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Tecnologias Limpas

Application technology in the culture of cauliflower: testing an electrostatic spray

Tecnologia de aplicação na cultura da couve-flor: testando uma pulverização eletrostática

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Abstract: The control of pests and diseases is one of the major challenges in the cultivation of cauliflower due to the plant's morphological characteristics and low application efficiency. These adverse conditions can cause great productivity losses when there is an incidence of pests and diseases. On these aspects, this study aimed to evaluate an electrostatic spraying system to increase the efficiency of the application of pesticides in the cultivation of cauliflower. An experiment was carried out with the use of different sprays, isolated or associated with silicon adhesive fouling, referring to the traditional spray, traditional spray + addition of silicone adhesive, electrostatic spraying, electrostatic spraying + addition of silicone adhesive. Results showed that the electrostatic spray system, isolated or associated with an adhesive spreader, promoted the greatest coverage in the low and medium part of the plants, considered 71% and 83% greater than the average of the traditional spray, respectively. At the bottom of the leaves, the electrostatic spraying system also performed better. Based on results, it was concluded that the electrostatic spraying system shows to be more efficient in the deposition and distribution of syrup in cauliflower, compared to the traditional spraying system.

Keywords: Adhesive spreader; *Brassica oleracea* var. *botrytis*; Defensive; Productivity.

Resumo: O controle de pragas e doenças é um dos grandes desafios na cultura da couve-flor devido às características morfológicas da planta e a baixa eficiência de aplicação. Essas condições adversas podem causar grandes perdas de produtividade quando há incidência de pragas e doenças. Sobre esses aspectos, esse estudo teve como objetivo avaliar um sistema de pulverização eletrostática para aumentar a eficiência de aplicação de defensivos agrícolas no cultivo da couve-flor. Um experimento foi realizado na Fazenda do Barreiro, em Itatiba, São Paulo, com uso de diferentes pulverizações, isolado ou associado com espalhafate adesivo siliconado, referente à pulverização tradicional, pulverização tradicional + adição de espelhante adesivo siliconado, pulverização eletrostática, pulverização eletrostática + adição de espalhante adesivo siliconado. O sistema de pulverização eletrostática, isolado ou associado com espalhante adesivo, promoveu a maior cobertura na parte baixa e média das plantas, considerado 71% e 83% maior que a média da pulverização padrão, respectivamente. Na parte inferior das folhas, o sistema de pulverização eletrostática também apresentou uma maior performance. De acordo os resultados, concluiu-se que o sistema de pulverização eletrostática mostra ser mais eficiente na deposição e distribuição de calda na couve-flor, comparado ao sistema de pulverização padrão, sendo assim uma boa opção para aplicação de produtos fitossanitários.

Palavras-chave: *Brassica oleracea* var. *botrytis*; Defensivos; Espalhante adesivo; Produtividade.

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1 INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis*) belongs to the *Brassicaceae* family, an olive tree, which can be grown in practically all Brazilian territory, due to cultivars adapted for different regions and times. In 2017, according to the Institute of Agricultural Economics (IEA, 2017), the area of cultivation and the average production of cauliflower in the state of São Paulo was 2,826 hectares and 88,096 tons, respectively, with the productivity of 31.17 t ha^{-1}.

In Brazil, the large concentration of cauliflower producers occurs in the region of Bragança Paulista (São Paulo), and the south of the state of Minas Gerais. These producing regions supply the metropolitan areas of the cities of São Paulo, Belo Horizonte, and Rio de Janeiro (IEA, 2017). According to Brazilian Institute of Geography and Statistics (IBGE, 2011), cauliflower production in Brazil is higher in the South and Southeast, with 94% of Brazilian production.

Cauliflower is considered a crop of high economic value and with a great opportunity for growth in the market of horticulture due to the variety of uses (Contaifer, 2018; Zanuzo *et al*. 2013). Also, the production of cauliflower presents great economic importance in producing regions, due to its capacity to remunerate the producer and generate jobs in the field (HF Brasil, 2019).

