DOI: 10.1515/agriceng-2019-0016

ISNN 2083-1587; e-ISNN 2449-5999
2019,Vol. 23,No.2, pp.49-56
Agricultural Engineering
www.wir.ptir.org

COMPARING NOZZLES WITH DIFFERENT WEAR RATE AND WORKING WITH THE SAME APPLICATION RATE OF DIFFERENT PLANT PROTECTION PRODUCTS IN ASPECT OF PLANTS CONDITION

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ARTICLE INFO

Article history:
Received: May 2019
Received in the revised form: June 2019
Accepted: June 2019

Key words:
Plants growth regulators,
wheat,
wear of nozzles,
application rate,
pesticide

ABSTRACT

Three different types of nozzles (different wear rate) were used in this study. They are classified depending on the severity of their wear to three groups: new, worn and damaged nozzles. Those nozzles were spraying with the same application rate (303 l/ha) on two-year field trials; this was achieved by changing the spraying pressure for each group of nozzles in order to get the same application rate. This practice is usually done by operators of sprayers, who calibrate the sprayers on the same application rate every year without changing the nozzles, so they tend to reduce the spraying pressure in order to compensate the flow rate increase due to the nozzles yearly wear. Two types of plant growth regulators (PGR) agents were used in this study, namely: Moddus and Kelpak, they were applied to wheat plants field to reduce lodging. The results showed that applying PGR in the year 2015 produced an increase in the wheat yield and reduction in the plant height regardless the nozzle type, although there was not any occurrence of wheat lodging. In the year 2016, the new nozzles produced higher values of wheat yield than other two types of nozzles.

Introduction

Dfferent parameters are used to characterize the agricultural nozzles that are used to apply pesticides. Some of them are related to the nozzle itself, like the nozzle orifice dimensions and their changes with the time of use. While others are related to the spray produced by the nozzle, for example the spray angle, size and velocity of drops, as well as distribution of spray in different levels. Using the nozzles for a specific time makes them wear. This wear depends on different factors, and the speed of this wear could be evaluated by comparing the flow rate after that time with the nominal flow rate value of this nozzle provided from the manufacturer and called “the wear rate”. Generally, the wear rate is defined separately for each nozzle of a set. However, (Huyghebaert 2015) suggested that the wear rate could be measured as a random variable, so the other statistical parameters (mean, standard deviation) could be defined as well. When the nozzles show irregular wear and/or their flow rates become 10% greater than the nominal flow rate (provided by the manufacturer), and when the spray pattern gets distorted, all those indicate that the nozzles need to be replaced. It is important to mention that each nozzles’ flow rate on a spray boom needs to be within 5% of the average nozzle flow rate (Klein et al., 2011).

One of the important factors concerning determination of the spray quality is the spray pressure which mainly affects the flow rate (capacity) of the nozzles. However, it affects the droplet size and the size distribution of these drops; usually this effect decreases the drops size, when the pressure increases (Womac, 2001; Braekman et al., 2010; Klein et al., 2011; Agüera et al., 2012). Nozzle manufactures usually define the range of the practical or feasible pressure of the spray for their nozzles to get better results of application and deposition. The effective pressure for most nozzles is 3.0 bars. However, some nozzles are designed to work under lower pressure, for example 1.0 bar (especially when spraying herbicides).

The application rate is determined by mixed variables such as boom travel speed, number of nozzles, spray pressure, size of nozzle orifice, spray viscosity, and pesticide concentration. For example, the latter could affect the efficacy (directly or indirectly), hence it is important to keep the total dose constant and changing viscosity. However, changing viscosity will alter the flow rates, droplet sizes, and droplet velocities. For compensating, transport speed, or spray pressure, or nozzle orifice could be changed - though these factors also modify droplet sizes, their number, and velocities (Ebert and Downer, 2006). Depending on the results of long-term research programs with a large number of field trials, the agrochemical companies recommend a robust dosage. They do this in order to get their products registered and meet the regulatory requirements. The application rate could be done with a high volume to get completely wet crop (in this case the dose is expressed in amount per hectoliter), and the spray volume is supposed to be at least 1000 liters per hectare. Instead, the dosage could be given as a rate per hectare, without mentioning the minimum volume (which is usually left to the operator to determine) (Matthews, 2008). Lodging is a vertically displaced process (permanently leaning or lying parallel to the ground) of shoots (of small grained cereals) just after the ear or panicle has emerged. A decrease in cereal yield about 80% happens because of lodging, and this could include grains quality, size and number, or/and losses during the mechanical harvesting (Berry et al., 2004). Anti-lodging products share about 25 % of the world PGR sales, the chlormequat chloride was the first PGR utilized to control lodging on a large scale in European cereal production (Rademacher, 2015).

