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Cientific Paper

Uniformity of droplets distribuition and control of *Ipomoea grandifolia* after simulated rainfall

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Abstract

The correct choice of herbicides assuming that there are differences in the behavior of the spectrum and deposition of the spray droplets isolated and associated with adjuvants can affect its effectiveness in controlling the rope in *I. Grandifolia*. In this context, this work aimed to evaluate the spectrum and droplet deposition by virtue of pesticides herbicides associated with the use of adjuvants and control *I. Grandifolia* after artificial rainfall simulation. The experiments were conducted in a completely randomized design in a factorial arrangement with five replications, and consisted of six grout herbicide, glyphosate and paraquat being isolated and used in combination with mineral fertilizer and vegetable oil, and tied in two conditions with and without simulation artificial rain and a control (water). The variables evaluated were: the diameter and uniformity of droplets surface tension of grout, volumetric distribution and spacing tips and control of *I. grandifolia* with artificial rain 1 h after application. The control of *I. grandifolia* with artificial rainfall simulation reduces herbicide efficiency with the highest dry matter of roots and root dry matter, regardless of the use of adjuvants.

Keywords: chemical control; syrups; droplet deposition; spray nozzle

Uniformidad distribución de las gotas y el control de Ipomoea grandifolia después de la lluvia simulada

Resumen

La elección correcta de herbicidas suponiendo que hay diferencias en el comportamiento del espectro y en la deposición de las gotas de los caldos de pulverización aislados y asociados con adyuvantes puede afectar a su eficacia en el control de la *Ipomoea grandifolia* (campanilla). En este contexto, este estudio tuvo como objetivo evaluar el espectro y la deposición de las gotas debido a caldos de herbicidas asociados con el uso de adyuvantes y control de la campanilla después de simulación artificial de lluvia. Los experimentos se llevaron a cabo en un diseño completamente al azar en arreglo factorial con cinco repeticiones, consistiendo de seis caldos de herbicida, con el uso de glifosato y paraquat aislado y en asociación con fertilizantes minerales y aceite vegetal, en las condiciones con y sin simulación de lluvia artificial y un control (agua). Las variables evaluadas fueron: el diámetro y la uniformidad de las gotas, la tensión superficial de los caldos, la distribución volumétrica y espaciamiento entre boquillas de pulverización y el control de *I. grandifolia* con lluvia artificial 1 h después de la aplicación. El control de *I. grandifolia* con simulación de lluvia artificial reduce la eficacia de los herbicidas con las mayores cantidades de materia seca de la parte aérea y materia seca de la raíz, independiente del uso de adyuvantes.

Palabras clave: control químico; caldos; deposición de gotas

Uniformidade de distribuição de gotas e controle de Ipomoea grandifolia após chuva simulada

Resumo

A escolha correta dos herbicidas pressupondo que exista diferença no comportamento do espectro e deposição de gotas da calda de pulverização isolado e associados com adjuvantes pode afetar sua eficácia no controle da corda-de-viola.

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Neste contexto, objetivou-se neste trabalho avaliar o espectro e deposição de gotas em virtude de caldas dos herbicidas associados ao uso de adjuvantes e o controle de corda-de-viola após simulação artificial de chuva. Os experimentos foram conduzidos em delineamento inteiramente casualizado, em esquema fatorial, com cinco repetições, sendo constituídos por seis caldas de herbicida, sendo utilizados glyphosate e paraquat isolado e em associação com fertilizante mineral e óleo vegetal, nas condições com e sem simulação de chuva artificial, mais uma testemunha (água). As variáveis avaliadas foram: determinação do diâmetro e uniformidade das gotas, tensão superficial das caldas, distribuição volumétrica e o espaçamento entre pontas e o controle de *I. grandifolia* com chuva artificial 1 h após a aplicação. O controle de *I. grandifolia* com simulação artificial de chuva reduz a eficiência dos herbicidas com as maiores quantidades de matéria seca da parte aérea e matéria seca da raiz, independente do uso de adjuvantes.

Palavras-chave: controle químico; caldas; deposição de gotas; ponta de pulverização

Introduction

The uniformity of deposition of the sprayed droplets is a characteristic which serve as a reference to verify the distribution of the active ingredient on the target, being altered by the spacing between tips, working pressure, height of the bar in relation to the target and opening angle of the spraying between the pulverization nozzles (BAUER and RAETANO, 2004; FERREIRA et al., 2009).

