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INFLUENCE OF THE AIR STREAM PRODUCED BY THE DRONE ON THE SEDIMENTATION OF THE SPRAYED LIQUID THAT CONTAINS ENTOMOPATHOGENIC NEMATODES

Summary

The results of research are related to the influence of the air stream produced by the drone on the distribution of the jet deposited under the drone that is sprayed with the aid of the XR 11002 slot sprayer, with water pressure of 0.4 MPa and Steinernema feltiae entomopathogenic nematodes contained in it. An influence was found of air on a change in distribution of the liquid that is deposited on the groove patternator and the concentration of the nematodes in the depositing liquid.
***Key words**: drone, liquid spraying, application of entomopathogenic nematodes*

WPŁYW STRUMIENIA POWIETRZA WYTWARZANEGO PRZEZ DRONA NA OSADZANIE SIĘ ROZPYLANEJ CIECZY ZAWIERAJĄCEJ OWADOBÓJCZE NICIENIE

Streszczenie

Przedstawiono wyniki badań wpływu strumienia powietrza wytwarzanego przez drona na rozkład osadzającej się pod dronem strugi rozpylanej za pomocą rozpylacza szczelinowego XR 11002, przy ciśnieniu 0,4 MPa wody i zawartych w niej owadobójczych nicieni Steinernema feltiae. Stwierdzono wpływ powietrza na zmianę rozkładu osadzanej na stole rowkowym cieczy i koncentracji nicieni w osadzającej się cieczy.
***Słowa kluczowe**: dron, rozpylanie cieczy, aplikacja owadobójczych nicieni*

1. Introduction

Owing to the development of technology, new devices have appeared that may be used in agricultural engineering. These are drones, i.e. unmanned aerial vehicles. Drones are already used to supply information concerning the condition of crops [1, 2, 10, 12, 14] and they are used as agricultural machinery to perform some operations in the field, e.g. spraying of crop protection chemicals [3, 11, 13]. Furthermore, drones can be used in crop protection in organic farming [19]. Airborne Robotics company has prepared a system for the application of bio-pesticides in croplands: AIRDROP. A container with an applicator was attached to the **AIR6** hexacopter, which distributes mite on the field against European corn borer [19]. One of the methods of the application of biological crop protection agents with the aid of drones consists in spraying plants with a liquid that contains biopesticides. Entomopathogenic nematodes are a popular crop protection agent that is used in organic farming: chiefly against the larvae of those pests that feed in soil [16, 18] and against worms [17]. A problem that may have a negative impact on the quality of operations performed with drones refers to the action of the air stream that is produced by the drone propellers on the jet of the drops sprayed. The influence of the air stream can be manifested by a change of the drop stream shape and in the distribution of the liquid that is sedimented under the sprayer. When the liquid that contains entomopathogenic nematodes is sprayed, there occurs a differentiation of the proportions between the volume of the liquid that is transversely sedimented in various places under the sprayer and the concentration in this liquid of entomopathogenic nematodes that are being sedimented with it [4, 9].

This phenomenon may be the result of an insufficient mixing of nematodes with the liquid from containers in sprayers [5, 7]. The reason of the lack of proportionality between the volume of the liquid that is sedimented in transverse distribution and the quantity of nematodes that are sedimented with this liquid may also be the sizes of nematodes, which with their volume are equivalent to the sizes of large drops. The paths of settling nematodes can be different from the paths of falling drops. This may result in a change in the nematode concentration in the liquid that is sedimented under the sprayers. This phenomenon depends of the value of the liquid pressure during spraying [6] and the height at which the sprayers are placed over the surface sprayed [8]. Another reason of the disproportion may also be the movement of air caused by wind blowing or the action of the front air stream [15].

When using drones in the pesticide applications of nematodes, there may occur phenomena that are similar to those that occurred during the pesticide applications of nematodes with the aid of field sprayers.

