Electronic Journal of Polish Agricultural Universities is the very first Polish scientific journal published exclusively on the Internet, founded on January 1, 1998 by the following agricultural universities and higher schools of agriculture: University of Technology and Agriculture of Bydgoszcz, Agricultural University of Cracow, Agricultural University of Lublin, Agricultural University of Poznan, Higher School of Agriculture and Teacher Training Siedlce, Agricultural University of Szczecin, and Agricultural University of Wroclaw.

ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

2002
Volume 5
Issue 1
Series
AGRICULTURAL ENGINEERING

HOŁOWNICKI R., DORUCHOWSKI G., ŚWIECHOWSKI W., JAEKEN P. 2002. METHODS OF EVALUATION OF SPRAY DEPOSIT AND COVERAGE ON ARTIFICIAL TARGETS **Electronic Journal of Polish Agricultural Universities**, Agricultural Engineering, Volume 5, Issue 1.
Available Online http://www.ejpau.media.pl

METHODS OF EVALUATION OF SPRAY DEPOSIT AND COVERAGE ON ARTIFICIAL TARGETS

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ABSTRACT

The paper presents the method of quantitative and qualitative evaluation of spray application based on deposit and coverage measurements on artificial targets. This relatively simple and fast method is proposed for small scale comparative field experiments with air-assisted orchard sprayers. Biological efficacy, being very important for the grower, is not enough informative method of evaluation of spraying technique from the cognitive point of view. Therefore fluorescent dye and filter paper as artificial targets was proposed. Water Sensitive Papers (WSP) are the most common artificial targets for spray coverage evaluation. Spray coverage expressed as a percentage of target area covered by spray give additional information what portion of protected area is in direct contact with the chemical. The method is demonstrated for the Joco tunnel sprayer and conventional air-assisted sprayers.

Key words: Spray deposit, spray coverage, artificial targets, fluorescence, image analysis

INTRODUCTION

The experiments on spray application technology concentrate on studying two groups of directly related problems:

- biological efficacy of disease and pest control,
- spray deposit and coverage on the target.

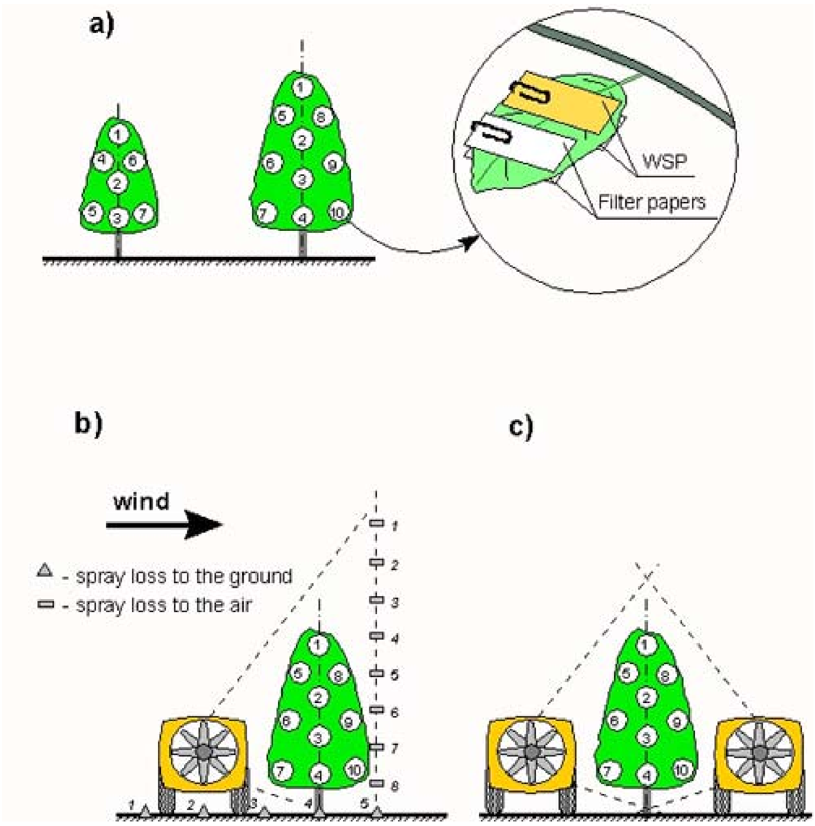
Biological efficacy, being very important for the grower, is not enough informative method of evaluation of spraying technique from the cognitive point of view. It is because it does not tell about effective use of chemicals and especially about spray distribution uniformity and possibly overdosing of spray and off target loss. Besides efficacy experiments are very costly, time consuming and requiring a lot of space in the field. Therefore biological experiments are often applied for the final verification of technical assessments of spraying techniques. The latter ones based on spray deposit and coverage measurements give either absolute or relative data determining the spray distribution within the crop canopy. Several quantitative methods of measurement of spray deposit expressed as amount of spray per area (leaf, cm^2) have been introduced. They usually use tracers which can be analysed chemically (foliar fertilizers, chelated copper, active pesticides) or optically (visible and fluorescent dyes). The fluorescent tracer first reported by Sharp [8] has been very much appreciated for its accuracy and being simple and fast to analyse [2, 3, 4, 7]. Visible or fluorescence dyes are widely used in spray deposit experiments. Even three different tracers with different absorbency spectra can be sprayed on trees during consecutive passes. Use of three water-soluble tracers allow for the comparison of tree different treatments on the same samples [1]. Spray deposit alone does not, however, tell much about the quality of application, especially about spray distribution uniformity on the leaves and overdosing of spray and does not give premises for determining the biological efficacy of the treatment. Spray coverage expressed as a percentage of target area covered by spray give additional, useful information indicating what portion of the protected area is in direct contact with the chemical. Image analysis allows for evaluation of spray coverage on the leaves [1, 5] and on artificial targets [3, 9].

