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Yield and quality of barley and silage corn exposed to natural contamination with fumonisin

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Abstract: The main feed materials maize (Zea mays) and barley (Hordeum vulgare) are sensitive to fumonisins, which are produced by fungi of the genus *Fusarium* spp. Fungi of the genus *Fusarium* spp. easily penetrate the seeds when the integrity of the seed coat is broken. The aim of this study was to determine to what extent the integrity of the seeds for sowing in barley and corn will naturally provoke the influence of fumonisins on the yield of the respective crops, as well as the influence of a.v. azoxystrobin on these processes. The results obtained show that barley and corn plants not treated with a.v. azoxystrobin have lower yield compared to treated plants. Barley and maize plants sprouted from healthy seeds have a significantly higher average height and yield, compared to plants sprouted from mechanically damaged seeds. The statistical analysis of the data from the yield of barley and corn for silage shows the separation of two homogeneous groups. Group A containing the two treatments with damaged seeds (treated and untreated with fungicide) and group B consisting of the two treatments with whole seeds (treated and untreated with fungicide).

Keywords: fumonisin; barley; corn; seeds quality; yield

INTRODUCTION

One of the main tasks in the science of animal nutrition is related to the protection of animals from diseases, caused by the consumption of mycotoxin contaminated feed.

Fumonisins are secondary toxic metabolites produced in cereal crops by pathogenic fungi, namely *Fusarium verticillioides, Fusarium proliferatum* and *Fusarium moniliforme* (Oswald et al., 2005). The most important mycotoxigenic fungi that produce fumonisins are of the species *Fusarium verticillioides*. It is a major contaminant in maize and other crops (Okoth and Kola, 2012; Hem, 2013).

Maize *(Zea mays)* and barley *(Hordeum vulgare)* are susceptible to fungi of the genus *Fusarium* spp. Their contamination with mycotoxins leads to several diseases, which is associated with a decrease in yield and quality of the product, which in turn leads to economic losses (Bottalico and Perrone, 2002). Barley is a favorable substrate for the development of fungal, bacterial and viral diseases. While in maize, several major diseases including seed rot, seedling blight, root rot and stem rot have been attributed to *F. verticillioides* (White, 1999). The fungus is capable of persistent asymptomatic infections (Bacon and Hinton, 1996), which is of concern due to the impact on control strategies. *Fusarium* wilt in cereals leads to complete crop damage and, under appropriate weather conditions, can cause losses of up to 100% (Desheva and Chavdarov, 2016). It causes significant damage to producers, as it most often manifests itself as an epidemic in plants (Ruckenbauer et al., 2001).

Mycotoxins produced by fungi of the genus *Fusarium* spp. are the most common contaminants affecting small-grain crops, which, depending on the concentration of contamination, lead to plant diseases, and in higher concentrations pose a risk to human and animal health. Fungi of the genus *Fusarium* spp. easily penetrate seeds, when the integrity of the seed coat is broken.

This study aimed to determine to what extent the integrity of barley and maize seed naturally provokes the impact of fumonisins on the yield of the respective crops, as well as the impact of azoxystrobin on these processes.

MATERIAL AND METHODS

The field experiment was conducted in the 2023 - 2024 season, on the experimental field of the Institute of Animal Sciences – Kostinbrod, Bulgaria.

The experiment used barley variety "Veslets", sown on 20.10.2023 according to the following scheme:

1. Control - healthy seeds, whose plants were untreated with fungicide.
2. Mechanically damaged seeds, whose plants were untreated with fungicide.
3. Healthy seeds, whose plants were treated with fungicide.
4. Mechanically damaged seeds, whose plants were treated with fungicide.

Each treatment was carried out in two repetitions, each with an area of 10 m2. The entire area of the experimental field is 100 m2.

The crop was treated once in the flag leaf formation phase at a dose of 800 ml. ha^{-1}. The fungicide used was "Zoxis" 250 SK with active ingredient 250 g/l azoxystrobin.

The harvest was carried out on 01.08.2024. Three m2 were harvested randomly from each repetition. The grain from all six m2 for each treatment was measured and converted into kg. ha-^{1}.

