https://doi.org/10.47456/bjpe.v9i2.40825

NÚCLEO DE PESQUISA EM GESTÃO DE SISTEMAS DE PRODUÇÃO - NP GSP
Brazilian Journal of Production Engineering
BJPE - Revista Brasileira de Engenharia de Produção
Disponível em: https://periodicos.ufes.br/bjpe
ISSN: 2447-5580
UFES
Campus São Mateus
UNIVERSIDADE FEDERAL DO ESPÍRITO SANTO
UFES
Pró-Reitoria de Pesquisa e Pós-Graduação
Universidade Federal do Espírito Santo

ORIGINAL ARTICLE OPEN ACCESS

TTI-110025 SPRAY TIP DROPS SPECTRUM UNDER DIFFERENT WORKING PRESSURES

ESPECTRO DE GOTAS DA PONTA DE PULVERIZAÇÃO TTI- 110025 SOB DIFERENTES PRESSÕES DE TRABALHO

TTI-110025 PUNTA DE PULVERIZACIÓN ESPECTRO DE GOTAS BAJO DIFERENTES PRESIONES DE TRABAJO

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ARTICLE INFO.

Received: 20.04.2023
Approved: 16.05.2023
Available: 16.06.2023

KEYWORDS: Uniformity, Application Technology, Droplet Diameter, Efficiency.
PALAVRAS-CHAVE: Uniformidade, Tecnologia de Aplicação, Diâmetro de Gotas, Eficiência.
PABAVRAS-CLAVE: Uniformidad, Tecnología de Aplicación, Diámetro de Gota, Eficiencia.

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ABSTRACT

Hydraulic nozzles with air induction are widely used in spray applications, mainly because they reduce the effect of primary drift. However, there are still questions about the behavior of the droplet spectrum at certain pressures. The objective of this work was to analyze the droplet spectrum of the TTI 110025 air induction tip subjected to different working pressures by means of a laser particle analyzer in a protected environment. The experiment was conducted in a completely randomized design (DIC), represented by the pressures 200, 300, 400, 500 and 600 kPa, with four replications. The technical variables analyzed were $Dv_{0.1}$, DMV, $Dv_{0.9}$, AR, %V < 100 µm and %V > 500 µm. The TTI 110025 tip showed better results due to the decrease in variables Dv0.1, DMV, Dv0.9 and % V > 500 µm as the working pressure increased. The low value of the variable % V < 100 µm indicated a low risk of drift and the high value % V > 500 µm indicated a high potential for runoff in post-emergence applications. It is suggested to operate the TTI 110025 tip at a pressure of 600 kPa.

RESUMO

As pontas hidráulicas com indução de ar são amplamente utilizadas nas aplicações via pulverização, principalmente por diminuir o efeito da deriva primária. Entretanto, ainda há questionamentos quanto ao comportamento do espectro de gotas em determinadas pressões. Objetivou-se neste trabalho analisar o espectro de gotas da ponta com indução de ar TTI-110025 submetida às diferentes pressões de trabalho por meio de um analisador de partículas a laser em ambiente protegido. O experimento foi conduzido em delineamento inteiramente casualizado (DIC), representados pelas pressões 200, 300, 400, 500 e 600 kPa, com quatro repetições. As variáveis técnicas analisadas foram Dv0.1, DMV, Dv0.9, AR, % V < 100 µm e % V > 500 µm. A ponta TTI-110025 apresentou melhores resultados devido à diminuição das variáveis Dv0.1, DMV, Dv0.9 e % V > 500 µm à medida que aumentou a pressão de trabalho. O baixo valor da variável % V < 100 µm indicou baixo risco de deriva e o elevado valor % V > 500 µm sinalizou alto potencial de escorrimentos em aplicações pós-emergentes. Sugere-se operar a ponta TTI-110025 a pressão de 600 kPa.

