(DOI): 10.5777/PAeT.V5.N3.05

This article is presented in English with abstracts in Spanish and Portuguese.

Brazilian Journal of Applied Technology For Agricultural Science, Guarapuava-PR, v.5, n.3, p.41-50, 2012.

Scientific paper

Efficiency of the spray tip using hydraulic hollow cone from the spectral analysis of the droplets

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Abstract

The goal of this study was to evaluate, through the droplet spectrum, the quality of the spray nozzle hollow cone JA-2. Working pressures ranged from 633 to 1477 kPa, as recommended by the manufacturer. The spraying was accomplished using a Yamaho pump, driven by an 1,5 kW electric motor. The nozzles volumetric distribution uniformity was determined according to the coefficient of variation of all operating pressures recommended by the manufacturer . For the realization of the study, five nozzles were randomly selected from a set of twenty. The analysis of droplets spectrum was performed using a *laser* particle analyzer. The coefficient of variation presented values varying from 13 to 22% for pressures ranging from 633 to 1477 kPa. The diameter of the volumetric median reduced from 151 to 109 µm with increase of pressure from 633 to 1477 kPa. The terminal velocity of droplets decreased from 0.77 to 0.37 m s^{-1} for the pressure of 633 kPa and 1477, respectively.

Keywords: droplet spectrum, working pressure, application technology.

Eficiência da pulverização utilizando ponta hidráulica tipo cone vazio a partir da análise espectral das gotas

Resumo

Objetivou-se com este trabalho avaliar a qualidade da ponta de pulverização de jato cônico vazio JA-2. As pressões de trabalho variaram de 633 a 1477 kPa, conforme recomendação do fabricante. Na pulverização, foi utilizada uma bomba Yamaho acionada por um motor elétrico com potência de 1,5 kW. A uniformidade de distribuição volumétrica das pontas foi determinada avaliando-se o coeficiente de variação dos perfis de distribuições de líquidos, considerando-se todas as pressões de trabalho recomendadas pelo fabricante. Para a realização deste trabalho foram sorteadas cinco pontas de um conjunto de vinte. A análise do espectro de gotas foi realizada utilizando-se um analisador de partículas a laser. O coeficiente de variação variou entre 13 e 22%, para as pressões de 633 e 1477 kPa. O diâmetro da mediana volumétrico reduziu de 151 para 109 µm com o aumento da pressão de 633 para 1477 kPa. A velocidade terminal das gotas reduziu de 0,77 para 0,37 m s^{-1} considerando o intervalo das pressões estudado.

Palavras-chave: espectro de gotas, pressão de trabalho, tecnologia de aplicação.

Eficiencia de pulverización usando la boquilla hidráulica tipo cono vacío desde el análisis espectral de las gotas

Resumen

El objetivo de este estudio fue evaluar la calidad de la boquilla de pulverización de jato cónico vacío JA-2. Las presiones de trabajo oscilaron desde 633 hasta 1477 kPa, tal como recomendado por el fabricante. En la pulverización se usó una bomba Yamaho accionada por un motor eléctrico con una potencia de 1.5 kW. La uniformidad de distribución volumétrica de las boquillas fue determinada mediante la evaluación de los perfiles de los coeficientes de variación de distribución

Received in: 26/03/2012 Accepted for publication: 05/10/2012

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de líquido, teniendo en cuenta todas las presiones de trabajo recomendadas por el fabricante. Para este trabajo se eligió por sorteo cinco boquillas de un conjunto de veinte. La análisis del espectro de gota fue tomada utilizando un analizador de partículas por láser. El coeficiente de variación osciló entre 13 y 22% para las presiones de 633 a 1477 kPa. El diámetro mediano volumétrico se redujo desde 151 hasta 109 μm con el aumento de la presión de 633 a 1477 kPa. La velocidad terminal de las gotas disminuyó desde 0,77 hasta 0,37 m s^{-1} considerando el rango de presiones estudiado.

Palabras clave: espectro de gotas, presión de trabajo, tecnología de aplicación.