The purpose of the study was to determine whether the air stream from a flying drone has an influence on the distribution of the liquid deposited under the drone and that comes from a jet of drops produced by the sprayer mounted on the drone, and whether this also has an influence on the distribution of the biological crop protection agent contained in the sprayed liquid, i.e. entomopathogenic nematodes.

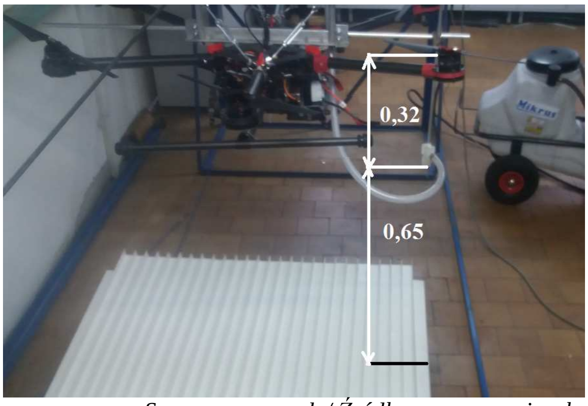
2. Material and methods

To implement the research objective, the test stand was to be constructed in such a manner so as to avoid the impact of external factors (in particular, wind blowing, which may have an influence on the shape of the drop jet and on the drone being carried away); for this reason, the test stand was built in a laboratory. A DJI S 900 drone: a hexacopter was used in the tests. The drone was rigidly fixed to a horizontal frame that was based on its ends on stands. The drone possessed folded propellers sized 15 x 5.2". The engines with the propellers were driven by current from a Lipo12000 mAh 22.2 V battery installed on the drone. All the propellers turned in pairs in opposite directions to each another.

In the middle, on the axis between the two rotors, a vertical rod was mounted, to which an XR 11002 slot sprayer manufactured by TeeJet was fixed. The outlet of the sprayer nozzle was at a distance of 0.32 m below the base of the drone propellers. The nozzle was fed with liquid from a "Mikrus" wheelbarrow sprayer. The pressure of the liquid flowing through the nozzle was set on the value level of 0.4 MPa. The liquid that was sprayed consisted of water mixed with *Steinernema feltiae* entomopathogenic nematodes. The average concentration of the nematodes was ca. 800 thousand items in one litre of water.

The tests were performed as comparative tests. Two measurement trials were performed under the drone in relation to the liquid that was sprayed while the drone rotors were not working and two further measurement trials were performed with working rotors. The rotational speed of the rotors was accepted of 2,500 revolutions·min^{-1}. Based on initial findings, it appeared that this speed enables the tested drone to fly. The rotational speed of the engines was controlled with the nozzle DT-2259 stroboscopic revolution counters.

The transverse distribution of the volume of the liquid from the drop jet that is deposited under the nozzle was assessed with the aid of a groove patternator (Fig. 1).



Source: own work / Źródło: opracowanie własne

Fig. 1. View of measuring stand

Rys. 1. Widok stanowiska pomiarowego

The height of the nozzle over the groove patternator was 0.65 m. The established height is higher than the typical height (0.50 m) over the plants as for field sprayers. This was the result of the assumption that in the future the flying height of the drone above the crops will be higher than the location of the sprayer boom in a typical field sprayer, yet lower than 2-3 m [3]. The widths of the slots that collect the liquid was 3.5 cm. The water that was flowing down with nematodes from the groove**s** of the patternator was collected into 100 ml containers. Due to a significant width of the produced stream, while assuming distribution symmetry, half distribution was accepted in the analysis. In order to compare the transverse distributions of the liquid that was deposited on the groove patternator and that was sprayed. In order to compare the transverse distribution of the spray liquid that was deposited on the groove patternator (in version with and without rotors operation), coefficients of variation of liquid distribution according to formula were determinedand were not working, coefficients of variation of liquid distribution were determined according to formula (1):

$$CV = \frac{\sqrt{\frac{\sum_{i=1}^{i=n}(q_i - q_{sr})^2}{n}}}{q_{sr}} 100 \qquad (1)$$

where:
CV – coefficient of variation of liquid distribution [%],
q_i – volumes of liquid contained in container under given groove [ml],
q_{sr} – average volume of liquid, in containers from all grooves [ml],
n – number of grooves under analysis.