Plant growth regulators (PGRs), also called biostimulants or bioinhibitors, can be considered as organic compounds (rather than nutrients), which can change the plant physiological processes. The value of those products (PGRs) was known in the 1930s; since then, the compounds (natural or synthetic) that change the function or shape or plant size have been discovered (Harms and Oplinger, 1988). (Harasim et al., 2016) found that the productivity of winter wheat stems, which is within the canopy height range (80-90 cm) and higher than 90 cm, was affected beneficially by using a growth regulator Moddus 250 EC. However, it resulted in slightly decreased grain weight/ear comparing with the control treatment. (Knoche et al., 1998) noted that applying spray with smaller drop size and higher application rate changed (improved) the efficiency of plant growth regulators due to the change in the coverage of this spray on target.

The aim of this research is to investigate the effect of using nozzles with different wear life but applying the same application rate (by using different pressure) on the yield, height and grain quality of wheat plants when applying products which are used to reduce lodging (plants growth regulators).

Materials and methods

The field trials took place at the UP Lublin experimental farm in RZD Czesławice village in spring seasons of 2015 and 2016. The treatment plots were marked out and randomly distributed in the field. There was 10 m safety distance between each of two successive plots. The control plots were of the same area and had safety distances like the treatment plots and were left without any treatment. There were three PGR "treatments" in the first year, i.e.: "Moddus", "Kelpak", and "Mix" (mixture of Moddus and Kelpak). It is worth mentioning here that the spraying speed, number of nozzles and nozzles space were kept the same during these trials.

A standard flat fan nozzle (TeeJet XR 110/03 VP Spraying Systems Co.) was used in the test. There were three levels of the factor "nozzles wear rate": new, worn and damaged. Those nozzles were spraying during the field trials with the same application rate (303 l/ha); this was gained by changing the spraying pressure for each group of nozzles in order to get the same application rate (Table 1). This practice was done by the sprayer operator, who calibrate their sprayers on the same application rate every year without changing the nozzles, so they tend to reduce the spraying pressure in order to compensate the flow rate increase due to the nozzles yearly wear.

Table 1
Setting of nozzles and sprayer before applying the spray agent

Nozzles	New	Worn	Damaged
Number of nozzles	12	12	12
Operating pressure, bar	3	2.45	1.8
Flow rate, l/min	1.20	1.20	1.20
Nozzles total output, l/min	14.52	14.52	14.52
Travelling speed, km/h	4.8	4.8	4.8
Spray swath, m	6	6	6
Application rate, l/ha	303	303	303
Nozzles spacing, cm	50	50	50

The application of PGR was made separately, which means that the "Moddus" was applied first, and then the Kelpak, and finally the two types of PGR were applied respectively in the "Mix" treatment. One wing of the sprayer was used to apply the liquid for a specific plot according to the nozzle type (new, damaged or worn). Changing of the nozzle type (new, worn and damaged) was done using treble holders. The pressure was changed before entering the plots for every nozzle set. The application was made, when the wheat growth stage was at the 2nd node stage (GS 32-35 BBCH).

During the day of spray application, the temperature and wind velocity were measured and recorded for regular intervals using Airflow™ Instruments Rotating Vanes LCA501 (TSI INSTRUMENTS Ltd) anemometer. The average values of meteorological conditions for every application day are presented in Table 2.

Table 2
Meteorological conditions during the day of spray application for the three years of trial

	Second year	Third year
Day of application	10/06/2015	16/06/2016
Average temperature	25º	26º
Average speed and direction of wind	2.66 m/s	2.0 m/s

Before harvesting, the stem length (with extended head) and plant height were measured (30 random measurements for every plot). The density of plants, which is the number of plants on a randomly selected square meter, was counted in every plot as well (Average = 677). Harvesting was performed using 1.5 m working width of Wintersteiger Nursery Master plot combine, and since the plots length was 25m, then the harvested area for every plot was 37.5m^2. The yield for every plot was collected into bags and weighed (after preliminary cleaning by the harvester), and the 5.0 kg samples for the laboratory analysis from every plot were taken from those bags.

Results

The results of the yield of wheat as affected by nozzles types (spraying at the same application rate) and PGR treatments with p-values for the factors and interaction was presented in Table 3.

