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STUDY OF DEPOSITED SPRAY QUALITY OF SPRAYING AGENTS WITH DIFFERENT PHYSICAL PROPERTIES

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Abstract

The spray quality of two spraying agents with different physical properties was investigated under laboratory conditions to find whether the measurement of deposited drops could be affected by spraying those agents. The first spraying agent Moddus, which is a plant growth regulator, has a surface tension of 28 mN m^{-1} with almost half the value of the second spraying agent Kelpak (58 mN m^{-1}). A mini boom sprayer containing three flat fan nozzles (XR 11003) was used in the test with three traveling speeds (4.74, 5.42 and 8.13 km. h^{-1}). The test was performed to evaluate the quality of spray drops (spray coverage, spray density and stains diameter) after they were deposited on water sensitive papers (WSP). The results showed a higher ability of Moddus drops to spread than in case of Kelpak which resulted in a bigger deposited area. However, at the same time, it resulted in a higher probability for those drops to merge during deposition which affected the measured stains diameter and the spray density on WSP. These results indicate that measuring the spray quality on WSP must take in account the physical properties of the sprayed materials because it could affect the merging of the adjacent stains and as a result it could influence the values measured by the image processing software.

Key words: Spray coverage; contact angle; WSP; flat fan nozzles; surface tension, spraying speed.

Introduction

The awareness of the risk to environment which results from the use of agrochemicals has led to production of those materials with different formulations and physical properties aiming at the improvement of the efficacy and efficiency of the pesticide application process; enhancement of the spray deposition and limitation of loses from off-target deposition and drift to the surrounding environment. Spray deposition and coverage on the plant canopy are influenced by many factors, for example: a nozzle type and their configuration; atomizing pressure; droplet size and velocity; application rate; properties of the spray liquid, static or dynamic surface tension and viscosity of the liquid which are altered with the pesticide formulation, and the concentration at which it is applied; the position and characteristics of the targeted surface (OZKAN *et al.,* 2012; MATTHEWS, 2002; ALHEIDARY, 2019; CAVALIERI *et al.,* 2015). Fine and very fine spray droplets (according to the classification of ASAE S572.1, 2009) result in the highest deposit density on water sensitive papers (WSP) with increased efficacy and coverage, followed by medium-size spray droplets and then the spray with the coarse droplet size. However, some authors have shown that greater efficacy is not necessarily caused by greater coverage (GULER *et al.,* 2012; VALLET AND TINET, 2013).

Surface tension influences the quality of the produced spray droplets which affects, in turn, the degree of coverage on the plant surface. XU *et al.,* (2011) reported an influence of the drops spread by the surface tension, and that the low value of the surface tension caused an increase in the wetted area. However, there were other factors which influenced this spread, like plant species, leaf surface structure, concentration and type of

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adjuvant. The same findings were reported by YU *et al.,* (2009). XU *et al.,* (2010) indicated a significant decrease in the contact angle as a result of a decrease in the surface tension values of the drops. Moreover, low values of the contact angle would result in larger wetted areas on leaves, a higher spread capacity and decrease in the evaporation time. The same findings were indicated by HE *et al.,* (2019).

Liquid physical properties could have affected the spray formation; addition of materials which could change these properties (adjuvants for example) will significantly change spray droplet size as FRITZ *et al.,* (2018) found in their study. Knowing such information could provide an idea about the possibility of improvements in the spray application efficiency. ELLIS *et al.,* (2001) concluded in a test with three types of nozzles that the drop size of pure spray was decreased as a result of a reduction in the surface tension. However, this decrease (which depends on the nozzle type) is less than predicted by the spray formation theories o. The WSP have been used to visualize and/or quantify the spray distribution and deposition of spray application by researchers, farmers, and others. The spray droplet, under suitable laboratory or field conditions, results in a blue stain (speck or spot) on the sensitive surface of WSP which has a yellow color. The cards have been used in the field trials to compare the spray coverage and quality for various sprayers, nozzles under diverse operating variables in different crops. The size of the spray drops spectra which will later form the stains on the WSP surface could influence the precision of the measurements, for example very small size drops cannot produce detectable spots (stains). On the other hand, very large drops may runoff and produce distorted stains. Merged (connected or overlapped) stains resulting from a dense spray are difficult to be evaluated precisely by any imaging system (SALYANI *et al.,* 2013). The spray coverage and spray density on the target (number of stains in square centimeters) are good indicators for spray penetration of the applied pesticide, although those two indicators do not give an idea about the coverage uniformity of the spray or the drops (stains) size distribution uniformity on the surface of the target.