In the following paper the method of quantitative and qualitative evaluation of spray application quality based on deposit and coverage measurements on artificial targets is described. This relatively simple and fast method is proposed for small scale comparative field experiments with air-assisted orchard sprayers.

LAYOUT AND SAMPLES

When the methods of spray efficacy evaluation are chosen, the objective of experiment and limited manpower in field condition have to be considered. The number of studied factors affecting the application quality, the number of replicates and a type of samples depend mainly on the human efficiency of sampling as well as time within which the experiment is to be done. Use of natural leaves as samples requires relatively high number of homogeneous trees to be sprayed for they can be treated only once. The buffer zones have to be kept between plots representing different treatments. Furthermore the surface area of leaves have to be measured in order to present data as a quantity of spray per unit area, which takes a lot of lab work. Besides, the simultaneous evaluation of path surfaces of leaves and use of the same leaf for deposit and coverage assessment is difficult, time consuming and requires the use of sophisticated methods. The experimental field can be reduced to as few as 4-5 trees when artificial targets are used. They can be attached to the same leaves several times ensuring the same conditions for all the compared treatments. As different types of samples can be attached the simultaneous evaluation of deposit and coverage on both sides of leaves is easy and fast. The best are samples that can be attached to the leaves (filter paper, mylar film, WSP – Water Sensitive Papers) so, that they move in the air jet.
The surface of samples should resemble the surface of the leaf to ensure a similar catch efficiency. A good correlation for deposit on leaf and mylar film was found by Salyani and Withney [7]. The size of samples should be so it covers a representative part of the leaf surface and does not stick out of the leaf to much. For apple trees the dimensions of samples 40×20, 50×25 or 60×30 mm are the most relevant.

Figure 1. Samples layout: a - samples location in the tree canopy; b - one side spraying; c - both side spraying



Four or five trees (replicates) are selected for the deposition/coverage tests. They should be similar in size, shape and density. The positions of the samples located on the vertical plane, perpendicular to the tree row are marked in the selected trees. The samples are attached in outer and inner zones of the tree. The number of samples, for one tree, depends on the size of the tree (Fig. 1a). The trees are sprayed from one (Fig. 1b) or both sides (Fig. 1c) depending on the objective of the experiment. When spray loss or penetration efficiency are studied one side spraying is preferable. For spray loss measurement the frame with artificial targets is placed right behind the tree to collect the spray that goes through and over the tree canopy. Deposit collected in the tree represents one-side application but both sides spraying may be simulated after appropriate calculation based on the assumption that both the passes give the picture of deposit which is symmetrical by the axis of the tree row.