In year 2015, the application of PGR influenced significantly on the yield (Table 1), the three types of nozzles (irrespective of the PGR) resulted in significantly higher yield mean value than the Control mean value. The increase percentages were 20.2%, 13.7% and 14.7% for the New, Worn and Damaged nozzles, respectively. There were not any significant differences between the nozzle types (different wear rate), although the New nozzles resulted in a higher percentage of yield increase but it was only numerical increase. The yield means values for Moddus and Kelpak were the same, while for Mix it was significantly higher than for both.

In the year 2016, the New nozzles outcame higher yield and it was significantly higher than the Control and both of other nozzles (Worn and Damaged). The last two nozzles did not differ significantly than the control; however, there was some numerical difference between them. The damaged nozzles mean the yield value was even lower than the Control, while the Worn nozzles mean value was a slightly higher than the Control, irrespectively of the used PGR. Again, the yield from plots treated with Mix was significantly different than Moddus and Kelpak, but in this year it was significantly lower than them.

Table 3
Yield of wheat as affected by types of nozzles (spraying at the same application rate) and PGR treatments with p-values for factors and interaction

Yield, ton/ha									
Year 2015					Year 2016				
Nozzle	Treatment				Nozzle	Treatment			
	Moddus	Kelpak	Mix	Mean		Moddus	Kelpak	Mix	Mean
New	4.82	4.57	5.06	4.82A	New	4.92	5.49	5.46	5.29A
Worn	4.45	4.39	4.86	4.56A	Worn	5.26	5.37	4.29	4.97B
Dama-ged	4.21	4.47	5.12	4.60A	Dama-ged	5.16	4.81	4.40	4.79B
Control	4.00	4.04	3.98	4.01B	Control	4.92	4.89	4.92	4.91B
Mean	4.37b	4.37b	4.75a		Mean	5.06a	5.14a	4.77b	

	p-value		p-value
Nozzle	<.0001	Nozzle	0.0002
Treatment	0.0006	Treatment	0.0004
Nozzle* Treatment	0.0584	Nozzle* Treatment	<.0001

Means in the same column followed by the same uppercase letter(s) are not significantly different, based on Tukey's test at the significant level 0.05.

Means in the same row followed by the same lowercase letter(s) are not significantly different, based on Tukey's test at the significant level 0.05.

The results of the plant height as affected by nozzles types (spraying the same application rate) and PGR treatments with p-values for the factors and interaction were presented in the Table 4.

Table 4
Plant height as affected by nozzles types (spraying the same application rate) and PGR treatments with p-values for the factors and interaction

Plant height, cm									
Year 2015					Year 2016				
Nozzle	Treatment				Nozzle	Treatment			
	Moddus	Kelpak	Mix	Mean		Moddus	Kelpak	Mix	Mean
New	73.4	71.8	64.8	70.0B	New	67.4	68.9	66.4	67.5A
Worn	70.8	71.1	68.1	70.0B	Worn	71.6	70.7	65.1	69.1A
Dama-ged	69.3	68.5	68.1	68.6B	Dama-ged	64.8	65.6	65.6	65.3A
Control	76.2	76.2	76.9	76.4A	Control	67.3	68.0	67.8	67.7A
Mean	72.4a	71.9a	69.5a		Mean	67.7a	68.3a	66.2a	

	p-value		p-value
Nozzle	0.0079	Nozzle	0.3144
Treatment	0.2984	Treatment	0.1466
Nozzle* Treatment	0.7297	Nozzle* Treatment	0.5550

Means in the same column followed by the same uppercase letter(s) are not significantly different, based on Tukey's test at the significant level 0.05.

Means in the same row followed by the same lowercase letter(s) are not significantly different, based on Tukey's test at the significant level 0.05.

There was a significant reduction in the plant height as a result of PGR use (regardless of the type) in year 2015 as Table 2 shows. In fact, there was a reduction in the plant height in all the nozzles and treatments used, but with different percentages. The percentage reduction was 8.4% for New and Worn nozzles and 10.2% for Damaged nozzles comparing with the Control mean value. However, there were no significant differences between the nozzle types (different wear rate) in spite of different reduction percentage. This indicates that those nozzles produced the same results concerning the plant height, although they were applied with different spraying pressure. There were no significant differences between the levels of "Treatment" factor concerning the plant height for this year, although, there were numerical differences between those levels and all mean values were lower than the Control mean value.

In the year 2016, there was no significant reduction in the plants height after applying the PGR, however, there was slightly numerical difference between plots with PGR and plots without treatment (control plots). There were no significant differences between the use of different types of PGR, as well. In turn, the interaction between Nozzles and Treatment factors was not significant either.