The aim of this study was to investigate whether the measurement of the deposited drops on WSP could be affected when spraying two agents with different physical properties. The investigation will focus on the probability of adjacent stains to be merged due to the different physical properties of the sprayed material. Moreover, the study also aims at investigation whether the increase of the spraying speed could affect the spray quality and the merging of stains.

Materials and Methods

Measurements of the surface tension and contact angle

Measurements of the surface tension (σ) were done for the spraying agents, after mixing them with water according to the dose presented in table 1, using the hanging drop (pendant drop) method and by utilizing the Drop Shape Analyzer device (DSA30 KRÜSS GmbH, Hamburg, Germany). The evaluation depended on the images obtained from the drop shape during the analysis. Before the process of analyses was initialized, the input data were entered into the device software which includes: a dispensing needle diameter (set to 1.83 mm) and density of analyzed liquids ($g.cm^{-3}$). After this, 30 measurements of the surface tension were performed by injecting drops with a volume that was large enough to keep the drop on the needle tip before it fell down (15 µl for Moddus and 30 µl for Kelpak). The contact angle (θ), which is a wettability measure of a certain liquid on surfaces, was measured using the same device which was used to measure the surface tension. This included measuring of the angle between the drop surface and the surface of the horizontal contact base (aluminum alloy EN AW 2017A plate) after the interface happens between them and for specific time intervals (every five seconds for 30 seconds) and by using the image of a sessile drop

Table 1: Properties of spraying agents (from product catalogue).

Spraying agent	Plant Growth Regulator (PGR)	Seaweed Concentrate (Sc)
Product name	**Moddus**	**Kelpak**
Usage	Crop enhancement and lodging control	Plant growth bioregulator (biostimulant)
Mixing dose, ml/ one liter water*	1.3 ml	6.6 ml
Density, g/cm^3	0.96 –1.00 at 20 ºC	1.01–1.03
Viscosity (dynamic), mPa.s	10.01 at 20 ºC5.45 at 40 ºC	24
Surface tension, mN/m	28.2 – 28.5 at 20 ºC	57.55
pH	2.0- 6.0 at 1.0 % w/v	4.6

*The recommended dose from the producers are: 2.0 l ha^{-1} for Kelpak and 0.4 l ha^{-1} for Moddus, the values in the table after taking into account the application rate used in the field which is 300 l/ha.

(volume: 15 µl). The spraying agents used in all the tests and their properties are listed in table 1. Those two spraying agents are used generally to reduce the plants lodging during and before harvesting and for enhancing the plants growth. They were chosen because they have a clear difference in their drops surface tension.

Laboratory test

A laboratory test to evaluate the deposited spray quality was carried out in the pesticide application laboratory of the University of Life Sciences in Lublin (UP Lublin). The WSP (Spraying Systems Co.®, Wheaton, USA; Dimension: 76 × 26mm) were positioned at 50.0cm under the nozzle tips with one level only (the ground level) and without using plants canopy. Spray application was done using a mini sprayer boom containing three adjacent nozzles, the distance between each two nozzles is 50cm and the spraying was done at 3.0 bar pressure which was provided from an air compressed spray tank. The spraying speeds which used to apply the materials were 4.74, 5.42 and 8.13 km. h^{-1}. The three traveling speeds were applied to obtain a lower application rate for a higher speed. Reducing the application rate means that less volume of the spraying agent will be sprayed on the WSP and this could reduce the merging effect of the deposited drops which could affect in turn the measurements by the image processing software. The same spraying pressure and nozzles spacing were used for the three speeds, this resulted in 300, 266 and 177 l/ha application rate for 4.74, 5.42 and 8.13 km.h^{-1} traveling speeds respectively. Flat fan nozzle XR 110/03 VP (TeeJet, Spraying Systems Co.) which is widely used by researchers and sprayer operators (in arable field crop) was used in the test. This nozzle, according to the manufacturer catalogue, has 1.18 l/min flow rate at 3.0 bar pressure and has 354 l/ha application rate when spraying with the forward speed of 4.0 km.h^{-1}. From the catalogue also, the spray quality of this type of a nozzle depending on the drop size is fine/medium according to the classification of ASAE S572.1, 2009.