The cauliflower, morphologically, is a medium-sized plant, with an average of fifty-five centimeters in height, and with an average of twenty-seven leaves until the floral emission. The leaves are highly waxy, superimposed on each other, and characterized as long and with an elliptical shape, fixed on a short stem (May *et al*. 2007).

Due to these morphological characteristics, the cauliflower suffers from the attack of various pests and diseases that cause great losses of productivity. The waxiness of the leaves promotes a low deposition/ adsorption of spray mixture, and without spreading the heavier drops fall on the soil surface, outside the target.

Also, the leaf on top of the other ends up playing the role of an umbrella, avoiding the deposition of syrup on the lower leaves. Under these conditions, pest and disease control stands out as one of several factors that affect cauliflower productivity. The main pests that attack cauliflower are; the Cruciferous Moth (*Plutella xylostella*), Thread Caterpillar (*Agrotis ipsilo*), and the Cabbage "Aphid" (*Brevicoryne brassicae*). Among the main diseases, Black Podridão (*Xanthomonas campestris* pv. Campestres), Pinta Preta (*Alternaria brassicae*), and Mildew (*Paronospora parasitic*) stand out. Most pests and diseases develop on the lower leaves of the cauliflower, making it difficult to control (Chaim, 2016). The recommended producers for pest and disease control in cauliflower are, for the most part, contact and ingestion, and products with systemic circulation in plants (Machado *et al*., 2007).

The application technology used is important to obtain a good result with the chemical control of pests and diseases. Effective control must be associated with applications that associate the lowest dose and number of applications (Baesso *et al*., 2014). Currently, the equipment used in spraying cauliflower crops is (i) boom sprayers with hydraulic circuit coupled to the tractor's third point; (ii) and manual coastal sprayers for applications that occur in the initial stage of the crop.

The applications present a low efficiency, nor effective, due to the use of inadequate technique or equipment, and the inappropriate use of pesticides (Cunha *et al*., 2011). In this sense, alternatives to improve the phytosanitary control programs and application technologies are necessary for the efficient control of pests and diseases in cauliflower, therefore, justifying the performance of this study.

The electrostatic spraying system (SPE) has been presented as an alternative to increasing the efficiency of application in crops such as cauliflower. The electrostatic spraying system is formed by electro-hydrodynamic nozzles, capable of generating drops with electrical charges, which during the spraying are attracted by the target due to the difference in electrical charge (Sasaki *et al*., 2015). This electrostatic attraction improves the uniformity of syrup deposition on the target, reaching the areas with the greatest difficulty of penetration and also the lower part of the leaves that are located in the lower parts of the plants (Chaim; Wadt, 2016).

Based on the hypothesis that the electrostatic spraying system presents a better uniformity in the deposition of syrup in cauliflower. This study aims to evaluate an electrostatic spraying system to increase the efficiency of application of pesticides in the cultivation of cauliflower.

2 MATERIAL AND METHODS

2.1 STUDY CHARACTERIZATION

The experiment was carried out on a commercial farm located in Itatiba, São Paulo (22 ° 57'26.89" S, 46 ° 43" 14.69" W, 813 m). The region's climate is classified as high altitude tropical, with temperatures ranging from 18 to 25 °C, and an annual average of 20.6 °C, with winds in the south and east (Clima-data, 2023).

The design of the study was in randomized blocks with the use of different sprays, isolated or associated with siliconized adhesive, with three repetitions, referring to (i) traditional spraying; (ii) traditional spraying + addition of silicone adhesive; (iii) electrostatic spraying; (iv) electrostatic spraying + silicone adhesive spreader. Each experimental unit had an application area of 30 m^2, with a total area of 360 m^2.

The traditional spraying system is classified as a tractor spraying system with a boom sprayer, hydraulic circuit, and hydraulic nozzles (Figure 1A). The traditional spraying was used in the treatment (i) and (ii), composed of a John Deere tractor, model 5085, 85 CV, the year 2018, boom sprayer coupled to the tractor, model Condor 800 AM 14 Jet circuit hydraulic, and empty conical hydraulic nozzle 80-02, regulated and calibrated for the flow of 500L ha^{-1} of spray solution.