RESUMEN

Las boquillas hidráulicas con inducción de aire se usan ampliamente en aplicaciones de aspersión, principalmente porque reducen el efecto de la deriva primaria. Sin embargo, todavía hay dudas sobre el comportamiento del espectro de gotas a ciertas presiones. El objetivo de este trabajo fue analizar el espectro de gota de la punta de inducción de aire TTI 110025 sometida a diferentes presiones de trabajo por medio de un analizador de partículas láser en un ambiente protegido. El experimento se realizó en un diseño completamente al azar (DIC), representado por las presiones 200, 300, 400, 500 y 600 kPa, con cuatro repeticiones. Las variables técnicas analizadas fueron Dv0.1, DMV, Dv0.9, AR, %V < 100 µm y %V > 500 µm. La punta TTI 110025 mostró mejores resultados debido a la disminución de las variables $Dv_{0.1}$, DMV, $Dv_{0.9}$ y % V > 500 µm a medida que aumentaba la presión de trabajo. El valor bajo de la variable %V < 100 µm indicó un bajo riesgo de deriva y el valor alto %V > 500 µm indicó un alto potencial de escorrentía en aplicaciones de post-emergencia. Se sugiere operar la punta TTI 110025 a una presión de 600 kPa.

1. INTRODUCTION

The use of phytosanitary products is essential in food production, since more than 30% of world crop loss is due to the adverse effects of pests, diseases and weeds (Guo et al., 2019). However, for the correct use of these products it is necessary to reduce the environmental risks inherent in chemical control operations, and for that, the knowledge and application of the concepts of technology for the application of agricultural pesticides are fundamental, in order to increase the efficiency of the application by positioning the drop with the active ingredient on the desired target and simultaneously achieve effective control and minimizing environmental impacts.

Hydraulic spraying is one of the most used application techniques in agriculture due to its practicality and flexibility. To increase the quality of applications via spraying, operational parameters, such as regulation and calibration of spraying equipment, working pressure (Ribeiro et al., 2022), application rate (Vitória et al., 2023), application range, weather conditions (Richardson et al., 2020), spray nozzles (Ribeiro et al*.,* 2023a) and among others, are the main factors that affect the effectiveness of the application.

With regard to the emission of spray droplets, spray nozzles are considered the main component of spray equipment, directly influencing the spectrum of sprayed droplets (Queiroz et al., 2018), determining the flow rate, droplet size and uniformity of the liquid pulverized. For the correct selection of spray nozzles, it is necessary to know the droplet size, which, depending on the target to be controlled, requires a larger or smaller diameter droplet size.

Spray tips that produce fine droplets (< 200 µm) are more appropriate for targets that need greater coverage, due to the higher density of droplets, and are indicated for applications of contact insecticides, contact herbicides and/or contact systemic fungicides; however, in unsuitable climatic conditions, the risk of drift and evaporation of droplets increases substantially (Cunha et al., 2007). Coarse drops (> 400 µm) provide less target coverage and simultaneously lower droplet density, being mainly indicated for herbicide applications. However, despite avoiding the risk of drift with the increase in the droplet diameter, the operational performance of the equipment is compromised due to the higher consumption of the application rate. In addition, thick drops allow product losses to the soil due to runoff caused by the lack of uniform distribution of the sprayed mixture (Baesso et al., 2014).

There are numerous models of spray nozzles on the market, commonly used for pesticide and foliar fertilizer applications. Hydraulic spray nozzles are initially differentiated by the shape of the jet, which can be of the flat jet, full conical jet and empty conical jet types. From this, there are numerous derivations, which, depending on the type of product, location, shape and size of the target, are indicated for the specific desired use. Among these, flat jet nozzles with air induction stand out, indicated for herbicide applications, as they have the characteristic of producing thick to ultra-coarse drops, minimizing the risk of drift due to the entry of air, which allows the formation of large drops with air bubbles inside (Minguela & Cunha, 2010).

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Efficiency in the application of phytosanitary products is linked to the study of the droplet spectrum, which is relevant to minimize undesirable problems during applications. The most important parameters are the volumetric median diameter (VMD), relative amplitude (AR) and the percentage of droplets with a diameter of less than 100 µm (Vitória *&* Leite*,* 2014). As far as it is concerned, these parameters define the potential for drift, homogeneity and the characteristic diameter of the sprayed drops (Vitória & Campanharo, 2016).