According to VIANA et al. (2010), the parameters of greater importance for the determination of droplets totality are the median volume diameter (MVD), the relative amplitude (RA) and the percentage of droplets with diameter inferior to 100 µm. The authors still report that, alongside, these factors define the potential of drift in pulverization, the homogeneity and size of droplets produced by the pulverization nozzles.

The process of droplets formation can be significantly altered by the use of certain formulations and by addition of adjuvants, since these alter the physicochemical characteristics of the sprayings, such as the superficial tension and the viscosity. On the other hand, the interaction of these products can influence the efficacy of pulverization (ANTUNIASSI, 2006).

As stated by QUEIROZ et al. (2008), the adjutants reduce the superficial tension of the pulverized droplets, causing its flattening, which increases its surface of contact with the biological target and improves the coverage of the same. The authors also reported that an advantage of adjuvants use is the fast absorption of the products, with lesser losses occasioned by rains after the application.

On the other hand, JAKELAITIS et al. (2003) studied the effect of different formulations of glyphosate (ammonium salt, isopropylamine and potassium) on the control of *Brachiaria decumbens*, submitted to rains of 20 mm and reported that the occurrence of simulated rain an hour after the application of the product reduced the efficacy of control in all used formulations.

In Brazil, due to the lesser number of researches about the behavior of interaction between adjuvants and herbicides in the pulverization spraying, it becomes important the comprehension of the superficial tension between other physicochemical characteristics of these solutions after the rains occurrence (MACIEL et al., 2010), therefore there is minimization of products losses after the same reaching the target, and there is maximum efficacy in the control of weeds (MONQUERO and SILVA, 2007).

In this context, assuming that there is difference in the behavior of the spectrum and the droplets deposition in pulverization sprayings with use of isolated herbicideswith adjuvants, the objective of this research was to compare the spectrum and the droplets deposition produced by the spraying of herbicides and adjuvants, and the control of morning glory (*Ipomoea grandifolia*) on the incidence of simulated rain.

Materials and Methods

The experiments were performed from September to November of 2011, using six sprayings of herbicides associated or not to the use of adjuvants. The laboratory of the study is located in the latitude 21º15’22’’S and longitude 48º18’58’’, with average altitude of 570 m. It was performed three experiments, being them constituted by the diameter determination and droplets uniformity, volumetric distribution and determination of spacing between tips and control of *I. grandifolia* through different sprayings with and without simulation of artificial rain.

Determination of droplets diameter and uniformity

In order to analyze the diameter and uniformity of droplets, that is, its spectrum produced by the nozzle DG 11001, it was used an analyzer of particle diameter by laser diffraction (Mastersizer S® version 2.19). In this equipment, an optical unity determines the droplets diameter of the spectrum pulverized through trajectory deviation on the laser when reaching the droplets.

According to the manufacturer recommendations, the equipment was adjusted to assess droplets between 0.5 to 900 mm (lens of 300 mm). An exhauster (coif type) localized over the equipment where the spraying is made retrieves the particles which remain suspended on the air, the presence of this particles could result in double readings or lodging on the equipment lens, compromising the analysis accuracy. The pulverization was activated by compressed air, and the pressure kept at a constant of 2.76 bar (40 lbf.pol^{-2}) with assist of a precision pressure regulator. It was used an oscillator, so then the spraying would cross transversely the laser during the device readings. The time spent by the oscillator to move from an edge to the other applied spraying was calibrated for 3 seconds. Each reading of the laser was performed with an interval of 2 milliseconds, totalizing 500 readings per second.

The treatments evaluated were: 2.5 L.ha^{-1} ^{of} glyphosate (Roundup®); glyphosate (Roundup®) + tributilcitrat (Vertex® – 0.1% v/v); glyphosate (Roundup®) + vegetal oil (Veget'oil® – 0.1% v/v); and 1.0 L.ha^{-1} of paraquat (Gramoxone®); paraquat (Gramoxone®) + tributilcitrat (Vertex® – 0,1% v/v) and paraquat (Gramoxone®) + vegetal oil (Veget'oil® – 0,1% v/v) and a control (water).

