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Performance of knapsack sprayers on uniformity of insecticide application and on control of *Aedes aegypti* (L.) (Diptera: Culicidae)

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Summary

Dengue fever is an acute infectious disease of short duration and variable severity, caused by a virus transmitted by the mosquito *Aedes aegypti* (L.). It occurs mainly in tropical and subtropical areas of the world. In Brazil, the social and environmental conditions are favourable to the expansion of *A. aegypti* and allowing the dispersal of vector and the increase of the disease.

The technique most used for mosquito control is the application of insecticides with knapsack sprayers, which often have shown difficulties in use, due to the size and shape of equipment, and variations in the control effectiveness due inadequate characteristics of the spray.

In this study we aimed to evaluate and compare the diameter and uniformity of droplets produced by two knapsack sprayers with different concentrations of water and oil in tank mix, to the mosquito control.

The experiments were performed in the Department of Crop Protection, UNESP – Jaboticabal – SP, Brazil. The insecticide Malathion 500 EC (1 mL L^{-1}) was applied by two sprayers (1. rotary spraying nozzle; 2. pneumatic nozzle). Both sprayers were positioned in a laser diffraction particle size meter, at a distance of 40 cm from the laser beam to assess diameter and uniformity of droplets. Water plus malathion received six concentrations of oil (0, 6.25, 12.5, 25, 50 and 100%). The parameters were: volume median diameter (VMD), coefficient of uniformity and percentage of volume with droplet less than 15 µm. Data were subjected to analysis of variance and averages were compared by Tukey test (P<0.05) in a fully randomized design.

In another experiment, an application was made in a room with mosquitoes held in cages. The evaluations were made immediately and 24 h after application. The mortality outcomes were compared by Tukey test (P<0.05) and the efficiency were estimated by Abbott's formula.

We conclude that the pneumatic nozzle showed greater uniformity and adequate droplet size compared to rotary nozzle efficacy in the control of *A. aegypti*, in the oil concentration of 12.5%.

Key words: Droplet, public health, dengue fever and mosquitoes

Introduction

Spatial application technology is the most used to control the winged form of the mosquito *Aedes aegypti*, using droplets with aerosol size, suspended in the air long enough to achieve an effective dose on insects during the flight (ABNT, 1988; ASAE, 1996). Studies on small droplets sprayed are necessary to determine the efficacy of treatments with less risk to population (Tambellini, 2006). The best possibility for reaching the target happens when the uniformity of droplet spectrum has an appropriate size (Bals, 1978).

There is a governmental issue in Brazil to limit aerosols to have less than 20% of droplets with less than 15 µm to observe a safety environment (ANVISA, 2005).

The aim of this study was to evaluate the effect of two knapsack sprayers with rotary and pneumatic nozzles on the mortality of *A. aegypti*, the volume median diameter, the uniformity of the drops and to the percentage of the volume in droplets smaller than 15 µm, in different oil concentrations in the tank mix.

Material and Methods

Description of the equipment used in the experiments

(a) *Canon Sprayer* made by Sistemas de Pressurização de Fluidos Ind. Com. Ltda (*pneumatic nozzle*): Portable motorized backpack sprayer, being developed for use to control of vectors of endemic diseases. Spray tank manufactured in polyethylene with volumetric capacity for 1.5 L. Engine connected to a 12 V battery and 5 A.

(b) *Multispray* made by Máquinas Agrícolas Jacto S.A. (*rotary nozzle*): Portable motorized backpack sprayer, used for the control of vectors of endemic diseases. Spray tank manufactured in polyethylene with capacity for 13.0 L. Two stroke engine operating on gasoline, air cooled with electronic ignition.

