ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
v.21, n.3, p.209-213, 2017
Campina Grande, PB, UAEA/UFCG – http://www.agriambi.com.br

DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v21n3p209-213

Performance of spray nozzles to control fusarium head blight and mycotoxin in the barley crop

Étore F. Reynaldo[1] & Thiago M. Machado[2]

[1] Monsanto Equipamentos. Uberlândia, MG. E-mail: etorereynaldo@hotmail.com
[2] Universidade Federal de Mato Grosso/Instituto de Ciências Agrícolas e Ambientais. Sinop, MT. E-mail: tm.machado@hotmail.com (Corresponding author)

Key words:
Hordeum vulgare L.
technology application
yield

A B S T R A C T

This study aimed to evaluate the performance of spray nozzles to control fusarium head blight (FHB) and mycotoxins in barley grains. The barley cultivar used in the test was 'BRS Aliansa', with a density of 300 plants m^{-2}. Fungicide applications were performed using a mechanized set formed by a sprayer (Jacto, model Falcon Vortex) and a tractor (Massey Ferguson, Model 283). The spray volume used was 150 L ha^{-1}. The nozzles used were single fan, single fan with air induction, hollow cone and double fan. The assay was performed in strips, totaling an area of 350 m^2 and the variables yield and concentration of mycotoxin in the grains were determined along the strips. The data were submitted to descriptive statistics; the results were compared by F test and the means were compared by Dunnett test, both at a minimum significance level of 0.05. The nozzle TurboDrop TD02 caused reduction of 9.18% in the mycotoxin concentrations in barley grains. There was significant difference in yield when specific control was performed for FHB and improved quality of the product.

Palavras-chave:
Hordeum vulgare L.
tecnologia de aplicação
produtividade

Desempenho de pontas de pulverização no controle da giberela e micotoxinas na cultura da cevada

R E S U M O

Objetivou-se avaliar, com o presente trabalho, o desempenho de pontas de pulverização para controle da giberela e micotoxinas nos grãos da cevada. A cultivar de cevada utilizada no ensaio foi a BRS Aliansa com densidade de 300 plantas m^{-2}. As aplicações de fungicida foram realizadas utilizando-se um conjunto mecanizado formado por um pulverizador da marca Jacto, modelo Falcon Vortex e um trator Massey Fergunson, modelo 283. O volume de calda utilizada foi de 150 L ha^{-1}. As pontas utilizadas foram leque simples, leque simples com indução de ar, cônico vazio e duplo leque. O ensaio foi realizado em esquema de faixas perfazendo área total de 350 m^2; ao longo das faixas foram determinadas as variáveis produtividade e concentração de micotoxina nos grãos. Os resultados obtidos foram submetidos à estatística descritiva sendo que os resultados foram comparados pelo teste F e as médias comparadas pelo Dunnett, ambos ao nível mínimo de 0,05 de significância. A ponta TurboDrop TD02 apresentou redução de 9,18% nas concentrações de micotoxinas nos grãos de cevada. Houve diferença significativa em relação à produtividade quando se realizou controle específico para giberela e melhoria da qualidade do produto colhido.

Ref. 020-2016 – Received 3 Mar, 2016 • Accepted 2 Dec, 2016 • Published 6 Feb, 2017

Introduction

Barley (*Hordeum vulgaris* L.) is the second most important winter crop in southern Brazil. In this region, the excess of rainfall during the crop growth season favors the increase in frequency and intensity of diseases (Agostinetto et al., 2014).

Fusarium head blight (FHB) is one of the main diseases of barley and wheat. It is caused especially by the fungus *Fusarium graminearumm* Schwabe and occurs in regions where the climate is hot and humid. Besides reducing barley yield, the fungus produces the mycotoxin deoxynivalenol (DON), which is harmful for both human and animal health (Draeger et al., 2007). The epidemics occur sporadically, generally associated with prolonged periods of rainfall or high humidity during the anthesis stage (Parry et al., 1995). FHB is a flower infectious disease and can be devastating when anthesis coincides with high temperature and prolonged wetting of the ears (Wiese, 1987). The biggest difficulties related to the chemical control of FHB are: a) sporadic occurrence; b) difficulty to apply fungicides at the correct moment; and c) difficulty to reach infection sites (anthers) with the fungicides.