The design used was completely randomized, in factorial scheme, being constituted by 3 x 6, in which was used three nozzles of the model DG 11001 and in each one of them was performed five repetitions per treatment (six sprayings), totalizing 15 readings by the end of each treatment, constituting a total of 105 readings. The parameters assessed were: median volume diameter ($DMV_{0,1}$, $DMV_{0,5}$ and $DMV_{0,9}$), uniformity coefficient and volume percentage applied with droplets of diameter inferior to 100 μm (%V < 100 μm).

The results of MVD, uniformity coefficient and %V < 100 μm were submitted to variance analysis by the F test and, when significant, the averages were compared through the Tukey test at 5% of probability.

Volumetric distribution and determination of the gap between nozzles

The assessment of the volumetric distribution profile was performed on a table of deposition composed by a corrugated metal plate, forming 67 channels in V, 2.5 cm apart from each other, totalizing 167.5 cm of width. In the inferior part of the deposition table were put test tubes of 100 mL to collect the sprayings, with a test tube for each channel. The spraying nozzle was positioned in the center of the table and at 50 cm of height, in such way that the spraying was released vertically. The volumetric distribution profile was assessed for the six sprayings and for the water, at the working pressure 40 lbf.pol-2. The used spacings were 50, 60, 70, 80, 90 and 100 cm.

The experimental design was entirely randomized, in a factorial scheme, constituted by 3 x 6, in which were used three nozzles model DG 11001 and in each one of them was performed five repetitions of each spraying, totalizing 15 readings by the end of the treatments (six sprayings), being a total of 105 readings. The pulverization was performed until the test tubes of the central channels (which received greater quantity of the spraying) achieved 90% of its maximum limit. Next, it was registered the volume of the sprayings contained in each test tube.

The volumetric distribution profile was determined based on the average of collected volume in both repetitions for each sprayings and for the pulverization nozzle DG 11001. The obtained volumetric distribution profile was used to determine, in a spreadsheet (Microsoft Excel®), the spacing between nozzles which should be used on a pulverization bar.

The distribution uniformity along the applied range was assessed through coefficient of variation, being acceptable up to a value of 10%. It was established the regression equation considering the relation of spacing between nozzles and its respective coefficients of variation of nozzles.

Control of *I. grandifolia* through different sprayings, with and without simulation of artificial rainfall

It was sowed *I. grandifolia* in pots of five liters, containing two parts of soil and a part of cattle manure. The experiment was conducted with a completely randomized design, with three repetitions, in factorial scheme 6 (herbicide sprayings) x 2 (with and without simulated rain) + 1 control, constituting twelve soil treatments. The application volume was set at 75 $L.ha^{-1}$ and the quantity of simulated rain of 20 mm. The application of treatments was performed in post-emergence of the weed, when these presented six to seven totally expanded leaves.

It was used a backpack sprayer pressurized with CO_2 at a constant working pressure 40 $lbf.pol^{-2}$, the weather conditions were: air temperature 22 ºC; relative humidity 62% and wind at 3 km h^{-1}. The pulverization bar was constituted by two DG 11001 nozzles, with a spacing of 50 c, for the pulverization of the total area. The rain simulation was performed through a stationary sprayer with a layer of 20 mm, during 7 min with an interval of 1h after the sprayings.

14 days after the pulverization, the plants were collected to obtain the dry mass from the aerial part and from the roots, being the collected vegetal material washed in running water, put in paper bags and kept by 96 hours in a greenhouse for forced drying at 60°C. The data was submitted to variance analysis by the F test, and when meaningful, the averages were compared by the Tukey test at 5% of probability.

Results and Discussions

Diameter and uniformity of droplets

The uniformity of the droplets spectrum was influenced by the pulverization sprayings, which provided lesser droplets diameter for DV0.1, in which are the glyphosate, glyphosate + tributylcitrate and paraquat + vegetal oil, being that for the DV0.5 and DV0.9 the smaller values were found for glyphosate, glyphosate + tributylcitrate and water, glyphosate, glyphosate + tributylcitrate, respectively. These droplets in field conditions are easily lost through drift, not reaching the target and reducing the quality of application of the crop protection products (Table 1).

