









## QUALITY CONTROL OF PNEUMATIC SPRAYING IN TOMATO

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volumetric index  
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### ABSTRACT

Tomato is a vegetable of great importance on the national scene. One of the problems of this culture is the great susceptibility to attack by pests and diseases. Thus, one of the most used practices is chemical control with phytosanitary products. The objective of this study was to evaluate the technical parameters of pneumatic spraying in tomato culture, through the study of the volumetric index and the population of spray droplets, aiming to reduce the spray volume, obtain the best efficiency and the social and environmental safety of the applications. The study of the droplet population was performed using water-sensitive paper labels. These labels were placed in the canopies of the tomato plants at three different heights and two positions. The sprays were made using a pneumatic backpack sprayer. After applying the syrup (dye + water), the water-sensitive paper labels were collected and subjected to the coverage and droplet density analyses by the computer program "CIR" version 1.5. The pneumatic sprayer proved to be efficient for the application of phytosanitary products in the tomato. The percentage of the target covered area ranged from 2.1 to 8.3% for volumetric indices as a function of thirds and positions, whereas the density of droplets ranged from 145.4 to 690.1 drops cm<sup>-2</sup> for thirds and positions of the tomato plants evaluated. Finally, the volumetric index of 5 mL m<sup>-3</sup>, with a consequent spray volume of 50 L ha<sup>-1</sup>, met the parameters of a quality spray.

### Palavras-chave:

tecnologia de aplicação  
índice volumétrico  
espectro da população de gotas

### CONTROLE DE QUALIDADE DA PULVERIZAÇÃO PNEUMÁTICA NO TOMATEIRO

#### RESUMO

O Tomate é uma hortaliça de grande importância no cenário nacional. Um dos problemas dessa cultura é a grande suscetibilidade ao ataque de pragas e doenças. Dessa forma umas das práticas mais utilizadas é o controle químico com produtos fitossanitários. Objetivou-se, neste trabalho, avaliar os parâmetros técnicos da pulverização pneumática na cultura do tomateiro, através do estudo do índice volumétrico e da população de gotas da pulverização, visando à redução do volume de pulverização, à melhor eficiência e à segurança socioambiental das aplicações. O estudo da população de gotas foi feito através de etiquetas de papeis hidrossensíveis. Essas etiquetas foram posicionadas nos dosséis das plantas de tomateiro em três alturas diferenciadas e duas posições. As pulverizações foram feitas utilizando um pulverizador pneumático costal. Após a aplicação da calda (corante + água), as etiquetas de papel hidrossensível foram coletadas e submetidas às análises de cobertura e densidade de gotas pelo programa computacional "CIR" versão 1.5. O pulverizador pneumático mostrou-se eficiente para aplicação de produtos fitossanitários no tomateiro. A porcentagem de área coberta do alvo variou de 2,1 a 8,3% para os índices volumétricos em função dos terços e posições, já a densidade de gotas variou de 145,4 a 690,1 gotas cm<sup>-2</sup> para os terços e posições das plantas de tomateiro avaliadas. Por fim, o índice volumétrico de 5 mL m<sup>-3</sup>, com consequente volume de pulverização de 50 L ha<sup>-1</sup>, atendeu os parâmetros de uma pulverização de qualidade.

## INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the main vegetables in terms of economic and food importance, being cultivated in all tropical and subtropical regions of the World (PEREIRA-CARVALHO *et al.* 2014). Tomato is part of the diet of most Brazilians, as its fruit is nutritious and healthy, being a source of several vitamins and minerals (ITAKO, 2011). Worldwide, it is the main vegetable in volume consumed in natura (HACHMANN *et al.* 2014). In 2017, world production was 182 thousand tons (FAOSTAT, 2018). The world's largest tomato producer with approximately 32% of all production was China, followed by India, Turkey, USA, Egypt, Iran, Italy, Spain, Mexico and Brazil (FAOSTAT, 2018). In Brazil the largest producers are the states of Goiás, São Paulo and Minas Gerais (IBGE, 2018).

