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Research Article

Influence of a New Generation Fungicide on Fusarium Head Blight in Spring Barley

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Abstract

Fusarium head blight is a serious problem in both traditional and intensive agriculture. The way to solve this problem is to use combined systemic fungicides. We therefore studied the effect of the new-generation fungicides Alto Super and KE (Propiconazole 250 g/l and Ciproconazole 80 g/l) combined with the foliar fertilizer Ultramag Super Sulphur-900. Laboratory studies were carried out at the Plant Pathology Laboratory of the People's Friendship University of Russia (RUDN), and field experiments were carried out in 2022 at the experimental field station of the Federal Research Centre "Nemchinovka." Fusarium head blight appeared in late July and early August. The application of the new-generation fungicide Alto Super, KE, alone and in combination with the new foliar fertilizer Ultramag Super Sulphur considerably reduced the development of the epiphytotic fungal disease. Their biological efficacy was 44.53–83.36%. The yield of Nur Spring barley in the experimental variants was higher than in the control variant. The yield gain of spring barley increased by 5.85% for Alto Super, KE, 9.40% for Ultramag Super Sulphur-900, and 12.85% for Alto Super, KE, and Ultramag Super Sulphur-900.

Keywords

Fusarium, Fungicide, Blight, Barley

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1. Introduction

Barley (Hordeum vulgare) is the fourth most important cereal crop in the world, after wheat, rice, and maize, and is second only to wheat in Russia [14]. It has been the most widely used plant for beer and malt production since Neolithic times, due to the chemical composition of its grain and its biological characteristics compared with other crops. Approximately 75–80% of global barley production is used for animal feed, 20–25% for malt, 2–5% for human food, and the remainder for bioethanol production [13, 9]. High-quality malting barley is selected for malt production. For malting barley grain, it must have a large size, thin cell walls, loose endosperm packing, a germination rate > 96%, suitable protein content, be sweet, heavier, free from microbial contamination, etc. [11].

Overall, global beer consumption is increasing, while the quantity of barley malt per unit volume of beer brewed is decreasing due to various constraints. Indeed, barley production, like that of any other cereal, in terms of both quality and quantity, remains one of the main problems facing agriculture due to the unpredictable evolution of various biotic and abiotic stresses. In Russia, one of the causes of the reduction in yield and quality of spring barley grain is the development of a complex of fungal diseases of various etiologies. Among spring barley diseases, the most widespread and damaging is fusarium head blight, caused by fungi of the genus Fusarium, which can reduce crop yields by more than 10%. The damage caused by these fungi not only reduces yield but also significantly impairs crop quality. Fungi of the genus Fusarium produce toxic secondary metabolites, mycotoxins (Fusarium toxins), which make cereals unfit for human and animal consumption [3, 4]. It is therefore necessary to have the most effective tools possible for implementing integrated protection of the ear. The most common species are *F. graminearum*, *F. culmorum*, *F. aveanaceum*, and *F. sporotrichioides*. The species of the Fusarium genus have different epidemiological characteristics, making control of this disease particularly difficult. In addition, the population dynamics of the Fusarium species complex vary for each cereal and are highly dependent on the soil and climatic characteristics of the region, annual weather fluctuations, and cultivation techniques (crop rotation, ratio of nitrogen and phosphorus in the soil, sowing dates, application of fungicides). The main conditions for the development of Fusarium can be summed up as the presence of primary inoculum during the cereal flowering period (monocyclic disease), periods of humidity close to saturation and fairly mild temperatures, and the plant genotype [2]. The use of combined systemic fungicides is a key element in solving this problem. In recent years, both in Russia and throughout the world, the use of systemic combination fungicides to control cereal diseases has shown great promise, due to their long-term efficacy, the reduction in the emergence of resistance in pathogen strains, and their very broad spectrum of therapeutic activity, meaning that they reach more target pathogens in a single application. As well as nitrogen, phosphorus, potassium, magnesium, sulfur, and trace elements have a crucial influence on the quality (protein and gluten content, etc.) and quantity of yields. Sulfur is essential for life, as it is a component of three essential amino acids (methionine, cysteine, and homocysteine), hormones (insulin), vitamins (B1, H, and U), taurine, and glutathione [12, 7]. Crop losses due to sulfur deficiency can be enormous. Among the types of applications, foliar application is very advantageous because of its economic, ecological, qualitative, and quantitative effectiveness. The research [1, 5] estimate that 20 to 75% of the nitrogen applied in the field is not consumed by the plants and is lost through leaching into the soil or escapes into the atmosphere through denitrification. In addition, foliar application of sulfur increases resistance to biotic and abiotic stresses, leading to qualitative and quantitative changes in malting barley yield. Above all, sulfur enables plants to assimilate nitrogen more efficiently. Therefore, effective crop protection using fungicides with new active components as well as new combinations and sulfur-based foliar fertilizers is crucial to optimizing spring barley grain production by improving the plant's ability to tolerate various biotic and abiotic stresses. In this respect, it is necessary to develop specialized and targeted measures to increase spring barley productivity qualitatively and quantitatively, taking into account the ecological situation. The aim was to study the effect of a systemic fungicide in combination with a liquid sulphur microfertiliser on the development of fusarium head blight and yield formation in malting barley. Study conditions. The agroclimatic parameters of the peatland regions are characterised by a moderate climate. During the barley growing period, from May to August, the weather conditions in the year under study differed from the long-term average values. In the early stages of the crop's development, there was a slight drop in air temperature accompanied by an abundance of rainfall, resulting in sprouts that were quick and easy to grow. Weather conditions during the active growth phase of spring barley up to full maturity were characterised by air temperatures higher than the long-term average annual data, and at the same time fairly dry. In general, agro-meteorological conditions during the 2022 season were favourable for the growth and development of the crop.