Thus, ensuring that spray droplets have uniform distribution and homogeneous sizes is an important factor that can interfere with the quality of pesticide application (Vitória et al., 2022a). However, many times the phytosanitary product to be applied is more important than the application technique. In this context, there is a need for further studies on the influence of working pressure on the formation of the spectrum of sprayed droplets. Therefore, the objective of this work was to evaluate the droplet spectrum of the TTI 110025 flat jet hydraulic spray nozzle with air induction subjected to different working pressures.

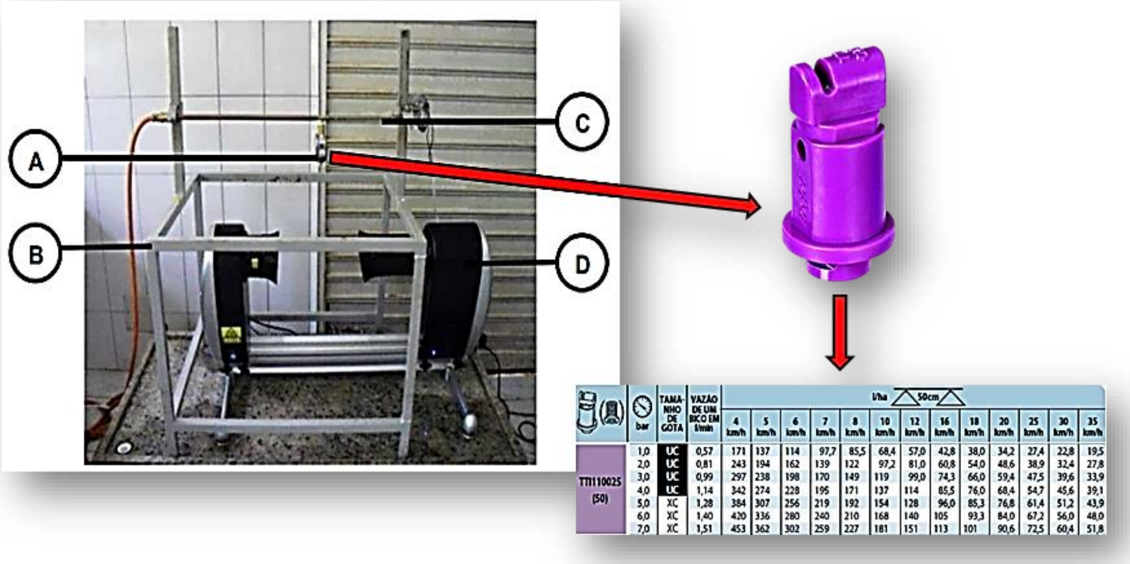
2. MATERIAL AND METHODS

The experiment was carried out at the Agricultural Defensive Application Laboratory, located at the Federal University of Viçosa, municipality of Viçosa, State of Minas Gerais, Brazil. The coordinates of the experiment site are 22º 33' S and 42º 52'W. According to the Köppen climate classification, the regional climate is Cwb type, humid mesothermal with rainy summers and dry winters.

A flat jet hydraulic spray nozzle with air induction was evaluated, manufactured by TeeJet® model TTI 110025, made entirely of polymer, angle 110°, with adjustable pressure from 100 to 700 kPa and flow rate from 0.57 to 1.51 L/min $^{-1}$ corresponding to each pressure, ideal for spraying at a height of 0.50 m from the ground, indicated for herbicide applications.

The analysis of the droplet spectrum was performed directly using water. For this, a Spraytec® real-time droplet analyzer (Malvern Spraytec Real Time Droplet Sizing System*)* was used, with an optical unit consisting of a focal lens. To determine the droplet spectrum of the TTI 110025 tip, a 750 mm focal lens was used, configured to count drops with a diameter between 0.1 and 2,500 µm in a reading time of 1.5 seconds. Figure 1 presents the structure to determine the droplet spectrum of the TTI 110025 tip used in the experiment.

