THE INFLUENCE OF WORKING SPEED ON THE QUALITY PARAMETERS FOR SPRAYING IN VINEYARDS

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INFLUENȚA VITEZEI DE LUCRU ASUPRA PARAMETRILOR CALITATIVI LA EFECTUAREA LUCRĂRILOR DE STROPIT ÎN VII

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ABSTRACT

In vine cultivation, pests are obstacles to obtaining crops that correspond both qualitatively and quantitatively. In this work, main working qualitative indices were determined. These working qualitative indices were determined under real field conditions using 2 types of nozzles, an air injection nozzle and a standard nozzle. The working qualitative indices determined were DV1, DV5, DV9, coverage degree, number of drops and the amount of solution deposited on target surface. For both speeds of 5 and 7 km/h, DV5 values classified the spray extra and ultra coarse spectrum. The coverage rate was between 55% and 99% regardless of travel speed.

REZUMAT

În culturile viticole, bolile reprezintă obstacole în obținerea culturilor care corespund atât calitativ, cât și cantitativ. În cadrul acestei lucrări, au fost determinați principalii indici calitativi. Acești indici calitativi de lucru au fost determinați în condiții reale folosind 2 duze, cu injecție de aer și o duză standard. Indicii calitativi determinați au fost DV1, DV5, DV9, gradul de acoperire, numărul de picături și cantitatea de soluție depusă. Pentru ambele viteze de 5 și 7 km/h, valorile DV5 clasifică spectrul în extra și ultra grosier. Rata de acoperire a fost între 55% și 99%, indiferent de viteza de deplasare.

INTRODUCTION

Plant viral diseases represent significant hurdles, leading to substantial yield losses globally across agricultural and horticultural crops. Conventional methods often fall short in completely eradicating viral loads from infected plants. Despite the ongoing utilization of unconventional approaches to prevent viral infections, their efficacy is not consistently reliable. Hence, there is an urgent need to identify the most promising and sustainable management strategies for economically significant plant viral diseases *(Manjunatha, et al., 2022; Signorini, et al., 2021).*

Continuous monitoring of the long-term effects of viticultural management practices is crucial, alongside assessing opportunities to enhance the environmental sustainability of vineyard operations. This holds particular significance for the wine industry, given the disruptive challenges posed by climate change, labour shortages, and increasing production costs faced by growers *(Tardaguila, et al., 2021).*

The aim of utilizing an air carrier sprayer for plant spraying is to achieve the deposition of spray material onto the canopy in adequate amounts, with uniform distribution, and minimal off-target loss, all within a timely manner. Spray droplets, formed via hydraulic or air shear atomization, are nevertheless conveyed to and onto the plant canopy by air jets generated by the sprayer. The turbulence of the air and the dispersion of the spray within the airflow are pivotal factors in ensuring optimal spray deposition within the canopy *(Manor, et al., 2002)*.

The effective utilization of crop protection products depends on various variables, including the type of application equipment *(Signorini, et al., 2023),* tank mix specifications *(Dai, et al., 2019)*, canopy porosity *(Diago, et al., 2016)*, operational features *(Sasturain, et al., 2024)* and environmental patterns such as meteorological aspects *(Belyakov, et al., 2021)*.

Research has shown that spray formulations and droplet size significantly determine the success of aerial applications *(Torrent, et al., 2019)*. All these aspects related to the management of the administration of phytosanitary treatments decide the effectiveness of the treatment carried out *(Grella, et al., 2020; He, et al., 2024)*.

Spray drifting represents a primary source of pollution identified during the application of pesticides on crops. So, in order to reduce environmental pollution, the characteristics of the droplets proved to be extremely important, because their size and weight are the most used factors taken into account in reducing the drift *(Creech, et al., 2015; Butler Ellis, et al., 2017; Rad, et al., 2022)*.

Other studies have demonstrated that a significant portion of the applied phytosanitary product is lost with previous studies indicating that only 30–40% of pesticide droplets are effectively deposited on the intended target. Typically, only a small fraction of the sprayed liquid adheres to the plant canopy, while the majority either falls to the ground or drifts away *(Ortiz, et al., 2023; Zhao, et al., 2023)*.

A new method for testing dispersion devices used for pesticide application in crops or orchards and not only has been discovered and was highly debated by other researchers with the same thoughts and aims to make an efficiency in pesticide management. Early researches in pesticide drift monitoring were also made using image analysis technique and LIDAR sensors *(Gheres, et al., 2023; Li, et al., 2023; Kashdan, et al., 2007; Gregorio, et al., 2014)*.