Figure 1. Electrostatic spraying system (A) and traditional spraying system (B)

The electrostatic spraying system is classified as a tractor spraying system with boom spray, and hydraulic circuit with electro-hydrodynamic nozzles, capable of generating drops between 50-80 microns with an electric charge. The set of electrostatic spraying used in the experimental field, specifically in treatment iii and iv, was the Jonh Deere tractor, model 5085 of 85 hp, boom sprayer coupled to the tractor which only served to support the SPE electrostatic spray kit.

The kit consisted of: a motor pump set with a 25.4-cylinder single-cylinder engine, powered by gasoline; a two-piston pump, capable of generating maximum pressure of 25 bar, and a flow rate of 8 L minute^{-1}; 20 L reservoir; spray bar of 3 meters. There were two control modules, module i: powered by the 12-volt tractor battery: module ii connected to module i; electro-hydrodynamic nozzles; power and distribution cables; and 6 electro-hydrodynamic SPE-03 nozzles spaced at 50 cm.

The electrostatic spraying system used in the experiment was regulated and calibrated for the flow rate of 100 L ha^{-1} (Figure 1B). Also, the study tested the addition of nonionic silicone adhesive fusion from the chemical group of silicones (polyether and silicone copolymer; dose: 10 mL 100 L^{-1}) due to the difficulty of spreading syrup on cabbage leaves-flower.

2.2 CHARACTERIZATION OF CAULIFLOWER MANAGEMENT

Cauliflower seeds (Korlanu hybrid) were sown in April 2019, in trays with coconut fiber substrate. The seedlings were monitored daily with applications of insecticides and fungicides and irrigated when necessary for seedling development. The transplant was performed 30 days after sowing when the seedlings had four to five definitive leaves.

For planting in the field, the soil was sampled in the 0-20 cm layer for characterization, correction, and fertilization. The soil was managed with the application and incorporation in the total area of dolomitic limestone (rate: 3 t ha^{-1}) in the plowing and harrowing. Planting fertilization was carried out with the application of the formulation 04-14-08 (rate: 1.5 t ha^{-1}), while in the cover fertilization applied the formulation 20-00-20 (rate: 0.6 t ha^{-1}), referring, respectively, to the addition of nitrogen, phosphorus, and potassium.

The cover fertilization was divided into two applications, the first after 20 days after transplantation and the second after 45 days. Planting was carried out in the spacing, 0.70 m between rows, and 0.40 m between plants, totaling 35,714 plants per hectare. Pesticides (Avatar 0.1 L ha^{-1}, Dithane 3.0 kg ha^{-1}, Immunit 0.5 L ha^{-1}) were applied 10 and 25 days after transplantation. In all treatments, the Luminol tracer (1 L to 50 L of water) was added to the spray, to allow visualization of the syrup distribution afterward. At the time of pesticide application, the climatic conditions were adequate and following the recommended technical standards (Azevedo, 2006).

2.3 DATA COLLECTION AND ANALYSIS

After 1 hour of application, 10 plants per experimental unit were randomly sampled in each plot. Cauliflower plants were divided into three parts (high, medium, and low), and the syrup deposition was monitored at the top and bottom of the leaf. In all sampled plants, in each plot, one leaf was collected from each part of the plant (low, medium, and high), thus adding up to 30 leaves analyzed per experimental unit.

The Luminol tracer was identified in ultraviolet light in a dark environment, generates a flowering green color. The spray deposition area was determined using photographic images and later analyzed on software (Canopeo), capable of determining the percentage of wetting of the leaf by the flourishing green color of the tracer.

The data were submitted to analysis of variance (ANOVA). When the F test was significant, the means and interaction (between the part of the plant and type of spray) were compared using the LSD test ($p < 0.05$). The general average of the coverage of the lower and upper parts of the leaves was tested with the t-test ($p < 0.05$).