Introduction

The chemical control is a quick and easy method to be implemented by farmers, since it is known the target to be hit and resources available to achieve this goal. In Brazil, the plant protection techniques are practiced intensively in phytosanitary management of insects, diseases and weeds with satisfactory results. However, the misuse of phytosanitaryicides has caused damage to the health of applicators, consumers and to the environment. SAYINCI and BASTABAN (2011), state that in Turkey the chemical control method is the most widely used in agriculture. In the United States, LUCK et al. (2011) also state that chemical control is essential as a method for the protection of plants.

Most methodologies employed to study the settled available droplet spectrum is through the hydrosensitive labels. However, new methodologies have been used to determine the size of the droplets in the air and the particle analyzer has been detached due to the great precision and simplicity in data acquisition. In these devices, according to CUNHA et al. (2007a), FERNANDES et al. (2007) and NUYTTENSET al. (2009), the deviation that occurs in the light beam of the laser, depends on the particle size, whereas, the smaller the particle, the greater the degree of diffraction the light beam will suffer.

The hollow cone tips are traditionally recommended for spraying insecticides and fungicides in crops with large leaves mass, in which the jet penetration and coverage are essential. These are the hydraulic tips which produce the thinner droplet spectrum, according to MASIÁ and CID (2010). According to SAYINCI and BASTABAN (2011), these tips were designed to increase the coverage of the target. Yet, farmers have decreased their use by virtue of drift caused due to the large number of droplets of small size produced (CUNHA et al. 2007b).

The drops after released into the environment are affected by the weather conditions of the atmosphere. The existence of large and small droplets in the spectrum affects the useful life thereof and sprays quality, whereas the larger droplets can acquire greater terminal velocity, reaching more distant targets. Since this velocity is a function of the diameter, the smaller droplets with lower velocity, remain longer exposed to conditions of evaporation, which of course, increases the loss of its volume. The Speed achieved by the droplet in fall or thrown in the air is governed by the Stokes Law, with interaction of the turbulence and the gradual loss of volume that occurs with the hanging drop.

The sprayers used in orchards generally use air jets for the transport of droplets to the interior of the tree canopy. The characteristics of the air jet, most of the times produced by an axial fan, as well as its flow rate influence in the cloud of droplets. The velocity of the air jet reduces rapidly, when increasing the distance of the exit of air from the fan to the treetops, with the attenuation of the air jet by divergent currents and the barrier created by the leaves, so the deposits in the top and center will be smaller (SVENSSON et al., 2003).

Thus, the objective was to study the quality of spray produced by the tip of jet JA-2, in thirteen working pressures.

Material and Methods

The experiment was conducted during the month of October 2011, in the Phytosanitaryicide Application Laboratory, Department of Agricultural Engineering, Federal University of Viçosa, Campus of Viçosa, Minas Gerais.

The quality of the spray produced by the jet tip JA-2 was evaluated as to the parameters that constitute the droplet spectrum. The tip is characterized by producing thin droplets, according to the American Association of Agricultural Engineering (ASAE) and the British Council of Protection of Crops (BCPC), by the standard S572 (ASAE, 2000) and also for being quite used in the phytosanitary management of insects and pathogens in hydropneumatic sprayers. The working pressures used were 633, 703, 774, 844, 914, 985, 1055, 1125, 1195, 1266, 1336, 1406 and 1477 kPa covering the entire pressure range recommended by the manufacturer for use in sprayers hydropneumatic.

During the spraying, to achieve the pressures studied is mounted a spraying system, using a hydraulic pump of piston Yamaho with speed 700-900 rpm, nominal flow rate between 8 and 11 L min^{-1}, power of 0.75 to 1.12 kW and maximum pressure of 3,516 kPa, driven by an electric motor Weg with potency of 1.5 kW. The water was placed in a 20 liter tank and used a lance of hydraulic backpack sprayer to spray.

