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EFFECT OF FOLIAR NITROGEN ON THE PRODUCTIVITY AND QUALITY OF BARLEY

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Abstract. *The influence of foliar fertilizer NitroTOP NG on productivity and grain quality of winter barley variety Emon was studied. A field trial was conducted at the experimental field of the Agricultural University of Plovdiv, Bulgaria during the 2023/2024 and 2024/2025 growing season. The experimental design consisted of a randomized, complete block design and it included four variants of foliar fertilization (0, 10, 20 and 30 L.ha^{-1}) in four replication. The size of individual trial plots was 18 m^2. The fertilizer was applied in the barley tillering phase in early spring, and before the sowing in autumn, soil fertilization was carried out with 50 kg P_2O_5.ha^{-1} as a triple superphosphate. Barley was grown under non-irrigated conditions and its predecessor was sunflower. It was established that application of 10, 20 and 30 L.ha^{-1} of NitroTOP NG foliar fertilizer proven increased the grain and grain+straw yields of malting barley, compared to the unfertilized control. A rate of 30 L.ha^{-1} was highly effective under drought conditions in 2024 and the obtained grain and grain+straw yields exceeded the control by 26.8% and 16.0%, respectively. In 2025, the highest productivity (5378 kg grain and 12140 kg grain+straw.ha^{-1}) was established in treatment of 20 L.ha^{-1}. Foliar nitrogen application slightly affected the test weight of barley grain. Fertilizer rates of 20 and 30 L.ha^{-1} had a positive effect on the mass of 1000 grains in 2025. The concentration of grain protein in both experimental years met the conditions for brewing qualities, with its content averaging 9.9% in 2024 and 11.1% in 2025. Only the rate of 30 L.ha^{-1} of foliar fertilizer NitroTOP NG proven increased a grain protein concentration compared to the N_0 variant during the study period.*

Keywords*: foliar nitrogen, barley productivity and quality*

INTRODUCTION

Barley is among the five most common crops in the world after maize, wheat, rice and soybeans. The main part of the production is used for fodder 55-60%, 30-40% for malt, 2-3% for food and about 5% for seeds (ULLRICH ET AL., 2010). In Bulgaria, barley, together with maize, is the main cereal fodder crop and the main source of raw material for the brewing industry (ANNUAL REPORT ON THE STATE AND DEVELOPMENT OF AGRICULTURE, MINISTRY OF AGRICULTURE AND FOOD OF BULGARIA, 2025). The area occupied by malting barley has been growing steadily since 2000. Currently, in Bulgaria, about 95% of the barley area is sown with varieties of Bulgarian selection, with the ratio between fodder and brewing varieties being 25-30% to 70-75%. Waste products from the brewing industry are valuable fodder. After sorting the malting barley, 20-25% of the total grain mass is obtained as screenings. The barley straw is very good fodder, which has better nutritional value than wheat and rye straw. Agricultural production in the world is facing the serious challenge of providing food for the growing population, which is projected to reach 8.9 billion in 2050. At the same time, according to FAO (2014), the land suitable for agriculture worldwide is extremely small and constantly decreasing, which means that production per unit area must increase significantly. To this end, it is imperative to improve the efficiency of all units of crop cultivation technologies, including the applied nutrients, thereby ensuring sustainable agricultural production without environmental risks. The world's use of nitrogen fertilizers depends largely on the production of cereals (CASSMAN ET AL., 2002). At the same time, one of the main problems in agriculture is the excessive use of fertilizers, which causes environmental pollution (GOOD & BEATTY,

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2011; WIMALAWANSA, & WIMALAWANSA, 2014). Nitrogen fertilization has the largest share in increasing average barley yields worldwide. At the same time, it is the most mobile of all nutrients and is subject to losses from washing and gaseous outgassing. Nitrogen has the largest energy and cost input in production costs, as well as a significant source of NO3- in groundwater pollution (PRATT, 1984). It is therefore of great importance that nitrogen fertilization is applied as efficiently as possible, for economic, environmental and energy reasons (KENNEY, 1982; OLSON & KURTZ, 1982). At present, the efficiency of nitrogen use in agriculture is relatively low and varies between 20-50%. The Green Deal and the European Commission aim to reduce nitrogen (N) use by at least 20% by 2030 (BECKMAN ET AL., 2022). Approximately 20–50% of applied nitrogen fertilizers are lost either as greenhouse gases (e.g. methane and nitrous oxide) or as ammonia (REPORT ON THE IMPACT OF EUROPEAN GREEN DEAL FROM A SUSTAINABLE GLOBAL FOOD SYSTEM APPROACH, 2021. http://www.triptolemos.org/). Fertilizer nitrogen management is mainly responsible for atmospheric losses of soil organic C as carbon dioxide (CO2) and methane (CH4) through increased respiration (MULVANEY ET AL., 2009). This has focused a number of scientific studies on the adoption of technologies and sustainable techniques capable of improving crop nitrogen use efficiency (BIERNAT ET AL., 2020). Their goal is to improve nitrogen use efficiency by ensuring better synchronization of crop nitrogen demand with nitrogen supply and have, increase yield while reducing N emissions and other losses (RÜTTING ET AL., 2018). At present, the efficiency of nitrogen use in agriculture is relatively low and varies between 20-50%. Drying during the application of granular nitrogen fertilizers reduces the efficiency of conventional nitrogen application. In this regard, there is increasing interest in fertilizing with liquid nitrogen fertilizers to compensate for its soil application. Under the soil and climatic conditions of Bulgaria, foliar nitrogen feeding has been poorly studied. The aim of the present study is to determine the influence of foliar nitrogen application during the growing season on the productivity and basic quality indicators of malting barley.