The concentration of nematodes in the liquid collected in the individual containers was assessed with the use of a microscope by counting the number of items in 0.050 ml samples. The measurement was repeated nine times for each container. To compare the distribution of the nematode concentration in the liquid, the coefficient of variation of distribution was determined by adapted to the nematode concentration in the containers under groovers, described with formula 2.

$$CVk = \frac{\sqrt{\frac{\sum_{i=1}^{i=n}(l_i - l_{sr})^2}{n}}}{l_{sr}} 100 \qquad (2)$$

where:
CVk - coefficient of variation of nematode concentration in the liquid, %
l_i - number of nematodes in the samples from liquid collected under given groove, items
l_{sr} - average number of nematodes in the liquid samples from all grooves, items
n - number of grooves under analysis.

3. Results and discussion

The transverse distribution of the liquid that is sedimented on the groove patternator is presented in Fig. 2. It shows a dependence of the percentage share of the volume of the liquid contained under all grooves: Q_t. Number 1 on the diagram denotes the middle slot on the measuring patternator. The concentrations of entomopathogenic nematodes in the individual containers is presented in Fig. 3 as a relation of the number of nematodes in the samples collected from the individual groove: l_i in relation to the average number of nematodes from all grooves: L_n.

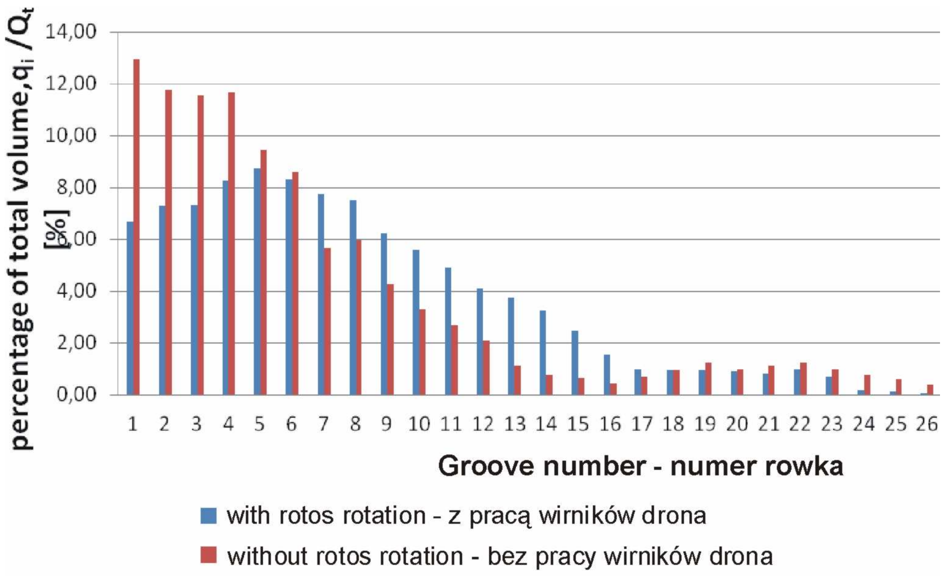
A comparison of coefficients of variation: *CV* – of liquid distribution and *CVk* – of nematode concentrations in the liquid in the container, with and without rotors operation, determined according to Formulas 1 and 2 are presented in Table 1.