3 RESULTS AND DISCUSSION

3.1 LEAF COVERING

The deposition of syrup in the cauliflower plants was higher in the upper part of the leaf, considered 70% higher than the deposition for the lower part (Figure 2). Similar results were obtained in the studies by Silva *et al*. (2000) and Scramin *et al*. (2002), in experiments with application efficiency in cotton (*Gossypium hirsutum* L.), and also by studies carried out by Chaim *et al*. (2003) in apple (*Malus domestica*).

Magno Júnior *et al*. (2011) developing a device to promote the attraction of drops (electric) into the canopy of the citrus plants, found that the largest depositions occurred on the outside of the plant as a result of the easier arrival of the drops. In the present study, the greater deposition on the upper part of the cauliflower leaf is due to the greater ease in the arrival of the drops in this area (Figure 2).

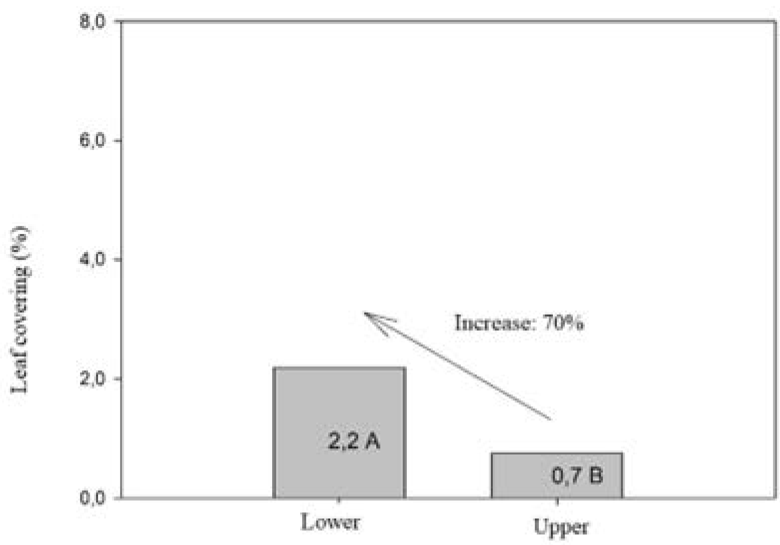

Figure 2. Leaf covering in the lower and upper part (%) using different spray systems, isolated or associated with the adhesive spreader. Means were compared using the t-test ($p < 0.05$)

Generally, inside the cauliflower, the deposition of the syrup is impaired due to the morphological conditions of the species (interposed leaves) and the presence of a waxy surface, making deposition at the bottom of the leaves difficult (Chaim, 2016).

3.2 PLANT COVERING AT THE UPPER PART

The electrostatic spraying system, isolated or associated with the adhesive spreader, promoted the greatest spray deposition in the low and medium part of the plant considered 71% and 83% greater than the average of the standard spray, respectively (Table 1).

The greater coverage in the low and medium part of the plant with electrostatic spraying is associated with the characteristics of the spraying system: where the system works with drops between 50-80 microns, depositing a greater number of drops per area, and the electrical charge. The presence of electrical charge does not allow collision drops during the flight which forms larger drops that often fall off target. Also, the presence of electric charges causes repulsion between the drops avoiding the deposit on each other. Studies carried out by Chaim (1999) found that the electrostatic spraying system directly affects the deposition of syrup on plants, with a high electric attraction between drops and plants.

Table 1. Plant covering with the use of different spray systems (traditional and electrostatic), isolated or associated with adhesive spreader

Spray systems	Low	Median	Upper
		------------------ (%) ------------------	
Traditional	2,17 Ba	0,07 Ca	0,10 Aa
Traditional + AS	1,64 Ba	1,14 BCa	0,01 Aa
Eletrostatic	5,85 Aa	4,23 Aa	0,27 Ab
Eletrostatic + AS	7,22 Aa	2,99 ABb	0,54 Ac

Notes: AS: adhesive spreader. Means were compared by the LSD test ($p < 0.05$), and results were represented by uppercase (column) and lowercase letters (lines).

At the upper part, there was no difference between the types of spray (Table 1), which may be associated with the shape of the leaves classified as curved, with the shape of a shell, and with the upper face turned inwards. These characteristics promote a low leaf exposition.