Contemporary vineyards, marked by monoculture and simplified landscapes, confront numerous challenges in pest management. These include increased pest and disease pressure, dependency on agrochemicals, the emergence of pesticide resistance, and susceptibility to the impacts of climate change. Also, the pest management comes with the necessity of access to finance which is a crucial aspect of vineyard development and performance. Several factors influence this access, including financial management capacity, which is closely tied to the level of financial literacy within the vineyard management *(Favor, et al., 2024; Hoxha, et al., 2023).*

These challenges can find their answer in increasing the “precision” of spraying, that might be able to provide maximum effective coverage while applying lower chemical doses. From economic and environmental standpoints this can be considered the most viable approach. For this purpose, air injection nozzles can be used, capable of reducing drift *(Zande, et al., 2008; Nuyttens, et al., 2006)*, and thus implicitly pollution, while keeping the degree of coverage similar to the classic nozzles, hydraulic, disc–core nozzles *(Derksen, et al., 2000; Ranta, et al., 2021)*.

Checking the quality of the application of pest control products by spraying can be done by applying WPS water-sensitive paper collectors on the target surface, after applying the products, the WPS collectors are scanned, and the results obtained are interpreted. When in contact with water droplets, WPS changes its colour from yellow to blue, so it is not necessary to use colorant in the applied solution *(Sundaram, et al., 1987; Thériault, et al., 2001; Deveau, 2024)*.

The quality of the coverage of the target area is checked considering a series of parameters such as: the degree of coverage and the number of deposits, as well as the size of the drops. Companies producing pest products such as Singenta recommend that for satisfactory results the thresholds should be: minimum 50-70 drops/cm^2 for fungicide, minimum 20-30 drops/cm^2 for insecticides or pre-emergence herbicides and minimum 30-40 drops/cm^2 for contact postemergence herbicides *(Deveau, 2024; Zhu, et al., 2011; Wang, et al., 2019)*.

The aim of this study was to comparatively evaluate the spraying parameters and to measure the quality of the spraying with two types of nozzles used for treatments in vineyards and orchards.

MATERIALS AND METHODS

In order to achieve the proposed objectives an experimental plot with a vineyard was organized near the municipality of Oradea, Bihor County. For this study, 2 types of nozzles were used, a standard set of nozzles and an air injection nozzle (figure 1) at 2 different speeds and the main qualitative parameters of pesticide application were determined.

These nozzles were tested at two working speeds of 5 km/h and 7 km/h, without changing the pressure (9 bar) in three repetitions. The amount of solution varied so that the pressure remained constant. For the standard nozzles the rate/hectare was 890 l for 5 km/h and 640 l for 7 km/h. For injection nozzle the rate/hectare was 660 l for 5 km/h and 470 l for 7 km/h. The rate/hectare was changed according to working speed and constant pressure.

a) b)

Fig. 1 - The types of nozzles used in the experiment
a) standard nozzle; b) air injection nozzle

To achieve these working conditions, a Lombardini brand TUBER 40 tractor, an ATOM 300 pest control application machine (sprayer) (figure 2 a), with the following technical characteristics: main tank 300 L capacity 12 nozzles (6 on each side), a membrane piston pump and a 550 mm fan with an air flowrate of 26.000 m^3/h *(tehnofavorit.ro, 2024)* were used.

The vineyard had a 2.2 m row spacing.

Before performing the experiment, the machine and the nozzles were tested using the HERBST Pflanzenschutztechnik stand *(http://www.herbst-pflanzenschutztechnik.de/, 2024)*. This is a special stand which can determine the flowrate on each nozzle. The sprayer was calibrated according to the data obtained from the stand software.

a) b)

Fig. 2 – Equipment used in research
a) TUBER 40 tractor and Atom 100 equipment used for the treatments: b) and WPS position (at the base of the plant, in the middle of the trellis and at the top of the trellis)