Therefore, the use of paraquat and paraquat + tributylcitrate ($DV_{0.1}$), paraquat + vegetal oil ($DV_{0.5}$) and paraquat + vegetal oil ($DV_{0.9}$) provided droplets with greater diameter when added to the spray solution. Nevertheless, when assessing the DMV (% <100 µm) it can be noticed that the highest values are found for the treatments glyphosate and glyphosate + tributylcitrate, being these superior to the adjuvant based on vegetal oil used with glyphosate and, then, with water (control). This situation can be explained by the percentage of droplets with diameter lesser than 100 µm, which are more susceptible to drift, be it through wind of evaporation (FERREIRA et al., 2011).

CUNHA and ALVES (2009), studying the physicochemical properties of pulverization sprayings with some adjuvants state that, in general, the elevation of viscosity of the spraying with adjuvant is associated to the generation of greater pulverization droplets and, therefore, with potential effect in the decrease of drift in the applications. These results, may have occurred for this research in the use of paraquat + tributylcitrate, where the treatment presents the lesser V<100% and also lesser coefficient of uniformity of droplets spectrum.

It can also be noted that the use of tributylcitrate adjuvant provided the lesser uniformity coefficients, however not differing from water, independent of the herbicide in association, indicating smaller variation

Table 1. Droplets diameter in which the DV 10, 50 and 90% of the total pulverized volume presented diameters inferior to the values indicated for diameter, uniformity of the droplets spectrum (Coef.) and percentage of droplets smaller than 100 µm (V% <100).

Treatments	**Droplets diameter (µm)**				
	DV 0.1	**DV 0.5**	**DV 0.9**	**Coef.**	**V % <100**
Water	76.81 b	139.33 b	219.02 a	1.02 a	22.64 b
Glyphosate	72.43 a	135.84 a	218.59 a	1.07 b	25.35 d
Glyphosate + tributylcitrate	73.97 a	134.72 a	215.02 a	1.04 a	25.34 d
Glyphosate + vegetable oil	75.97 b	137.95 b	222.85 b	1.06 b	23.75 c
Paraquat	78.64 c	144.53 c	237.33 c	1.09 b	21.06 a
Paraquat + tributylcitrate	80.06 c	142.77 c	227.16 b	1.03 a	20.76 a
Paraquat + vegetable oil	73.80 a	148.97 d	257.99 d	1.23 c	22.64 b
C.V (%)	3.65	2.21	3.30	5.01	7.32

**Averages followed by the same letter in the columns do not differ between them, by the Tukey test p<0.05.*

in the spectrum of droplets size. CAMARA et al. (2008) studied volumetric distribution and droplets spectrum of hydraulic flat fan tips of expanded range XR11003 and found out that the use of surfactant in the pulverization provided lesser coefficient of uniformity, agreeing with the results of this research.

In this context, CUNHA et al. (2010) assessed the effect of different adjuvants (fosfatidilcoline, polyglycolic ether of monilfenol, esters of fatty acids and ethoxylated nonyl phenol) added to the sprayings in the generated droplets spectrum through nozzles of flat spray deflector and with air induction, and verified that the use of adjuvant did not influence the uniformity of the pulverized droplets spectrum, different from the found in this research.

It is further emphasized that, by the low values of variation coefficient, it can be considered smaller variability between each type of assessed spraying, providing greater security to the analysis, being the smaller coefficient of determination found for the pulverization with paraquat + vegetal oil. THEBALDI et al. (2009) observed increase of DMV when adding an adjuvant (ethoxylated alkyl ester of phosphoric acid - LANZAR®) to the pulverization, thus reducing the drift in two types of nozzles of empty cone. However, the authors did not specify the used spraying.

In the spraying, greater droplets are less subjected to lost by drift; thus, the addition of adjuvant can reduce the drift potential in the pulverization of phytosanitary products, however, its use must be careful in order to do not inhibit the active substance of products when it is added more than one spraying, also existing influence of the used water quality (QUEIROZ et al., 2008).

Volumetric distribution and determination of spacing between nozzles

In the application with only water (control), it can be noticed that the acceptable variation coefficients are between 75 and 90 cm of spacing, in which 90 cm achieves the value of 10%, indicating that until this point the distribution will be uniform (Figure 1).