2. Methods

The laboratory studies were carried out at the Plant Pathology Laboratory of the Peoples' Friendship University of Russia (RUDN), and the field trials were carried out in 2022 at the experimental field station of the Federal Research Centre in Nemchinovka. The subject of the study was Nur spring barley, listed in the State Register of Breeding Achievements of the Russian Federation since 2002. The experiments were carried out in the field as shown in Table 1. The surface area of the

experimental plots (blocks) was 40 m2 and there were a total of 16 blocks. The experiment was repeated four times and the locations of the blocks were randomised. Tillage: ploughing from autumn after the harvest of the previous crop. In the control and experimental variants, a pre-sowing treatment with Oplot Trio (azoxystrobin, 40 g/l, tebuconazole, 45 g/l and difenoconazole, 90 g/l) at a rate of 10 l/t was carried out. Spraying was carried out during the ear emergence phase (heading). The precursor was the legume crop. The soil in the experimental plot consisted of peat and podzol. All observations in the experiment were made in accordance with generally accepted methods [8, 10]. Disease development was determined using the test method for fungicides, antibiotics and seed treatment products for agricultural crops. Disease prevalence P (%) was determined using the following formula:

$$P = \frac{n}{N}100,$$

where n is the number of plants showing signs of the disease in the sample;

N is the total number of plants analysed in the sample.

The biological efficacy of the fungicide (%) in terms of disease prevalence compared with the control is calculated using a formula:

$$C = \frac{(P-p)}{P}100$$

where P and p are the prevalence of disease in the control and experimental variants respectively. Harvesting was carried out directly by harvester. The technological properties of the grains were determined in the laboratory in accordance with standards GOST 10987-76, GOST 10842-89, GOST R 54478-2011 and GOST 54895-2012.

Table 1. *Experimental design.*

TREATMENT	DOSAGE (l/ha)
1. Control	0
2. Ultramag Super Sulphur-900 (70% de soufre et 5% d'azote)	3l/ha
3. Alto Super, KE (Propiconazole 250 g/l Ciproconazole 80 g/l)	0,5l/ha
4. Alto Super, KE + Ultramag Super Sulphur-900	0,5l/ha + 3l/ha

3. Results

Among the fungal diseases of the Nur malting barley crop, *Fusarium* head blight was observed after 25 days of treatment, appearing at the end of flowering and the beginning of milk ripening. Its prevalence is shown in Table 2 and varied from 1.02-16.25% depending on the sampling period. Light spots with a purple border appear at heading, first on the basal part of the barley flag leaf, then on the scales. Pink spots on the scales can be observed on affected parts: these are spore accumulations. The disease causes discoloration of the ear and desiccation of the upper part of the ear (figure 1). In the case of late *Fusarium*, the outward signs of infestation are even less visible, even if sporulation is present on the scales. Consequently, the best time to identify diseased plants in the field is 18 to 24 days after flowering, when fungal sporulation is clearly visible on the background of the still green tissue [3]. Therefore, to protect growing barley plants against a range of diseases, it is necessary to apply systemically acting fungicides.