On 08.04.2024, on the experimental field of the Institute of Animal Sciences - Kostinbrod, corn for silage, variety ''KN 509'' was sown according to the following scheme:

1. Control - healthy seeds, whose plants were not treated with fungicide.
2. Mechanically damaged seeds, whose plants were not treated with fungicide.
3. Healthy seeds, whose plants were treated with fungicide.
4. Mechanically damaged seeds, whose plants were treated with fungicide.

The crop was treated once in the fifth-sixth leaf phase at a dose of 1000 ml. ha^{-1}. The fungicide used was "Zoxis" 250 SK with an active ingredient of 250 g/l azoxystrobin.

The barley and corn seeds intended for sowing were tested for the presence of fumonisins. The results were negative.

Chemical analysis

The variations in the chemical composition of barley seeds treated and untreated with fungicide were monitored. The samples were analyzed for crude protein, crude fat, crude ash and crude fiber.

The statistical processing of the data was carried out using the software product Statgraphics 19. The method used to distinguish the mean values is the Fisher least significant difference (LSD) procedure. With this method, there is a 5.0% risk of seeing that each pair of treatments is significantly different when the actual difference is equal to 0.

RESULTS AND DISCUSSION

Field experience with barley

The highest yield of 6050 kg. ha^{-1} was recorded in the treatment with whole seeds and fungicide-treated plants (Figure 1). In second place in yield is the treatment with healthy seeds and fungicide-untreated plants (5750 kg. ha^{-1}). The higher yield corresponds with data presented by Hřivna (2003), who achieved similar results in barley after the application of fungicides. The lowest yield was recorded in the treatment with damaged seeds and fungicide-untreated plants (4800 kg. ha^{-1}). It should be noted that the two treatments whose plants were treated with fungicide had a higher yield than their counterparts in treatments with plants not treated with fungicide. In confirmation of this, the mycotoxicological analysis found the presence of fumonisin - 0.325 mg kg^{-1} in untreated fungicide-germinated plants from mechanically damaged seeds. Similar results (0.274 mg kg^{-1} fumonisin) were found by Nikolov et al. (2024), in untreated fungicide germinated plants from mechanically damaged seeds. However, in plants not treated with fungicide and sprouted from healthy seeds, the presence of fumonisin was recorded at 0.265 mg/l. Close to these results are data (2.89 $mg.kg^{-1}$ fumonisin) found by Ignatova and Sertova (2021) in plants not treated with fungicide and sprouted from healthy seeds.

This is because plants that are not treated with fungicide contain traces of *Fusarium* spp., whose pathogenic influence is most often expressed in disruption of the plant's metabolism, and from there it also affects the grain yield. In addition, it is possible that adverse climatic conditions, i.e. high temperatures and drought, can also affect the production of the mycotoxin. However, in the absence of phytopathogens on the fungicide-treated plants, we can talk about the positive effect of azoxystrobin. There is also a tendency for treatments with healthy seeds to have a higher yield than treatments with damaged seeds. Apparently, even the slightest deficiency of nutrients in the initial phase of plant development has

