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Impact of forced air flow upon introducing pesticides under conditions of lateral wind

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Abstract

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Pesticide application is accompanied by its losses due to the drift of the droplets of the working liquid caused by the wind outside the treatment area, which reduces the efficiency of chemical protection and increases impact on the ecological state of the environment. Influence of the precipitating (i.e. top-down) air flow has been determined upon the reduction of the drift of sprayed liquid droplets under the impact of a lateral wind, as well as distribution of the sprayed liquid studied by weight and length depending on the pressure of the working fluid in systems of various sprayers. At speed side wind 5.0 $m \cdot s^{-1}$ and deposition of flow at a speed of 15 $m \cdot s^{-1}$ the amount of fluid that settled, increased to 30% for spray ST 110-02 and 12% for spray ID 120-02.

Keywords: distribution; sprayed liquid; pressure; speed

Pesticide application is accompanied by losses due to the drift of the droplets of the working liquid caused by the wind outside the treatment area, which reduces the efficiency of chemical protection and increases impact on the ecological state of the environment (Hanafi et al. 2016). At the expense of improved quality indicators of spraying agricultural crops the recommended norms of pesticide application and pollution of the environment can be significantly reduced.

The degree of influence of the wind speed depends on the size of droplets during their spraying. For instance, the big droplets are less sensitive to drifting by the wind than the small ones. However, even using modern technologies, minimising the losses of the preparations, it is impossible to avoid the drift of droplets completely. The drift of droplets from the treatment area can occur both by the wind and by the precipitation of droplets onto the ground from the air stream (Baranowski, Pya-tachenko 2006). Drifting of the atomised preparation increases in proportion to the increase in the wind speed. When the speed of the wind is more than 5 $m \cdot s^{-1}$, chemical treatment by conventional spraying methods is not purposeful because a significant part of the sprayed droplets will be blown off by

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the wind. So, according to firm Hardi (Denmark) (Hardi 2015), with a conventional spraying method, when the working fluid flow rate is 100 l·ha^{-1}, the working pressure is 0.23 MPa and the travel speed is 7.7 km·h^{-1}, and the wind speed is 3.0 m·s^{-1}, the losses of the preparation due to the drift make 2.4%; at the wind speed of 4.5 m·s^{-1} they are 3.6%, and at the wind speed 8.5 m·s^{-1} they are 5.1%. According to other data (Wolfe 2007), by using sprayers with flat-spray nozzles XR 8001 TeeJet (Spraying Systems Co., USA) with the working fluid flow rate 50 l·ha^{-1}, the drift of the pesticides at the wind speed of 10 km·h^{-1} is 3%, at the wind speed of 20 km·h^{-1} is 7%, and at the wind speed of 30 km·h^{-1} is 11%.

The drift of preparations is one of the most acute problems of chemical plant protection. Of course, the drift of droplets during spraying can be significantly reduced by increasing their size, but at the same time the biological effect of the substance decreases. The size of the droplets affects the content of the preparation on the plants, the degree how much of the surface of the plant is covered by the preparation, its penetration into the plant tissue (leaf absorption), and its toxicity to pests. The droplets of less than 80 μm are more subject to drifting by the air flows, on the other hand, the droplets bigger than 350 μm poorly hold to the plants and roll down to the ground. It has been established by investigations (Baranowski, Pyatachenko 2006). that application of forced precipitation of the sprayed droplets of the working liquid in sprayers improves the quality indicators of the technological process.

Very great attention is devoted to compliance with the environmental legislation and the reduction of the drift of the sprayed droplets of pesticides in the developed countries where, according to standards, there are accepted measurement methods of the pesticide drift during the laboratory tests in the wind tunnels (ISO 22856:2008; Wei, Hou 2017), using a testing standard (ISO 22369-3:2012), as well as field measurements (ISO 22866:2005). Standard (ISO 22369-2:2010) assigns a classification methodology for boom sprayers of the field crops according to the results of the field measurements by the drifting degree of the sprayed droplets, including the testing methods and estimation criteria of the drifting degree. However, the effect of the precipitating air flow in these investigations and publications is not discussed.

The purpose of the present research is to determine the drift of the sprayed liquid droplets caused by the precipitating air flow under the conditions of a lateral air flow (wind).