The tomato plant and fruits can present different types of problems that, possibly, will affect its appearance, nutritional quality and its commercial value. Like many other commercial crops, tomatoes and their fruits are subject to attacks from various pests and harmful diseases. In order to minimize the consequences of this exposure, phytosanitary products are applied to the plant to ensure greater productivity with a satisfactory degree of quality (PENIDO *et al.* 2019).

The use of phytosanitary products, although it is responsible for reducing losses in agricultural production due to the control of pests, diseases and invasive plants, may be questionable due to the risk of environmental contamination provided by the potential loss of products to the environment (SASAKI, 2011). In plants with high leaf density, it is common that most of the sprayed drops containing phytosanitary products do not reach the interior of the plant canopy, impairing the dispersion and uniformity of distribution of the drops, which may result in low control effectiveness (MEWES *et al.* 2015). For this reason, it is necessary to offer efficient alternatives to the tomato production chain. Beyond the requirements in the field, the producer must meet the demands of the consumer market with high quality fruits.

The consumption of phytosanitary products has increased in recent years. However, it is important to

monitor spraying to ensure that the correct amount of active ingredient from the pesticide reaches the target with the minimum possible losses. Therefore, it is important to avoid contamination of people involved in the processes and ensure lower levels of residues, both in food and in the environment. An alternative to reduce losses and contamination is to decrease the applied volume, in such a way as to make an application that meets all the requirements for control, increasing the quality of the fruit, however, with a low volume of spray applied and without considerable losses.

In order to apply the ideal amount of phytosanitary to arboreal crops, the correct amount of plant material present in the area to be treated must be defined. One of the methods of quantifying leaf mass per unit area is that of TRV (Tree Row Volume). The TRV concept was developed in order to optimize the amount of phytosanitary product to be applied into the canopy of the plant. Therefore, the volume of syrup to be used should never result from the wishes of the producer or from predefined recommendations, but from the volume of the aerial part of the plant, reflecting the conduction system, age and other characteristics of the crop.

Thus, the objective of this study was to evaluate the technical parameters of pneumatic spraying in tomato culture, through the study of the volumetric index and the population of spray droplets, aiming to reduce the spray volume, to obtain the best efficiency and the social and environmental safety of the applications.

## MATERIAL AND METHODS

The study was performed in a commercial tomato crop conducted in a vertical staking system, in the municipality of Cajuri, Minas Gerais, Brazil, located in the micro region of Viçosa. The region's climate is classified as Cwa (mesothermal), with rainy summers and dry winters, and the average temperature of the hottest month exceeds 22 ° C, according to the classification of Köppen (1948).

The average spacing was 1.2 m between planting lines, and the plants had an average height of 2.0 m, an average crown width of 0.6 m and a leaf area index of 2.8 m<sup>2</sup>. The applications were performed using a pneumatic backpack sprayer (Guarany, model PL 52 2500), with the sprayer on at its maximum acceleration and the fan on, using

dosing tips according to each treatment applied. The applications were made with the spray boom always in the same direction from the bottom up, and the spray tank always full. The applications were performed in the morning, always monitoring the psychrometric conditions of the air. During the application, the average values of the relative humidity of the air and ambient temperature were respectively 72 %, 24.7 °C and the wind speeds ranged from 2 to 10 km h<sup>-1</sup>, considering the study feasible in relation to evaporation losses and drift.

