EFFECTS OF BIOSTIMULANTS ON YIELD AND QUALITY OF WINTER CEREALS

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Summary

Cereals are the most important cultivated crop in the world. Bosnia and Herzegovina (B&H) have relatively lower cereal yields than their surrounding countries. Unfavourable environmental conditions are one of the reasons for low grain yields. However, farmers can mitigate the adverse effects of environmental conditions on yield by applying various agronomic practices. One possible way to eliminate the environment's negative consequences on cereal yield is the application of biostimulants. Therefore, the aim of this study was to examine the influence of biostimulants on cereal yields and quality in the environmental conditions of central Bosnia and Herzegovina. A field experiment was conducted at Sarajevo, B&H, at the Faculty of Agriculture and Food Science. The treatments used in this research consisted of a combination of biostimulants (applied and unapplied) and different cereal species (wheat, barley and oats). Experimental results showed a significant impact of biostimulant application on the quality traits. The oats' mass of 1.000 seeds ranged from 35.9 g (unapplied) to 37.0 g (applied). Biostimulant barley variants had more test weight (60.7 kg hL^{-1}) than those without it (59.3 kg hL^{-1}). Wheat content protein ranged from 10.94 (unapplied) to 11.25% (applied).

Key words: *cereals, biostimulants, yield, quality, protein*

INTRODUCTION

Cereals are the most important cultivated crop in the world, both in terms of the area they occupy and the value of production. Thanks to the nutritional value of nutrients, cereals are present in people's diets daily. Cereals are used in milling, baking, confectionery, pharmaceutical, and brewing industries (Moshawih *et al.*, 2022; Serna-Saldivar, 2010). In recent years, cereals have become increasingly popular because of the straw that is used to produce pulp and paper (Tutus *et al.*, 2016), ethanol (Li *et al.*, 2022) and fuels (Keppel *et al.*, 2013). They are cultivated in almost all countries thanks to many species and cultivars that adapt well to different growing conditions. For instance, in 2021, wheat was cultivated worldwide in about 220 million ha with an average yield of 3.5 t ha^{-1} (FAOStat, 2023). Notably, Ireland (10.7 t ha^{-1}), Netherlands (9.7 t ha^{-1}), United Kingdom (7.8 t ha^{-1}) and Belgium (7.8 t ha^{-1}) achieved

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the highest average wheat yields during the same period (FAOStat, 2023). Meanwhile, in Bosnia and Herzegovina (B&H), wheat was harvested in an area of 65,649 ha, with an average yield of 4.8 t ha^{-1}. However, compared to neighbouring countries (e.g. Serbia with 5.7 t ha^{-1} and Croatia with 6.7 t ha^{-1}), the wheat yield in Bosnia and Herzegovina remains relatively low. These differences can be attributed to unfavourable environmental conditions affecting grain productivity. Similar data are available for other winter cereals. Unfavorable environmental conditions contribute to low cereal yields. Nevertheless, farmers can mitigate the adverse effects of environmental conditions on yield by applying various agronomic practices. Besides selecting cultivars, crop rotation, plant protection, and irrigation, crop nutrition significantly influences grain yield (Gavrić & Omerbegović, 2021). Therefore, the correct application of fertilisers is a prerequisite for achieving a high grain yield. Mineral fertilisers are primarily used in the cultivation of cereals. Mineral fertilisers are known for their substantial concentration of macronutrients that are readily available to plants and contribute to achieving higher crop yields (Gavrić *et al*., 2023; Gavrić *et al*., 2021; Timsina, 2018). In addition, biostimulants have recently gained importance alongside traditional fertilizers. Biostimulants have recently been introduced into plant production (Martínez - Gutiérrez *et al*., 2022). They are substances applied to plants to increase nutrition efficiency, resist environmental conditions and improve product quality. The composition of biostimulants is very different. They usually contain humic acids, hormones, vitamins, algae extracts and bacteria that stimulate plant growth (Du Jardin, 2015; Martínez-Gutiérrez *et al*., 2022).

In recent years, research on the impact of biostimulants on several crops has increased. However, most of these studies focused on horticultural crops and were conducted in greenhouses. A limited number of research studies have been conducted on cereals, primarily in environmental conditions outside Bosnia and Herzegovina. Therefore, the aim of this study was to examine the influence of biostimulants on cereal yields and quality in the environmental conditions of central Bosnia and Herzegovina.

MATERIALS AND METHODS

Experiment location. The field experiment was conducted in the growing seasons of 2022 and 2023. The field experiment was conducted at Butmir of the Faculty of Agriculture and Food Sciences (43°49'34.41" N, 18°19'18.49" E; 506 m asl).

Weather analysis. Weather data was collected using an automatic weather station type WH2900. The meteorological station was located at a distance of 150 meters from the experimental location. The research used data on the average monthly air temperature and monthly amount of precipitation.