WSP analyzing

After spraying, the WSP were scanned with 600 dpi resolution. According to Marçal and Cunha (2008) this resolution was a relevant option of scanning because the computational load was much lower compared with 1200 dpi resolution with nearly the same stain profiles. The scanned photos after this were analyzed with the image processing software (Image-Pro Premier 3D, Media Cybernetics, Inc.). The stains average diameter, spray percentage coverage (%) and spray density were calculated by the software and the data were kept for further processing. The percentage coverage refers to the ratio between the sum of the stains area and the area of the WSP. Spray density refers to the total number of stains in one square centimeter of the WSP.

Single drops test

The percentage coverage and stain diameter was investigated also by dropping five single drops (volume: 15.0 µl) of the spraying agents using a needle with 0.51 mm diameter and from 12.0 cm height (using the Drop Shape Analyzer device) towards a horizontally situated WSP. Photos of the scanned WSP which contains five individual drops were analyzed using the image processing software and only 10 cm^2 of its area were considered (2.0 × 5.0 cm). The results were then reported as the averaged diameter and coverage for the five single drops.

Results and Discussion

Surface tension and contact angle

The measured surface tension for Moddus after mixing with water (according to the recommended dose) was 31.06 ± 0.76 mN m^{-1} while it was 67.66 ± 1.29 mN m^{-1} for Kelpak. The decreasing change in the contact angle of Moddus drops with time was higher and clearer Fig. 1 than Kelpak, which indicates a higher ability for

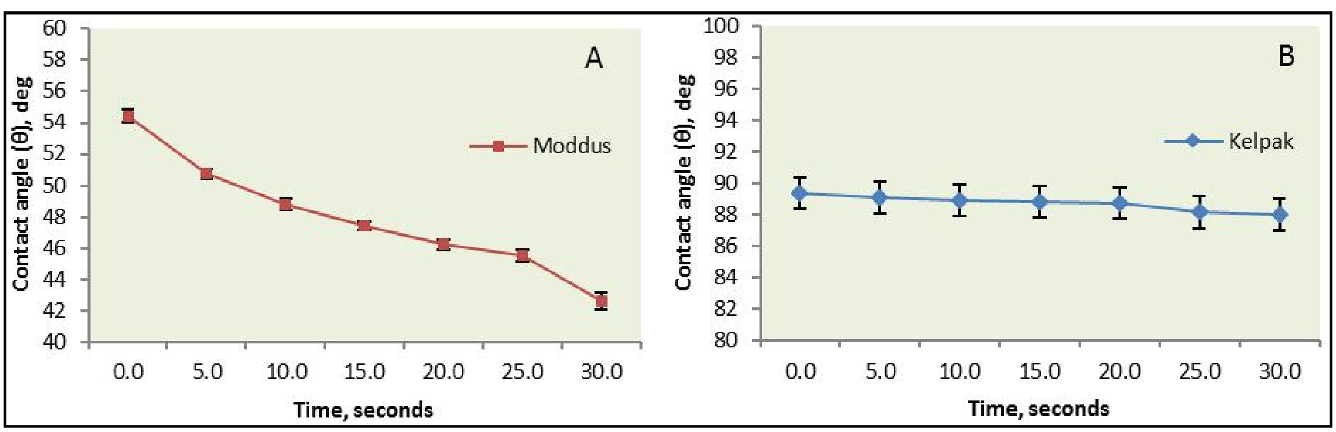

Fig. 1: Contact angle for A. Moddus; B. Kelpak (after mixing with water) at different time periods.

Moddus to spread over the surface which was sprayed. Kelpak drops have a higher surface tension which makes them tend to stay in an upright position and resist spreading over the surface, this will result in higher values of the contact angle. The decrease in the drops spreading of the Kelpak drops will affect the spray coverage percentage and the wetting ability of this product on plant leaves. These spreading differences of the drops from the two spraying agents on the aluminum surface are shown also in the photographs Fig. 2 which were taken at different time intervals.