The evaluations were performed at the Agricultural Defensives Application Laboratory (LADA) of the Agricultural Engineering Department of the Federal University of Viçosa (UFV). The criterion for determining the syrup volume for application was defined based on the canopy volume method of the plants (SUTTON; UNRATH, 1984), considering the average diameter, canopy height and spacing between planting rows (Equation 1):

$$TRV = \frac{h L 10000}{D} \quad (1)$$

Where:

TRV = Tree Row Volume per area (m<sup>3</sup> ha<sup>-1</sup>);

h = Canopy height (m);

L = Canopy width (m); and

D = Distance between lines (m)

Based on the calculated TRV value (m<sup>3</sup> ha<sup>-1</sup>) and the volumetric indices stipulated as treatments (5, 10, 15, 20, 25 mL m<sup>-3</sup>), it was possible to calculate the spray volume, using Equation 2:

$$SV = \frac{TRV VI}{1000} \quad (2)$$

Where:

SV = spray volume (L ha<sup>-1</sup>);

TRV = canopy volume of plants per area (m<sup>3</sup> ha<sup>-1</sup>); and

VI = volumetric index (mL m<sup>-3</sup>)

These volumetric indices stipulated as treatments (5, 10, 15, 20, 25 mL m<sup>-3</sup>) were chosen in order to test volumes below those recommended by Barthelemy *et al.* (1990) in the application of fungicides. The intention was to reduce the

application volumes and consequently the losses and costs of the application.

Based on the calculated spray volumes, it was possible to determine the tip flow rate (L min<sup>-1</sup>) necessary for spraying, from Equation 3:

$$q = \frac{Q V f}{600} \quad (3)$$

Where:

q = tip flow (L min<sup>-1</sup>);

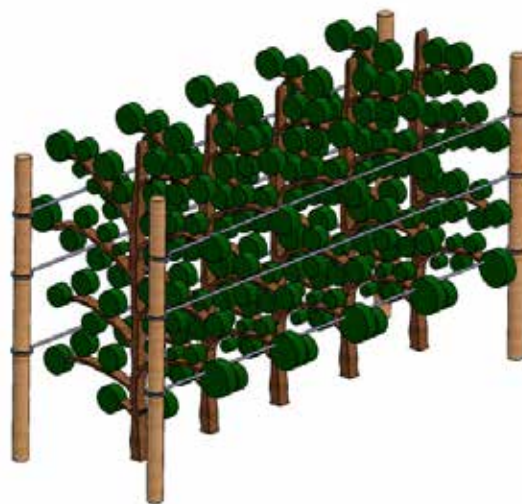
Q = syrup volume (L ha<sup>-1</sup>);

V = working speed (km h<sup>-1</sup>); and,

f = applied range (m)

In the upper, middle and lower third of the plants, two water-sensitive paper labels with dimensions of 31 x 32 mm were fixed according to the external and internal positions, totaling six labels per evaluated plant, six repetitions and 36 samples per treatment. The spray quality was assessed indirectly, based on the population density of drops present on the labels and the coverage area.

For the sampling of the spraying, a mesh with three threads at different heights was used, where the water-sensitive paper labels were fixed to check the deposition of drops on the plant in different positions (external and internal) and at different heights (lower, middle and upper third) (Figure 1).



**Figure 1.** Sampling mesh with three threads at different heights and positions, where the water-sensitive paper labels were fixed

After the dye drying, the hydrosensitive paper labels were collected with the aid of surgical gloves and were subsequently digitized and subjected to the coverage and droplet density analysis by the computer program “CIR” (Counting and typification of spray impacts) version 1.5 (INTA, 2002). The percentage of coverage of the target by the syrup was obtained by the relationship between the area covered by the drops and the total area of the labels, with a maximum coverage of 20% being allowed as a limit, as values above this reference can cause losses by run-off and probably environmental impact.

The experiment was developed according to a subdivided plot scheme, with the volumetric indices in the plots, the thirds of the plants in the subplots, and the horizontal positions in the subsubplots, in the Fully Randomized Design (DIC) with six repetitions (six plants) per treatment. The data were analyzed using analysis of variance. The averages were compared using the Tukey test, at 5% probability level.