Evaluation of volume median diameter of droplets

The experiments were conducted at the Laboratory of Particle Size Analysis (LAPAR), Department of Crop Protection, UNESP, SP, Brazil from January to July 2009. The insecticide used was Malathion CE 500 (organophosphate) at a dose of 1 mL commercial product (c.p.) L^{-1} of water, which was applied with both sprayers described above, with nozzle producing droplets positioned at a distance of 40 cm from the laser light beam. For the measurements a particle size analyser (Mastersizer S, version 2.19, from Malvern Instruments Ltd) was used. The spray liquids with malathion were prepared with water and different concentrations of edible soybean oil (0, 6.25, 12.5, 25, 50 and 100%), as practiced by SUCEN - Endemic Control Superintendence, Sao Paolo State Health Department, Brazil. This analyser is based on measurement of light – laser beam – that undergoes diffraction during the passing of the droplet at the device sampling region (Schick, 1997). The device has an optical unit which detects the diffraction pattern of light hitting a set of particles. To the smaller particle, the greater is the degree of diffraction of the light beam. The parameters evaluated were: Dv0,5 – droplet such that 50% of the volume of liquid sprayed is constituted of droplets of larger size or smaller than this value, also known as volume median diameter (VMD), coefficient of uniformity (SPAN) and percentage of volume applied of droplets in diameter equal or less than 15 µm (ANVISA, 2005). The value of the coefficient of uniformity indicates the uniformity degree of the droplets, being maximum uniformity when the coefficient is equal to zero. Particles with VMD between 10 µm and 50 µm are recommended for insects in flight (Matthews, 2000). These results are used to adjust and suggest development of the sprayers in order to obtain the desired range of droplet diameter. The droplet diameter data were submitted to analyses of variance and averages were compared using Tukey's test ($P<0.05$). The experimental design was completely randomized plots with six treatments and four replications.

Control of Aedes aegypti

The mosquitoes used were the Rockefeller strain, considered sensitive, raised by Department of Zoology, Institute of Biology, UNICAMP, Campinas – SP, Brazil. They were kept in cages and fed with a 10% solution of honey mixed with water. To complete the reproductive cycle, the females were fed with human blood meal. The experiments were performed at Department of Crop Protection, UNESP, Jaboticabal – SP, Brazil. The insecticide used was Malathion 500 CE mixed in six concentrations of oil (0, 6.25, 12.5, 25, 50 and 100%) in water. The cages containing mosquitoes were placed into a room. The application happened from outside to inside the room, placing the nozzle facing the window of the room. The room measured 2.5 m in length × 1.5 m wide. The cages were arranged at the top of a box with 40 cm height. The spraying had a time of three seconds for each repetition. The cages used were the same type used by SUCEN (2006). Twenty five female adults mosquitoes were used per treatment with four replications. After spraying, the cages remained inside the room that had received the spraying for 5 mins. Then the air inside was removed to outside through the door before the next application by using a fan device for another 5 mins. The evaluation of mortality of mosquitoes was conducted immediately after application and after 24 h, counting the number of dead insects inside each cage. The mortality outcomes were compared using Tukey's test ($P<0.05$) and treatment efficiency by Abbott's formula (Abbott, 1925).

Results and Discussion

Evaluation of volume median diameter

The pneumatic spray nozzle had greater uniformity of droplet size than the rotary nozzle (Fig. 1). For the rotary nozzle, the higher uniformity occurred for the treatments with 6.25, 50 and 100% of oil. For the pneumatic nozzle, there was no significant difference between uniformity of droplets with or without oil.