MATERIAL AND METHODS

The experimental investigations of spraying, drifting and precipitation of the liquid droplets were conducted by means of laboratory equipment (Figs 1 and 2), which included the systems of feeding and spraying the liquid, creation of an air flow, precipitation and collection of the liquid. The system of feeding and spraying the liquid comprised a water tank with a filter, an electric motor, and a collector, fixed on the holder, with a manometer and a spraying nozzle. The air flow generation system included a centrifugal fan and a wind tunnel. The axis of the fan outlet was arranged so that it was placed on the axis of the wind tunnel. The liquid precipitation system contained a blower and a device for precipitation. The blower drive was effected from the electric motor. The liquid collection system included a corrugated surface with a 48 mm pitch,

(a) (b)

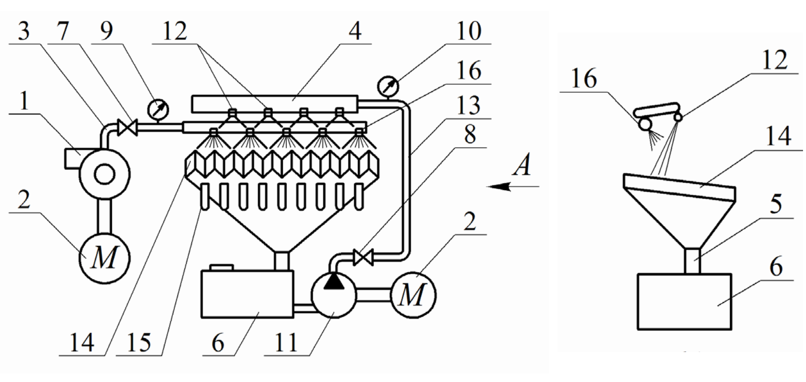

Fig. 1. A scheme of laboratory equipment for the investigation of spraying with forced sedimentation of the pesticide droplets (a) a general view; (b) a view A (a side view)

1 – air blower (fan); 2 – electric motor; 3 – air line; 4 – collector of the working fluid; 5 – connecting pipe; 6 – tank; 7, 8 – valve; 9, 10 – manometer; 11 – hydraulic pump; 12 – sprayer; 13 – pipeline (for pesticides); 14 – corrugated surface; 15 – measuring chambers; 16 – air nozzle

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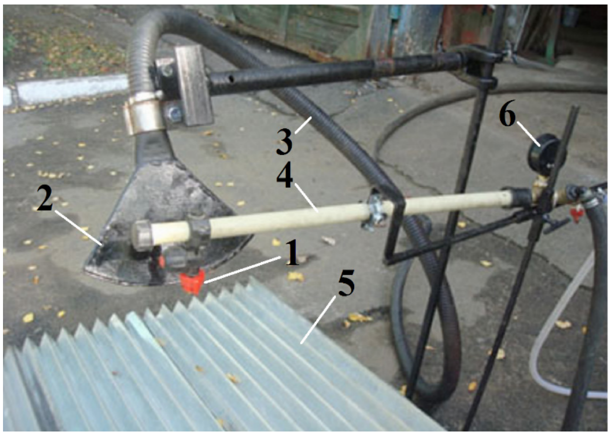

Fig. 2. A view of the laboratory equipment for experiments

1 – pesticide sprayer; 2 – air nozzle; 3 – air line; 4 – pipeline (for pesticides); 5 – corrugated surface; 6 – manometer

placed in an inclined position, for the runoff of the liquid. The settled liquid was collected in weighing cups, arranged under the under the depressions.

Before starting the research according to the standard (74.3-37-266:2005) the flow rate of the liquid through the sprayers was determined. For the sprayer ST 110-02 at a pressure of 0.2 MPa it was 0.647 l·min^{-1} and at a pressure 0.35 MPa it was 0.853 l·min^{-1}, but for the sprayer ID 120-02 it was 0.645 and 0.588 l·min^{-1}, respectively.

The variable factors were the fluid pressure, the airflow speed and the rate of precipitation. In order to determine their impact upon the distribution of the atomised liquid on the corrugated surface of the laboratory installation and its drift, experimental studies were carried out for four variants:

A – spraying of the liquid without the action of lateral and precipitating flows;

B – drifting of the sprayed liquid under the action of a lateral airflow;

C – precipitation of the sprayed liquid on which the lateral flow acts by the precipitating air flow;

D – precipitation of the sprayed liquid without the action of a lateral air flow.