Roman *et al*. (2009), testing hydraulic nozzles (conical jet tip and two flat jet tips) and spray volume (100, 150, and 200 dm^3 ha^{-1}), in the percentage of coverage in three plant positions (upper, middle, and low of the canopy), also did not verify any statistical difference between the spray tips and between the spray volumes. In contrast, the greater coverage in the low and medium part can be explained by the fact that the electrostatic spray system works with very fine drops. This system, when associated with the adhesive spreader, has a better penetration between less exposed leaves, with increased deposition on cauliflower leaves.

3.3 PLANT COVERING AT THE LOWER PART

There was no interaction between spray systems and adhesive spreader ($p > 0.05$), and results will be presented individually (Figure 3). Electrostatic spraying, isolated or associated with the adhesive spreader, showed a greater coverage of the lower part of the leaves, considered 89% greater than the application with standard spraying (Figure 3).

Studies by Stawniczyi *et al*. (2019) showed that electrostatic spraying with fungicide syrup promoted greater coloration of epidermis and cluster length for 'Niágara Branca'. These authors found a higher content of anthocyanins and a lower volume of syrup with the use of electrostatic spraying.

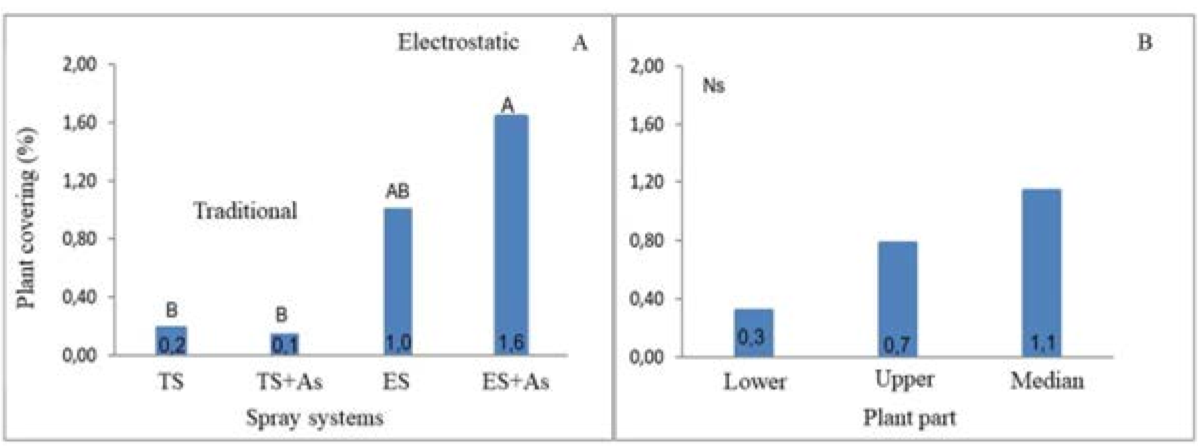

Figure 3. Plant covering in the plant part (upper, median, and low part, %; (A) with the use of different spray systems (Traditional and Electrostatic%; (B), isolated or associated with adhesive spreader (AS). Means were compared by the LSD test ($p < 0.05$), and results were represented by uppercase in the spray systems. There was no interaction between spray systems and the plant part.

Among the plant parts, there was no difference between the median, upper, and lower parts with an average coverage of 1.1; 0.7; and 0.3%, respectively (Figure 2). This result indicates that there was a good uniformity in the distribution of syrup in the target in the lower part of the plant, promoting a good distribution of the insecticides and fungicides.

4 FINAL CONSIDERATIONS

The application efficiency in cauliflower is higher in the upper part of the leaf considered 70% greater than the deposition in the lower leaf.

The electrostatic spray system, isolated or associated with the adhesive spreader, is a great alternative to increase the application efficiency with 71% and 83% greater than the average of the traditional spray, respectively.

The electrostatic spraying system proved to be more effective, compared to the traditional spraying system, and is considered a good option for applying phytosanitary products.

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