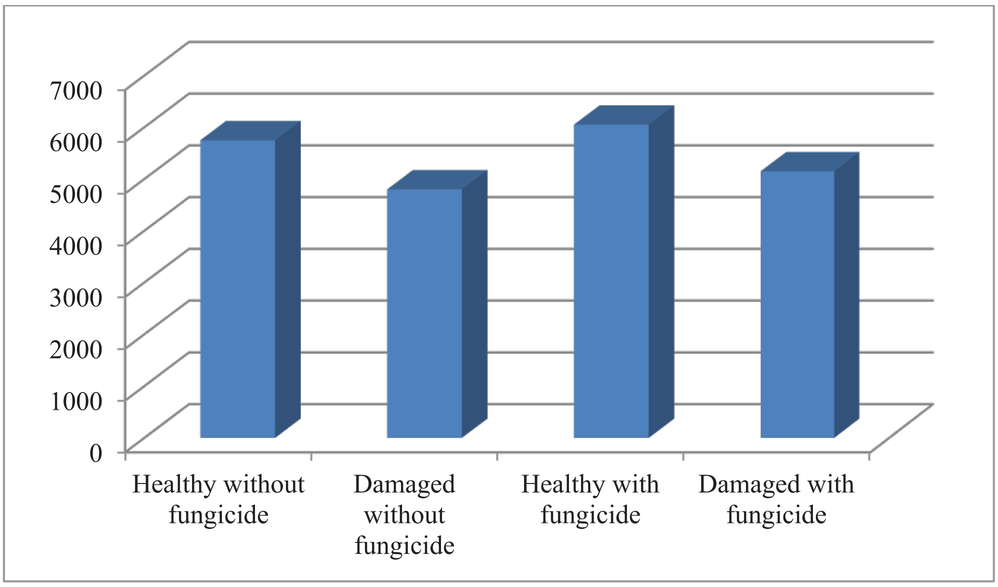

Figure 1. Barley yield in a field trial

Table 1. Multiple range tests for yield by treatments

Method: 95.0 percent LSD

Treatments	*Count*	*Mean*	*Homogeneous Groups*
Damaged without fungicide	2	4800.0	A
Damaged with fungicide	2	5150.0	A
Healthy without fungicide	2	5800.0	B
Healthy with fungicide	2	6050.0	B

Contrast	*Sig.*	*Difference*
Damaged with fungicide - Damaged without fungicide		350.0
Damaged with fungicide - Healthy with fungicide	*	-900.0
Damaged with fungicide - Healthy without fungicide	*	-650.0
Damaged without fungicide - Healthy with fungicide	*	-1250.0
Damaged without fungicide - Healthy without fungicide	*	-1000.0
Healthy with fungicide - Healthy without fungicide		250.0

an adverse effect on the overall development of plants, including grain yield.

Table 1 applies a multiple comparison procedure to determine, which treatments differ from each other. The lower half of the table shows the calculated difference between each pair of means. Up to 4 pairs are marked with an asterisk, indicating that these pairs show statistically significant differences at the 95.0% confidence level. At the top of the table, two homogeneous groups are identified using columns of letters. In each column, levels containing the same letter form a group of means, within which there are no statistically significant differences. Homogeneous group A is composed of the treatments with damaged seeds not treated with fungicide and damaged seeds treated with fungicide (Figure 2). Homogeneous group B is composed of the treatments with whole seeds not treated with fungicide and whole seeds treated with fungicide.

Chemical analysis of barley samples

The crude protein content (12.57%) in the samples before sowing was slightly higher than that in the treated and untreated plants. This difference could be attributed to the barley variety and the influence of environmental conditions (Oscarsson et al., 1996).

The crude fat content varied in insignificant amounts from 1.6% in the fungicide-treated plants to 1.83% in the untreated ones, and the crude ash in the studied samples varied between 2.55% and 2.6%. The fiber content (8.36%) was higher in the fungicide-treated ones compared to 7.8% in the untreated ones (Table 2).

The present study showed insignificant differences in the chemical composition of the samples studied. As can be seen, the values of the measured indicators do not differ significantly in untreated and fungicide-treated plants.

Field experiment with corn

The highest average height was recorded in the treatment with healthy seeds, whose plants were treated with fungicide (127.1 cm) (Figure 3). The second place in average height was taken by the treatment with healthy seeds, whose plants were not treated with fungicide (120.8 cm). The