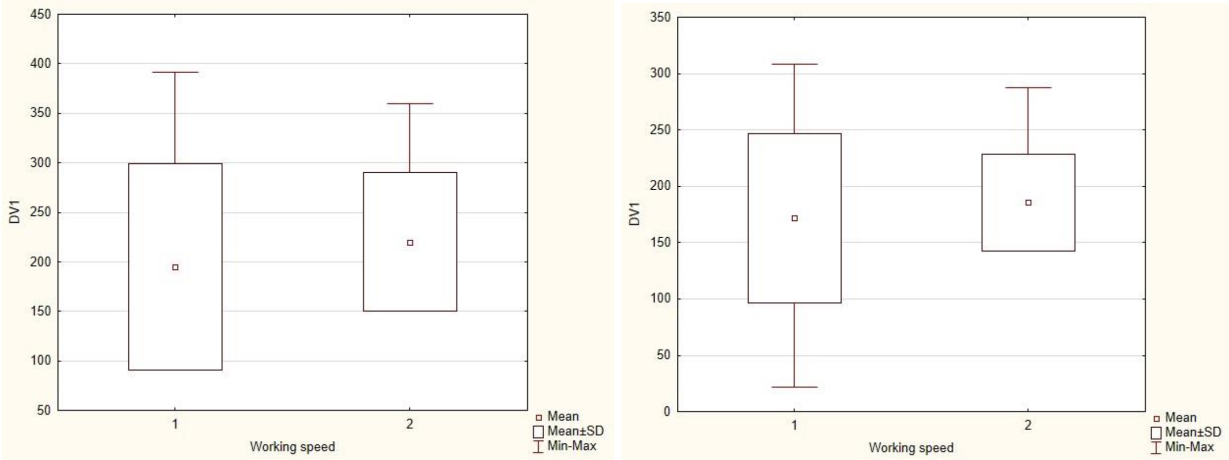
For each data collection point, water sensitive paper WPS was mounted on 3 positions, at the base, in the middle and at the top of the vine plant (figure 2 b). The WPS were scanned with a CANON scanner and later the images were processed using the imaging software ImageJ using the algorithm DepositScan created by USDA ARS *(DepositScan, 2024)*, the program calculates DV 1 (10% of the volume sprayed is in droplets smaller than the expressed value), DV 5 (half of the volume of spray is in droplets either smaller or higher) and DV 9 (indicates that 90% of the volume of spray is in droplets smaller than the given values). The obtained results were analyzed with the Statistica 10 program, interpreted with the help of Whisker Box Plots.

Based on droplet characteristics (volume median diameter) drops can be classified into eight categories as follows: extremely fine (<60 µm), very fine (60–145 µm), fine (146–225 µm), medium (226–325 µm), coarse (326–400 µm), very coarse (401–500 µm), extremely coarse (501–650 µm) and ultra-coarse (>650 µm) *(https://pesticidestewardship.org/, 2024)*.

RESULTS

Results on the influence of working speed on the main qualitative indices in the case of injection nozzle and standard nozzle show a dependence on the speed of work.

For the first indicator DV1 the influence of travel speed is shown in figure 3.



a) b)

Fig. 3 - Influence of the working speed on the DV 1
a) injection nozzle; b) standard nozzle

The DV 1 parameter indicates that 10 % of drops are lower than this value. Thus, in the figure 1 at speed V1 (5 km/h) this parameter varies from the minimum value (103.4 µm) to 391.4 µm in case of the injection nozzle. This indicates a relatively symmetrical distribution of data with the mean at 195 µm. This indicates that 90 % of the droplet spectrum are smaller than 195 µm. In the case of operating speed V2 (7 km/h) the data distribution range is between 154.4 µm and 359.6 µm. The distribution in this case is a symmetric distribution. In this case, the average is 220.2 µm. It can be seen that with increasing speed from 5 km/h to 7 km/h, the droplet size increases.

Standard nozzle at V1 speed (5 km/h) shows that the minimum value of the range is 21.7 µm and the maximum value is 308.3 µm. This indicates a relatively wide distribution of data with the mean at 171.67 µm. This indicates that 90 % of the droplet spectrum is smaller than 171.67 µm. In the case of operating speed V2 (7 km/h) the data distribution range is between 149.1 µm and 287.4 µm. In this case, the average is 220.71 µm.

In the case of the first working speed of 5 km/h the differences between the lower limits of the 2 nozzles are small, about 80 microns. For the upper limits the differences reach around 80 microns. In the case of the nozzle with air injection, the average of 197 microns compared to the standard nozzle whose average is 171.6 microns indicates that it generates droplets of a larger size.

