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Practical deviation in sustainable pesticide application process

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Abstract

Using agrochemicals becomes essential practice of modern farming but in the same time it puts risk to human, animal health and the environment. The initial actions to create balance between this negative impact and the necessity to use the pesticides concerning the environment, people's living conditions and the economic, those factors are defined as the sustainable development. In this paper the algorithm to gain the sustainability of pesticide application was set to highlight some places (during some logistic steps of pesticide application) where the sprayer operator has to make subjective decisions about the correct procedure; these decisions are subjected to the "practical deviations". The paper presents also some results of investigation on using nozzles with different physical wear. The results of laboratory test showed that damaged nozzles produced flow rate higher than the allowed limits of nozzles inspection regulations. Also, the decision to use damaged nozzles with lower pressure to compensate the increase of flow rate, results in bigger drop sizes comparing with the new nozzles, which may affect in turn the biological efficacy and put risk of pesticide non target contamination. The decision, which is made by sprayer operator, is an example of "practical deviations" during pesticide application process.

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Keywords: pesticide application;agricultural nozzles;practical deviation;nozzles wear.

1. Introduction

Using pesticide poses danger and risk to human, animal health and the environment, but at the same time cease controlling the crop infections which may result in big loss of yield and probably unhealthy food.

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Environmental and health hazards caused by pesticides were the basis for the development of regulations that prescribe rules for the safe trade and application of pesticide, for example: Directives; ISO Standards, National standards (in Poland: GIORiN (1999) recommendations), etc. "A common legal framework for achieving a sustainable use of pesticide should be established, taking account of precautionary and preventive approaches " this was one of the points to adopt the directive 2009/128/EC.

Agricultural nozzles are important for their effect on: biological efficacy (spray coverage, distribution, deposition and retention on plants); environment (drift, off-target deposition); pest control process efficiency (put the exact amount of pesticide on target) and doing the work in a variety of weather conditions, wide range pressure, different application rate with travel speed (flexibility). Worn nozzles produce more quantity of pesticide (bigger flow rate) with irregular distribution pattern, this means higher cost and risk to the environment and human life due to contamination of pesticide on plants or fruits. Irregular distribution of pesticide reduces the efficiency of the control process and put the risk of spreading the blight again and this requires repeating the control process again. Barber (2009) estimated the total cost of using worn nozzles by $182,800 by using nozzles that are spraying just 15% over the rated capacity and work 2080 hours per year.

Worn nozzles affect essential spray characteristics such as: flow rate; spray angle; droplet size. Sawa et. al (2012) suggested that one of the important factors is the good choice of the used nozzles and the measured parameters to evaluate the nozzles performances, also the spraying quality of nozzles is characterized by: flow rate, individual pattern (spraying angle, coefficient of asymmetry) and transverse distribution under the boom (Coefficient of Variation - CV). Reichard et al. (1991) compared different types of nozzles with 10% greater flow rates than the nominal flow rate, the stainless steel tips had average use times 5.6 and 2.1 times longer than brass and nylon tips, respectively, this stainless steel tips also had the least increase in flow rate while the brass tips had the greatest increase. The same authors mentioned the factors which influence nozzle wear include spraying pressure, duration of test, type and concentration of material used in the spray mixture, time of use of abrasive before it is changed during the test, and type of nozzle and size, shape and material of the orifice.

Sprayer boom with standard flat fan nozzles need to have nozzles overlapping to get uniform distribution along the boom because of the differences of spray quantity sprayed from standard flat fan nozzle across the spray pattern (tapered shape), this overlapping is affected by the nozzles height of the target and the spray angle, worn nozzles can affect this distribution by changing the spray angle or the uniformity of the distribution although Huyghebaert (2015) reported in his extensive study about the sprayers inspection that nozzle spray distribution deformation can be a weak indicator for the nozzle physical state, preferring the nozzle flow rate as indicator for nozzle wear and sprayer inspection and suggesting for the future inspection method of combining the flow rate and transverse distribution in one device for complete inspection of nozzles. Flat fan nozzles also provide different size of droplet along the spray spectrum, Ozkan et al. (1992) found out with their experiment on new and worn nozzles with 0.8 l/min flow rate that Dv5 for spray droplet spectrum were generally smaller in the center of the spray pattern for both new and worn nozzles, for the capacities 1.5, 2.3 and 3.0 L/min it decreased away first from the centers of the patterns, then began to increase at about ±20 cm away from the center of the pattern.

