Influence of Nitrogen Application on the Yield and Quality of Barley and Triticale Feed Grains

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Abstract

Cereals are used in animal feed because of their high dry-matter yield and low production costs. Unfavourable environmental conditions contribute to these low cereal yields. Grain production can be enhanced by implementing various agronomic practices. One of the ways to boost yields is to apply fertilisers. This study aimed to investigate the impacts of different nitrogen doses on the yields and quality of barley and triticale in the central Bosnia&Herzegovina. A field experiment was conducted at the Faculty of Agriculture and Food Science at Sarajevo, B&H. The treatments included two nitrogen doses (F1 and F2) and two cereal species (Barley and Triticale). The results demonstrated a significant influence of fertilisation and cereal species on both yield and quality. The barley yield ranged from 5.1 t ha^{-1} (F1) to 5.5 t ha^{-1} (F2), while the triticale yield varied from 5.0 t ha^{-1} (F1) to 5.5 t ha^{-1} (F2). Protein content was also notably affected by nitrogen application. Barley protein content ranged from 11.7% (F1) to 12.3% (F2). Triticale protein content ranged from 10.6% (F1) to 11.9% (F2). A strong positive correlation was observed between crude fibre and ash, while test weight showed strong negative correlation with ash and crude fibre content.

Keywords: nitrogen, fertiliser, yield, protein, fibre, ash.

1. Introduction

Cereals are used in livestock nutrition due to their high dry-matter yield and low production costs [1]. Cereals can provide animals with a large amount of energy. However, they have a relatively low protein content. Corn is the most commonly used grain in livestock nutrition. However, other cereal species are also valued as animal feed. That's right, barley is one of the most important grains for ruminants, pigs, and poultry in many parts of the world. It is grown in many environmental conditions and is characterised by relatively stable yields. Previous research has shown that, compared with corn, barley contains higher levels of protein, fibre, ash, methionine, cysteine, lysine, and tryptophan [2,3]. In addition to barley, recently triticale has been increasingly used in production. It is a hybrid obtained by crossing plant species from the genera *Triticum* and *Secale*. One of the main triticale characteristics is its relatively high yield in poor environmental conditions [4]. The nutritional value of triticale grain is most similar to that of wheat. Compared to wheat, the grain has higher protein content, with an average lysine content of 3.4%. An undesirable component of triticale grain is its relatively high pentosan content, which interferes with nutrient digestion and absorption in poultry diets [5].

Barley and triticale are cultivated in almost all countries thanks to many cultivars that adapt well to different growing conditions. For instance, in 2024, barley was cultivated on about 44 million ha worldwide, with an average yield of 3.2 t ha^{-1} [6]. On the other hand, triticale was cultivated on about 32.7 million ha worldwide, with an average yield of 3.7 t ha^{-1} [FAOStat, 2026]. Notably,

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Ireland (7.0 t ha^{-1}), Germany (6.3 t ha^{-1}), Belgium (6.2 t ha^{-1}), Netherlands (6.1 t ha^{-1}), United Kingdom (5.9 t ha^{-1}) and achieved the highest average yields during the same period. Meanwhile, in Bosnia and Herzegovina (B&H), barley was harvested over 21,404 ha, with an average yield of 3.6 t ha^{-1}. However, compared with neighbouring countries (e.g., Serbia at 5.2 t/ha and Croatia at 5.0 t/ha), barley 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 [7]. Unfavourable environmental conditions contribute to low cereal yields. Nevertheless, farmers can mitigate the adverse effects of environmental conditions on yield by applying various agronomic practices. In addition to choosing cultivars, crop rotation, plant protection, and irrigation, crop nutrition significantly influences grain yield [8]. 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 high concentrations of readily available macronutrients, which help achieve higher crop yields [9,10]. Previous research has shown that the use of mineral fertilisers can cause significant variations in the quality of grain used in livestock nutrition. For example, nitrogen application in barley increased yield, seed weight, and grain protein content [11],

Numerous studies have explored the effects of nitrogen application on cereal yield and quality under various environmental conditions. However, only a few studies have specifically examined barley and triticale under the environmental conditions of B&H. Therefore, this study aimed to investigate the impacts of different nitrogen doses on the yields and quality of barley and triticale in the central B&H environment.

2. Materials and methods

Experiment location. The field experiment was carried out during the 2024 and 2025 growing seasons at the Faculty of Agriculture and Food Science in Sarajevo, B&H. (43°49'34.40" N, 18°19'18.50" E; 501 m asl).

