Evaporation and wettability of fungicide spray, with or without adjuvant, on leaves of vegetables

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ABSTRACT

On tomato, cucumber and bell pepper cultivation, commonly large quantities of plant-protection products are applied, to control pests and diseases, as a way to guarantee better productivity and final product quality. The knowledge of spreading and evaporation time of spray droplets is fundamental to understand the interaction between fungicides and target surface for proper distribution of this fungicide. This study was installed to determine the wetting area and droplet evaporation of sprays containing the fungicide Cabrio Top, with or without adjuvant Nimbus®, deposited on leaves and artificial surfaces (glass slide). A system was used which analyzes images composed of a droplet generator, a stereoscope camera for capturing images and a climatic chamber for controlling temperature and relative air humidity. Droplets of 600 µm in diameter containing spray solution were deposited on leaf surfaces and on glass slide and sequential images were used to quantify the wetting area and the evaporation time. The spray solution and the target surface are determinant for wetness and droplet evaporation after deposition. Evaporation time and surface tension were inversely proportional to the wetting areas. Addition of adjuvant Nimbus® (0.5%, v/v) reduced the surface tension and provided an increase in the wetting surface area, except on tomato leaves which had shown low wetting capacity in both fungicide solutions applied.

Keywords: Vegetables, application technology, greenhouse, image analysis, spray droplets.

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Research
images can contribute to understand interaction between fungicide and adjuvant on leaf surfaces and optimize the use of phytosanitary products under field conditions or greenhouse. Therefore, the aim of this study was to determine the wetting area and the evaporation time of droplets containing fungicide Cabrio Top with and without adjuvant Nimbus® deposited on leaf surfaces of tomato, bell pepper and cucumber crops, in comparison with an artificial surface (glass slide).

MATERIAL AND METHODS

The authors evaluated the wetting area and droplet evaporation time with and without fungicide and with adjuvants on the leaves of tomato, cucumber, bell pepper and glass slides under controlled conditions of temperature and relative humidity. The surface tension of applied solutions was determined through the method proposed by Mendonça et al. (1999), consisting of weighing droplets of a liquid formed at the end of a burette. Fungicide Cabrio Top (methyram + pyraclostrobin), from the chemical group alkylenebis and strobilurin, and the adjuvant Nimbus® (mineral oil) were used.

The experimental design was entirely randomized, in 2x4 factorial scheme, consisting of two spray solutions [fungicide Cabrio Top (0.2%, m/v) with and without adjuvant Nimbus® (0.5%, v/v)], and four kinds of surfaces [three natural (leaves of tomato, cucumber and green pepper) and one artificial or hydrophilic surface (glass slide)], with five replicates.

The sprays were prepared with distilled water in 1-L volumetric flasks. Plants were grown in commercial production system and collected in greenhouses in the municipality of Bandeirantes-PR on the same day the researches were performed. Leaves of long shelf-life tomato ‘Pizzadoro’, red bell pepper ‘Pampa’ and ‘caipira’ cucumber ‘Campeiro’, were used. Plants were in vegetative stage.

In order to determine wetting area and evaporation time, the authors used an automatic system with controlled temperature and relative humidity, which also generates droplets and captures sequential images, demonstrated by Oliveira et al. (2015). Trial was performed at 30±1.5°C and 60% relative humidity (±3%). Relative humidity was altered using humidification-dehumidification process and the temperature was changed using an air conditioned and an infrared heater, interconnected to temperature and humidity sensors with high accuracy and reproducibility using a programmable logic controller (PLC). Sequential images of the droplets deposited on different surfaces were performed by a stereooscope equipped with a high-definition digital camera and software for capture. Droplets with 600±25 μm diameter were deposited; these droplets were formed using a droplet generator which contemplates a quantity of liquid spray regulator based on the time regulation, air pressure of the dispersed fluid and vacuum (ModelUltimus V, EFD Inc; East Providence, RI).

For calibration and standardization of droplet size, twenty droplets were deposited on silk threads attached to a support, which allows these droplets to remain in spherical shape in order to measure their diameter. Droplet ejection interval, pressure and droplet generator vacuum were altered until the droplets formed a 600 μm diameter. This calibration was done for each solution to analyze all droplets of the same size.

Droplets on the surface were visualized with the aid of a stereooscope (zoom 1.5x) and range extensions with 10x magnification in a combination objective-special eyepieces (Bel Engineering) coupled to a digital camera generating bitmap images, with 1260x960 resolution. Droplet diameter was measured, in mm, with the function line of the software Iscapture 2.2.1 (Scienon Technology Co. Ltda) which comes together with the camera used to capture the images. The program was calibrated with an image of a ruler of 0.01 μm in the same objective and zoom lens used in image capture.