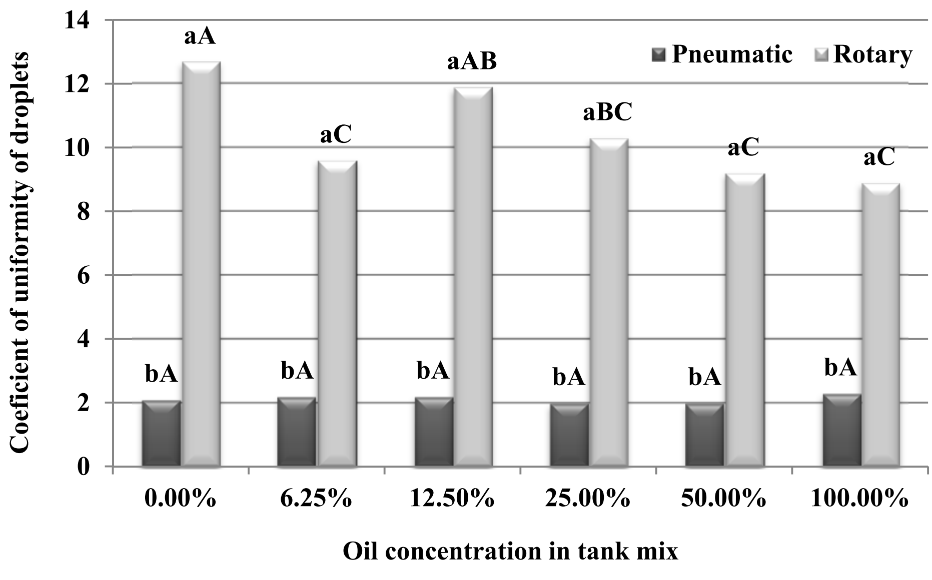

Fig. 1. Coefficient of uniformity of droplets sprayed by different nozzles and concentration of oil in tank mix. Jaboticabal, SP - Brazil, 2009. Averages followed by the same lowercase letter (type of nozzles into concentration of oil), and uppercase letter (concentration of oil into type of nozzle) do not differ by Tukey test at 5% probability.

The two types of equipment produced less than 20% in volume of droplets with a diameter less than 15 µm (Fig. 2). Fine droplets (lower than 15 µm in diameter) are usually not deposited on any surface, but remain in the air (Matthews, 2000), thus becoming available for inhalation by people, especially indoors. For registration of a safe condition to household aerosol insecticides in Brazil, the ANVISA – National Agency of Sanitary Vigilance in Brazil - establishes a maximum limit of 20% of the volume with droplets smaller than 15 µm (ANVISA, 2005). According to

Rimel & Moore (1967), 93% of droplets that land on insects are less than 50 µm in diameter, with the majority of the droplets being deposited on the wings and antennae (Lofgren *et al.*, 1973). According to Takebayashi (1998), the diameter considered good for efficacy to control of mosquitoes and flies is set within the range 30 to 55 µm.

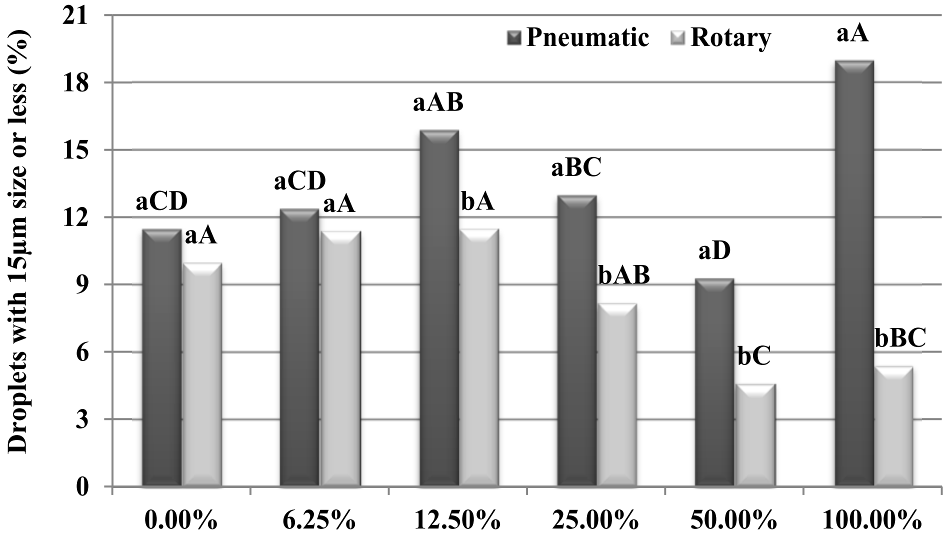

Fig. 2. Percentage of spray volume in droplets with 15 µm or smaller, sprayed by different nozzles and concentration of oil in tank mix. Jaboticabal, SP - Brazil, 2009. Averages followed by the same lowercase letter (type of nozzles into concentration of oil), and uppercase letter (concentration of oil into type of nozzle) do not differ by Tukey test at 5% probability.