SAMPLING PROCEDURE

Spray deposit. The most commonly used sodium salt of fluorescein is a water-soluble tracer for spray deposit evaluation. The main disadvantage of fluorescein is its poor photostability. In bright sunlight the dye degrades by 20% in 30 minutes. Immediately after targets dry out they have to be removed from the leaves and placed into separate light proof couvettes. The sample collection should be terminated within 5-10 minutes. The 20 ml of washing solution (eg. 0.02% solution of sodium hydroxide in deionised water and 0.06% of Lisapol) is added to each cuvette to extract fluorescent tracer. The samples are analysed with fluorescence spectrophotometer or a digital filter fluorometer. Data is recalculated to obtain results expressed as deposit (ng/cm^2, nl/cm^2) or as recovery (%, l/ha).

Different treatments are applied on the same plot. Well organised team (6 persons) is able to collect 700-900 samples during 5 hours. To obtain reliable results early morning hours (5-10 a.m.) or cloudy weather, with low solar radiation, are recommended to carry out the experiment in the orchard.

Spray coverage. The most common artificial targets for spray coverage evaluation are Water Sensitive Papers (WSP). They are widely used for visual assessment of spray distribution as well as for image analyses in spray application experiments. The WSP turns blue at relative humidity above 80%, and therefore it cannot be used under very humid conditions. The image analysing system consist of CCD camera with zoom lens, the monitor

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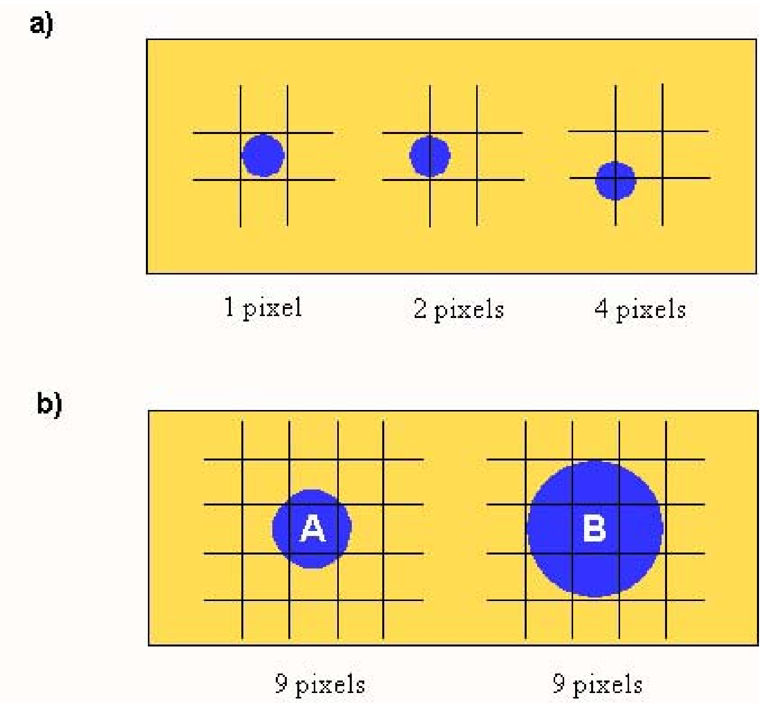
to control the analysed picture, and PC with a Frame Grabber card. The area resolution of the system is 1/417600 of field of view (720×580 pixels) and with 260 grey levels.

With this software the following features can be analysed:

- number of objects,
- dimensions and area of objects,
- distance between objects,
- % area covered.

For samples with overlapping spots, which are many in that type of experiments, only the last feature mentioned is worth analysing. The image analysis consists in changing a real image into binary image (based on established threshold of grey level) and then scanning so obtained binary picture and counting the black pixels against the white ones. When the object takes only a position of the pixel's area it will be considered as a whole pixel. Figure 2a shows the object that, depending on the location on the pixel net, will be represented by 1, 2 or 4 pixels, giving three different readings. This leads to considerable overestimating of very small objects. However the system may be protected so that it ignores the objects smaller than 9 pixels. With such a protection the lack of very small objects that are not seen by the system is compensated by some overestimation of bigger objects such as spot A (Fig. 2b) taking for 9 pixels (compare with spot B of bigger diameter and also taking for 9 pixels).