FHB control requires fungicides with high efficiency and it must be performed at the adequate moment the maximum number of anthers are exposed (Reis et al.,1997; Panisson et al., 2004).

In the application technology, some factors, such as target plants, fungicide and adjuvant used, application rate, drop size and meteorological conditions during the spraying, among others, influence the level of control of the diseases and these factors are related to the efficiency of application of agrochemicals (Fritz et al., 2007; Halley et al., 2008; Xu et al., 2010; Ferreira et al., 2011; Chechetto & Antuniassi, 2012).

One of the forms to obtain greater deposition of the active ingredient on the biological targets is the correct selection of spray nozzles (Cunha et al., 2008). These nozzles are the most significant components of the sprayers, directly affecting the efficiency of the application of agrochemicals (Nuyttens et al., 2007).

This study aimed to evaluate spray nozzles available in the market, which provide higher efficiency in FHB control and, consequently, reduction in the concentration of mycotoxins in barley grains.

Material and Methods

The experiment was carried out at the Agrarian Foundation of Agricultural Research - FAPA, in Entre Rios, municipality of Guarapuava, PR, Brazil, located at the central geographic coordinates: latitude of -25° 33' and longitude -51° 28', at altitude of 1124 m above the sea level.

The barley cultivar used in the experiment was 'BRS Aliansa', sown in 2012, in a population density of 300 plants m^{-2}, under basal fertilization with 100 kg ha^{-1} of 08-30-20 and top-dressing fertilization with 100 kg ha^{-1} of urea when the crop reached the booting stage. Diseases were controlled with an application of Caramba, 0.6 L ha^{-1}. The fungicides used for the specific control of FHB were Novazim + Folicur (Carbendazim + Tebuconazole) at the proportion of 1.5 + 0.5 L ha^{-1}. Two applications were performed, the first one with 75% of the awns exposed and the second one with interval of 10 days from the first one.

Table 1 shows the description of the treatments used in the experiment. The nozzle TTVP 110-02, commonly used in the region, was taken as a reference.

Applications were performed using mounted sprayer (Jacto, model Falcon Vortex) with 14 m of bars and nozzle supports spaced by 0.50 m, attached to a tractor (Massey Ferguson, model 283). The spray volume was 150 L ha^{-1}.

The test was conducted in strips, each one was 7 m wide and 50 m long, totaling an area of 350 m^2, with 4 replicates. Six points were evaluated and harvested along the strips to determine quantitative and qualitative variables, such as: yield (area - 1.8 m wide x 4 m long) and concentration of mycotoxin in the grains.

The levels of mycotoxin in the grains were determined based on the methodology described by Almeida et al. (2014), while the Deoxynivalenol (DON) was determined through UPLC-MS. The 10 g samples of each treatment were ground and extracted with agitation using 40 mL of acetonitrile/water (80:20, v/v) in an HS50 laboratory agitator for 2 h at 200 rpm. Then, the samples were centrifuged at 2320 rpm for 10 min. The supernatant was filtered through a PVDF syringe filter. The extract was diluted in ultra-pure water, taking an aliquot of 250 μL and diluted until 1000 mL. Aliquots of 20 μL were injected in the UPLC-MS/MS system. The separation through liquid chromatography was performed with 50 mm x 2.1 mm ID, 1.7 μm, Acquity UPLC C18 column, using the following parameters: solvent A, water 0.1% of formic acid; solvent B, acetonitrile 0.1% of formic acid; procedure of gradient, 10-90% of solvent B in 10 min, 2 min at 90% hold of solvent B, 90-10% of solvent B in 3 min; rate, 0.4 mL min^{-1} of flow; injection volume, 20 μL. The samples were analyzed through an Acquity UPLC system attached to a triple-quadrupole mass spectrophotometer equipped with electrospray interface operated in the positive ion mode. All analyses were performed in triplicate.

Thousand-grain weight (TGW) was obtained through count and weighing of 10 replicates of 100 seeds lot^{-1}, using the arithmetic mean of the replicates to obtain the weight of 100 seeds. This result was multiplied by 10 to obtain the weight of a thousand seeds (Brasil, 1992).