In the case of travel speed of 7 km/h the differences are more pronounced. Thus, for the air injection nozzle, the minimum value of 154.4 microns indicates that with the increase in speed comes another factor that influences the size of the droplets. This factor can be identified as an interaction between the speed of the air current at which the solution is sprayed and the air currents existing in the atmosphere. This interaction causes further fragmentation of droplets. The same trend is observed for the upper limit of this indicator.

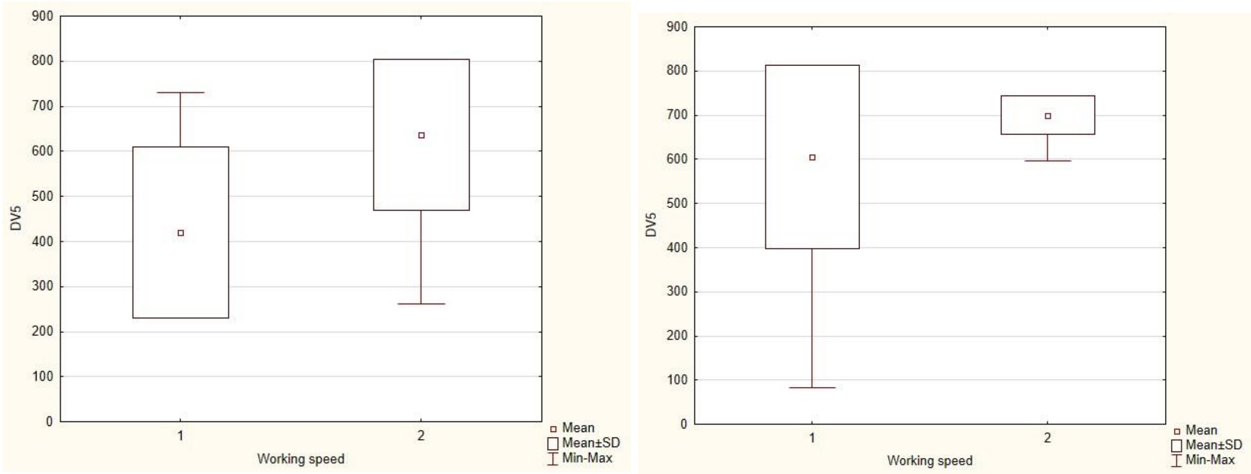
The influence of travel speed on the DV5 indicator is shown in figure 4.

In the figure 4 the influence of travel speed on the DV5 parameter is shown. This parameter indicates that 50 % of the droplet spectrum is lower than its value and the volume of 50 % of droplets is greater. This parameter is also the parameter characterizing the spectrum of droplets in terms of droplet size.

For the air injection nozzle at low speed of 5 km/h droplets have a diameter between 233.9 and 731.6 µm. The average droplet value is 419.7 µm. At 7 km/h it can be seen that the droplet spectrum is in the range of 260.4 µm to 718 µm. The average value of DV 5 is 636.8 µm. The increase in speed causes an increase in the DV5 parameter, which indicates an increase in the average diameter of droplets. Both speeds frame the spectrum of droplets in very coarse and extremely coarse spraying.

For the standard nozzle the influence of travel speed on the DV5 parameter is shown in figure 2 b). At low speed of 5 km/h droplets have a diameter between 83.8 and 763 µm. The average droplet volume value is 605.44 µm. At 7 km/h it can be seen that the droplet spectrum is in the range of 596.3 µm and 733.7 µm. The average value of DV 5 is 700 µm.

The increase in speed causes a slight increase in the DV5 parameter, which indicates an increase in the diameter of droplets. Also, as for the injection type, both speeds fit the droplet spectrum into the very ultra-coarse spray type.



a) b)

Fig. 4 - Influence of the working speed on the DV 5
a) injection nozzle; b) standard nozzle

For the first travel speed of 5 km/h, analyzing the data presented in figure 2, it is found that for the nozzle with air injection the minimum droplet diameter value for the DV5 parameter was 233.9 microns and for the standard nozzle it was 83.8 microns. The maximum recorded values of the 2 nozzles register a difference of about 30 microns. The mean values are close, the difference between the 2 averages being 190 microns, with higher values at the standard dose.