It can still be noted that the maximum distance between nozzles on the bar, calculated for a variation coefficient was 90, 100 and 100 cm for glyphosate (C.V. 8.19%), glyphosate + tributylcitrate (C.V. 7.87%) and glyphosate + vegetal oil (C.V. 8.79%), respectively. For the model of the nozzle, the manufacturer recommends spacing of 0.50 cm from the target (TEEJET, 2013), being that in these conditions, the values of C.V. were inferior to 5% for all the tested sprayings, being the spacing able to achieve up to 0.60 m in these conditions.

From a practical point of view, the variation coefficient (CV) under the bar is the most important indicator related to the deposition homogeneity, and the unsatisfactory uniformity can be indicated by a coefficient of volumetric distribution variation higher than 10%. On the other hand, these threshold values in Brazil are different from the European values, where the maximum is 7% in laboratory conditions, when followed by recommendation of the manufacturer, and for other pressures and heights indicated as being possible of use, the maximum coefficient of variation is 9%.

Furthermore, verifying the application with paraquat herbicide, the distribution is more uniform in relation to the use of glyphosate (Figure 2), be it with or without adjuvant use, however, the spacing correspondent to the limit of the variation coefficient can oscillate between 0.50 and 1.00 m when using paraquat, because the coefficient of variation does not surpass the 10% limit.

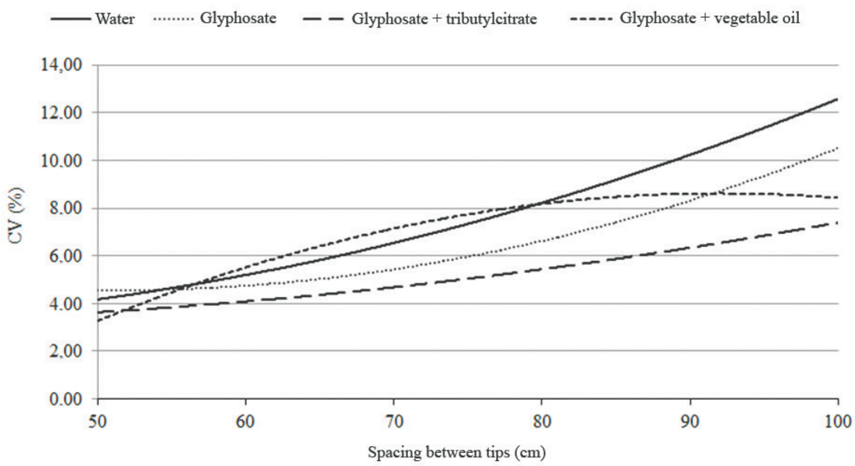
It is observed that for the use of paraquat, with or without adjuvant, the ranges in which the distribution coefficient is closer to 10%, the spacing between nozzles (1.00 m) are much higher than the indicated by the manufacturer or the used regularly on the field. This can be explained by the height of the pulverization bar, once the application occurred at 0.50 m from the soil, and with the decrease of the working height, the coefficient of variation would reach an acceptable potential value in a greater distance between nozzles.

The possibility of increasing the space between nozzles on the pulverization bar can occur also with the use of adjuvant or spreaders, which trigger a decrease of the superficial tension and increase the spreading of spray on the treated surface (CUNHA and RUAS, 2006).

Control of Ipomoea grandifolia with different sprayings, with and without use of artificial rainfall

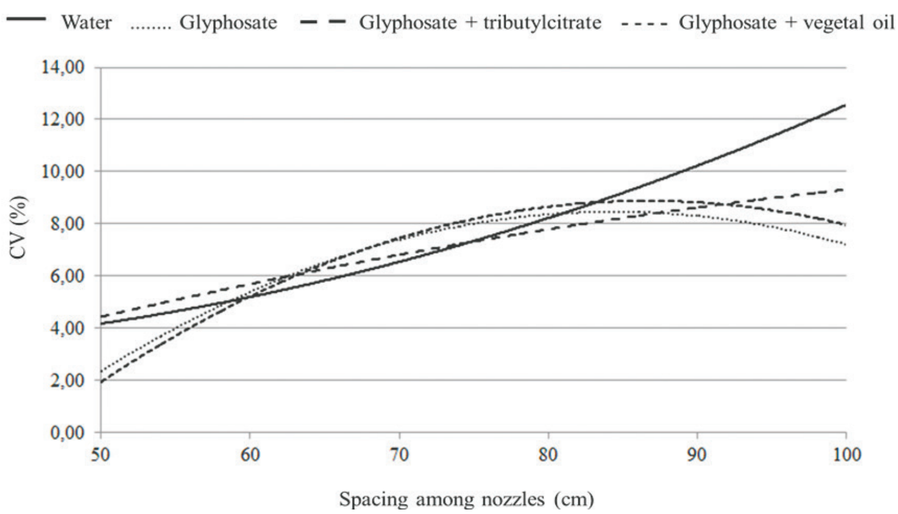
Table 2 presents values of variance analysis performed through the F test, in which was verified the significance for the tested factors and the interaction between them.