Table 1. Values of the coefficient of variation of transverse liquid distribution and nematode concentrations in the liquid

Tab. 1. Wartości wskaźników nierównomierności rozkładu cieczy i koncentracji nicieni w cieczy, w naczynia

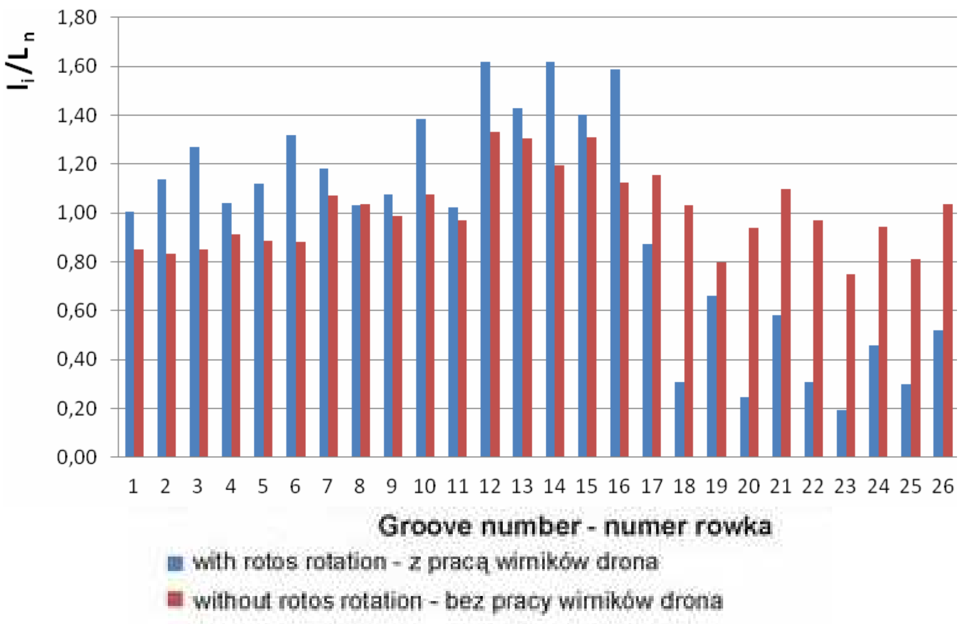
	with rotors rotation	without rotors rotation
CV, %	109.9	80.2
CVk, %	16.7	46.2

Source: own work / Źródło: opracowanie własne



Source: own work / Źródło: opracowanie własne

Fig. 2. Transverse distribution of liquid sedimented on the groove patternator
Rys. 2. Poprzeczny rozkład osadzonej na stole rowkowym cieczy



Source: own work / Źródło: opracowanie własne

Fig. 3. Transverse distribution of nematode concentrations in the liquid sedimented under the nozzle
Rys. 3. Poprzeczny rozkład koncentracji nicieni w osadzonej pod rozpylaczem cieczy

When analysing the diagrams of the transverse distribution of the liquid that is sedimented under the nozzle with and without working rotors, one can notice that they divide into the fundamental part of the liquid sprayed, which begins with slot 1 and finishes between slots 14 and 17 and an over-sprayed part, which may be the result of too high position of the sprayer over the patternator, which covers ca. 8 per cent of the volume of the liquid sedimented on the remaining 9 slots. The air stream from the working rotors caused narrowing on the groove patternator of the fundamental part of the liquid sedimented thus deteriorating the overall unevenness of its sedimentation.

The entomopathogenic nematodes contained in the liquid, during spraying, can form particles themselves, ones that separate from the liquid or that constitute the majority of the drop volume. The work of the rotors has resulted in an improvement (a reduction in the value) of the coefficient of variation of nematode concentration in the liquid, chiefly as a result of blowing a cloud of little drops apart, one that includes falling nematodes, over the groove patternator.

4. Conclusions

The air stream from a flying drone exerts an influence on the distribution of the volume of the liquid that is sedimenting under the drone and that comes from the jet of drops produced by the nozzle installed on the drone. Furthermore, it has an influence on changes in concentrations of the biological plant protection agent: entomopathogenic nematodes contained in the sedimented liquid.

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