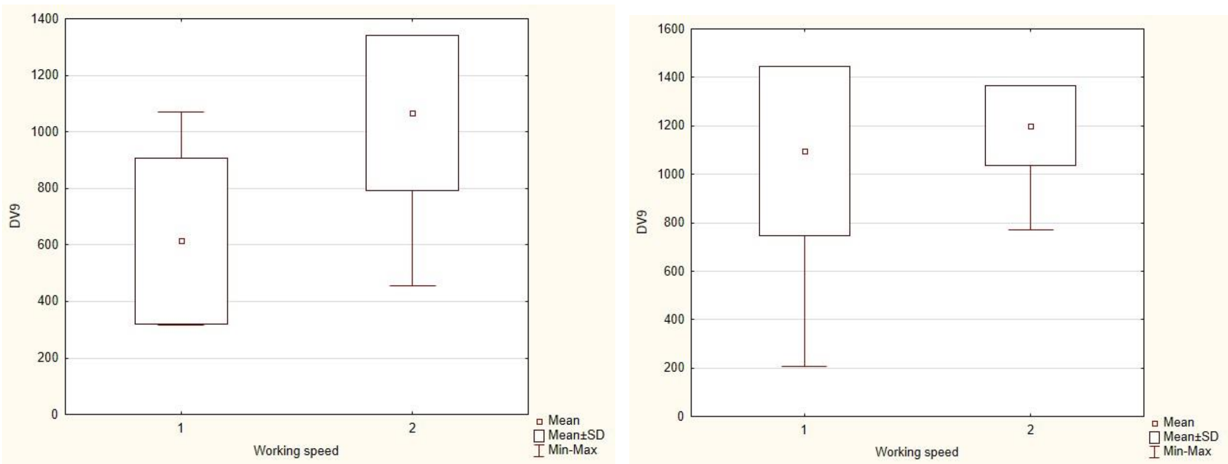
Raising the speed to 7 km/h shows the differences between the 2 nozzles in terms of DV 5. Thus, the difference between the recorded minimums of the 2 nozzles is 330 microns. In the case of maximum recorded values, the difference is much smaller, namely 15 microns. The mean value of DV 5 showed a difference of 64 microns, the higher value being recorded for the standard nozzle.

The DV5 parameter is representative of the overall droplet spectrum. The results indicate that half of the droplets have a diameter greater than or less than 419.7 microns in the case of the air-injected nozzle and a travel speed of 5 km/h. Increasing this speed, the average value drops to 636.8 microns. For both speeds, the mean values of the DV5 parameter frame the droplet spectrum in a very coarse or extremely coarse spray.

The standard nozzle used in phytosanitary treatment machines in vineyards and orchards recorded an average droplet diameter of 605.4 microns at 5 km/h and increased as the speed increased to 700 microns.

Regardless of the speed of travel and the type of nozzles tested, the spray is classified as very coarse or extremely coarse. The large droplet size that characterizes the spray spectrum indicates that many droplets could reach the target surface, thus reducing the risk of drift leading to environmental pollution.

In figure 5, the influence of travel speed on DV 9 for both nozzle is shown.



a) b)

Fig. 5 - Influence of the working speed on the DV 9
a) injection nozzle; b) standard nozzle

This parameter indicates that 90 % of the droplet spectrum is lower than this value and the volume of 10 % of droplets is greater.

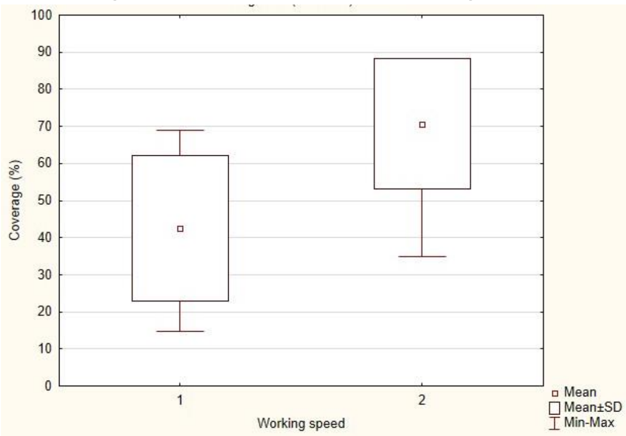
The injection nozzle registers at a low speed of 5 km/h an average diameter of DV9 of 614.2 µm. The range varies from 315.9 µm to 1071.8 µm. At 7 km/h the mean value of DV9 shows an increase to 1066.22 µm. In contrast, the range in which values are found is greater, from 456.4 µm to 1219.1 µm.

