass flux deposition were comparably smaller at initial than at the earlier stage. This had been observed before (Pergher, 2005 and 2006), and seemed to be related to the reduced mobility of older, thicker leaves, as well as of the shoots, which at this stage were laden with grapes. Because of this, a low ($0.132m^3/s$) air flow rate may be recommended even at this stage, because of reduced drift potential, and power consumption of the fan.

The Liquid and Air flow rates of the sprayer showed a significant effect on spray mass flux, and distribution but were conspicuously greater at a lower the Airflow rate. In an air-assisted sprayer, increasing flow rates significantly increased drift force and increased tree canopy area in spraying thereby increasing the Spray mass flux. The efficiency of spray mass flux increased with an increase in blower speed and Liquid flow, this agrees with Jadav (2019). The conveying efficiency of spray particles, penetration, and distribution of pesticide was increased with an increase in operating pressure. The performance of the sprayer was found better with an increase in operating pressure (1 to 15 kg/cm^2) of spraying.

Conclusion

The study was carried out on the use of pesticides due to the economic and environmental cost on plants and humans. This study has shown a high linear correlation relationship between sprayer performance parameters (liquid and airflow rates) and sprays mass flux. The relationships could be used on other tree crops using other types of sprayers. The research project will help in obtaining the effective distribution of disease and insect control agents at the target in above and below-ground applications; obtaining prompt and effective delivery to the sites of action once the control agent arrives at the target; minimizing off-target loss of control agent and determining the fate of material that does go off target; sensing, detection, and tracking of pest populations to determine if, when, where and how to control treatment should be applied and optimizing interactions in pest management programs for orchard nursery crops with reduced production cost and improved environmental stewards. It is recommended among other things that further analysis should be carried out to study the effect of Liquid flow on spray depositions leaves.

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