Performing experiments of the studies, the corrugated surface was wetted with water and kept in a wetted state all the time of research. For spraying the liquid slotted standard sprayers ST 110-02 and injector sprayers ID 120-02 (Lechler GmbH, Germany) were used. The investigations were conducted at a pressure of 0.20 and 0.35 MPa and at a 0.50 m spraying height above the corrugated surface. The nozzle with the sprayer was installed in such a way that the jet of the spray is perpendicular to the direction of the depressions of the corrugated surface. The precipitating nozzle was placed at a distance of 0.06 m from the axis of the sprayer in a horizontal surface and 0.03 m below the outlet of the sprayer at an angle of 30° to the vertical surface. The weighing cups for the collection of the liquid were arranged in every second depression of the corrugated surface, the first weighing cup being placed under the first depression. In order to specify the fluid distribution pattern, additional studies were carried out when the cups were positioned under each depression of the corrugated surface. The study of the droplets drift was conducted at the lateral air flow velocities 1.5; 3.0; 5.0; 7.0 and 9.0 m·s^{-1}. Investigation of the precipitation of the sprayed liquid was carried out at the precipitation air flow rate of 15 m·s^{-1}. The time of collecting the sprayed liquid on the corrugated surface was 1 minute. After spraying was finished, we waited for about 4 min, until all the liquid had flown into the cups, and then the weight of the liquid in each bag was measured. Each test was repeated three times.

RESULTS AND DISCUSSION

In the course of the research, the impact of the speed of the lateral air flow (wind) and the speed of the precipitating air flow (i.e. additionally acting vertically downwards) upon the displacement (drift) of the sprayed pesticides aside was measured. In addition, the speed of the air flow vertically down was ensured by additional pressure created by a special fan (blower) provided in the experimental design of the sprayers (Fig. 1).

It was found, when using slotted standard sprayers ST 110-02 at a wind speed of 3 m·s^{-1} and a pressure of 0.2 MPa, that the max. drift of the sprayed droplets in the direction of the lateral air flow, observed on the corrugated surface of the laboratory installation, increases in comparison with spraying in windless weather by 0.51 m, but at the wind speed of 5 m·s^{-1} by 0.84 m. When the speed was 0.35 MPa, such an increase was 0.80 and 0.86 m, respectively. The use of forced precipitation at a speed of 15 m·s^{-1} reduced the drift distances at the working pressure of 0.2 MPa by 0.39 and 0.24 m, respectively, but at the pressure of 0.35 MPa the drift was reduced by 0.175 and 0.29 m, respectively (Fig. 3).

The effect of the precipitating air flow, when using the injector sprayer ID 120-02, was not so clearly pro-

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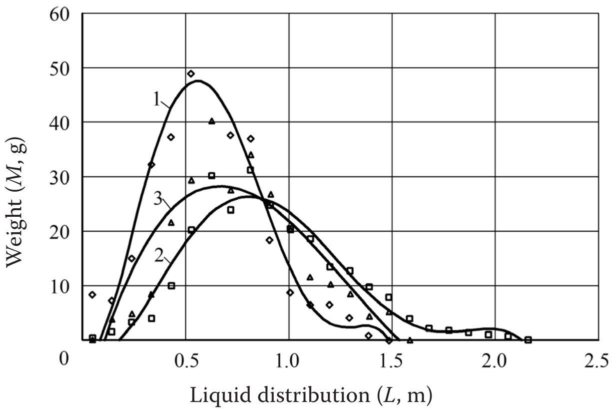

Fig. 3. Distribution of the sprayed liquid by the weight using sprayers ST110-02

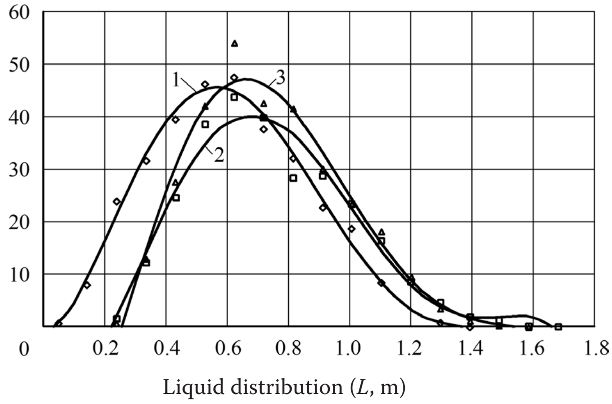

Fig. 4. Distribution of the sprayed liquid by the weight using sprayers ID 120-02