Images were captured on the top view of the drop, right after droplets were deposited on the surfaces, at intervals of three seconds until the total evaporation of the droplet liquid, leaving only the solution solids on the surface. Wetting area (mm²) was determined delimiting the drop ends by the polygon function, considering the maximum area of each replicate. Evaporation time was measured through the interval between droplet deposition and extinction of the liquid part, recorded by the sequential images captured during evaporation. Thus, evaporation time was calculated using number of photos multiplied by the interval between photos, according to the methodology developed by Zhu et al. (2008).

Normality of data was verified using Shapiro-Wilk test (p<0.05) and homogeneity of variances using Levene’s test, Cochran’s test and Hartley’s test, and then the authors performed the analysis of variance using F test. The interaction of the solution and contact surfaces were observed and surface averages were compared using Tukey test (P<0.05); solutions were compared using Student’s t test (P<0.05).

RESULTS AND DISCUSSION

Significant interaction between deposition surface and spray solution for wetting area and droplet evaporation time was noticed. This fact indicates that spreading process and droplet evaporation are determined both by physical and chemical properties of the spray solution and by the deposition surface characteristics of the sprayed droplets, also discussed by Oliveira et al. (2015) in studies with herbicides on weeds.

Surface tension and droplet wetting on different application surfaces are represented in Figure 1. Spray solution and target surface are determinant in spreading and droplet evaporation after deposition, showing a negative relation between surface tension and spreading. Addition of adjuvant Nimbus® reduces surface tension and provides an increase in surface wetting area, with exception on tomato leaves which presented lower capacity of leaf wetness in both syrups.

Surface tension is one of the
mechanisms which determine droplet spreading on the target; however, this mechanism cannot be used alone in order to evaluate wetting capacity of a plant protection product, since spreading is also influenced by droplet deposition surface (Oliveira et al., 2015). This can explain the exception on the tomato leaf surface which represented greater resistance to drop spreading and did not show the same relation between the surface tension and wetting area as on other surfaces. Costa et al. (2014) also could not establish a direct relation between the surface

Figure 1. Surface tension (a) and wetted area (b) of spray droplets on different application surfaces. Averages followed by the same capital letters for surface do not differ significantly from each other by Tukey test (p<0.05) and lowercase letters for spraying solution do not differ significantly from each other by Student’s t test (p<0.05). Bandeirantes, UENP, 2017.

Figure 2. Maximum wetting area of droplets of 600 µm in diameter (mm²) containing spray solution deposited on four target surfaces, at 30°C temperature and 60% relative humidity. Bandeirantes, UENP, 2017.
tension reduction and droplet wetting increase of solutions formulated with herbicides and adjuvants applied on *Conyza canadensis* surfaces. Thus, in order to obtain a correct interpretation of the droplet behavior onto the target, the authors suggest the use of methods to evaluate directly spreading of droplets of solutions used for spraying.

For both spray solutions, the tomato leaf surface showed non-glandular trichomes which could be a barrier to spreading. The authors also observe greater droplet spreading on glass surface of both solutions (Figure 2). These differences between natural targets and glass slides are related to the fact that slides are hydrophilic, which facilitates droplet spreading, reducing the effect of morphological variability factors which leaf surfaces present. Morphological diversity between plant species, just like trichomes, cuticle, ribs and waxes, may exert great influence on spreading of sprayed droplet and alter solution absorption (Iost & Raetano, 2010).

Addition of adjuvant Nimbus® increased droplet evaporation time only on the cucumber leaf surface, reduced on the tomato surface and maintained the same timing on bell pepper leaf surface and glass slide (Figure 3), showing that the adjuvant can alter droplet behavior onto the target, increasing or decreasing evaporation time, or still not producing any effect at all. Addition of adjuvant into the spray solution not always provides the expected effect, since leaf surface characteristics have great influence on spraying droplet deposition.

The longer evaporation time of the droplets deposited on the tomato leaf surface in the absence of adjuvant can be explained due to the less spreading observed in this treatment. The analysis of the sequential image of the droplets deposited on leaf surface and glass slide allows observing the longevity of spraying droplets and spreading. Observing these factors is important, since the liquid of the droplet evaporates, absorption and leaf penetration of this plant protection product are reduced and formed crystals can be removed by the wind, decreasing its efficiency (Yu et al., 2009).

Glass slide showed less droplet evaporation time, in relation to leaf surfaces. This fact may have happened due to more droplet spreading on this surface, exposing the droplet to greater contact surface with the environment. Less evaporation time may be related to the difference between thermal capacity of glass slide and vegetable surfaces, considering that glass slide heats faster and, because of this, it accelerates the evaporation rate of the deposited droplets (Oliveira et al., 2015).

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