Figure 1. Structure to determine the droplet spectrum. A. Hydraulic spray tip (TTI 110025 tip and TeeJet® catalog); B. Metal structure; C. Structure simulating a spray bar; D. Laser Particle Analyzer.



	bar	TAMANHO DE GOTA	VAZÃO DE UM BICO EM l/min	l/ha 50cm 4 km/h	5 km/h	6 km/h	7 km/h	8 km/h	10 km/h	12 km/h	16 km/h	18 km/h	20 km/h	25 km/h	30 km/h	35 km/h
TTI110025 (50)	1,0	UC	0,57	171	137	114	97,7	85,5	68,4	57,0	42,8	38,0	34,2	27,4	22,8	19,5
	2,0	UC	0,81	243	194	162	139	122	97,2	81,0	60,8	54,0	48,6	38,9	32,4	27,8
	3,0	UC	0,99	297	238	198	170	149	119	99,0	74,3	66,0	59,4	47,5	39,6	33,9
	4,0	UC	1,14	342	274	228	195	171	137	114	85,5	76,0	68,4	54,7	45,6	39,1
	5,0	XC	1,28	384	307	256	219	192	154	128	96,0	85,3	76,8	61,4	51,2	43,9
	6,0	XC	1,40	420	336	280	240	210	168	140	105	93,3	84,0	67,2	56,0	48,0
	7,0	XC	1,51	453	362	302	259	227	181	151	113	101	90,6	72,5	60,4	51,8

Source: Authors.

The tips were adjusted on a spray bar, 0.50 m away from the laser beam and moved to allow the entire jet to be exposed to the beam during reading. It was necessary to use an electric motor reducer, located at one end of the bar, Bosch brand, CEP model, 12.0 V and maximum torque of 48.0 N, driven by an electric wrench for this movement to be carried out. Hydraulic pressure was maintained constant through compressed air coming from a compressor controlled by a Farmabras manometer with an accuracy of 20.0 kPa. The experiment was carried out in a protected environment; the environmental conditions were: air temperature between 20.0 and 23.0°C, relative air humidity between 75.0 and 81.0% and absence of wind.

The experiment was conducted in a completely randomized design (DIC), being represented by pressures of 200, 300, 400, 500 and 600 kPa (pressures within the range recommended by the manufacturer), with four replications. Table 1 presents the data of the experimental treatments.

Table 1. Experimental treatments.

Treatments	Working pressure (kPa)	Flow (L/min-1)*
T1	200	0,81
T2	300	0,99
T3	400	1,14
T4	500	1,28
T5	600	1,40

* tip flow rate corresponding to each pressure during the experiment.
Source: Authors.

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The following parameters were evaluated: volumetric median diameter (VMD µm); D $_{v0.1}$ droplet diameter such that 10% of the sprayed liquid volume consists of drops smaller than this value; D $_{v0.9}$ droplet diameter such that 90% of the sprayed liquid volume consists of drops smaller than this value; coefficient that determines the homogeneity of the population of drops called relative amplitude (AR); volume percentage of droplets with a diameter below 100 µm (% < 100 µm); and percentage of the volume of drops with a diameter greater than 500 µm (% V > 500 µm).

Droplet spectrum data were submitted to analysis of variance, and means were compared by Tukey's test at 5% probability.

3. RESULTS AND DISCUSSION

Analysis of variance indicates that there was interaction between work pressures in all analyzed variables, being significant between 1 and 5% (Table 2). Thus, the variances are not homogeneous, as well as the residuals are not independent and there is rejection of the hypothesis of equality between treatments.

Table 2. Analysis of Variance (ANOVA) of the droplet spectrum.

Variables =	Dv$_{0.1}$ (µm)	DMV (µm)	Dv$_{0.9}$ (µm)	AR	%V < 100 µm	%V > 500 µm
F	4,86*	158,23**	80,35**	68,0**	4,68*	5,46**
CV (%)	4,85	3,54	2,67	2,15	23,11	5,93