The manometer used was Famabras brand, classified by the Brazilian Association of Technical Standards (ABNT) as Class B, with full scale from 0 to 2500 kPa and division of 200 kPa. Was standmarked on standard test stand, using a hydraulic pressure generator, equipped with a manometer Salcas, Class A3 with accuracy of ± 0.25% and division of 10 kPa. The assays were performed according to the norm NBR-12446/1992, similar methodology to that used for Dornelles et al. (2011).

The uniformity of horizontal volumetric distribution in the bar was obtained with the distance between centers and bar height of 0.5 meters, and the time of observation for the analysis of distribution profile was of 60 seconds. The uniformity of distribution was determined in standard stand, consisting of V-shaped channels, standardized according to the ISO norm 5682/1 (ISO 1986). The water volume was measured using 200 mL test tubes. The results were transformed to percentage of the total volume sprayed to eliminate the time factor of the analyzed data, methodology similar to that used by CUNHA and SILVA (2010) and FREITAS et al. (2005). The uniformity of volumetric distribution was determined for all working pressures recommended by the manufacturer and used five tips randomly selected from lot of 20 tips, similar methodology was adopted by FREITAS et al. (2005), BAUER et al. (2006) and CUNHA and SILVA (2010) in determining the quality of hydraulic tips. Subsequently, four tips were selected to characterize the distribution profile. The tips were studied individually at the stand. We used a plumb bob for the alignment of the center of the jet with the upper edge of the channel, with the objective of position the jet symmetrically on the table.

The analysis of the droplet spectrum was carried out using a laser particle analyzer (Spraytech, Malvern Instruments Co.). This equipment has a 750 mm focal lens, and is based on the diffraction of light path when hitting the drops to determine their sizes. The spraying was performed so that the spray hit transversely the light beam, allowing obtaining directly the droplet spectrum $Dv_{0,1}$; $Dv_{0,5}$; $Dv_{0,9}$, Span, percentage of droplets below 100 µm, percentage of droplets between 100 and 200 µm, 200-300 µm and greater than 300 µm. The tip was positioned at 0.40 meters from the optical beam. In the test, we used pure water, methodology also used by CAMARA et al. (2008) and CUNHA et al. (2010). The analyzer was calibrated for accounting drops in the size class from 0.10 to 2500 µm thus was the most rigorous possible to obtain the full spectrum of droplets.

Starting from the volumetric median diameter (VMD) of the droplets obtained in particle analyzer was applied the methodology proposed by MATTHEWS (2000), to determine the terminal velocity of the droplets (Equation 1).

Where:

$$V_t = \frac{g\, d^2 Q_d}{18\, \eta} \qquad (1)$$

V_t = terminal velocity of the droplet (m s^{-1});
g = acceleration of gravity (m^{-2} s);
d = diameter of the droplet (m);
Q_d = density of water (kg m^{-3});
η = viscosity of gas (N s m^2).

The psychrometric conditions during the experiment were monitored as an indicator of temperature and relative humidity of the Ummi ® brand. This meter has a temperature sensor with a scale ranging from -20 to 100 ° C, 1 ° C resolution and accuracy of ± 0.6 ° C and a relative humidity sensor with a scale of 0 to 100%, 1% resolution , accurate to ± 3%, with absence of wind.

The experiment was conducted in a completely randomized design. To compare the parameters in different pressures, the data were subjected to analysis of variance to establishment of regression models in order to find a model that best explains the behavior of the data. The comparisons were performed using the Tukey test and by selection of regression model that best fit the data behavior, using the program Statistical Analysis System (SAS) version 9.2 and four repetitions. The criteria adopted for the choice of models were significance of regression, method of model selection Stepwise, for elimination of non-significant coefficients, and coefficient of determination. In the analysis of uniformity of volumetric distribution of the tips it was used the descriptive statistics for presentation of results.

Results and Discussion

The psychrometric conditions during the experiment were: relative humidity between 70 and 80%, air temperature of 22 to 26 ° C and absence of wind.