Percentage coverage of stains

The results of the spraying quality on the WSP using different travel speeds of the mini sprayer boom are shown in Fig. 3. Spraying Moddus resulted in higher values of the percentage coverage on the WSP for all the traveling speeds, this was because of a higher ability of Moddus drops to spread as showed by the results of the contact angle. Increasing the spraying speed resulted in a decrease in the percentage coverage for both Moddus and Kelpak. This probably arises from a smaller volume 7of the applied material when applying with higher speeds.

Stains diameter

The average stains diameter for Moddus was by 16.25% higher than Kelpak when applying with 4.74 km. h^{-1} speed. The increase of the spraying speed did not show a different trend, the percentage difference between Kelpak and Moddus were 15.73% and 18.73% higher average stains diameter for Moddus than Kelpak for 5.42 and 8.13 km. h^{-1} speeds respectively. Generally, higher spraying speeds resulted in lower values of stains diameter (comparing with lower speeds), with higher values of the measured diameter during spraying with 5.42 km. h^{-1} speed.

Smaller values of the surface tension result in a smaller drop size (ELLIS *et al.,* 2001; BASI *et al.,* 2012; COSTA *et al.,* 2017). Since the surface tension of Kelpak is almost twofold of the Moddus one, it would be obvious to have bigger drops when applying Kelpak. However, the deposited results of those drops on the WSP showed that he average stains diameter had higher values than in case of Kelpak in the lab test. This could be partly explained by the contact angle results Fig. 1 and 2 which show a higher ability for Moddus to spread over the surface than Kelpak. This ability for Moddus to spread could result in more stains to be merged with the adjacent stains and producing a larger stains diameter due to the merge effect, not due to the original drops before depositing. However, the contact angle measurements were done on the aluminum surface which could have a different reaction with the drops than the surface of WSP.

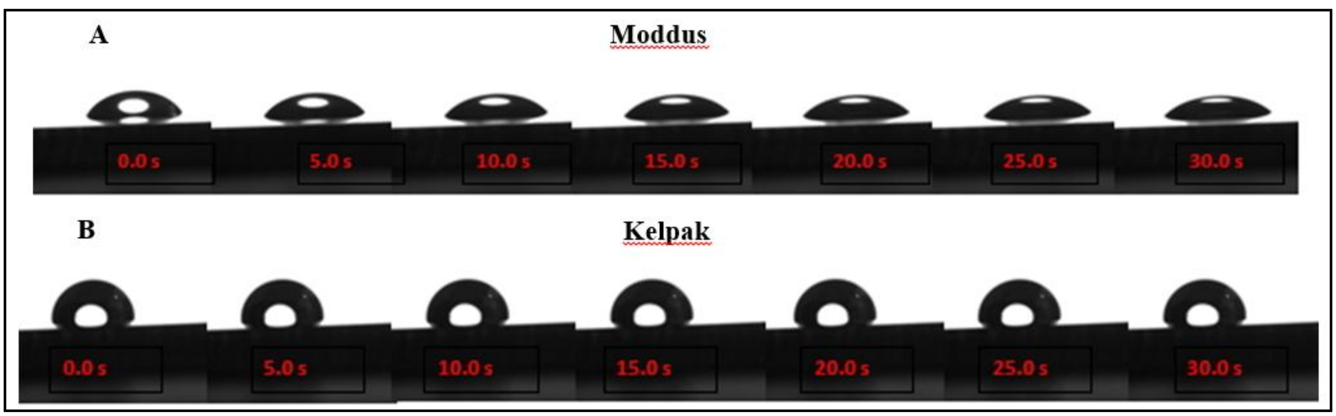

Fig. 1: Photography shots for A. Moddus; B. Kelpak (after mixing with water) showing the spread over hard surface at different time periods.