Standard nozzle at a low speed of 5 km/h has the DV9 average diameter of 1094.7 µm. The values range from 204.9 µm to 1363.4 µm. At 7 km/h the average value of DV9 is kept approximately constant with a slight increase of 100 µm. In contrast, the range is smaller, from 769.1 µm to 1292.7 µm.

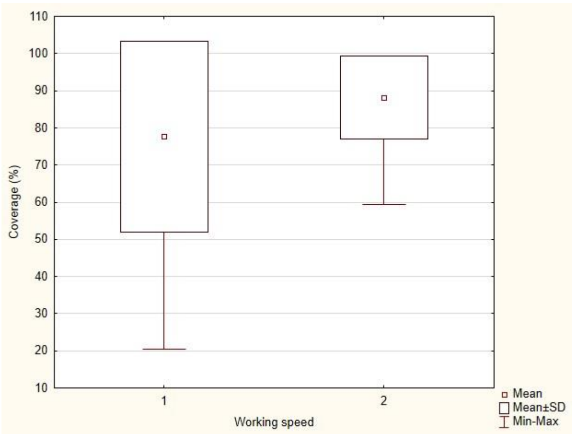
In the case of parameter DV9, it is observed that the minimum and maximum values differ in the case of the 2 nozzles. Thus, in the case of the nozzle with air injection at the first travel speed of 5 km/h, the maximum value of this parameter is almost double compared to the minimum value, with an average of 614.2 microns. If the speed is increased to 7 km/h, the minimum and maximum values differ by 102 microns for the minimum value and 130 microns for the maximum value. The average value doubles at higher speed, reaching 1066.2.

In the case of the standard nozzle at a low speed of 5 km/h, the maximum value of the parameter DV9 tripled from the minimum value. The average value of this parameter is high, being 1094.7 microns. If the speed is increased to 7 km/h, the standard nozzle registers an increase in limit values of approximately 500 microns for the minimum values, while at the same time recording a slight increase in the maximum value of this parameter. The average value of DV9 is 1292.7 microns, slightly higher than the value recorded at the previous speed.

In figure 6, the influence of working speed on the degree of coverage is shown.



a)



b)

Fig. 6 - Influence of the working speed on the Coverage degree
a) injection nozzle; b) standard nozzle

The degree of coverage is one of the most important indicators of the phytosanitary treatments and is directly associated with its effectiveness. Therefore, a high degree of coverage represents a better efficacy of the phytosanitary treatment. Regardless of the speed of movement of the agricultural aggregate and the nozzle, the coverage was above 55 % lower limit and close to 99 % upper limit.

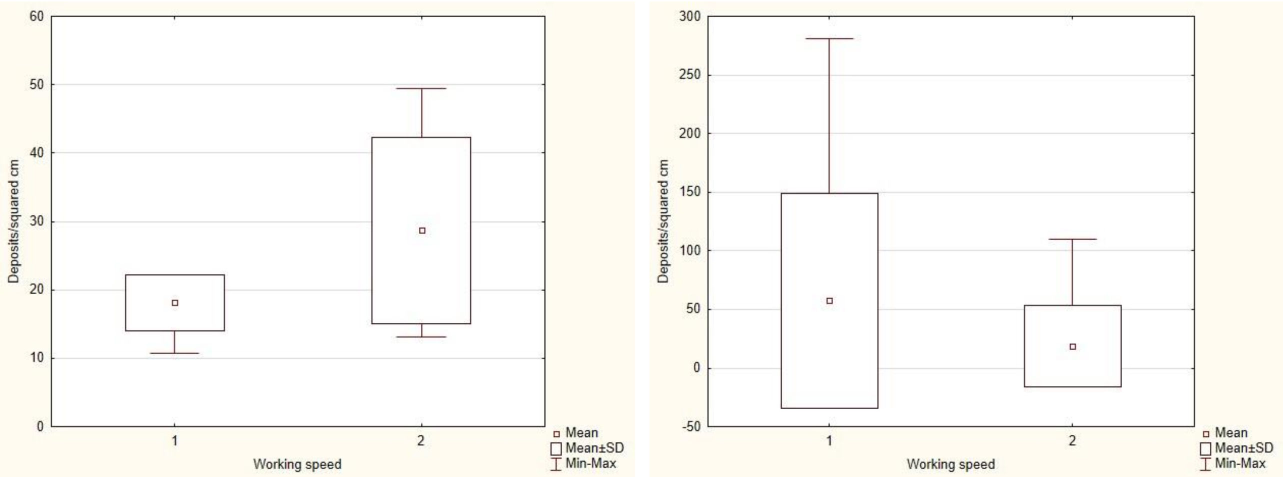
For the injection nozzle the coverage rate for speeds of 5 km/h is in the range of 14.8-69 percent. The average value recorded for the speed of 5 km/h is 42.5 %. Increasing the speed to 7 km per hour causes increased coverage. The average coverage value recorded at this speed is 70.7 %. The coverage range is between 34.9 % and 85.6 %.