Figure 1. *Symptoms of Fusarium head blight in spring barley.*

In order to reduce the development of *Fusarium* head blight, treatments with the products tested are recommended at the

heading-flowering phase. The analysis of variance revealed the efficacy of the products tested (Table 2). Biological efficacy ranged from 44.53% to 88.41%. Individual applications of Ultramag SuperSera-900 and Alto Super, KE, reduced the prevalence of Fusarium head blight by 44.53% and 83.36%, respectively, during the flowering period and by 45.41 and 80.61% in the milky ripening phase. Their combination reduced Fusarium head blight by 50.73% during the flowering period and by 72.30% in the milky ripening phase. The fungicidal effect of sulfur is to burn fungal spores by oxidizing on contact with the leaves and transforming into a gas under certain conditions of heat and light (this phenomenon is called sublimation). This creates a highly effective sulfur vapor barrier against pathogenic fungi.

Table 2. *Effect of preparations on the prevalence of Fusarium head blight (Nur variety).*

Treatment	Sampling of plant material			
	Floraison		Milky ripeness	
	Fusarium head blight Prevalence, %	Efficacity, %	Fusarium head blight Prevalence, %	Efficacity, %
Control	6,13	-	16,25	-
Ultramag SuperSera-900	3,40	44,53	8,87	45,41
Alto Super, KE	1,02	83,36	3,15	80,61
Alto Super, KE + Ultramag SuperSera-900	3,02	50,73	4,50	72,30

Comprehensive crop protection with Alto Super, KE, and Ultramag Super Sulphur-900 had a positive effect on yields. In the control, the yield was 4.020 t/ha. The increase in yield obtained in the variants with the tested products Alto Super, KE: 5.81%, Ultramag Super Sulphur-900: 9.40%, and Alto Super, KE + Ultramag Super Sulphur-900: 12.85% compared with the control. The weight of 1000 grains also increased in Alto Super, KE%, and Alto Super, KE + Ultramag Super Sulphur-900 compared with the control. These results are similar to those of [6], in which a single application of fungicide (active ingredient content: 250 g/l propiconazole, 80 g/l cyproconazole) during flowering inhibited the development of Fusarium head blight while slightly increasing the number of grains in the barley ear and thousand-seed weight.

The most important indicators of grain quality are protein content, starch content, and extractability. The extractivity index in the control was 11.7%, which was higher than in the experimental variants. Grain protein content in the Alto Super, KE, and Alto Super, KE + Ultramag Super Sulphur-900 variants and starch content in the Ultramag Super Sera-900 and Alto Super, KE + Ultramag Super Sera-900 variants were equal to or slightly higher than in the control (Table 3). In general, the preparations tested had no significant effect on malting barley grain quality.

Table 3. *Effect of preparations on productivity and quality indices of the spring barley variety Nur.*

Grains quality	Control	Ultramag Super Sera-900	Alto Super, KE	Alto Super, KE + Ultramag Super Sera-900
Weight of 1000 grains, g	49,36	47,97	50,76	50,22
Protein (N 5.7), % w.w.	11,70	11,60	11,90	11,80
Starch, % s.w.	57,00	57,30	57,00	57,2
Extractability, %.	77,60	76,90	77,3	76,8
Yield, T/ha	4, 02	4,4	4,25	4,54
Increases, %		9,40	5,81	12,85

4. Conclusions

Application of the fungicide and microfertilizer showed that the biological efficacy of Alto Super, KE (0.5 l/ha), and its combination with Ultramag Super Sulphur-900 (3 l/ha), was 44.53–83.36%. We observed no phytotoxicity in the preparation, providing further insight into the fungicide's impact on plants. Further results are required to demonstrate the necessity of using more than one of the systemic fungicides in combination with foliar fertilizers, in order to obtain a profitable crop that is sufficiently abundant and satisfies the quality criteria of the malting barley trade.

Abbreviations

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Author Contributions

Simbo Diakite: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

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Conflicts of Interest

The authors declare no conflicts of interest.

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