**RESULTS AND DISCUSSION**

According to the dimensions evaluated in the tomato, the TRV value was 10,000 m<sup>3</sup> ha<sup>-1</sup> and the

spray volumes varied according to the volumetric indexes. After determining the volume to be applied according to each treatment, the necessary flow rate for each tip was calculated, considering an application speed of 3 km h<sup>-1</sup> (Table 1).

In Table 2 are presented the interaction averages for the percentage of covered area (coverage) between the volumetric indices and the thirds of the plants.

Applying the Tukey test to the average percentage of coverage of the labels with sprayed drops for the different volumetric indices used, we observed that there was no significant difference between treatments with volumetric indices 15, 20 and 25 for the upper, middle and lower, but volumetric indices 5 and 10 differed significantly from the other volumetric indices with respect to thirds. The average coverage values ranged from 3.0 to 6.9%.

The volumetric index 10 mL m<sup>-3</sup> was the only one that the percentage of coverage significantly differed according to the plant height and the middle third had a coverage value higher than the other thirds. This result may have occurred due

**Table 1.** Volumetric index (VI) (mL m<sup>-3</sup>), sprayed volume (SV) (L ha<sup>-1</sup>), speed (km h<sup>-1</sup>) and tip flow (L min<sup>-1</sup>) after calibrating the pneumatic sprayer

VI	SP	Speed	Tip flow
5	50	3.0	0.2
10	100	3.0	0.3
15	150	3.0	0.5
20	200	3.0	0.6
25	250	3.0	0.8

**Table 2.** Average values of spray droplet coverage in the interaction between volumetric index (VI) and thirds in the tomato plant

VI (mL.m <sup>-3</sup> )	Coverage (%)		
	Third of the plant		
	Upper	Middle	Lower
5	3.0 bA	3.2 bA	3.6 cA
10	4.7 abB	6.7 aA	4.3 bcB
15	5.2 aA	5.4 aA	6.3 abA
20	5.8 aA	5.6 aA	6.9 aA
25	6.6 aA	6.0 aA	5.8 abA

The averages followed by at least the same uppercase letter in the lines and lowercase in the columns do not differ statistically, by the Tukey test at the 5% probability level.

to the smaller number of leaves presented in the middle third, causing the syrup to settle in a larger quantity on the leaves.

The interaction averages for coverage between volumetric indices and plant positions are shown in Table 3.

When analyzing the interaction between volumetric indexes and positions, a statistical difference was observed for the external part, in which the first treatment (5 mL m<sup>-3</sup>) differed from the other treatments. In the internal part of the plant, the first treatment (5 mL m<sup>-3</sup>) and the last one (25 mL m<sup>-3</sup>) differed statistically and the values of the averages varied from 2.1 to 8.3% of coverage.

All treatments showed statistical difference between the external and internal position of the plant. We could observe that in all treatments the percentage of coverage was higher on the external part of the plant. The trend towards greater coverage on the external part of the plant is reported by the

proximity, position and direction of the dosing tips in relation to the target.

In Table 4 can be seen the average droplet density for the interactions between volumetric indices and plant thirds and in Table 5, for the interactions between volumetric indices and the position of the sample mesh.

Applying the Tukey test at the level of 5% of probability, in Table 4, we observe that the different volumetric indices had no significant difference in relation to the droplet density of the middle third. This result was not observed in the upper and lower thirds, since the volume of liquid applied to the plant is influenced by the density of droplets in these thirds.

Only the second treatment (10 mL m<sup>-3</sup>) showed a significant difference between the thirds of the plant, with the middle third having the highest density of drops. Droplet density values for the evaluated thirds ranged from 250.7 to 456.0 drops cm<sup>-2</sup>.

**Table 3.** Average values of spray droplet coverage in the interaction between volumetric index (VI) and positions in the tomato plant

VI (mL m <sup>-3</sup> )	Coverage (%)	
	Position	
	External	Internal
5	4.5 bA	2.1 bB
10	7.8 aA	2.7 abB
15	7.8 aA	3.3 abB
20	8.3 aA	3.8 abB
25	8.2 aA	4.1 aB

The averages followed by at least the same uppercase letter in the lines and lowercase in the columns do not differ statistically, by the Tukey test at the 5% probability level.