The test weight (TW) of the samples was determined using a test weight scale, based on the weight of a known volume of

Table 1. Nozzles evaluated in the control of fusarium head blight

N° treatment	Nozzle description	Jet type	Working pressure (Bar)
1	Teejet TTVP 11002 (reference)	Single fan	4.5
2	Agrotop AirMix 11002	Single fan with air induction	4.5
3	Agrotop AirMix 80025HC	Hollow cone	3.5
5	Agrotop TurboDrop TD 02 (Back/Front)	Double fan (angulation)	4.5
6	Agrotop TurboDrop TD 02	Double fan (angulation)	4.5

seeds. The TW was obtained by the mass of seeds contained in 125 mL, per sample, transformed to mass of seeds that occupies a volume of 100 L (Brasil, 1992).

The statistical analysis was performed with the program SAS, using the 'Box Cox' analysis to test data normality. Then, the data were subjected to descriptive statistics. The results were compared by F test and the means were compared by the Dunnett test, both at a minimum significance level of 0.05.

Results and Discussion

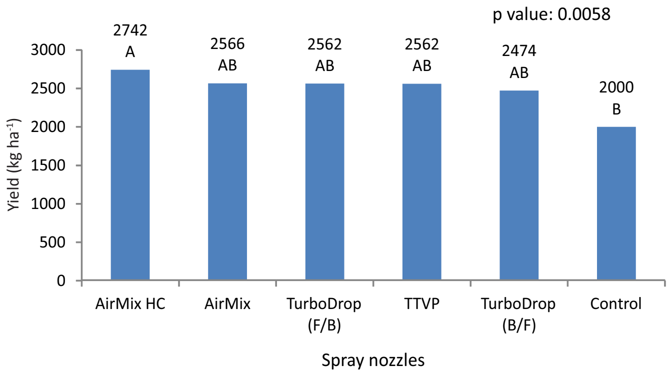
The results of the evaluation of nozzles exhibited a low coefficient of variation in all analyzed variables (Table 2). Gomes (1990) suggests intervals of coefficient of variation as: low, when below 10%; medium, between 10 and 20%; high, between 20 and 30%; and very high, above 30%.

Figure 1 shows the values of grain yield. The control produced 1,999 kg ha^{-1} of barley, obtaining significant result in relation to the hollow cone jet nozzle AirMix 80, with yield of 2,742 kg ha^{-1}. Although it is the highest yield among the nozzles, there was no significant difference between them.

The treatment using the nozzle TTVP 110-02, taken as a reference, because it belongs to the group of nozzles (single fan) most used in the region, did not differ from the other treatments of nozzles, leading to production of 2,562.4 kg ha^{-1} (Figure 1).

Figure 2A shows the results of thousand-grain weight (TGW) for the different spray nozzles used in the test. There were no statistical differences between the evaluated treatments at 0.05 probability level.

As the results of TGW, the test weight (TW) (Figure 2B) did not show significant statistical differences. Both attributes (TGW and TW) are correlated with grain quality and, in this case, there were no differences according to the types of spray nozzles for FHB control (visual), corroborating the results found by Panisson et al. (2004).



*Means followed by the same letter do not differ statistically at 0.05 probability level