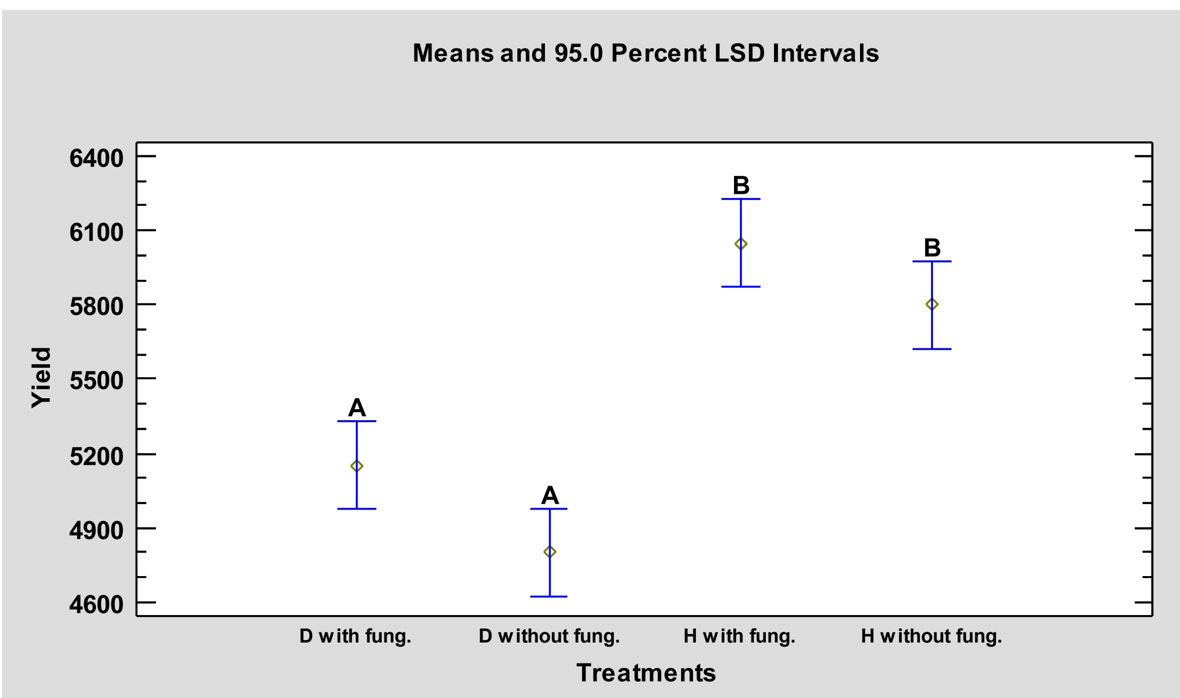

Figure 2. Homogeneous groups in barley yield

** D – Damaged; H – Healthy; fung. – fungicide* lowest average height was measured in the treatment with mechanically damaged seeds, whose plants were not treated with fungicide (102.8 cm).

The average weight of the plants has a similar distribution by treatments to that of their average height (Figure 4). Again, the highest average weight was recorded in the treatment with healthy seeds, whose plants were treated with fungicide (235.7 g). The second place in average weight is the treatment with healthy seeds, whose plants were not treated with fungicide (219.3 g). The lowest average weight was measured in the treatment with mechanically damaged seeds, whose plants were not treated with fungicide (157.3 g). It confirms that fungicide treatment is beneficial for corn silage yield and quality (Haerr et al., 2015).

Neumann et al. (2024) found that preventive fungicide application reduced the leaf area affected by the main fungal diseases of corn, leading to fewer dry leaves and higher silage yields.

Since the corn in this experiment is harvested for silage, the weight of the plants can also be considered as yield. In this regard, we have to say that the yield of the two crops – corn and barley - is identical in distribution by treatments. In corn, the trend remains for treatments with healthy seeds to have a higher yield than treatments with damaged seeds, as well as for the two treatments whose plants were treated with fungicide to have a higher yield than their counterparts in treatments with plants not treated with fungicide. Kalebich and Cardoso (2017) observed

Table 2. Chemical analysis of barley samples

Sample	Humidity, 105°C, %	Crude protein, %	Crude fibers, %	Crude fat, %	Crude ash, %
Barley treated with fungicide	7,14	10,41	8,05	1,54	2,8
		11,21	8,67	1,65	2,3
Barley untreated with fungicide	6,82	10,9	7,52	1,76	2,51
		11,70	8,07	1,90	2,69