Treatments and experiment design. The experiment was set up by a split-plot design. The size of the basic plot was 40.0 m^2. The treatments used in this study consisted of a combination of biostimulants (applied and unapplied - control) and different cereal

species (Wheat cv. sothys, Barley cv. nonius, ant two Oats cultivars, that is cv. BC Marta, and Oats of unknown cultivar - local name ″crna zob″). The biostimulant (Fitofert speed-g) was used foliar twice in the BBCH 30-35 stage and BBCH 50-53 in 10 L ha^{-1}.

Crop Management and data collecting. Cereals sowing was done manually. The sowing date was 14.10.2022. The sowing rate was following the recommendations for certain cereal species. During the growing season, weeds were eliminated by hand. Cereals were harvested at the stage of technological maturity (July 10, 2023). The yield, mass of 1000 grains and test weight were determined after harvesting and cleaning samples. Measurements of the research traits were performed in four repetitions.

Determination of protein content. Nitrogen content was determined by the Kjeldahl method described by ISO 5983-2. Microkjeldahl instrument (Foss Kjeltec 2200) was used for distillation. After distillation, the seed protein contents were calculated by multiplying nitrogen contents and 6.25 factor.

Statistical methods. Statistical analyses of the data were performed by analysis of variance (ANOVA test) with a significance level of 5% ($P<0.05$). The SPSS 22.0 program (IBM, USA) was used for statistical data processing.

RESULTS AND DISCUSSION

The analysis of weather conditions utilised data obtained from the automatic meteorological station type WH2900. The data presented in Table 1 show that the average air temperatures during the field research varied widely. The lowest average monthly temperature was recorded in February 2023 (1.0 ^{o}C), and the highest was in July (18.5 ^{o}C). Recorded amounts of precipitation during the study were relatively high during the study period, except for the beginning of the growing season. More precisely, the lowest rain was in October 2022 after sowing (23.9 mm), and the highest was in May 2023 (191.3 mm). High amounts of rainfall were also recorded in the ripening stage, that is, in June and July, which amounted to 112.7 and 165.1 mm, respectively. Ellis and Yadav (2016) stated that precipitation during vegetative growth promotes high cereal yield, but heavy rainfall during seed ripening can negatively affect seed quality.

Table 1. Average monthly air temperature and precipitation from October 2022 to July 2023

Tabela 1. Srednja mjesečna temperatura, suma oborina i relativna vazdušna vlaga za period od oktobra 2022. do jula 2023. godine

Month / Mjesec									
X	XI	XII	I	II	III	IV	V	VI	VII
Average monthly air temperature / Srednja mjesečna temperatura zraka (ºC)									
11.5	6.3	4.3	1.7	1.0	6.5	8.5	14.9	18.5	22.8
Amount of precipitation / Suma oborina (mm)									
23.9	143.6	105.3	149.6	43.3	81.3	111.8	191.3	112.7	165.1

The influence of biostimulants and cereal species on yield and quality are presented in Tables 2 and 3. The research findings indicated that the qualitative traits (mass of 1.000 seeds, test weight and protein contents) in the applied biostimulants were significantly higher than in the unapplied treatment (Table 2). For example, significantly higher mass of 1000 kernels, test weight and protein contents were recorded in barley in the variant with biostimulator application (44.9 g, 60.7 kg hL^{-1} and 9.44%, respectively) compared to the unapplied biostimulator (42.9 g, 59.3 kg hL^{-1} and 9.25%, respectively). A similar observation was observed with other research cereals. This result was expected because the plant received additional nutrients for growth from the applied biostimulants. Namely, biostimulants contain various compounds, such as micronutrients, humic acids, hormones, and vitamins, that stimulate plant growth (Du Jardin, 2015; Martínez-Gutiérrez *et al*., 2022) and increase the effectiveness of nutrition and resistance to stressful environments (Martínez-Gutiérrez *et al*., 2022).

Table 2. Effect of biostimulants application on mass of 1000 seeds, test weight and protein contents
Tabela 2. Utjecaj biostimulatora na apsolutnu masu, hektolitarsku masu i sadržaj proteina

Biostimulant	Wheat				Barley				Oats cv. Marta				Oats-crna zob			
	y - t ha^{-1}-	ms -g-	tw -kg-	pc -%-	y - t ha^{-1}-	ms -g-	tw -kg-	pc -%-	y - t ha^{-1}-	ms -g-	tw -kg-	pc -%-	y - t ha^{-1}-	ms -g-	tw -kg-	pc -%-
Applied	6.7ns	43.2a	76.5a	11.25	8.3ns	44.9a	60.7a	9.44	7.0ns	37.0a	41.8a	9.31	4.7ns	31.1a	38.4ns	7.94
Unapplied	6.6ns	40.6b	76.0b	10.94	7.2ns	42.9b	59.3b	9.25	6.8ns	35.9b	41.0b	9.31	4.0ns	29.5b	38.2ns	7.75
Average / Prosjek	**6.7**	**41.9**	**76.3**	**11.10**	**7.7**	**43.9**	**60.0**	**9.65**	**6.9**	**36.4**	**41.4**	**9.31**	**4.4**	**30.3**	**38.3**	**9.31**

Different letters indicate significant differences at the 0.05 level; ns: nonsignificant difference.
y- yield, ms - Mass of 1.000 seeds, tw - Test weight, pc – Protein contents