The results of the percentage of the good grains as affected by types of nozzles (spraying the same application rate) and PGR treatments with p-values for the factors and interaction was presented in the Table 5.

Table 5

Good grains percentage as affected by types of nozzles (spraying the same application rate) and PGR treatments with p-values for the factors and interaction

Good grains* percentage, %									
Year 2015					Year 2016				
Nozzle	Treatment				Nozzle	Treatment			
	Moddus	Kelpak	Mix	Mean		Moddus	Kelpak	Mix	Mean
New	64.2	55.5	54.7	58.1A	New	78.1	80.5	81.2	79.9A
Worn	74.0	67.7	56.7	66.1A	Worn	78.1	76.6	80.4	78.4AB
Dama-ged	68.6	58.8	32.8	53.4A	Dama-ged	80.7	78.8	82.5	80.7A
Control	79.8	56.7	63.1	66.5A	Control	77.5	70.9	79.7	76.0B
Mean	71.6a	59.7b	51.8b		Mean	78.6ab	76.7b	80.9a	

	p-value		p-value
Nozzle	0.0696	Nozzle	0.0005
Treatment	0.0010	Treatment	0.0011
Nozzle* Treatment	0.2695	Nozzle* Treatment	0.0608

*3.15 second year; 3.15+2.8 third year

Means in the same column followed by the same uppercase letter(s) are not significantly different, based on Tukey's test at the significance level 0.05.

Means in the same row followed by the same lowercase letter(s) are not significantly different, based on Tukey's test at the significance level 0.05.

Applying the PGR (regardless the type) did not produce any significant effect on good grains percentage (3.15mm size) in 2015 as compared to the Control treatment (Table 3).

However, Moddus resulted in significantly higher good grains percentage with the mean value 71.6%, comparing with Kelpak 59.7% and Mix 51.8%.

In 2016, applying PGR produced a significant influence on the concerning trait; the Damaged and New nozzles resulted in higher good grain percentage than Worn nozzles and Control plots without taking into account the type of the applied PGR. Applying Mix was significantly different than applying Kelpak and resulted in higher percentage of good grains (80.9%).

Summary

During the two years field trials there was not a sign of wheat lodging across the field which could affect the yield. The study results showed that applying PGR increased the yield of the wheat crop and reduced the plants height. The New nozzles produced significantly higher yield than worn, damaged nozzles and Control treatment in the field trail of 2016 and numerically higher in 2015. The plants height was reduced significantly in 2015 when using all the nozzles types compared to the Control treatment. Damaged nozzles (and slightly New nozzles) reduced the height of plants in 2016 althought this decrease was not significant.

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PORÓWNANIE DYSZ O RÓŻNYM STOPNIU ZUŻYCIA I PRACUJĄCYCH Z TĄ SAMĄ CZĘSTOTLIWOŚCIĄ APLIKACJI RÓŻNYCH ŚRODKÓW OCHRONY ROŚLIN W ASPEKCIE STANU ROŚLIN

Streszczenie. W pracy zaprezentowano wyniki badań polowych, w których wykorzystywano trzy różne rozpylacze sklasyfikowane w zależności od stopnia ich zużycia w trzech grupach: dysze nowe, zużyte i uszkodzone. Podczas dwuletnich badań polowych rozpylacze pracowały z zachowaniem takiej samej dawki aplikacji (303 l/ha), którą uzyskano przez zmianę ciśnienia rozpylania dla każdej grupy rozpylaczy. Praktyka ta jest zwykle wykonywana przez operatorów opryskiwaczy, którzy corocznie kalibrują opryskiwacze przy tej samej dawce bez zmiany rozpylaczy, więc mają tendencję do zmniejszania ciśnienia rozpylania w celu skompensowania wzrostu natężenia przepływu z powodu zużycia rozpylaczy. W badaniu wykorzystano dwa rodzaje środków regulujących wzrost roślin (PGR): Moddus i Kelpak. Zastosowano je na polu pszenicy w celu zmniejszenia wylegania. Wyniki pokazały, że zastosowanie PGR w 2015 r. spowodowało wzrost plonu pszenicy i zmniejszenie wysokości roślin bez względu na rodzaj stopień zużycia rozpylacza, chociaż nie wystąpiło wyleganie pszenicy. W roku 2016 wykorzystanie rozpylaczy nowych przyczyniło się do uzyskania większego plonu, niż stosując pozostałe dwa rodzaje rozpylaczy.

Słowa kluczowe: regulatory wzrostu roślin, pszenica, zużycie dysz, dawka stosowania, pestycyd