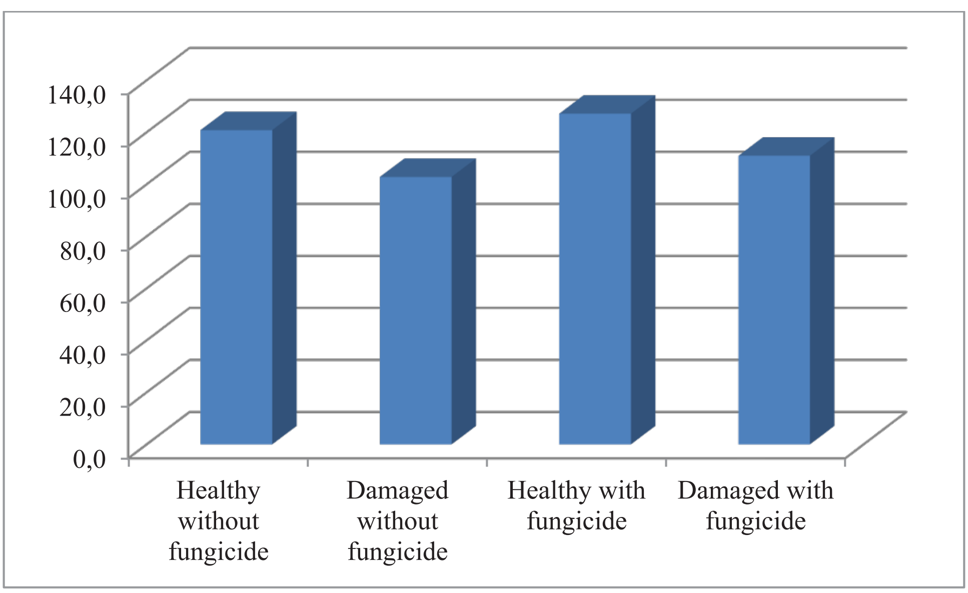

Figure 3. Average height of corn plants

improvements in the characteristics related to the yield of corn plants with fungicide used in vegetative stage.

Table 3 applies a multiple comparison procedure to determine which treatments differ from each other. The lower half of the table shows the calculated difference between each pair of means. Up to 4 pairs are marked with an asterisk, indicating that these pairs show statistically significant differences at the 95.0% confidence level. At the top of the page, 2 homogeneous groups are identified using columns of letters. In each column, levels containing the same letter form a group of means, within which there are no statistically significant differences. Homogeneous group A is composed of treatments with damaged seeds untreated with fungicide and damaged seeds treated with fungicide, Figure 5. Homogeneous group B

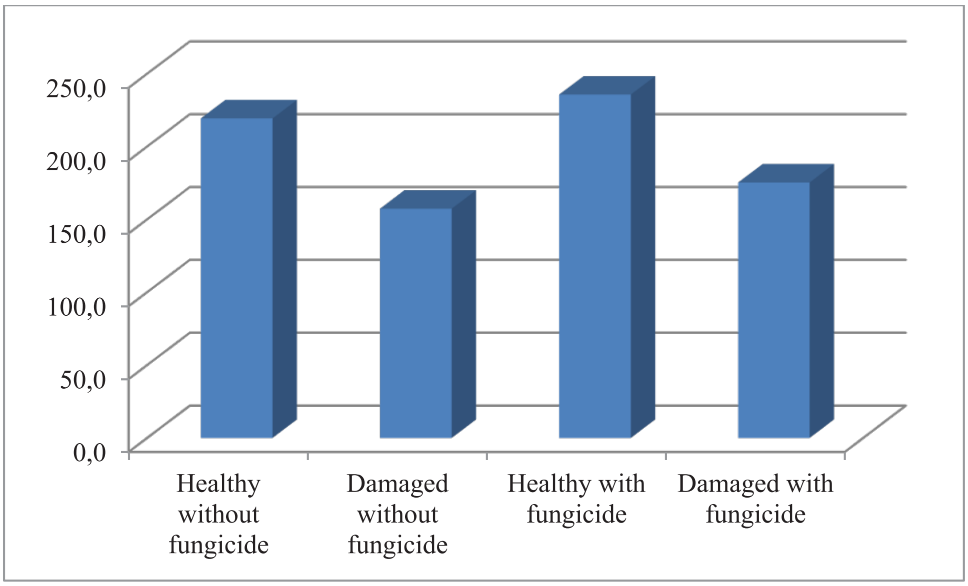

Figure 4. Average weight of corn plants

Table 3. Multiple range tests for yield by treatments

Method: 95.0 percent LSD

Treatments	*Count*	*Mean*	*Homogeneous Groups*
Damaged without fungicide	2	157.3	A
Damaged with fungicide	2	175.35	A
Healthy without fungicide	2	219.3	B
Healthy with fungicide	2	235.7	B