So both nozzles are in accordance with these criteria from 0% to 25% oil in tank mix. Rotary nozzle resulted in a bigger VMD for concentrations of 50% and 100% of oil, while pneumatic nozzle results in all values smaller than 50 µm (Fig. 3). However, for the treatment with 0% of oil there is no significant difference between the two devices, but the differences become bigger as the oil concentration increases.

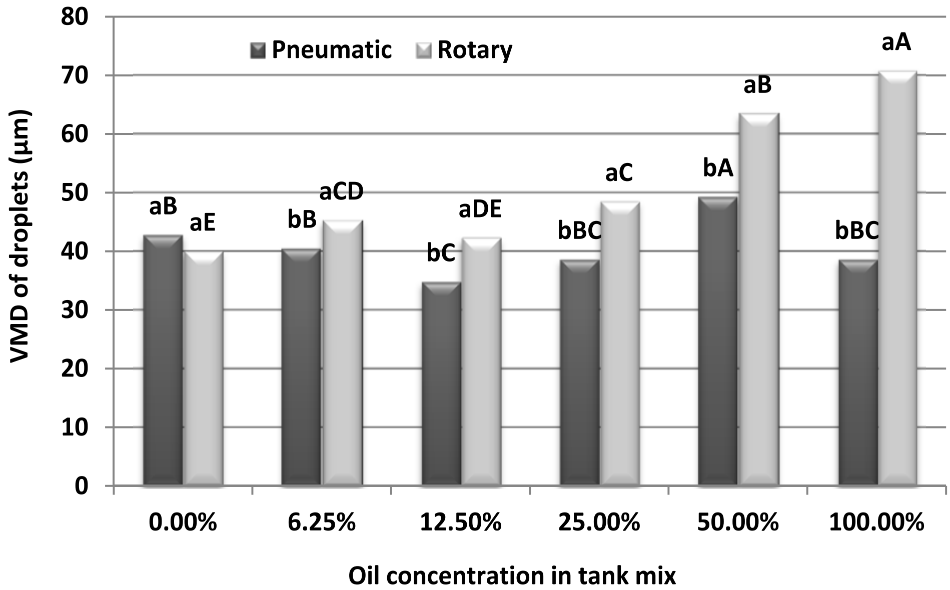

Fig. 3. Volume median diameter or droplets (µm), sprayed by different nozzles and concentration of oil in tank mix. Jaboticabal, SP - Brazil, 2009. Averages followed by the same lowercase letter (type of nozzles into concentration of oil), and uppercase letter (concentration of oil into type of nozzle) do not differ by Tukey test at 5% probability.

With respect to VMD, the treatment with 12.5% resulted in a lower value, not differing significantly from the treatment with 25% of oil to pneumatic nozzle and to 0% and 6.25% to the rotary one. The biggest VMD of pneumatic nozzle happened with 50% of oil. With the rotary nozzle, the biggest value occurred at 100% of oil (no water) followed by 50% value (Fig. 3). The treatment with 50% of oil resulted in highest VMD for pneumatic nozzle. The lowest VMD happened with 12.5% of oil and this one did not differ from 25% and 100%. The treatment with 100% of oil resulted in highest VMD for rotary nozzle. The lowest VMD happened with 0% of oil and this one did not differ from 12.5% of oil (Fig. 3). Wodageneh & Matthews (1981) have found different sizes of collected droplets with different concentration of oil in tank mix (0–40%), 30 cm downwind from a rotary nozzle. Most of time increasing concentration of oil results in decreasing of droplet size. However, between 5000 and 15000 rpm, the rotary nozzle produced close results mainly from lower concentrations of oil (from 0% to 10%). The differences verified by Wodageneh & Matthews (1981), and in the case of the present work, probably come from three main effects, being the surface tension of the mix that decreases as the concentration of oil becomes bigger (Decardo Junior *et al*., 2013), the difference of energy to droplet formation (rotary and pneumatic), and the stability of the equipment. The effect of surface tension was greater with the rotary nozzle than the pneumatic one. On the other hand, the quality of the pneumatic nozzle was better than the rotary in respect to droplet size and uniformity influencing sprayer performances.