The calibration of the manometer showed that the manometers used showed good accuracy with respect to standard manometer. The selection of the manometer is quite neglected by operators, farmers, agronomists and technicians because it is common the scale not be compatible with the recommended pressures for the spray tip. The manometers are essential for calibration of agricultural sprayers, its accuracy affects the entire spectrum of the population of droplets, spray volume, wear of the tips, opening of the angle of the jet of hydraulic tips, flow of the tips, among others.

On the analysis of distribution uniformity of liquid it was used the variation coefficient as a parameter of the dispersion of the distribution profile. The coefficient of variation provided by the distribution profile of the tip JA-2 increased with the spray pressure. The coefficient of variation ranged from 13 to 22% at pressures of 633 and 1477 kPa, respectively (Figure 1). Cunha et al. (2007b) found values of coefficient of variation between 28.1 and 41.5% at pressures of 600 and 500 kPa, respectively. According to the authors, this variability occurred due to the uneven distribution profile presented by the tips of hollow cone TVI 80-015 and TVI 80-02 and the overlap obtained with the tips at 0.5 meters high.

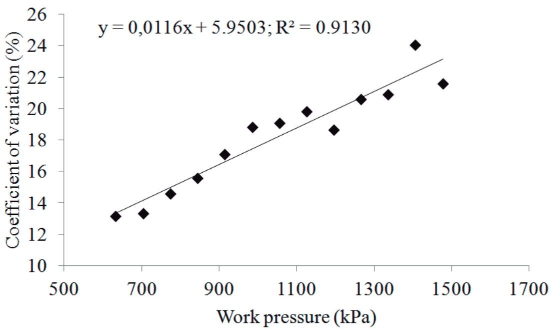

Figure 1. Effect of pressure on the distribution uniformity of liquid of the tip JA-2.

The uniformity of volumetric distribution of the set of spray tips arranged in the bar depends on the distribution profile of the tips individually. In hydropneumatic sprayers due to air assistance, the effect of the variation in homogeneity of distribution caused by the high coefficient of variation of the tip is reduced by the effect of the air flow, produced by the fan. The results of the coefficient of variation were similar to those obtained by CUNHA and SILVA (2010) FOQUÉ and NUYTTENS (2011) for hollow cone tips.

The uniformity of volumetric distribution, visually, provides information quite revealing, when observing about the spray quality. The uniformity of volumetric distribution, visually, provides information quite revealing, the observer about the spray quality. For comparison purposes, however, the coefficient of variation is the most accurate method to evaluate the quality of the distribution of slurry along the bar. BOLLER and RAETANO (2011) argue that it is common for hollow cone tips present coefficient of variation greater than 30% over the bar. This may be one reason that explains their preference for use in hydropneumatic sprayers. The results of coefficient of variation obtained in this work are still below those suggested for the tips hydraulic in Europe, which advocates through the standard EN 12761-2 values of coefficient of variation below 7%.

The volumetric distribution profile was characteristic of hollow cone tips. It was observed that the center of the jet was a depression of the deposition and in the extremities was the formation of peaks with sharp drop and marked reduction of the volume collected in the tubes. As the pressure is increased, the profile showed peaks with highest percentage of volume. These points have reduced the uniformity of distribution of the set of tips disposed in the bar, consequently, increased the coefficient of variation. In the 633 kPa pressure, the coefficient of variation was 13.1%, giving a larger deposit of liquid in the center of the jet to the detriment of the extremities. In this case, it was found that the distance between tips was a fundamental factor, for distances greater than 0.5 meters, possibly, would increase the coefficient of variation. At higher pressures, the ends showed higher deposit in relation to pressure of 633 kPa, due to larger opening of the angle of the jets (Figure 2).

The distribution profile affects the quality of phytosanitary control in the region of encounter of the adjacent streams along the bar. It was observed that at higher pressures occurred acute depressions in the central area of the stream, corroborating with the results obtained by CUNHA and SILVA (2010) at high pressures. The results indicated that the tip JA-2 can be used to pulverization in the total area. These tips dispense the occurrence of large overlap of the bursts due to the uniformity thereof.