Figure 1. Barley yield according to the spray nozzle

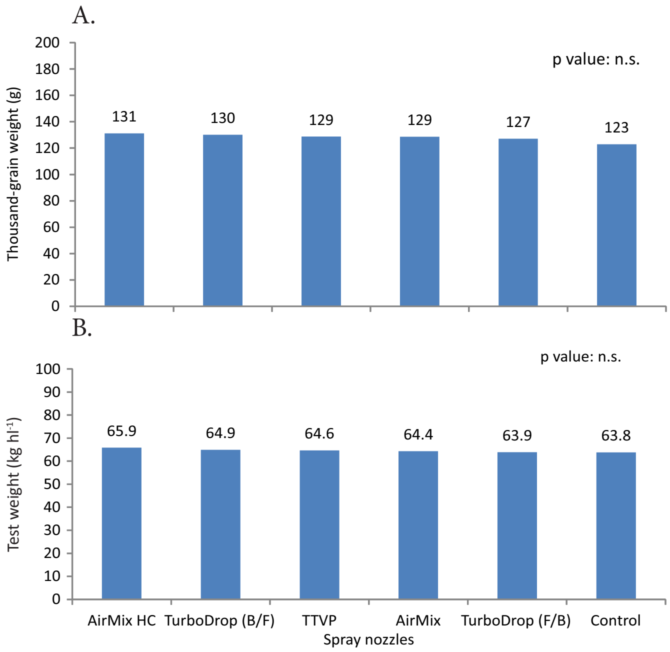


Figure 2. Thousand-grain weight of barley per treatment (A) and weight per hectolitre of barley per treatment (B)

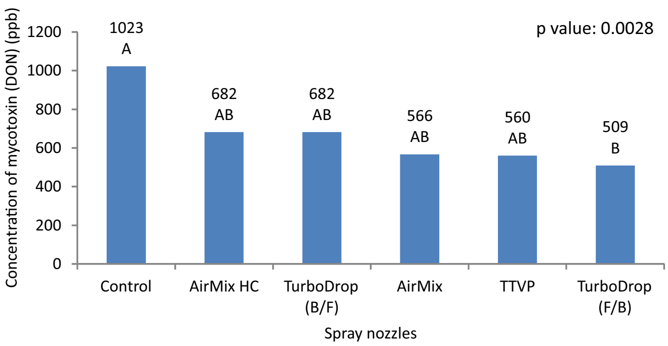
Table 2. Evaluated nozzles, analyzed variables and descriptive statistics

	Nozzle	Replicates				Descriptive statistics				
		1	2	3	4	Maximum	Minimum	Mean	SD	CV (%)
PMS (g)	AirMix HC	132	136	128	129	136.0	128.0	131.3	3.6	2.7
	TurboDrop (B/F)	125	133	129	131	133.0	125.0	129.5	3.4	2.6
	TTVP	126	129	132	129	132.0	126.0	129.0	2.4	1.9
	AirMix	129	128	129	130	129.0	128.0	129.0	0.8	0.6
	TurboDrop (F/B)	126	128	128	127	128.0	126.0	127.3	1.0	0.8
	Control	122	124	120	124	124.0	120.0	122.5	1.9	1.6
TW (kg hl^{-1})	irMix HC	65.2	66.8	64.2	66.1	66.8	64.2	65.6	1.1	1.7
	TurboDrop (B/F)	63.9	66.2	64.8	65.01	66.2	63.9	65.0	0.9	1.5
	TTVP	64.6	66.01	64.71	65.9	66.0	64.6	65.3	0.8	1.2
	AirMix	63.2	64.8	66.7	64.86	66.7	63.2	64.9	1.4	2.2
	TurboDrop (F/B)	62.91	65.34	64.26	66.1	65.3	62.9	64.7	1.4	2.1
	Control	63.61	63.94	65.86	64.58	65.9	63.6	64.5	1.0	1.5
Yield (kg ha^{-1})	AirMix HC	2772	2754	2756	2686	2772.0	2686.0	2742.0	38.2	1.4
	TurboDrop (B/F)	2351	2444	2502	2596	2502.0	2351.0	2473.3	102.8	4.2
	TTVP	2621	2652	2494	2483	2652.0	2483.0	2562.5	86.5	3.4
	AirMix	2566	2568	2576	2555	2576.0	2555.2	2566.3	8.6	0.3
	TurboDrop (F/B)	2426	2598	2685	2542	2685.0	2426.0	2562.8	108.5	4.2
	Control	1897	1968	2010	2123	2010.0	1897.0	1999.5	94.6	4.7
DON (ppb)	AirMix HC	695	681	676	676	695.0	676.0	682.0	9.0	1.3
	TurboDrop (B/F)	686	693	661	691	693.0	661.0	682.8	14.8	2.2
	TTVP	544	589	536	574	589.0	536.0	560.8	24.9	4.4
	AirMix	586	564	561	554	586.0	554.0	566.3	13.8	2.4
	TurboDrop (F/B)	492	522	526	498	526.0	492.0	509.5	17.0	3.3
	Control	1048	1023	1026	996	1048.0	996.0	1023.25	21.3	2.1

Figure 3 shows the results of the evaluation of mycotoxin concentration in barley grains according to utilized treatment/ nozzle. The spray nozzle with best control of the amount (concentration) of mycotoxins in the grain was TurboDrop TD 11002, with 509 ppb. However, the result was significant only in relation to the control; with respect to the other nozzles, there were no differences.