Agricultural production and the plant protection are "business activities" and they are subjected to economic activity (minimizing the cost for an effect or to maximize the effects while maintaining the level of costs). This situation forms the behaviour of the sprayer operator, which is reflected in the formation of specific plant protection treatment standards (parameters of the sprayer and accompanying measures) at their own discretion. These actions which referred to as "practical deviations" are depend primarily on a “safety culture” of sprayers users or the administration and may cause: Operating errors; Operational infractions, and even Operational violations.

This work is an attempt to identify risk activities (places where there is "practical deviations") in the process of plant protection and also present selected results of laboratory tests which refer to the consequences of use "maximum practical deviations" for some stages of the pesticide application. These activities, in practice, can decide about the quality of the operation, safety of work, or may cause environmental risks which limit the opportunities to implement sustainable use of pesticides, according to Directives 2009/128 / EC.

2. Material and methods

Reducing the amount and risk are the key points to maintain sustainability of pesticide use during the phase of
preparing and application according to directive 2009/128/EC, an observation from a study conducted in 53 family farms all over the country (Poland) has been made during the implementation of research projects at the University of Life Sciences in Lublin, Sawa et al. (2004) and ITP Falenty Wójcicki et al. (2009) was used first to develop Table (1), later the key points in this table were applied to every step in the algorithm for the process of sustainable applications of pesticides figure (4). These observations were analysed to detect the possible risk "practical deviations" and the recommendation to avoid it.

The information presented in the algorithm and Table 1 relates to the organizational activities, but in each of these activities may occur decisions of a "practical deviations", an example would be the use of nozzles that are in various states of physical wear.

Nozzles wear is difficult to observe visually figure (1), it is difficult also to observe by human eye, which nozzle on the spray boom gives more quantity of pesticide or irregular shape of distribution, usually this task need measuring device to decide which nozzle is over wear, Krause et al. (2002) observed the nozzle wear and other changes of different types of fan-pattern nozzles by using scanning electron microscopy.

![Fig. 1. Dimensions of new and damaged nozzles](image)

Widely used standard flat fan nozzles (24 Nozzles TeeJet XR 110/03 VP Spraying Systems Co.) was investigated in the test, 12 of them were exposed to the wear test inside the wear tank figure (2). In this 1000 L tank there were 5 pipes in the upper side, every pipe holding six nozzles, all nozzles were subjected first to 10 hours for warm-up with water only in the tank after this flow rate was measured figure (3) with 1, 1.5, 2, 2.5, 3 bar pressure (recommended from the manufacturer). Droplets size were measured with Sympatec GmbH Laser Diffraction device which uses HELOS/R system with measuring range from R1 to R8 (0.1-8,750 μm). The measurements were taken 50 cm under the nozzle orifice with 1, 2, 3 bar pressure and in seven positions to the left and right side of the spray centreline (across the long axis of the spray pattern), the distance between each two positions was 10 cm. These data considered to be for the new nozzles or nozzles before wear process.

![Fig. 2. Wear tank](image)  ![Fig. 3. Measuring flow rate](image)

After this, 12 nozzles were subjected to wear process in the tank with the mixture of water and the wear agent (Kaolin KOM 18.2 kg mixed with 300 L of water) for 100 hours with 4 Bar pressure, data were collected after this and considered to be data for damaged nozzles.
3. Results and discussion

The basic principles of pesticide application are shown in the algorithm (figure 4) and they include each step in the process of pesticide application from the planning and application of pesticide in the field, until the management of empty packages and residues or sprayer storage. These activities are linked to the decision-making process, and it could be loaded with "practical deviations" aimed at increasing the efficiency of the process, for example: a longer use of worn nozzles in spite of its efficiency.