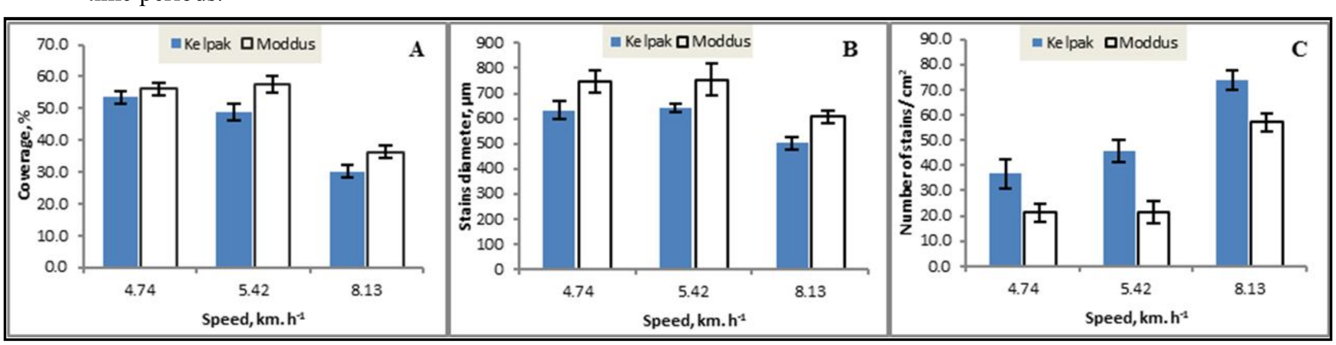

Fig. 3: Spray quality parameters: A. percentage coverage; B. stains average diameter; C. number of stains on square centimeter at different travel speed of application, lab conditions.

This issue was investigated further by the results of the single drops test on WSP, where the average stains diameter for Kelpak was 6.95 mm with 3.8% percentage coverage (averaged), while it was 6.53 mm with 3.35% percentage coverage (averaged) for Moddus. These results apparently differ from the findings from the lab test in which a nozzle boom was used. This probably results from the impact force and shattering of the atomized drops from 50.0 cm height when using a boom sprayer which is higher for Moddus than dropping a single drop from 12.0 cm height when using the Drop Shape Analyzer device. Besides this, the high surface tension of Kelpak drops will keep them in a spherical shape and prevent shattering which will also influence the rebound of drops from the sprayed surface as REICHARD *et al.,* (1986) and ALLAGUI *et al.,* (2018) reported.

Spray density and spraying speed

Merging of adjacent stains gives incorrect measuring results, this is due to the limited ability of the image processing software to distinguish between the stains before merging. Stains merging affect in particular the measurements of stains diameter and the spray density (number of stains on the square centimeter). An attempt to reduce the occurrence of stains merging by reduction of the spray density, which was done by the use of higher traveling speeds (a lower value of the application rate) produced adverse results. A higher number of stains in a square centimeter was observed when using a higher spraying speed and for both Kelpak and Moddus. However, there was a slight decrease in the spray density observed when the speed of applying Moddus was increased from 4.74 to 5.42 $km.h^{-1}$. The reason for this increase in the spray density when increasing the spraying speed is probably a higher percentage of fine drops when increasing the spraying speed. This was pointed out in CAVALIERI *et al.,* 2015 study where the percentage of the drop size smaller than 100 µm increased with the spraying speed increase. Moreover, spraying Kelpak, which has a bigger surface tension, produced higher values of the spray density than Moddus, which could be explained the same way as the diameter of stains which was due to a higher stains merging effect for Moddus than for Kelpak.

Conclusions

Based on the results of the study tests, the following can be concluded

1. Measuring the spray quality on the WSP must take in account the physical properties of the sprayed material, especially when comparing different materials with different application parameters, since these properties could affect the probability of adjacent stains merging which is difficult for the image processing software to distinguish.

2. Depending on the contact angle measurements, Moddus drops spread faster with the larger deposited area than Kelpak. This spreading of the Moddus drops will increase the merging probability of the stains produced from those drops after depositing on the WSP surface which, in turn, will affect the measurement of stains diameter and the spray density.

3. Spraying with higher traveling speed (less application rate) produced less amount of the deposited stains (percentage coverage) on WSP. However, it did not reduce the merging probability of the adjacent stains because a higher spraying speed usually produces a higher number of fine drops (higher spray density).

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