For the variable dry mass of the aerial part (DMAP) without the rain simulation, all treatments (sprayings) were efficient in the control of morning glory in post emergence in relation to water (control), being able to be verified the decrease of dry mass,



Sprayings	Equation adjustment	*R2
Water	y = 0.0016x2 - 0.0791x + 4.0057	0.918
Glyphosate	y = 0.0025x2 - 0.2584x + 11.196	0.773
Glyphosate + tributylcitrate	y = 0.0008x2 - 0.0376x + 3.63	0.697
Glyphosate + vegetable oil	y = -0.003x2 + 0.5589x - 17.091	0.821

Figure 1. Profile of the volumetric distribution of water and of sprayings with the use of glyphosate and adjuvant (coefficient of variation – C.V. versus spacing). *R^2 – Determination coefficient.



Sprayings	Equation adjustment	*R^2
Water	y = 0.0016x2 - 0.0791x + 4.0057	0.918
Paraquat	y = -0.0052x2 + 0.8717x - 28.313	0.890
Paraquat + tributylcitrate	y = -0.0007x2 + 0.2044x - 4.0171	0.928
Paraquat + vegetable oil	y = -0.0052x2 + 0.8968x - 29.95	0.808

Figure 2. Profile of volumetric distribution of water and of sprayings with the use of paraquat and adjuvants (coefficient of variation *versus* spacing) * R^2 - Coefficient of Determination.

however there was no difference between sprayings with the use of herbicides or herbicides associated with adjuvant (Table 3).

Moreover, when it was performed rain simulation, it is found control of morning glory for all used sprayings in relation to water (control), existing however difference between types of used sprayings. The ones that presented greater quantity of DMAP were with use of glyphosate + tributylcitrate and glyphosate + vegetal oil, possibly indicating less effectiveness in the control of this weed after occurrence of rains.

The production of dry mass of roots (DMR) in absence of simulated rain presented decrease when it was used different sprayings in relation to water (control), nevertheless, the use of glyphosate + tributylcitrate obtained the lesser value of dry mass, differing from the other treatments based on the paraquat herbicide and with use of glyphosate + vegetal oil.

However, when there was use of artificial rain, it could also be verified the reduction of the quantity of DMR when using isolated herbicides and in association to adjuvant, being the smaller values found for the sprayings with isolated use of glyphosate in relation to the treatment with glyphosate + tributylcitrate, not differing from the other used sprayings.

The pulverizations with paraquat + tributylcitrate and paraquat + vegetal oil did not influence for the DMAP values, independent of the absence or presence of artificial rain, yet, the other treatments with use of glyphosate, glyphosate + tributylcitrate, glyphosate + vegetal oil and paraquat did not present lesser quantities of DMAP in absence of artificial rain in relation to the use of the same. These findings may reflect in greater efficacy in the control of morning glory.

On the other hand, the treatment with paraquat + vegetal oil did not present difference between absence or presence of simulated rain for the DMR value, yet, the other sprayings with use of glyphosate, glyphosate + tributylcitrate, glyphosate + vegetal oil, paraquat and paraquat + tributylcitrate presented lesser quantity of DMR in absence of rain.

Assessing just the adjuvants tributylcitrate and vegetal oil, it is interesting to observe that with application of simulated rain, when both were added to the glyphosate, it was obtained the smaller values for DMAP. This may have occurred due to the tributylcitrate and vegetal oil, comparing to the use with paraquat, it presented higher values of superficial tension, thus resulting lesser spreading of the spray on the leaf, potentially because of the chemical interactions between the molecules, being that when it was applied artificial rain, this may have removed great part of the spray on the leaf, harnessing the weed control.