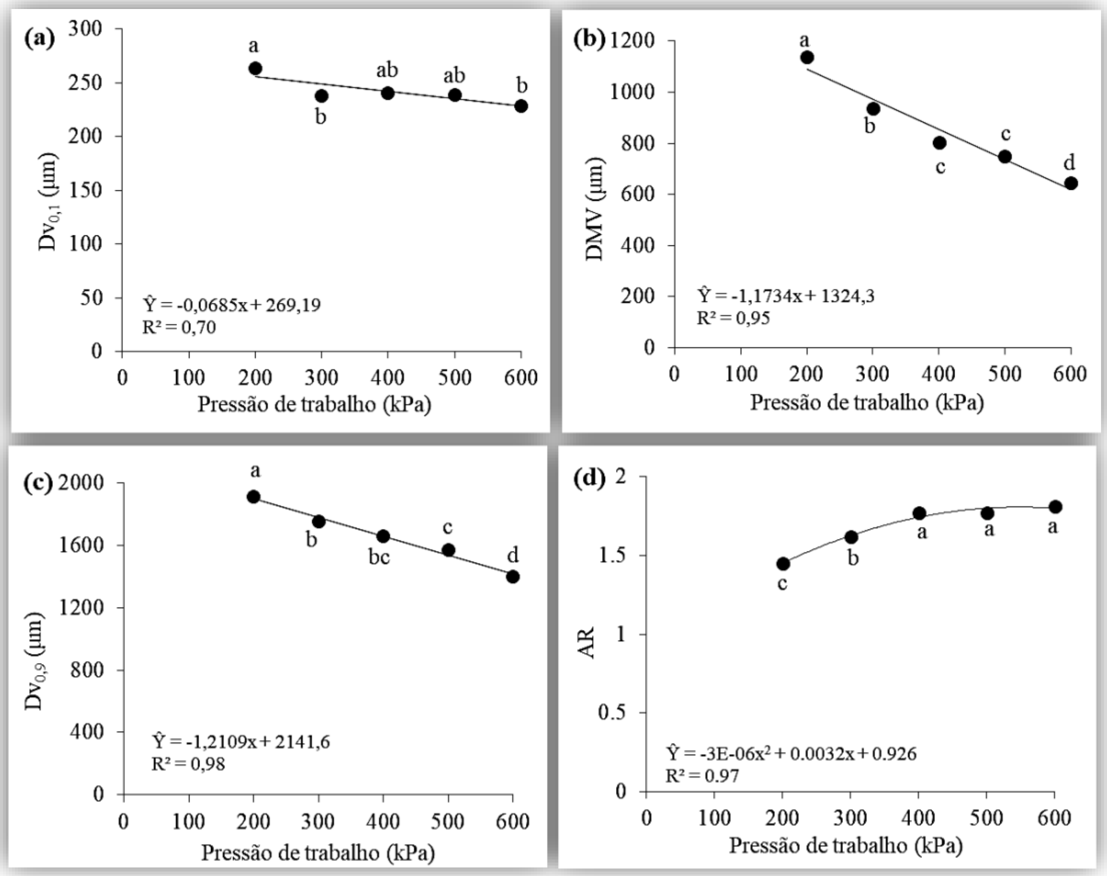
F value of calculated F; CV (%): Coefficient of Variation; *significant at the p<0.05 level, **significant at the p<0.01 level. Source: Authors.

Dv $_{0.1}$ values between the pressures of 300 and 500 kPa were similar to each other, 237, 240, 239 µm, respectively (Figure 2a). The values of Dv $_{0.9}$ (Figure 2c) follow the same conformity as the previous variable, indicating that working pressures close to each other have little variation in droplet size. The lowest pressure (200 kPa) in both variables, provided the largest droplet size, indicating that 10% of the sprayed liquid has drops smaller than 263 µm, and at the same pressure, the Dv 0.9 provided the droplet size of 1910 $_{\mu m}$, indicating that 90% of the sprayed liquid has droplets smaller than this size. During the evaluation of the droplet spectrum, Cunha et al. (2007) observed similar behavior in the API 110 -02, -04 and ADI 110-02 spray nozzles, in which the lowest pressure (200 kPa) provided higher mean values of Dv 0.1, Dv $_{0.9}$ and DMV.