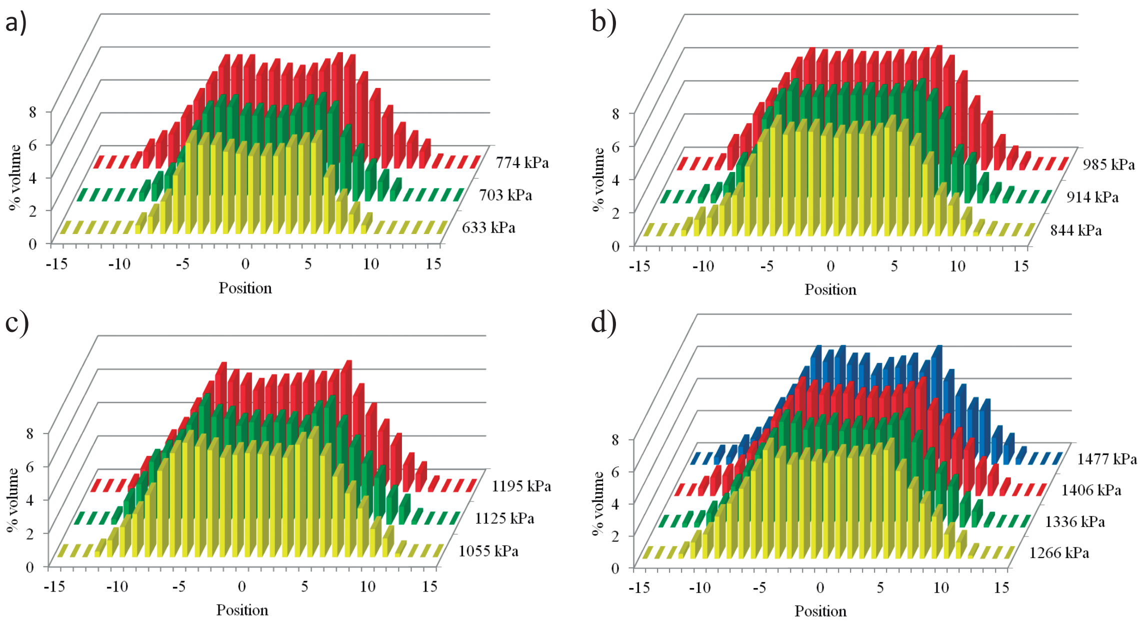

Figure 2. Distribution profiles of the tip JA-2 in different working pressures, considering the pressures 633, 703 and 774 kPa (A), pressures of 844, 914 and 985 kPa (B), pressures of 1055, 1125 and 1195 kPa (C) and pressures of 1266, 1336, 1406 and 1477 kPa (D).

The use of hollow cone tips on hydraulic sprayers in the bar is greatly influenced by the vibration of the same, since the overlap is too small to compensate the oscillation of the bar no matter how small. Its use is widespread in turbo atomizers, for producing a reduced droplet size, with greater ability to penetrate the canopy of plant trees and for the same reasons, is often associated with spraying of fungicides and insecticides. The increased pressure provided an elongation of the base profile as the angle of the jet was opened, as a function of working pressure, similar results to those obtained by CUNHA and RUAS (2006) and CAMARA et al. (2008) working with flat spray tips.

The droplets, no matter small it may be, has in its interior the active ingredient of the product added to the spray solution, hence the need to take in account all droplets formed, independent of their size, because the smaller droplets, despite having less active ingredient than larger ones, have the same concentration. Thus, the density of small droplets not accounted could be sufficient to exert control over the biological target, as long as the spraying is carried out in a technical manner, within ideal weather conditions, to allow the droplets to deposit on the target.

The parameter $Dv_{0,1}$ is still little studied in Brazil, where few jobs present and discuss their importance in the application of pesticides. The highest and lowest value of $Dv_{0,1}$, was observed in the pressure of 774 and 1266 kPa, respectively, being observed a reduction of 89 to 40 µm in the size of the droplets between the two pressures. The number of drops which represents this value in the application of agrochemicals, it is often underestimated, when the measurement of the drops is carried out using sensitive labels to water and oil, due to coalescence and the overlapping of the droplets and also to the difficulty of analysis programs of droplets to measure precisely the stain on the label. In critical situations for the spraying the ideal is that the size of droplets corresponding to $Dv_{0,1}$ is larger than 100 µm, because thereby reduce the losses by evaporation and drift (Figure 3).