Table 1. Possible risk and the recommended to prevent it

<table>
<thead>
<tr>
<th>No.</th>
<th>Treatment action: possible risks</th>
<th>Recommended action to prevent risks (use GIORiN* recommendations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Purchase of pesticide: purchase wrong types, not original pesticide.</td>
<td>Purchase only original, undamaged packaging which provided with a label by a person’s having training certificates, predict or calculate the amount of pesticide.</td>
</tr>
<tr>
<td>2</td>
<td>Transport of pesticide: pollution to the environment, people, animals, food and feed through spillage of pesticide containers during transport.</td>
<td>Transport without contact with people, animals, food and feed. Pesticides containers should also pack during transport and put in separate place from passengers and luggage.</td>
</tr>
<tr>
<td>3</td>
<td>Storage of pesticide: poisoning people, animals and the environment through accidental ingestion and spillage.</td>
<td>Storage should be in rooms designed for this purpose (locked) with all safety precautions.</td>
</tr>
<tr>
<td>4</td>
<td>Preparing the sprayer for work: working with damaged devices or parts.</td>
<td>Checking the technical condition and the correct operation of the sprayer, in order to eliminate contaminates to the environment and defective performance and spraying threats, replace worn parts.</td>
</tr>
<tr>
<td>5</td>
<td>Parameters selection of sprayer operation: wrong dose of spraying agent, inappropriate drops size (drift), not good distribution of pesticide, inappropriate setting for weather conditions.</td>
<td>Test the operation of the sprayer nozzle type and flow rate, spray pressure, travel speed of the sprayer, high of boom and sprays angel etc.). calibrate according to the pesticide label and weather conditions.</td>
</tr>
<tr>
<td>6</td>
<td>Preparing the mixture for work: pollution of the operator or the environment (spillage). Improper water source for mixing.</td>
<td>Use of protective clothing, compliance with recommendations and instructions for preparing the liquid, and information on using water for filling the sprayer tank, using induction hopper.</td>
</tr>
<tr>
<td>7</td>
<td>Start of the spraying action: direct risk to the operator, pollution of the environment (drift to rivers, lakes, and ground water), soil, air, nearby crops, residential area near the spray location.</td>
<td>Use of protective clothing, perform the treatment under favorable weather conditions. In special cases inform neighbors about the planned treatment, consider using buffer zones.</td>
</tr>
<tr>
<td>8</td>
<td>Checking the work of the sprayer during application: hidden defects on devices, technological or technical stoppages and bad weather conditions.</td>
<td>Replace or repair defective parts according to the sprayer manual, transfer the liquid to another sprayer, calibration according to new weather conditions, delay the spray process.</td>
</tr>
<tr>
<td>9</td>
<td>Disposal of pesticide residue and remnant: risk of operator, pollution of the environment and treated plants.</td>
<td>Dilute and spray the remnant of spray liquid in places designated by the terrain authorities, using biobeds.</td>
</tr>
<tr>
<td>10</td>
<td>Sprayer rinse: pollution of the environment and treated plants.</td>
<td>Wash all the sprayer and distribute the washing mixture in the field or farm land (as recommended). Avoid contamination point, using biobeds.</td>
</tr>
<tr>
<td>11</td>
<td>Recycling and disposal of packages: pollution of the environment and human health.</td>
<td>Triple rinse containers after using. Follow the information on the packaging or GIORiN instructions.</td>
</tr>
<tr>
<td>12</td>
<td>Cleaning and maintenance of the sprayer for storage: appearance of hazardous remnant spray mixtures during cleaning in a storage place, the development of corrosion of the sprayer units, threat to the surrounding places.</td>
<td>Clean with the addition of special cleaning agents, use of protective clothing, perform work in appropriate place. Washing liquid should not get to watercourses. Avoid contamination point, perform maintenance in accordance with the instructions of the sprayer.</td>
</tr>
<tr>
<td>13</td>
<td>Preparation the sprayer for the postseason storage: pump and pipe damage due to freezing.</td>
<td>Drainage of the control valve, pump, filters, protect working units from the weather, sprayer inspection.</td>
</tr>
</tbody>
</table>