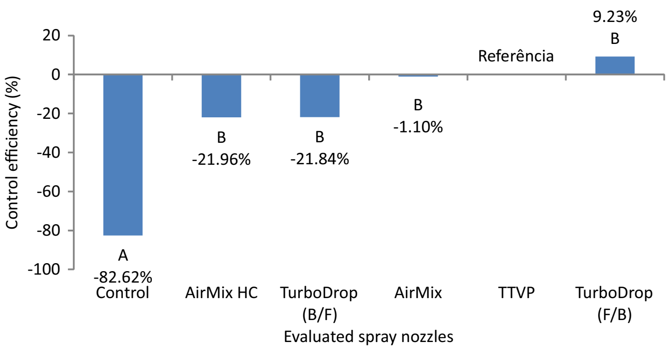
Except for the control, which did not receive application of fungicide for FHB control, exhibiting a concentration of 1,023 ppb, the other treatments showed reduction of the concentrations in relation to the control, exceeding 100%.

According to the different concentrations (Figure 4) and comparing them with the concentrations found using the reference nozzle (0%), the nozzle TurboDrop TD 11002 led to reduction of 9.2% in the levels of mycotoxins. This type of nozzle has double fan jet with different angles of inclination in each jet, contributing to better coverage and penetration of the spray into the ear and, consequently, higher efficiency in the reduction of mycotoxin concentration in the grains. The data corroborate those of McMullen et al. (1997), who used two nozzles with flat jet, one directing the jet to the front and another one directing the jet to the back, and obtained better results of coverage of drops in wheat ears. These authors report that the application of fungicides using different hydraulic nozzles can lead to different levels of control; however, in general, there are no statistical differences. Panisson et al. (2004), evaluating a modified spraying bar, on which a nozzle with flat jet inclined at 30º on the front and 30º on the back, comparing with different spray nozzles and their arrangements on the bar, did not observe significant effects on FHB control in wheat.



* Means followed by the same letter do not differ statistically at 0.5 probability level

Figure 3. Concentration of mycotoxins in the grains (DON)



* Means followed by the same letter do not differ statistically at 0.05 probability level

Figure 4. Percentage of efficiency of the different spray nozzles

A second option of spray nozzle would be the single fan jet AirMix 11002, which led to 1.1% (Figure 4) of mycotoxin concentration, whose results are lower than those of the reference spray nozzle. The other nozzles showed lower performance in comparison to the reference nozzle.

Cunha et al. (2007), analyzing different nozzles with flat fan, with and without pre-orifice and hollow cone, claim that hollow cone spray nozzles were relatively more prone to drift than the flat fan nozzles with pre-orifice, regardless of the pressure. The results can explain the performance of the cone jet nozzle AirMix 80 HC (Figure 4), which did not show better result on the concentrations of mycotoxins, while drift was one of the factors responsible for the data.

Conclusions

1. There was no significant difference between the nozzles regarding the variables yield and levels of Deoxynivalenol, resulting in an increase of quality of the harvested product.

2. The nozzle TurboDrop TD02 showed better performance, with reduction of 9.18% in the concentrations of mycotoxins in barley grains.

3. The nozzle AirMix 80 HC led to higher barley yield in relation to the control.

Literature Cited

Agostinetto, L.; Casa, R. T.; Bogo, A.; Sachs, C.; Reis, E. M.; Kuhnem, P. R. Critical yield-point model to estimate damage caused by brown spot and powdery mildew in barley. Ciência Rural, v.44, p.957-963, 2014. http://dx.doi.org/10.1590/S0103-84782014005000005

Almeida, J. L.; Tessmann, D. J.; Couto, H. T. Z.; Fostim, M. L. Effect of Fusarium head blight on deoxynivalenol levels in whole grain and patent flours from different wheat genotypes. World Mycotoxin Journal, v.9, p.229-236, 2014.