The coverage rate for the standard nozzle at 5 km/h is in the range of 20.3 – 98.4%. The average value recorded for the speed of 5 km/h is 77.6 %. Increasing the speed to 7 km per hour causes increased coverage. The average coverage value recorded at this speed is 88 %. The coverage range is between 59.4 % and above 95 %.

In figure 7, the influence of working speed on the number of drops/cm^2 is shown.

The air-injected nozzle at a working speed of 5 km/h recorded several droplets per unit area between 10.8 and 22.1. The mean number of drops was 18.1 drops/cm^2. At 7 km/h the minimum number of drops increased slightly to 13.1 drops/cm^2. The maximum number of drops recorded per unit area was 49.5 and the mean number of drops per de-termination was 28.7 drops/cm^2.

The standard nozzle for phytosanitary treatments recorded at a speed of 5 km/h a number of droplets between 2 and 281.3 drops per unit area. The mean number of drops was 57.5 drops/cm^2. At 7 km/h the number of droplets recorded was between 1.4 and 110 drops per unit area. The mean number of drops was 18.6 drops/cm^2.

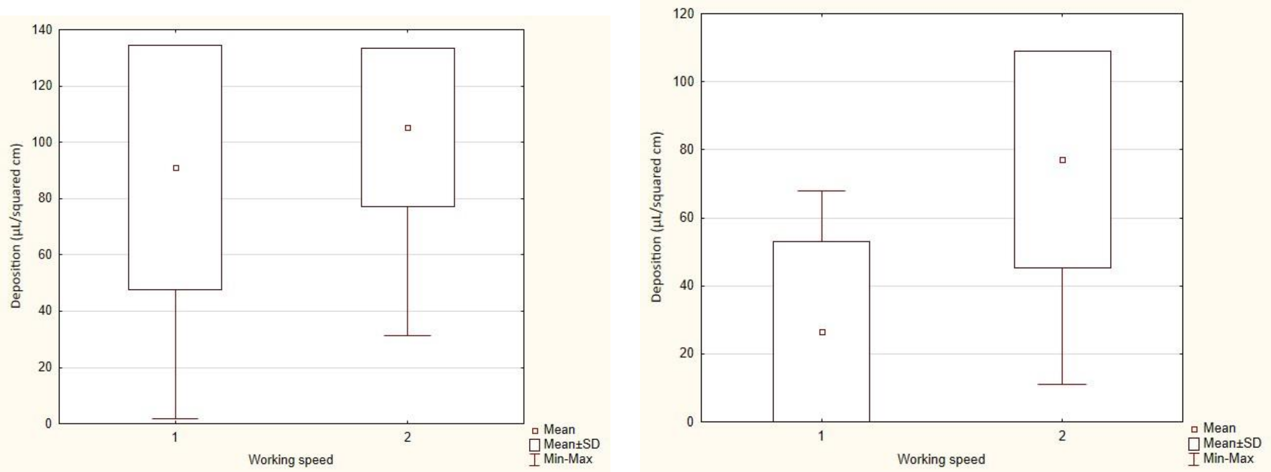


a) b)

Fig. 7 - Influence of the working speed on the number of droplets/cm^2

a) injection nozzle; b) standard nozzle

In the figure 8 the influence of working speed on the deposition/cm^2 is shown.



a) b)

Fig. 8 - Influence of the working speed on the deposition/cm^2

a) injection nozzle; b) standard nozzle

The amount of solution deposited on the target surface is an important indicator of phytosanitary treatment work. The analysis of this parameter was performed using the algorithms of the DepositScan program, and the amount of solution is measured in µL/cm^2.