VIANA et al. (2010) reported that the diameter of the volumetric median and the uniformity coefficient are the most important parameters for determination of number of droplets, which together define the potential of drift in the pulverization, the homogeneity and the size of droplets produced by the pulverization nozzles, reflecting in greater control of the weed in absence of rain. Such statement agrees with this research, with exception to the droplets percentage with diameter inferior to 100 μm in the treatment which was used glyphosate + tributylcitrate.

SOUZA (2010) assessed intervals of rain in

Table 2. Variance analysis by the F test for the variables: Dry mass of the aerial part (DMAP) and dry mass of the root (DMR) in the absence and presence of artificial rain simulation and sprayings originated from glyphosate and paraquat associated with adjuvants.

FACTORS	DMAP	DMR
F Test		
Artificial rain	3.63*	2.12*
Sprayings	2.29*	1.61*
Artificial rain x sprayings	2.97*	1.62*
MSD		
Artificial rain	0.29	0.17
Sprayings	0.85	0.50
CV (%)	12.29	9.24

Significant at $p<0.01$ of probability, by the F test; VC: coefficient of variation, MSD: minimum significant difference.

Table 3. Split of dry mass of the aerial part (DMAP) and root (DMR) of *Ipomoea grandifolia* in function of different sprayings of glyphosate and paraquat with use of adjuvants at 14 days after application (DAA) with and without artificial simulation of rain.

Treatments	DMAP (g)		DMR (g)	
	Without rainw	With rain	Without rain	With rain
Water	5.78 Ab	5.73 Ae	8.83 Ae	8.78 Ac
Glyphosate	1.83 Aa	4.55 Bbc	0.70 Aab	2.22 Ba
Glyphosate + tributylcitrate	1.72 Aa	5.31 Bd	0.54 Aa	3.17 Bb
Glyphosate + vegetable oil	2.22 Aa	5.01 Bcd	1.26 Abc	2.77 Bab
Paraquat	2.70 Aa	3.51 Bab	2.31 Ad	2.28 Aa
Paraquat + tributylcitrate	2.87 Aa	3.34 Aa	1.50 Ac	2.54 Bab
Paraquat + vegetable oil	2.64 Aa	3.15 Aa	2.41 Ad	2.55 Aab

Averages followed by the same uppercase letter in the line and lowercase in the column do not differ between them, by the Tukey test p<0.05.

the efficiency of herbicides based on glyphosate applied in post emergence of l weeds, among them the morning glory (*Ipomoea grandifolia*), and reported that the occurrence of rains, up for 8 hours after the glyphosate herbicide application reduces the efficiency of control of the morning glory plants, similar situation was observed in this research, with the occurrence of rains 1h after the pulverization.

RAMIRES et al. (2010) studying the control of *I. grandifolia* with use of isolated glyphosate or in association with latifolicides, observed almost total control of this specie of weed at 35 days after the application with glyphosate herbicide, with a dosage of 960 g e.a. ha^{-1}, in the absence of rain. Different situation to what happened in this research, due to non difference of dry mass of the aerial part between the sprayings used.

Conclusions

The use of vegetal oil adjuvant presents the smallest variation coefficients for the use in association with glyphosate and paraquat, resulting in a more uniform distribution of the spraying, with spacing of 0.50 m between nozzles.

The control of *I. grandifolia* with simulation of artificial rain reduces the efficiency of herbicides with the greater quantities of dry mass of the aerial part and dry mass of the root, independent of the adjuvant use.

The use of glyphosate plus adjuvants reduced the superficial tension of droplets resulting in higher spreading of these, however, on the other hand the paraquat did not suffer influence of adjuvant use.

References

ANTUNIASSI, U.R. Tecnologia de aplicação de defensivos. Revista Plantio Direto, v.15, n.94, p.17-22, 2006.

BAUER, F.C.; RAETANO, C.G. Distribuição volumétrica de calda produzida pelas pontas de pulverização XR, TP e TJ sob diferentes condições operacionais. Planta Daninha, v.22, n.2, p.275-284, 2004.