In the Volumetric Median Diameter (VMD) (Figure 2b), as the pressure decreases, the droplet diameter values were greater; however, when there is an increase in pressure, the values tend to be smaller. For example, at a pressure of 200 kPa, the DMV was higher (1139 µm); however, at a pressure of 600 kPa, the DMV was the lowest (645 µm), a significant difference of 494 µm, equivalent to 43.37% greater. Similar results were observed by Viana et al., (2010) using tips with air induction. In practice, the DMV ratio is inversely proportional to the application efficiency variables, that is, the larger the droplet size, the lower the coverage, density and deposition of drops on the desired target, as recently observed by Ribeiro et al. (2023b).

The DMV values need to be analyzed together with the relative amplitude to characterize the homogeneity of the application (Vitória & Campanharo, 2016; Machado et al. 2019). It was observed that the lower the pressure, the lower the AR values (Figure 2d), indicating greater homogeneity of the application, since the lower the relative amplitude value, the more homogeneous the droplet spectrum will be (Viana et al., 2010). All pressures showed heterogeneity in relative amplitude, with values between 1.45 and 1.80, similar to the results observed by Cunha et al. (2010) analyzing the TTI 11002 tip and Sasaki et al. (2016) with AI 3070-015VP and AI 3070-02VP tips, all with air induction.

Figure 2. Spectrum of droplets produced by the TTI 110025 air induction tip at different working pressures. (a) $Dv_{0.1}$ (µm); (b) DMV (µm); (c) $Dv_{0.9}$ (µm); (d) Relative Amplitude (AR).



*,**. Significant regression coefficient at 5% and 1% probability, respectively, by the F test; distinct lowercase letters differ by Tukey's test (p≤0.05). Source: Authors.

It is observed that, both in the $Dv_{0.1}$ and $Dv_{0.9}$ and in the DMV, as the pressure increases, the greater the amount of sprayed liquid that passes through the tip orifice, with a greater fractionation of droplets in reduced sizes; the contrary happens when the pressure decreases. Soela et al. (2021) and Ribeiro and Vitória (2022) verified the same effect using a costal sprayer pressurized with CO_2 on conilon coffee seedlings and a hydropneumatics sprayer on the macadamia crop, respectively. In this sense, the droplet size has a direct impact on the effectiveness of herbicide applications, since, depending on the characteristic of the product,

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whether it is contact or systemic, it will define the average size of the drops to be applied and, consequently, the selection of the spray tip.

Contact herbicides act only at the place where the liquid is sprayed, in which case greater coverage by drops with smaller diameters is preferable; however, systemic herbicides are absorbed and translocated into the interior of the plant, which in most cases, drops with larger diameters are sufficient. For example, Butts et al. (2019), using a mixture of Dicamba + Gliphosate, both systemic, in weed control, concluded that the droplet size of 620 μm can maintain 90% of weed mortality and mitigate the rich drift potentials. Minguela and Cunha (2010) established droplet size criteria for herbicides, with a minimum droplet diameter of 150 m and a maximum of 500 μm being preferable for pre-emergence, contact and systemic herbicides.

Drops with larger diameters are easily found in air induction tips, as in the TTI 110025 tip. Due to this characteristic, the drops tend to be larger, as described by Ribeiro et al. (2023a) using the AI 11002VS tip. In addition, another typical feature of air-inducing tips is the reduction of primary drift due to the larger droplet diameter (Hunter et al., 2020; Lamare et al., 2022), avoiding the potential risk of phytotoxicity due to air drift. herbicide on cultivated plants, which in turn is extremely undesirable on agricultural crops. Other studies elucidate this statement, such as Vitória et al. (2019) in pumpkin culture and recently by Vitória et al. (2022) in the watermelon crop, both studies using the AITTJ60 -1102 VP and -11025 VP spray nozzles, which provided greater droplet diameters and a lower percentage of drops smaller than 100 µm, preventing spray drift in both cultures.

The highest percentage values of droplets smaller than 100 µm were found when there was an increase in pressure (Figure 3a), given that, the higher the pressure, the smaller the droplet size, and consequently the greater the droplet coverage, as observed with DMV values. However, the risk of primary drift during applications is closely related to droplet size (Hilz & Vermeer, 2013). It was observed that drops below 100 µm are highly subject to drift, being easily transported by the wind, and in conditions of high temperature and low relative humidity, they are more conducive to evaporation. Cunha et al. (2003) state that values lower than 15% of the sprayed volume composed of droplets <100 µm are adequate for a safe application.