Thus, for the nozzle with air injection, an average amount per unit area of 26.39 µL was recorded for the speed of 5 km/h. The range of determined values was 3.94 µL/cm^2 and 68.06 µL/cm^2. At 7 km/h, the average amount deposited on the target surface was 77.14 µL/cm^2. The minimum value recorded was 10.94 µL/cm2 and the maximum value was 104.32 µL/cm^2.

The standard nozzle for phytosanitary treatments in vineyards and orchards, recorded at a speed of 5 km/h an average value of the amount of solution of 90.93 µL/cm^2. The minimum value recorded was 1.9 µL/cm^2, the maximum value was 131 µL/cm^2. The mean value of the amount of solution deposited on the target surface at 7 km/h was 105.37 µL/cm^2.

Analysing the data presented in terms of parameters characterizing the droplet spectrum for the two nozzles, it is observed that for parameter DV1, at a speed of 5 km/h the nozzle with air injection generates larger droplets by approximately 20 µm. The increase in speed generated an average droplet size of about 220 µm for both nozzles. The DV5 parameter characterizing the droplet spectrum at 5 km/h recorded a lower value for the air-injected nozzle than for the standard nozzle.

This can be explained on the one hand from the perspective of field conditions, and on the other hand from the perspective of the capabilities of DepositScan algorithms. Under field conditions, droplets carried in the air stream generated by the fan, in the case of standard nozzles, have a higher probability of collision, depositing a slightly higher amount of liquid on the target surface. Air-injected nozzles generate air-filled droplets that have a more stable trajectory. From the perspective of the DepositScan algorithm, the determination of the size of drops is carried out by comparing the fingerprint of the drop with the shade of the background. Thus, if there are overlapping droplets, even if not completely, the imprint of several drops is regarded as a single drop.

The parameters characterizing the quality of the treatment are influenced by the working speed. The coverage degree of air injection nozzles is higher at 7 km/h by approximately 60%. This is also observed in standard nozzles, only the increase is less pronounced (13%). The number of drops increases to 7 km/h in the case of the air-injected nozzle, while in the case of standard nozzles the number of drops decreases. Atmospheric conditions can influence the trajectory of droplets, especially wind gusts, depending on the vector of travel. In the case of air-injected nozzles, the increase in the number of droplets can be explained by the resultant speed of movement of the aggregate of phytosanitary treatments, the distance from the nozzle to the target surface and possible gusts of wind. In the case of standard nozzles, wind gusts have a great influence through the fact that they generate small droplets with a small mass that can deviate from the target surface. The amount of substance deposited on the target surface in the case of air injection nozzles also increases with increasing speed, a phenomenon that is also observed in the droplet count parameter. In contrast, at the standard nozzle, the amount of substance increases, although the number of drops parameter decreases. Swirling effects can affect the amount of the substance, with the likelihood of several drops reaching the same site is high.

CONCLUSIONS

This research conducted in field, determined the qualitative indices for vineyard treatments. The factor which was tested was working speed under two gradients (5 km/h and 7 km/h). Based on the droplets spectra characterization under the volume median diameter (DV1, DV5 and DV9) and the coverage degree, one can draw the following conclusions: for the 5 km/h speed, the average coverage degree was 42.53 % with a droplet DV5 of 419.7 μm for the injection nozzle set and 77.64% with a droplet DV5 of 605.44 μm for the standard nozzle set; for 7 km/h the average coverage degree was 70.72% with a droplet DV5 of 636.81 μm for the injection nozzle set and 88% with a droplet DV5 of 700 μm for the standard nozzle set. Both speeds classify the treatment as extra coarse and ultra coarse.

Both nozzles generated droplets with a high median diameter, but the coverage degree was higher than 40% for both nozzles at 5 km/h, and 70% at 7 km/h. Although the working qualitative indices for the 2 nozzles were close, the air injection nozzle required a smaller amount of substance per hectare for both speeds. Thus, the use of the nozzle with air injection generates larger droplets, a high degree of coverage in general, a smaller number of drops than the standard nozzle. This makes that with a smaller amount of substance per hectare high working qualitative indices are obtained.

The results show that in this experiment, there are several factors that interfere with the droplets spectra and coverage degree which needs further investigation.

Promoting sustainable agriculture and responsible pesticide use requires ongoing research to enhance spraying precision. This includes achieving better coverage and using larger droplets. Effectively treating crops at higher canopy levels remains a significant challenge that warrants attention. This research aims to build upon the existing knowledge and develop more efficient approaches for managing spatial crops.

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