1 – spraying of the liquid without the impact of the lateral and precipitating flows; 2 – the drift of the sprayed liquid under the impact of the lateral flow at a speed of 3 m·s^{-1} (left) and 5 m·s^{-1} (right); 3 – precipitation of the sprayed liquid under the impact of the lateral flow at a speed of 3 m·s^{-1} (left) and 5 m·s^{-1} (right), precipitation flow at a speed of 15 m·s^{-}

nounced. At a pressure of 0.2 MPa and a wind speed of 5 m·s^{-1}, the drift of the sprayed droplets in the direction of the lateral air flow was 0.38 m, but at a wind speed of 7 m·s^{-1} – 0.76 m; at a pressure of 0.35 MPa the drift was 0.38 and 0.85 m, respectively. The use of forced precipitation reduced the drift distances at a pressure of 0.2 MPa by 0.19 and 0.16 m, respectively, but at a pressure of 0.35 MPa by 0.105 and 0.032 m (Fig. 4).

By processing the research results, the distribution of the liquid by weight was determined over the entire length of the corrugated surface of the laboratory equipment of spraying for each of the four variants (Table 1).

Table 1. Weight of the liquid collected in the weighing cups for the variants

Sprayer	Working pressure (MPa)	Speed of the air flow (m·s^{-1})	Weight (g) of the liquid in the weighing cups for variants			
			A	B	C	D
ST110-02	0.2	0.0	0.646			0.582
		1.5		0.588	0.632	
		3.0		0.448	0.504	
		5.0		0.334	0.435	
	0.35	0.0	0.801			0.762
		1.5		0.712	0.770	
		3.0		0.579	0.692	
		5.0		0.465	0.594	
ID120-02	0.2	0	0.638			0.640
		3.0		0.615	0.629	
		5.0		0.568	0.613	
		7.0		0.543	0.582	
		9.0		0.542	0.579	
	0.35	0.0	0.813			0.838
		3.0		0.764	0.810	
		5.0		0.719	0.776	
		7.0		0.686	0.740	
		9.0		0.672	0.715	

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As one can see from the table, when standard nozzle sprayers ST 110-02 were used, in windless weather (i.e., by simulating windless weather in the experiments), the additional precipitating air flow (acting vertically down) at a speed of 15 m·s^{-1} causes a decrease in the amount of the sprayed liquid, falling onto the corrugated surface of the laboratory equipment.

Under the same conditions, using injector sprayers ID 120-02, the amount of the sprayed liquid, falling onto the corrugated surface of the laboratory equipment, remained the same as without the above-mentioned additional precipitation stream.

This can be explained by the fact that sprayers ST 110-02 produce droplets of a lesser diameter than sprayers ID 120-02, and the precipitating flow brings them outside the corrugated surface.

The influence of the precipitating flow was particularly pronounced when the speed of the wind was increased (more than 3.0 m·s^{-1} for sprayers ST 110-02, and more than 5.0 m·s^{-1} for sprayers ID 120-02). In this case the amount of the liquid captured on the corrugated surface of the laboratory equipment, when the speed of the wind was 5.0 m·s^{-1} and the speed of the precipitating flow was 15 m·s^{-1}, increased to 30% for the sprayers ST 110-02 but for the sprayers ID 120-02 – only to 12%.

CONCLUSION

Influence of the precipitating air flow was determined upon the decrease of the drift of the atomised liquid droplets under the impact of the lateral air flow, the precipitating air flow and the distribution of the atomised liquid by weight and length depending on the working pressure of the liquid in the system of sprayers of various types.

Using injector sprayers ID 120-02 at a pressure of 0.2 MPa and a wind speed of 5 m·s^{-1}, the drift of the sprayed droplets in the direction of the lateral airflow was 0.38 m, and at a wind speed of 7 m·s^{-1} was 0.76 m. At a pressure of 0.35 MPa, the drift was 0.38 and 0.85 m, respectively. The use of forced precipitation reduces the drift distances at a pressure of 0.2 MPa by 0.19 and 0.16 m, respectively, and at a pressure of 0.35 MPa by 0.105 and 0.032 m.

At a lateral wind speed of 5.0 m·s^{-1} and a precipitating flow speed of 15 m·s^{-1}, the amount of the precipitated liquid increases to 30% for the sprayers ST 110-02 and up to 12% for the sprayers ID 120-02.

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