Weather analysis. Weather analysis was conducted using data from the Bjelave meteorological station in Sarajevo, situated 10 km from the field site [FHMZ, 2016]. The study utilised average monthly air temperatures and monthly precipitation totals.

Soil characteristics

Soil fertility was assessed through chemical analysis in the research area prior to setting up the experiment. Soil samples were collected from the upper 20 cm horizon before starting the field study. These samples were analysed for soil pH [12], organic matter content [13], and the concentrations of P_2O_5 and K_2O [14]. The analysis indicated that the soil has a pH of 7.0, contains 5.0% organic matter, and has P_2O_5 at 55.0 mg per 100 g and K_2O at 57.0 mg per 100 g. It was classified as an alluvial soil.

Treatments and experiment design. The experiment was set up using a split-plot design. The size of the basic plot was 50.0 m^2. The treatment consisted of two nitrogen supplementation doses (60 and 80 kg N ha^{-1}) and two cereal species (Barley cv. LG Zebra and Triticale cv. Bikini).

Crop Management and data collecting. Cereals were sown with seed drills, with row spacing of 12.5 cm. The sowing date was October 20, 2024. The sowing rate followed the recommendations for certain cereal species. Cereals were harvested on July 03, 2025. Samples were collected in four replicates in each treatment. The sampling area was 1 m^2. In the laboratory, seeds were manually separated from the straw and cleaned of harvest residues. The yield was determined by weighing the collected seeds per 1 m^2 and converting the weight to a hectare. The yield, mass of 1000 grains and test weight (mass of 100 L) were determined after cleaning the seeds.

Determination of the chemical composition of grains.

Nitrogen content was measured using the Kjeldahl method [15] with a Foss Kjeltec 2200 MicroKjeldahl apparatus facilitating the distillation. After distillation, seed protein content was calculated by multiplying nitrogen levels by 6.25. Starch analysis was conducted using a polarimetric method as outlined by Ewers [16],

crude fiber content was determined following ISO protocol [17]. Ash content was measured in accordance with the ISO protocol [18].

Statistical methods. Statistical analyses were conducted using ANOVA at a 5% significance level ($P<0.05$). Data processing was performed with SPSS version 22.0 (IBM, USA).

3. Results and discussion

Weather analysis was conducted using data from the Bjelave meteorological station in Sarajevo, located 10 km from the field site. The data presented in Table 1 indicate that the average air temperatures during the field research varied significantly. The lowest average monthly temperature was recorded in December 2024 (1.4 °C), while the highest was in July (32.0 °C). Precipitation levels during the study period were generally quite high, except towards the end of the growing season. Specifically, the lowest rainfall was in June 2025 (1.8 mm), and the highest was in April 2025 (165.2 mm). Previous research has shown that rainfall distribution in cereal crops affects both yield and quality. Ellis and Yada [19] observed that rainfall during the vegetative stage promotes high cereal yields, but excessive rainfall during seed ripening can harm grain quality. Similarly, Song et al. [20] noted that rainy periods during seed ripening reduce grain quality due to fungal infection.

Table 1. Average monthly air temperature and precipitation from October 2024 to July 2025

Months	X	XI	XII	I	II	III	IV	V	VI	VII
Average monthly air temperature, °C	13.7	3.8	1.4	3.4	2.8	9.2	12.3	14.7	22.8	23.0
Amount of precipitation, mm	73.9	62.6	90.4	149.6	30.4	18.4	165.2	79.5	1.9	82.2

The research results showed that qualitative characteristics and yield vary with fertiliser application (Table 2). Specifically, higher 1000-seed mass, test weight, and yield were recorded in barley in the F2 treatment (42.5 g, 54.7 kg hL, and 5.5 t ha^{-1}) compared to the F1 treatment (41.2 g, 53.5 kg hL, and 5.1 t ha^{-1}). A similar observation was made with triticale. The findings align with previous research indicating that mineral fertilisers can lead to significant differences in cereal yield and quality. For instance, nitrogen application in barley positively influenced yield, seed weight, and grain protein content [11]. These results are expected because mineral fertilisers are rich in easily accessible macronutrients, which promote higher yields [7].