Figure 2. Overestimating of objects by image analysis - the object is represented by pixels it has contact with:
a - the object smaller than one pixel can be represented by one, two or four pixels, depending on the position it takes on the pixel net (analysing system can be set so that it ignores the small objects);
b - considerably smaller object A is represented by the same number of pixels, and considered by the system to be of the same size as object B



During the analysis the lighting of samples must not change for the system is very sensitive to illumination. The apparatus is calibrated prior to measurements. The samples with spots of known dimensions and overall coverage are used to set the focus and aperture of lens, light intensity, grey level threshold which ensure obtaining the most reliable results. The size of the image and number of spots within the image have significant effect on spot sizing and coverage measurements [6]. The resolution of the image analysing system is limited. It is however, possible to reduce the field of view (close up by zoom lens) and by that make the system detect smaller objects. At the samples with coverage higher than 20% overlapping spots are observed. They negatively affect the accuracy of image analysis. The separation of touching objects can improve the accuracy of measurements [5]. Anyway, the results are reliable within the most demanded range of coverage because the coverage higher than 30% is considered to be excessive.

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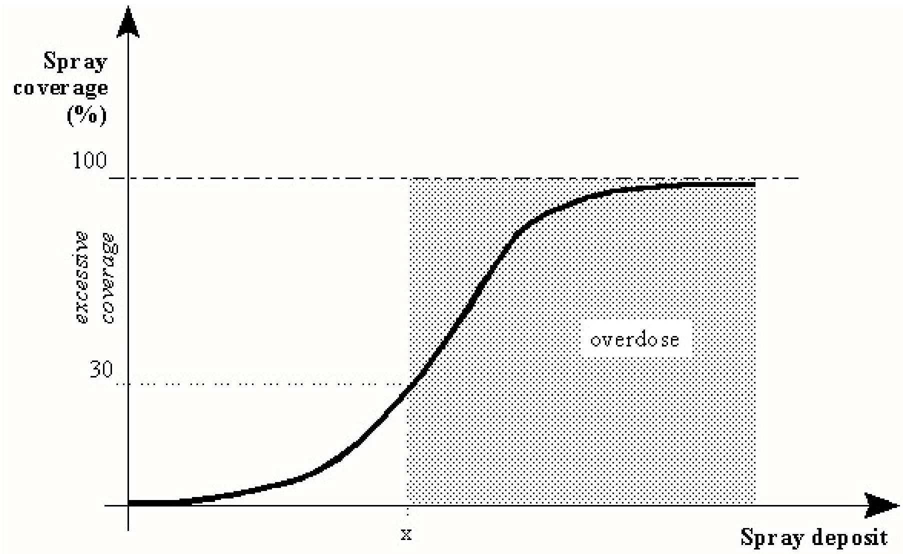
Figure 3. Spray deposit/coverage relation



Spray deposit/coverage relation. Spray deposit and distribution uniformity are related to biological efficacy of chemical control, but the relation between the level of tracer deposited on the target and control efficacy is hard to establish. More is known about coverage-efficacy relation. It is believed that for most chemicals and agrofags the coverage 30% is to ensure the satisfactory control. In the experiments where tracer deposit and coverage are measured simultaneously the relationship between those two features may be determined. According to Doruchowski [2] this relationship is represented by sigmoidal curve (Fig. 3) described by a logistic model. Thus, for the particular experiment it is possible to find the tracer deposit (x) corresponding to the required coverage (30%). Deposit higher than (x) can be considered to be spray overdose for the represent excessive coverage.

RESULTS

Example. Joco OSG-N1 tunnel sprayer with two horizontal jets (one on each side of the tunnel) blown by cross-flow fans and standard directed air jet sprayer with ten adjustable air outlets (five on each side of the sprayer) were compared. Spray volume rates 150 and 350 l/ha were applied at travel velocities 4 and 6 km/h. The trees were sprayed at full leaf stage from both sides with 0.02 of fluorescent tracer (Sodium Salt of Fluorescein). Treatments were made on Lobo/M26, planted 3.0×1.5 m. Four trees (replicates) were selected for each treatment. The trees were of similar size and shape. The average height of the trees was 2.2 m and width 1.4 m. Filter papers and WSP were attached on upper and lower leaf surface (Fig. 1a).