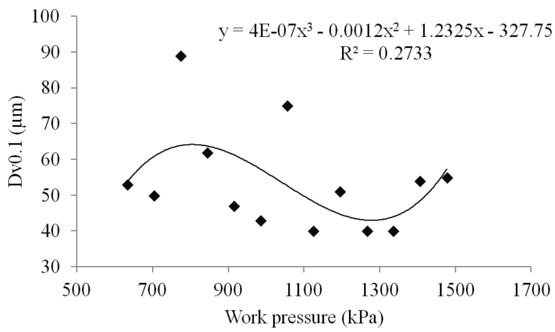

Figure 3. $Dv_{0,1}$ in function of the work pressure

The tip JA-2 is suitable for work in the pressure range from 633 to 1477 kPa. It was noted, however, that from 1055 kPa the pressure effect in the volumetric median diameter was small, and indicating that from a certain pressure the droplet size is little changed. In this way, increasing pressure represents higher flow, energy cost, tip wear, broken of hoses and connectors, filters, and small changes in the droplet size. The volumetric median diameter presented a reduction of 151 to 109 mM between the highest and lowest value, at pressures between 633 and 1477 kPa (Figure 4).

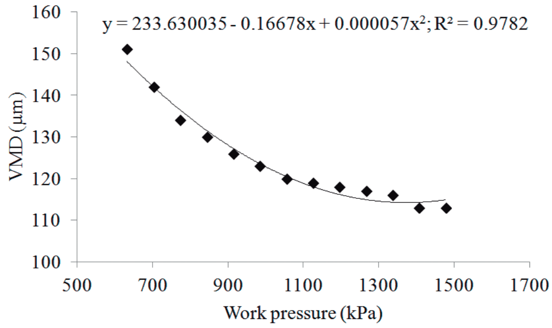

Figure 4. Volumetric median diameter of the tip JA-2 in different working pressures.

The $Dv_{0,5}$ is the parameter most studied in research on pesticide application technology, presenting high relation with the pressure established by the manufacturers of tips. The droplets produced by this tip are quite susceptible to drift and evaporation in adverse weather conditions, so the selection of the tip is so important to the success of phytosanitary control.

For the $Dv_{0,5}$ highest and lowest value was obtained at pressures of 633 and 1055 kPa, a decrease of 286 to 192 µm in the droplet size (Figure 5). This, together with the $Dv_{0,1}$, a parameter little discussed, but which has representation in the spectrum of droplets. However, the behavior of this parameter was not linear with the working pressure. The distance between the values of Dv0, 9 and $Dv_{0,1}$ should be the lowest possible in spraying so that the homogeneity of the droplet spectrum is achieved.

The relative amplitude of the population of droplets represents the dispersion of the droplet size.

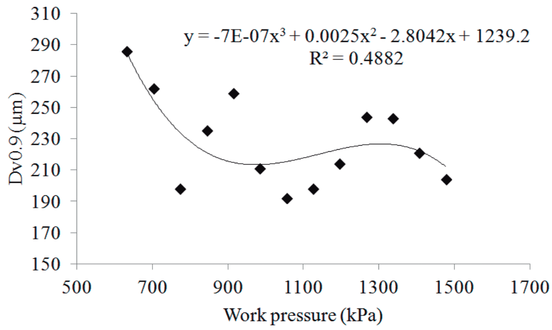

Figure 5. $Dv_{0,9}$ In function of the working pressure.

The values obtained showed that the tip produced a droplet spectrum very homogeneous in all pressures used (Figure 6). The lowest and the highest value found for relative amplitude were 0.8 and 1.8 at pressures of 774 and 1336 kPa, respectively, similar results were obtained by CUNHA et al. (2007a) for hollow cone tips.