*GIORiN - Main Inspectorate of Plant Protection and Seed Inspection
Source: developed by using: Owczarczyk (2001)
Figure 5 shows the effect of 100 hours of wear on flow rate with different pressures, all the damaged nozzles with the pressures were out of the ± 10% limit permitted for the flow rate according to EN 13790-1 (2003). We can notice from the figure also that the flow rate for the new nozzles was slightly higher than the nominal flow rate provided by the manufacturer for every pressure. The percentage of flow rate increase with pressure for the damaged nozzles was 21%, 15%, 11%, 10% for the pressures 1, 1.5, 2, 2.5, 3 bar respectively, these increase percentages were almost the same for the new nozzles.
Figure (6) shows the VMD (volume median diameter) for the new nozzles with three bar pressure across the spray spectrum compared with damaged nozzles with three, two and one bar pressure. The drop size increased when reducing pressure from three bars to two or one bar, similar results was reported by Braekman et al. (2011) and Dorr et al. (2013) (although their measurement was close to the zone of drop formulation and also with using of concurrent airflow) for the flat fan nozzles.

Using damaged nozzles will give more quantity of water during calibrating due to the higher flow rate of these nozzles, to compensate this situation, the sprayer operator has another options beside replacing the nozzles, for example driving with higher speed which will result in higher drift percentage as indicated by Van de Zande et al. (2005), Arvidsson (1997). As example of practical deviation is the situation when the sprayer operator will try to reduce the pressure for the damaged nozzles from three to two bar to get flow rate for his damaged nozzles similar to the flow rate for the new nozzles which he used to calibrate his sprayer with it (from 1.52 L/Min with three bar to 1.25 L/Min with two bar), this critical decision instead of replacing nozzles will affect the sprayed drops size which in turn may influence the biological efficacy (bigger drops mean less surface area of drops comparing with small size drops) of the applied pesticide as well as environmental hazards as reported by Nuyttens et al. (2007) indicating that the ideal nozzle–pressure combination will maximize spray efficiency for depositing and transferring a lethal dose to the target, whilst minimising off-target losses such as spray drift and user exposure. Using lower pressure will also produce lower drops velocity as reported by Dorr et al. (2013) which will affect the spray impact on target.
Figure (7) shows the cumulative volume percentage of the drops size ranges for new and damaged nozzles on the left side of the spray spectrum (the right side was almost the same like the left side), the new nozzles produced bigger percentage of drops size under 150 μm in position L30 and centreline of spray spectrum, whilst the damaged nozzles gave the biggest percentage of drops size in the range 250-350 μm and ≥ 350 μm in all positions of spray spectrum.

![Graph showing cumulative volume percentage of drops size ranges for new and damaged nozzles](image)

Fig. 7. Left side spectrum of drops for new and damaged nozzles, spraying pressure of 3 bar

4. Conclusion

Pesticides are poisons and their use requires a precise and well-organized implementation of clearly defined actions. Threats and methods of their elimination which occurred in the subsequent stages of plant protection are illustrated in the algorithm. If we analyse main points concerning the sustainable pesticide application in Directive 2009/128/EC we can say that “Sustainable pesticide application” as part of “Sustainable Agriculture” it is more ethical than technical problem, and the implementation of its principles into practice is problematic.

Reducing the risk and achieving the sustainability of pesticide application is possible if users will take into account in this process all requirements of the Directive 2009/128/EC concerning the sustainable use of pesticide during the preparation and application phase.

"Practical deviation” refers not only to the sprayer operator, but may be perpetrated services and by the authorities which put down the rules of pesticide application. These actions, in practice, can decide about the quality of the operation, safety of work or small environmental cause-risk which limit the opportunities to implement sustainable use of pesticides, according to Directives 2009/128/EC.

The behavioural study of the sprayer operator which is so called “practical deviations “ in the opinion of the authors is an important problem in the process of sustainable applications of pesticides.

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