Table 1. Mean deposit in apple tree canopy (ng/cm^2) – full leaf stage

Sprayer	Velocity (km/h)	Spray volume (l/ha)	
		150	350
a – total on upper (U) + lower (L) leaf surface			
tunnel JOCO	4.0	167.6 ab	148.3 a
	6.0	155.9 a	184.2 a-c
standard directed air-jet	4.0	192.9 a-d	192.4 a-d
	6.0	176.3 ab	196.6 a-d
b – CV (%) for deposit on upper (U) + lower (L) leaf surface			
tunnel JOCO	4.0	90.7	70.2
	6.0	68,8	64.0
standard directed air-jet	4.0	56.2	53.2
	6.0	52.6	74.4
c – on lower leaf surface			
tunnel JOCO	4.0	23.1 ab	21.0 a
	6.0	21.0 a	24.5 a-c
standard directed air-jet	4.0	43.4 c-g	55.3 d-i
	6.0	35.7 a-d	38.2 a-e

Table 1. cont.

1	2	3	4
d – mean deposit in apple tree canopy – upper/lower ratio			
tunnel JOCO	4.0	9.24 b-e	11.58 ce
	6.0	9.53 b-e	7.53 a-d
standard directed air-jet	4.0	5.82 ab	9.26 b-e
	6.0	8.88 a-e	12.69 de

Means in tables followed by the same letter do not differ significantly at P = 0.05 (Duncan's Multiple Range Test)

Spray deposit and coverage. The average coverage and deposit on the target are not a sufficient mean for describing application quality of orchard sprayers. Results of example experiment are shown in Table 1. There were no significant differences for mean in-canopy deposit and its uniformity (CV%) between treatments (Tab. 1b). Spray deposit measured separately on both sides of the leaves give additional information. Significantly higher deposit was obtained on the lower leaf surface for standard directed air-jet sprayer at low travel velocity. A tendency of decreasing of spray deposit with increasing driving speed was observed (Tab. 1b). Spray coverage results usually confirm the deposit ones and give some additional information. Additionally the data in table 2a shows significantly higher coverage as a spray volume increase.

Table 2. Mean leaf coverage (%) – full leaf stage

Sprayer	Velocity (km/h)	Spray volume (l/ha)	
		150	350
a – average for upper (U) + lower (L) leaf surface			
tunnel JOCO	4.0	8.3 a	21.0 b-d
	6.0	10.6 a	32.1 de
standard directed air-jet	4.0	18.2 bc	31.5 e
	6.0	16.0 b	17.7 b-d
b – on lower leaf surface			
tunnel JOCO	4.0	1.2 a	4.5 c-e
	6.0	1.8 ab	3.0 bc
standard directed air-jet	4.0	6.1 de	12.7 fg
	6.0	6.6 de	3.7 cd
c – mean coverage (%) – upper/lower ratio			
tunnel JOCO	4.0	34.4 f	28.9 ef
	6.0	24.3 de	24.9 d-f
standard directed air-jet	4.0	9.5 ab	8.4 a
	6.0	13.9 c	14.4 c

Means in tables followed by the same letter do not differ significantly at P = 0,05 (Duncan's Multiple Range Test)

Spray deposit uniformity. The chemical rates recommended on the labels are overestimated to ensure that with all the mistakes that grower may do during the application and with all technical imperfections even a small portion of emitted chemical that is deposited on the target will give a satisfactory control. The U/L ratio of spray deposit and coverage on upper and lower leaf surface, being a measure of local spray distribution uniformity are presented in Tables 1d and 2c. They indicate that the lower leaf surfaces on the trees sprayed with the lateral air jets produced by the standard directed air-jet sprayer and tunnel cross-flow sprayer were given 6 to 12 times less chemical and were 8 to 35 times less covered than upper surfaces. The spray deposit uniformity on upper and lower leaf surface is a decisive factor influencing spray retention on the target and run-off losses. The lower leaf surface is a difficult place to deposit a chemical, but it is important to control sucking insects, which usually feed on undersides of leaves.

CONCLUSIONS

1. The evaluation of spray deposit and coverage on artificial targets is the efficient and relatively cheap method for relative describing application quality of orchard sprayers. They have to be verified in biological efficacy experiments to obtain the absolute quality of the treatments.
2. Upper/lower ratio, being a measure of local spray deposit and/or coverage uniformity, can be the supplementary result for describing spray quality.
3. The technique possibilities of computer vision analysis are not yet fully utilised in spray application technology.
4. Further studies are needed to improve proposed method.

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