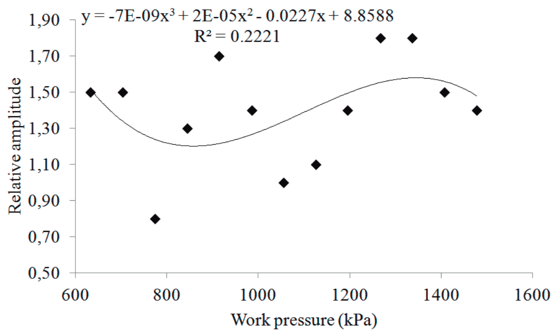

Figure 6. Relative amplitude in function of the working pressure

The terminal velocity of the droplets is related to the drift and evaporation, because as higher the speed of fall of the droplet, lesser the time of evaporation of the same in the air during the path to the target. The droplets with greater terminal velocity suffer less displacement from the launch site to the target, by the wind action. The terminal velocity values obtained in this study were consistent with those found by CARVALHO et al. (2011) simulating different diameters of droplets in order to determine their terminal velocity or sedimentation. The minimum and maximum speeds reached by the droplets were of 0.77 and 0.37 m s^{-1} (Figure 7). MINGUELA and CUNHA (2010) state that droplets of 100 µm thrown at one meter of the soil are dragged by 360 meters by winds of m 2 s^{-1}, therefore, the authors did not recommend spraying with drops below 100 µm.

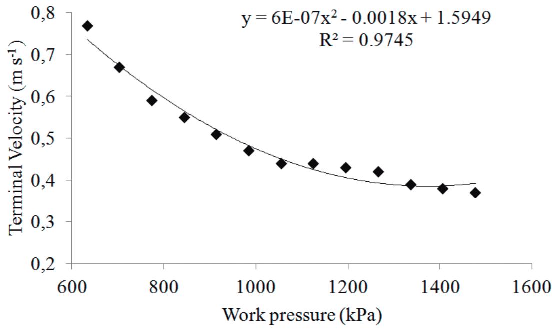

Figure 7. Terminal velocity of the droplets in function of the working pressure

The increase in the working pressure provoked an increase of 17.5 to 42.2% in the percentage of droplets smaller than 100 µm, to pressures from 774 to 1336 kPa. Now, the percentage of droplets with a diameter between 100 and 200 µm was reduced from 72.7 to 38.6% in relation to the pressures from 774 to 1336 kPa. The class of droplets between 200 and 300 µm showed a reduction from 21.7 to 9.6% between the pressures of 633 and 774 kPa. The pressure that presented the highest percentage of droplets in the classes of size smaller than 100 µm s, between 100 and 200 um, between 200 and 300, and above 300 µm was 774 kPa with percentages of 17.5, 72.7, 9.6 and 0.08% of the droplets respectively (Figure 8).