The species of cereals significantly influenced the yield. Experimental research with ″crna zob″ oats showed a significantly reduced yield compared to wheat, oats cv. Marta and barley (6.7, 6.9, and 7.7 t ha^{-1}). The qualitative characteristics (mass of 1.000 seeds, test weight and protein contents) also significantly depended on the cereal species. Observed results (Table 3), it can be said that the lowest values of mass of 1000 seeds, test weight and protein contents were recorded in ″crna zob″ oats (38.2 kg and 7.85%, respectively), while the highest values were recorded in wheat (76.3 kg and 11.10%, respectively). Therefore, our research found that oats have the lowest values of qualitative traits, and wheat has the highest values, which aligns with a previously published study (Serna-Saldivar, 2010). However, by comparing the obtained numerical data from our research with literature data, it can be said that there are certain differences. For example, Mlinar (2009) studied oat cv. Bc Marta was in four different locations over three years and recorded that the average test weight was 50.75 kg, and the protein content was 12.13%. At the same time, research conducted by Pržulj and Momčilović (2009) shows that barley cv. nonius had a test weight of 76 kg hL^{-1}, and the protein content was 12.2%. However, our research recorded lower values for quality indicators (test weight and protein content). Unfavourable weather conditions during the seed ripening stage could be one of the reasons for this decline. Namely, in our research, much rain was recorded during grain ripening (Table 1). According to Ellis and Yadav (2016), these weather conditions can negatively affect the seeds' quality. Song *et al*. (2019) share similar opinions, pointing out that excessive precipitation during seed filling and ripening reduces cereal yield and compromised quality due to *Fusarium sp*. infection.

Table 3. Effect of cereal species on yield, mass of 1000 seeds, test weight and protein contents

Tabela 3. Utjecaj vrste žita na prinos, apsolutnu masu, hektolitarsku masu i sadržaj proteina

Cultivars	Yield / Prinos - t ha^{-1}-	Mass of 1.000 seeds / Apsolutna masa -g-	Test weight / Hektolitarska masa - kg hL^{-1}-	Protein contents / Sadržaj proteina -%-
Wheat	6.7a	41.9b	76.3a	11.10
Barley	7.7a	43.9a	60.1b	9.65
Oats cv Marta	6.9a	43.4a	41.4c	9.31
Oats – crna zob	4.4b	30.2c	38.3d	7.85
Average / Prosjek	**6.4**	**39.8**	**54.0**	**9.48**

Different letters indicate significant differences at the 0.05 level; ns: nonsignificant difference.

The research provided data on the yield and quality of several cereal species grown in relatively unfavourable weather conditions. However, this research did not answer the question of the impact of biostimulants on grain yield and quality in relatively favourable weather conditions. In order to eliminate this limitation, future simila research should focus on the study of biostimulants in different environmental

conditions. Furthermore, future research should include the influence of different types of biostimulators and their concentrations on cereal yields and quality.

CONCLUSIONS

The results of the experiments have demonstrated that the biostimulant used can affect the quality traits. Biostimulants increased the mass of 1.000 seeds, test weight and protein contents. Therefore, using these biostimulants could be a practice for improving the quality of cereals.

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UTJECAJ BIOSTIMULATORA NA PRINOS I KVALITET OZIMIH ŽITA

Rezime

Žita su najvažniji gajeni usjevi na globalnoj razini. U Bosni i Hercegovini (BiH), prinos žita je relativno niži u usporedbi s okolnim zemljama. Ovaj fenomen djelomično proizlazi iz nepovoljnih agroekoloških uvjeta. Međutim, poljoprivredni proizvođači mogu ublažiti negativne učinke okolišnih uvjeta na uzgoj žita primjenom različitih agrotehničkih mjera. Jedan od potencijalnih načina za smanjenje negativnih utjecaja agroekoloških uvjeta je apliciranje različitih biostimulatora. Stoga je cilj ovog istraživanja bio istražiti utjecaj biostimulatora na prinos i kvalitetu ozimih žitarica u agroekološkim uvjetima centralne BiH. Poljsko istraživanje je provedeno u Sarajevu (BiH), na oglednom polju Poljoprivredno-prehrambenog fakulteta. Tretman u ovom istraživanju sastojao se od kombinacije biostimultora (sa i bez apliciranja) i različitih vrsta ozimih žita (pšenica, ječam i zob). Rezultati istraživanja pokazali su značajan utjecaj primjene biostimultora na svojstva kvalitete žita. Apsolutna masa zobi kretala se od 35,9 g (bez biostimulatora) do 37,0 g (sa biostimulatorom). Varijante ječma u kojima je apliciran biostimulator imale su veću hektolitarsku masu (60,7 kg hL^{-1}) od onih bez apliciranja (59,3 kg hL^{-1}). Sadržaj proteina u pšenici kretao se od 10,94 (bez biostimulatora) do 11,25% (sa biostimulatorom).

Ključne riječi: *žita, biostimulatori, prinos, kvaliteta, protein*