Brasil. Ministério da Agricultura e Reforma Agrária. Regras para análise de sementes. Brasília: MARA, 1992. 365p.

Chechetto, R. G.; Antuniassi, U. R. Espectro de gotas gerado por diferentes adjuvantes e pontas de pulverização. Energia na Agricultura, v.27, p.130-142, 2012.

Cunha, J. P. A. R.; Moura, E. A. C.; Silva Júnior, J. L.; Zago, F. A.; Juliatti, F. C. Efeito de pontas de pulverização no controle químico da ferrugem da soja. Engenharia Agrícola, v.28, p.283-291, 2008. http://dx.doi.org/10.1590/S0100-69162008000200009

Cunha, J. P. A. R.; Teixeira, M. M.; Fernandes, H. C. Avaliação do espectro de gotas de pontas de pulverização hidráulicas utilizando a técnica da difração do raio laser. Engenharia Agrícola, v.27, p.10-15, 2007. http://dx.doi.org/10.1590/S0100-69162007000200002

Draeger, R.; Gosman, N.; Steed, A.; Chandler, E.; Thomsett, M.; Srinivasachary; Schondelmaier, J.; Buerstmayr, E.; Lemmens, M.; Schmolke, M.; Mesterhazy, A.; Nicholson, P. Identification of QTLs for resistance to Fusarium head blight, DON accumulation and associated traits in the winter wheat variety Arina. Theoretical and Applied Genetics, v.115, p.617-625, 2007. http://dx.doi.org/10.1007/s00122-007-0592-3.

Ferreira, M. C.; Lohmann, T. R.; Campos, A. P.; Viel, S. R.; Figueiredo, A. Distribuição volumétrica e diâmetro de gotas de pontas de pulverização de energia hidráulica para controle de corda-de-viola. Planta Daninha, v.29, 697-705, 2011.

Fritz, B. K.; Hoffman, W. C.; Martin, D. E.; Thomson, S. J. Aerial application methods for increasing spray deposition on wheat heads. Applied Engineering in Agriculture, v.23, p.709- 715, 2007.

Gomes, P. F. Curso de estatística experimental. 13.ed. Piracicaba: Nobel, 1990. 468p.

Halley, S.; Ee, van; Hofman, V.; Panigrahi, S.; Gu, H. Fungicide deposition measurements by spray volume, drop size, and prayer system in cereal grains. Applied Engineering in Agriculture, v.24, p.15-21, 2008.

McMullen, M.; Jones, R.; Gallenberg, D. Scab of wheat and barley: a re-emerging disease of devastating impact. Plant Disease, v.81, p.1340-1348, 1997

Nuyttens, D.; Baetens, K.; Schampheleire, M. de; Sonck, B. Effect of nozzle type, size and pressure on spray droplet characteristics. Biosystems Engineering, v.97, p.333-345, 2007. http://dx.doi.org/10.1016/j.biosystemseng.2007.03.001

Panisson, E.; Boller, W.; Reis, E. M.; Hoffmann, L. Modificação de uma barra de pulverização para a aplicação de fungicida em trigo visando ao controle de giberela. Engenharia Agrícola, v.24, p.101-110, 2004. http://dx.doi.org/10.1590/S0100-69162004000100012

Parry, D. W.; Jenkinson, P.; McLeod, L. Fusarium ear blight (scab) in small grain cereals - A review. Plant Pathology, v.44, p.207-38, 1995.

Reis, E. M.; Casa, R. T; Forcelini, C. A. Doenças do trigo. In: Kimati, H.; Amorim, L.; Bergamin Filho, A.; Camargo, L. E. A.; Rezende, J. A. M. Manual de fitopatologia: Doenças de plantas cultivadas. 3.ed. São Paulo: Agronômica Ceres, 1997. p.675-685.

Wiese, M. V. Compendium of wheat diseases. 2.ed. St. Paul: The American Phytopathological Society, 1987. 106p.

Xu, L.; Zhu, H.; Ozkan, H. E.; Bagley, B. Adjuvant effects on evaporation time and wetted area of droplets on waxy leaves. Transactions of the ASABE, v.53, p.13-20, 2010.