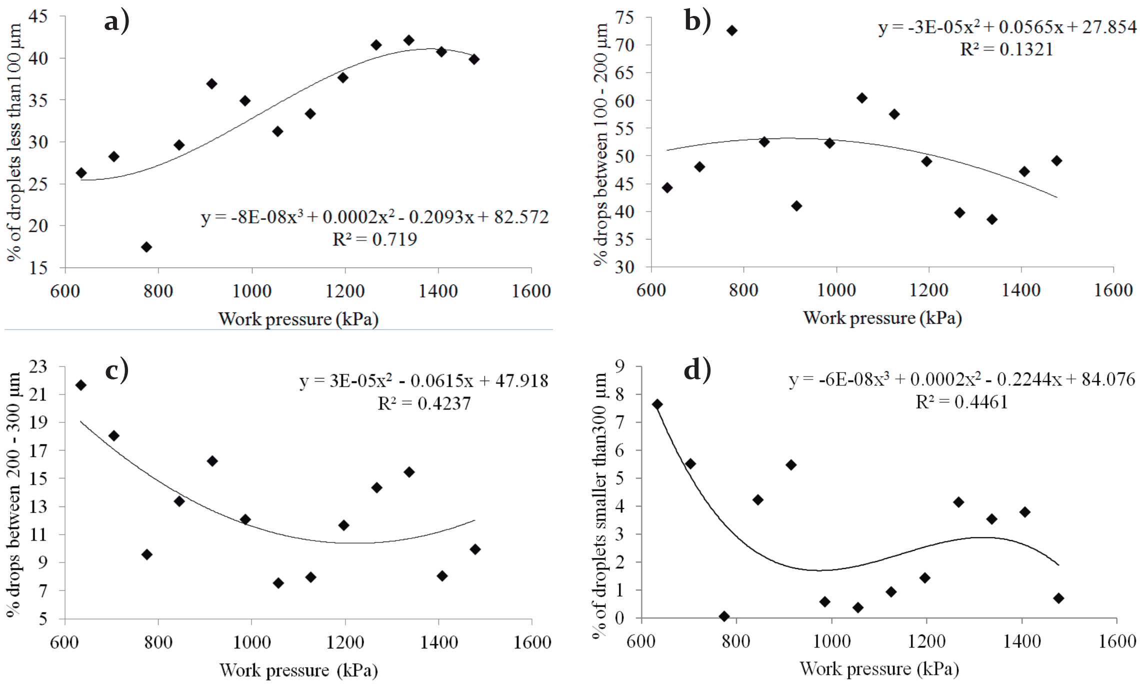

Figure 8. Spectrum of the droplets in function of the working pressure. Percentage of droplets smaller than 100 µm (A), percentage of droplets from 100 to 200 µm (B), the percentage of droplets from 200 to 300 µm (C) and the percentage of droplets greater than 300 µm (D).

The increase in the percentage of droplets less than 100 μm increased the percentage of droplets susceptible to drift and evaporation. The percentage of droplets between 100 and 200 um comprised the majority of the droplets produced by the tip JA-2. Under these conditions, the hydraulic spraying, the percentage of drift is probably higher in sprays of bar. However, the spray with hydropneumatic sprayers, the effect of drift is reduced due to the air curtain generated by the fan. In this model of spraying, the phenomenon of evaporation is what most contributes to the achievement of a quality application with reduced risk to the environment, operators and investors, support staff in properties, among others.

The analysis of the quality of the spray produced by a hydraulic tip or any other device responsible for the fractionation of drops for the application of pesticides should be based on all parameters of the spectrum, together. The exclusion of one of the variables that make up the spectrum of drops of this analysis leads the responsible for spraying to take wrong decisions and compromise the efficiency and effectiveness of the spraying.

The use of more accurate equipments to determine the droplet size is urgently needed in the technology of application. The hydro sensitive labels are outstanding tools for farmers have an idea of the quality of spraying using, primarily, the parameter of the density of droplets. The quality of the labels, however, is very important and the same have been found in the market with high sensitivity to touch, which requires expertise in handling by users.

The provision of more information about the quality of the droplet spectrum produced by hydraulic tips is an urgent need in the field. The elaboration of catalogs by manufacturers with information about the tips and conditions of use, availability of graphs of pressure versus the droplet diameter, becomes a facilitator in selecting the tip and the spectrum by users. Another aspect is the training of technicians, agronomists, producers and people involved in the spraying of pesticides to correctly interpret the information available in catalogs.

Conclusion

1. The tip of jet JA-2 provided a spray of quality, but its droplet spectrum requires very favorable weather conditions.

2. The coefficient of variation presented values between 13 and 22% for pressures of 633 and 1477 kPa, respectively.

3. The lowest value of Span was of 0.8 in the pressure of 774 kPa and of 1.8 at pressures of 1266 and 1336 kPa.

4. The volumetric median diameter reduced from 151 to 109 μm with the increase of pressure.

5. The terminal velocity of the droplets decreased from 0.77 to 0.37 m s^{-1} for pressures between 633 and 1477 kPa.

Acknowledgement

To the National Council of Scientific Research and Development and Technology for granting scholarships and the Foundation for Research Support of the State of Minas Gerais for funding this research.

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