AMARA, F.T.; SANTOS, J.L.; SILVA, E.A.; FERREIRA, M.C. Distribuição volumétrica e espectro de gotas de pontas hidráulicos de jato plano de faixa expandida xr11003. Engenharia Agrícola, v.28, n.4, p.740-749, 2008.

CUNHA, J.P.A.R.; RUAS, R.A.A. Uniformidade de distribuição volumétrica de pontas de pulverização de jato plano duplo com indução de ar. Pesquisa Agropecuária Tropical, v.36, n.1, p. 61-66, 2006.

CUNHA, J.P.A.R.; ALVES, G.S. Características físico-químicas de soluções aquosas com adjuvantes de uso agrícola. Interciência, v.34, n.9, p.655-659, 2009.

CUNHA, J.P.A.R.; BUENO, M.R.; FERREIRA, M.C. Espectro de gotas de pontas de pulverização com adjuvantes de uso agrícola. Planta Daninha, v.28, número especial, p.1153-1158, 2010.

FERREIRA, M.C.; DI OLIVEIRA, J.R.G.; PIETRO, I.R.P.S.D. Distribuição da calda herbicida por pontas de pulverização agrícola utilizadas em áreas de reflorestamento com eucalipto. Engenharia Agrícola, v. 29, n. 2, p. 267-276, 2009.

FERREIRA, M.C.; LOHMANN, T.R.; CAMPOS, A.P.; VIEL, S.R.; FIGUEIREDO, A. Distribuição volumétrica e diâmetro de gotas de pontas de pulverização de energia hidráulica para controle de corda-de-viola. Planta Daninha, v.29, n.3, p. 697-705, 2011.

JAKELAITIS, A.; SILVA, A.C.; SILVA, A.A.; MACHADO, A.F.L.; FREITAS, G.L. Efeitos da chuva sobre a eficácia de formulações de glyphosate no controle de Brachiaria decumbens. Revista Ceres, v.50, n.290, p.461-469, 2003.

MACIEL, C.D.G.; GUERRA, N.; OLIVEIRA NETO, A.M.; POLETINE, J.P.; BASTOS, S.L.W.; DIAS, N.M.S. Tensão superficial estática de misturas em tanque de glyphosate + chlorimuron-ethyl isoladas ou associadas com adjuvantes. Planta Daninha, v.28, n.3, p.673-685, 2010.

MONQUERO, P.A.; SILVA, A.C. Efeito do período de chuva no controle de Euphorbia heterophylla e Ipomoea purpurea pelos herbicidas Glyphosate e Sulfosate. Planta Daninha, v.25, n. 2, p. 399-404, 2007.

QUEIROZ, A.A.; MARTINS, J.A.S.; CUNHA, J.P. A.R. Adjuvantes e qualidade da água na aplicação de agrotóxicos. Bioscience Journal, v.24, n.4, p.8-19, 2008.

RAMIRES, A.C.; CONSTANTIN, J.; OLIVEIRA Jr., R.S.; GUERRA, N.; ALONSO, D.G.; BIFFE, D.F. Controle de Euphorbia heterophylla e Ipomoea grandifolia com a utilização de glyphosate isolado ou em associação com latifolicidas. Planta Daninha, v.28, n.3, p.621-629, 2010.

SOUZA, G.S.F. Intervalos de chuva na eficiência de herbicidas aplicados em pós-emergência. 2010. 82f. Tese (Doutorado em Agronomia) – Faculdade de Ciências Agrárias – UNESP, Botucatu.

TEEJET®. Technologies. Catálogo 51 – PT. Spraying systems Co®. 2013. Disponível em: www. Teejet.com. Acesso em: 12 out. 2013.

THEBALDI, M.S.; REIS, E.F.; GRATÃO, P.T.S.; SANTANA, M.S. Efeito da adição de adjuvante na redução de deriva em pontas de pulverização tipo cone vazio. Revista Ciências Técnicas Agropecuárias, v.18, n.2, p.1-6, 2009.

VIANA, R.G.; FERREIRA, L.R.; FERREIRA, M.C.; TEIXEIRA, M.M.; ROSELL, J.R.; TUFFI SANTOS, L.D.; MACHADO, A.F.L. Distribuição volumétrica e espectro de gotas de pontas pulverização de baixa deriva. Planta Daninha, v.28, n.2, p.439-446, 2010.