**Table 4.** Average values of droplet density in different thirds of the sampling mesh of tomato plants, according to the volumetric index (VI) applied in the treatments

VI (mL.m <sup>-3</sup> )	Density (drops cm <sup>-2</sup> )		
	Third of the plant		
	Upper	Middle	Lower
5	280.0 bA	318.0 aA	315.4 abA
10	334.9 abAB	434.2 aA	250.7 bB
15	367.7 abA	406.5 aA	352.1 abA
20	449.9 aA	408.2 aA	456.0 aA
25	354.2 abA	338.7 aA	300.7 bA

The averages followed by at least the same uppercase letter in the lines and lowercase in the columns do not differ statistically, by the Tukey test at the 5% probability level.

**Table 5.** Average values of density of droplets sprayed in different positions of the sample mesh according to the volumetric index applied in the treatments

VI (mL m <sup>-3</sup> )	Density(drops cm <sup>-2</sup> )	
	Position in the plant	
	External	Internal
5	448.3 bA	160.5 aB
10	534.5 bA	145.4 aB
15	558.8 abA	192.1 aB
20	690.1 aA	185.9 aB
25	458.0 bA	204.5 aB

The averages followed by at least the same uppercase letter in the lines and lowercase in the columns do not differ statistically, by the Tukey test at the 5% probability level.

In Table 5 we can observe that there was no significant difference in the average values of droplet density, between volumetric indices and the internal position of the plant. In the external part of the plant, a significant difference was obtained between the volumetric indices studied.

Droplet density values for the evaluated thirds ranged from 145.4 to 690.1 drops cm<sup>-2</sup>. There is a tendency for droplets to accumulate on the external part of the plant, with lower values on the internal part of the canopy of plants. This behavior can be explained by the fact that, as droplets travel along a flow of air, they tend to lose energy, and droplets that have a larger diameter tend to intercept targets more easily than drops with reduced diameters (PASSION, 2016). The same behavior was observed for the percentage of area covered by the drops, whose the external part tends to accumulate a greater amount of drops in relation to the other positions.

Based on the results, the pneumatic sprayer proved to be feasible for spraying low volumes of syrup in tomato, since it provided good coverage and high droplet density, even when applying a syrup volume below that recommended by Barthelemy *et al.* (1990). Taking into account all volumetric indices studied, regardless of the third or the position, the population density of drops for a fungicide application was met. All treatments met the recommendation established by Barthelemy *et al.* (1990) for the application of fungicides, which would be in the range of 50-70 drops cm<sup>-2</sup>.

We could observe that the volumetric index of 5 mL m<sup>-3</sup>, with consequent lower spray volume

applied (50 L ha<sup>-1</sup>), can be recommended for the control of pests and diseases in the tomato crop, aiming to reduce the spray volume, helping to prevent environmental problems and thus seeking to ensure consumer health. In summary, it is possible to reduce the spray volume, increasing the efficiency and socio-environmental safety of the applications.

## CONCLUSION

- The backpack pneumatic sprayer proved to be efficient for spraying low volumes on tomato.
- The percentage of covered area of the target ranged from 3.0 to 6.9% for volumetric indices as a function of thirds and from 2.1 to 8.3% as a function of positions in the tomato plants evaluated.
- The density of droplets ranged from 250.7 to 456.0 drops cm<sup>-2</sup> for volumetric indices as a function of thirds and from 145.4 to 690.1 drops cm<sup>-2</sup> as a function of the positions of the tomato plants evaluated.
- The volumetric index of 5 mL m<sup>-3</sup>, with a consequent spray volume of 50 L ha<sup>-1</sup>, met the recommendation of the drop density for control in the tomato crop.

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