Control of Aedes aegypt

It was observed that the pneumatic nozzle results in a higher mortality of mosquitoes in relation to rotary nozzle (Fig. 4). Treatments with concentration of oil at 12.5% and 25% resulted in a mortality of mosquitoes over than 85%. Treatments of 0% and 6.25% result in about 65–70% mortality and concentrations of oil of 50% and 100% result in less than 50% mortality (Fig. 4). Rotary nozzle results in less than 22% of mortality to mosquitoes in all cases. These results of mortality confirm the observed resulted from the droplet sizes for pneumatic nozzle related to uniformity and adequate droplets size. However, those results supply some information to manufacturers on the development path to follow, and they are working on it.

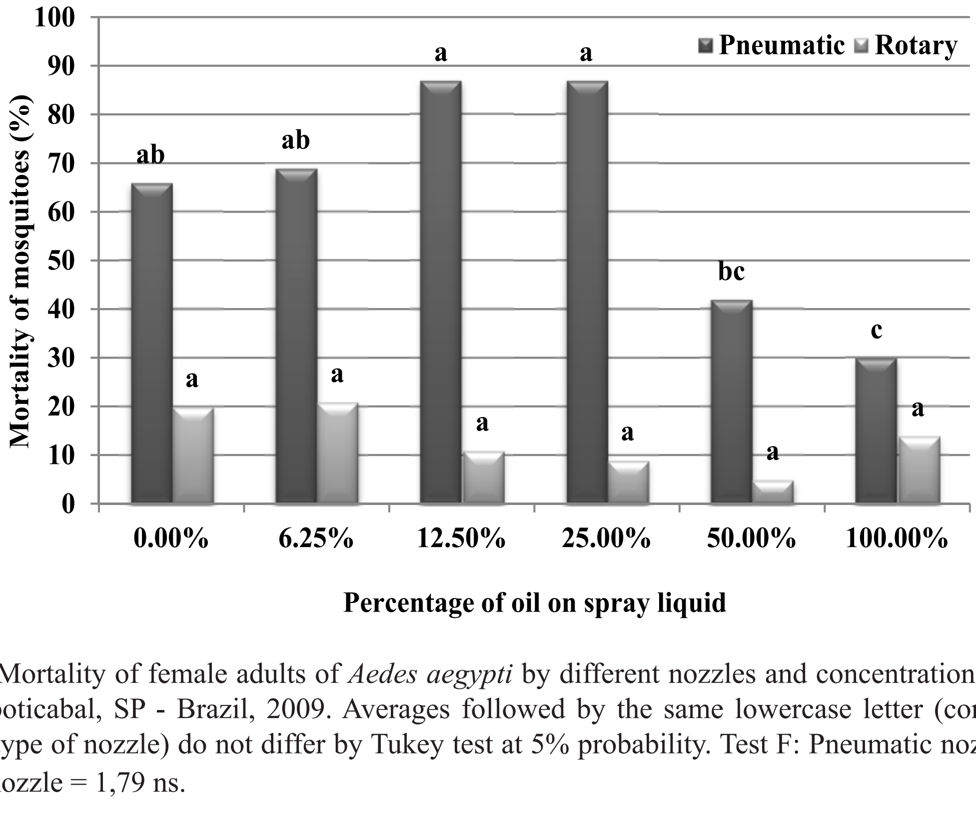

Fig. 4. Mortality of female adults of *Aedes aegypti* by different nozzles and concentration of oil in tank mix. Jaboticabal, SP - Brazil, 2009. Averages followed by the same lowercase letter (concentration of oil into type of nozzle) do not differ by Tukey test at 5% probability. Test F: Pneumatic nozzle = 9,36**; Rotary nozzle = 1,79 ns.

Conclusions

In the circumstances of this research, the pneumatic nozzle showed greater uniformity and optimum droplet size, compared to of the rotary nozzle. This correlated with increased efficacy of control of *A. aegypti*, in the oil concentration of 12.5%.

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