Table 2. Effect of fertiliser application on mass of 1000 seeds, test weight and yield

Fertiliser	Barley			Triticale		
	Mass of 1000 seeds -g-	Test weight -kg-	Yield -t ha^{-1}-	Mass of 1000 seeds -g-	Test weight -kg-	Yield -t ha^{-1}-
F1	41.2^{ns}	53.5^{ns}	5.1^{b}	42.2^{ns}	73.6^{ns}	5.0^{b}
F2	42.5^{ns}	54.7^{ns}	5.5^{a}	42.0^{ns}	73.9^{ns}	5.5^{a}
Average	41.9	54.1	5.3	42.1	73.8	5.3

F1- 60 kg N ha^{-1}; F2- 80 kg N ha^{-1}; Different letters indicate significant differences at the 0.05 level; ns: nonsignificant difference.

Examining the results in Table 3, it can be concluded that the fibre and ash contents were not influenced by fertiliser treatments.

In addition to fertilisation, cereal species significantly affected the chemical composition of grains. More specifically, barley had a higher fiber and ash content compared to triticale.

On the other hand, triticale had a higher starch content than barley. The observed differences are, to some extent, expected, since the plant's genetic

variation has the greatest influence on the grain's chemical composition [7].

Table 3. Effect of fertiliser application on the content of protein, starch, fiber and ash, %

Fertiliser	Barley				Triticale			
	Protein	Starch	Fiber	Ash	Protein	Starch	Fiber	Ash
F1	11.7^{b}	51.0^{b}	6.2^{ns}	3.2^{ns}	10.6^{b}	68.3^{a}	2.0^{b}	2.0^{ns}
F2	12.3^{a}	50.2^{a}	6.2^{ns}	3.1^{ns}	11.9^{a}	64.7^{b}	2.3^{a}	1.9^{ns}
Average	12	50.6	6.2	3.15	11.25	66.5	2.15	2.0

F1- 60 kg N ha^{-1}; F2- 80 kg N ha^{-1}; Different letters indicate significant differences at the 0.05 level; ns: nonsignificant difference.

Our research also showed that cereal species and fertilisation significantly affected the chemical composition of the grain. The results show that the contents of crude protein and starch were significantly affected by nitrogen application. The average content of barley crude protein ranged from a minimum of 11.7% (F1) to a maximum of 12.3% (F2). Also, a similar pattern was recorded in triticale. More precisely, the protein content ranged from 10.6% (F1) to 11.9% (F2). The protein content of triticale is consistent with earlier research reporting values ranging from 7.5 to 15.2% [21]. Our research showed that nitrogen has a positive effect on protein content, consistent with previous studies [22,23], indicating that nitrogen is an essential nutrient for increasing protein content in cereals. On the other hand, nitrogen application negatively affected starch content. In particular, triticale had the highest starch content in the F1 treatment (68.3%) compared to the F2 treatment (64.7%). That is, treatments with higher grain protein content had lower starch content. Some researcher [24] state that starch content is negatively correlated with protein content, which is confirmed by the estimated value of the correlation coefficient (-0,569) (Table 4). Starch content was also negatively correlated with fibre (-0.951) and ash (-0.964).

Table 4. Coefficient correlation between researched traits

	Yield	Mass of 1000 seeds	Test weight	Protein	Ash	Fiber	Starch
Yield	1						
Mass of 1000 seeds	-0.228	1					
Test weight	-0.105	0.146	1				
Protein	0.445	-0.044	-0.466	1			
Ash	-0.018	-0.047	-0.963^{**}	0.450	1		
Fiber	-0.005	-0.010	-0.947^{**}	0.432	$0,986^{**}$	1	
Starch	-0.111	0.085	0.967^{**}	-0.569^{*}	-0.964^{**}	-0.951^{**}	1

**. Correlation is significant at the 0.01 level; *Correlation is significant at the 0.05 level

The research provided data on the yield and quality of barley and triticale under the environmental conditions of central B&H in relation to nitrogen application. However, it did not address the effects of different fertiliser types and doses on the quality of cereal grains for animal feed. To address this limitation and improve fodder production across the territory of the state of B&H, future similar research should focus on studying different fertilisers under varying environmental.

4. Conclusions

The results of the experiment showed that the nitrogen fertiliser used can affect the yield and quality of barley and triticale under the environmental conditions of B&H. A higher dose

of nitrogen had a positive effect on yield and on the protein content of the grains. On the other hand, a higher amount of nitrogen fertiliser lowered the starch content in the grain. To improve fodder production in B&H, future similar research should continue to examine different types and doses of fertilisers.

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