Inversely to the previous variable, in the percentage of drops larger than 500 µm (Figure 3b), the highest values are found as the pressure decreases. These high values potentiate runoff losses, which during spraying applications is called endoderive, in which there is loss of spray mixture to the soil by runoff within the target area, which is most often associated with high rates of application and droplets of larger diameters. For example, Sossai et al. (2020) found that the AI110015 tip had lower deposits on weeds and simultaneously increased endoderive, as it has a larger droplet diameter. In this case, during spraying, the use of adjuvants is essential in order to achieve greater efficiency when covering drops under the desired target (Camolese & Baio, 2016).

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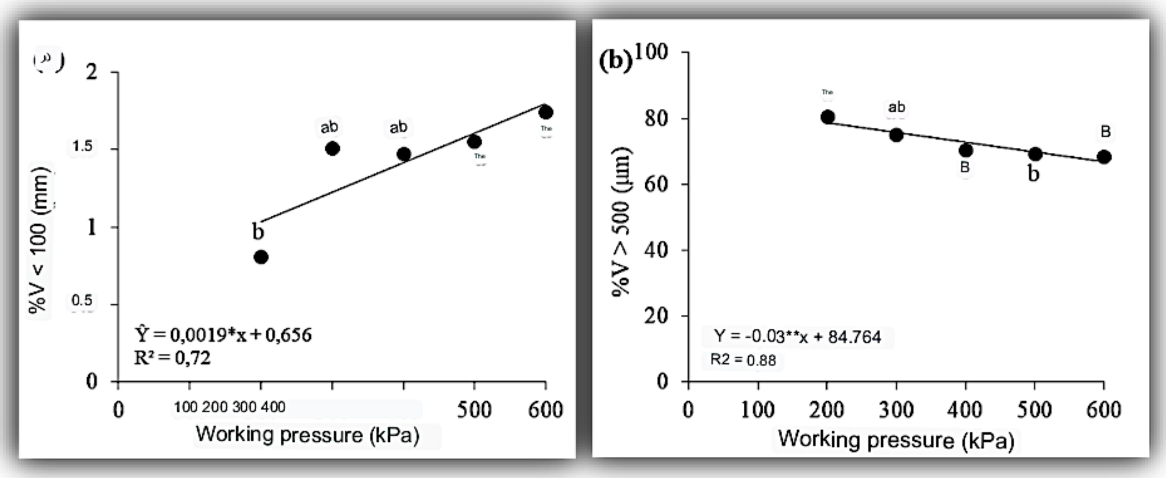
Figure 3. (a) % < 100 (µm); (b) %V > 500 (µm).



*,**. Significant regression coefficient at 5% and 1% probability, respectively, by the F test; distinct lowercase letters differ by Tukey's test (p≤0.05). Source: Authors.

Although the results of the present study were significant in the droplet diameter of the TTI 110025 tip, few studies clarify the interaction of the working pressure in the droplet spectrum, as well as in the possible environmental impacts. In this sense, other experimental studies are needed to elucidate the interaction between the working pressure and other operational parameters of the technology for the application of agricultural defensives and foliar fertilizers, in order to increase the efficiency of the applications and jointly analyze the effectiveness of the application in the control of pests, diseases, weeds and in the application of foliar fertilizers.

4. CONCLUSION

The increase in working pressure resulted in a decrease in the spectrum of drops in the volumetric distribution by size class (Dv $_{0.1,}$ DMV, Dv $_{0.9)}$ and in the percentage of the volume of drops with a diameter greater than 500 µm.

The potential for runoff in post-emergence applications with this tip was high since the volume percentage of droplets with a diameter >500 µm reached considered values (68.47 to 80.52%).

It is suggested to operate the TTI 110025 nozzle using a pressure of 600 kPa, provided that the characteristics of the phytosanitary product, spraying equipment, climatic conditions, desired target and area conditions allow such conditions.

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