Contrast	*Sig.*	*Difference*
Damaged with fungicide - Damaged without fungicide		18.05
Damaged with fungicide - Healthy with fungicide	*	-60.35
Damaged with fungicide - Healthy without fungicide	*	-43.95
Damaged without fungicide - Healthy with fungicide	*	-78.4
Damaged without fungicide - Healthy without fungicide	*	-62.0
Healthy with fungicide - Healthy without fungicide		16.4

**denotes a statistically significant difference.*

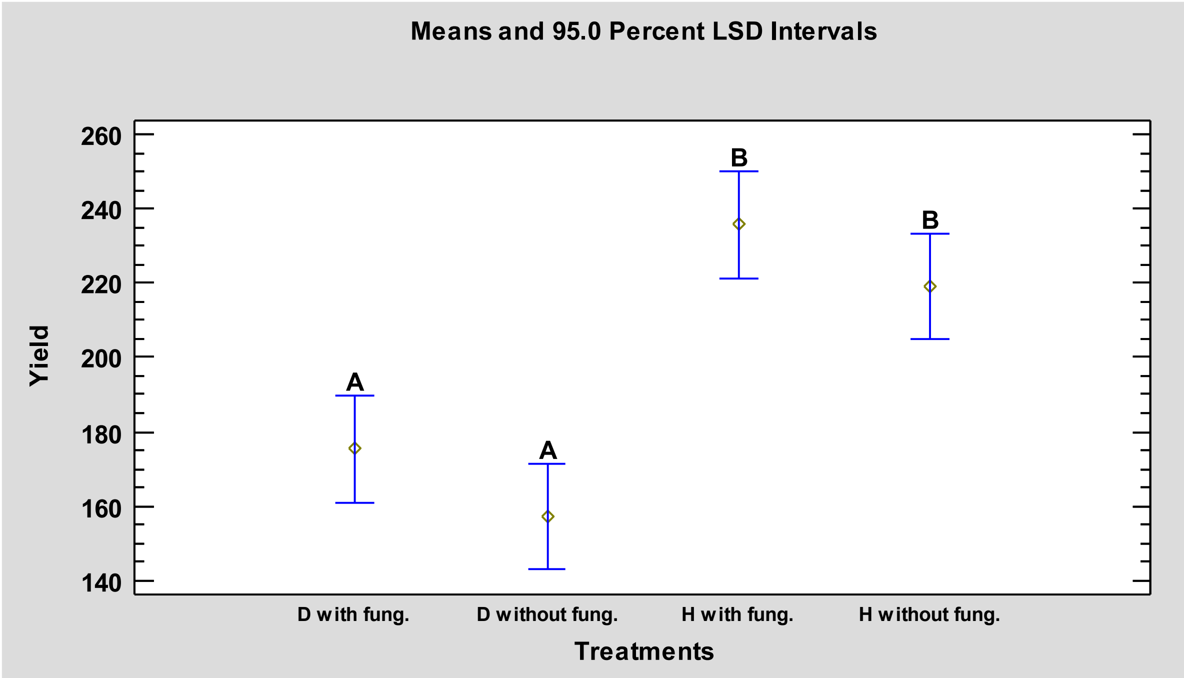

Figure 5. Homogeneous groups in corn silage yield

** D – Damaged; H – Healthy; fung. – fungicide*

is composed of the treatments with whole seeds untreated with fungicide and whole seeds treated with fungicide.

CONCLUSIONS

1. Barley and corn plants not treated with a.v. azoxystrobin have lower yield compared to the treated plants.

2. Barley and corn plants sprouted from healthy seeds have a significantly higher average height and yield compared to plants sprouted from mechanically damaged seeds.

3. Statistical analysis of the data on the yield of barley and corn for silage shows the separation of two homogeneous groups. Group A containing the two treatments with damaged seeds (treated and untreated with fungicide) and group B consisting of the two treatments with whole seeds (treated and untreated with fungicide).

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