MATERIAL AND METHODS

A field trial was conducted at the experimental base of the Agricultural University of Plovdiv, Bulgaria during the 2023/2024 and 2024/2025 growing season of winter barley. The influence of foliar fertilizer NitroTOP NG on Bulgarian malting variety Emon was studied. The experimental design consisted of a randomized, complete block design and it included four variants of foliar fertilization (0, 10, 20 and 30 $L.ha^{-1}$) in four replications. The size of individual trial plots was 18 m^2. Foliar fertilizer NitroTOP NG of the French company Soufflé had the following composition: 300 g $N.L^{-1}$; 1.33 g $MgO.L^{-1}$; l.67 g $SO_3.L^{-1}$. The fertilizer was applied in the barley tillering phase in early spring, and before the sowing in autumn, soil fertilization was carried out with 50 kg $P_2O_5.ha^{-1}$ as a triple superphosphate. Barley was grown under non-irrigated conditions and its predecessor was sunflower. During the growing season, standard agrotechnical practices for Southern Bulgaria were carried out. The soil on which the experiment was conducted was alluvial-meadow type (FAO & IIASA, 2023). The soil has a slightly alkaline reaction (pH water = 7.24) and it was characterized as poorly supplied with mineral nitrogen, moderately supplied with mobile phosphates and very well supplied with absorbable potassium.

The hydrothermal conditions during the two experimental barley growing seasons were represented in Table 1. In both years, the average monthly temperatures were relatively similar, with the experimental 2023/2024 being warmer in some of the critical months such as February and April. The sowing month of October in 2023/2024 was also relatively warmer

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(16.2 ºC), which was 2.5 degrees higher than the average monthly temperature in October 2024/2025. The data showed that all months with crop vegetation for the two experimental years had higher values compared to the long-term norm. In terms of precipitation, there was a huge difference between months in the two experimental years, as well as compared to the average annual rate. The month of October was as much as 40 liters below the average annual rate for both experimental years, which prevented the timely germination of barley. The month of December in 2024/2025 was twice the normal in terms of precipitation, while the month of January 2023/24 was nearly one and a half times the average annual precipitation. The spring months in both experimental years were close to the long-term norm for average annual precipitation, while the month of June was both years was over 60 liters below the norm, which prevented the quality filling of the grain, which directly affected the crop yield.

Table 1

Air temperature and c precipitation during barley vegetation period

	October	November	December	January	February	Mart	April	May	June
Temperature (ºC)									
2023/24	16.2	9.4	4.6	3.3	9.2	10.6	16.4	17.1	26.5
2024/25	13.7	6	5.6	3.3	1.9	10.3	12.5	17.5	24.8
Long-term norm	12.7	7	1.4	-0.2	1.7	5.7	11.4	16.7	20.7
Precipitation (mm.m^{-1})									
2023/24	2.75	67.25	54.5	75.25	5.25	44.25	31.25	82.25	1.25
2024/25	0.3	15.1	143	26	20	49	78	64	28
Long-term norm	43.5	51	59	46.4	37.5	36.5	46.6	51.1	65.7

At full maturity, grain and straw yields were determined and the harvest yield index was calculated as the ratio of grain yield to aboveground biological yield. The thousand-grain weight (TGW) was determined by weighing on two subsamples of 500 grans of each eperimental plot. The test weight of the grain was determined by the pound in kg.hl^{-1}. Determination of the grain nitrogen and calculation of the crude protein content of barley grain was done according TOMOV ET AL., 2009.

The data were statistically analyzed with the ANOVA procedure and Duncan's multiple range test at level of significance $p \leq 0.05$ was used to find significant differences among means. The regression analysis was done for assessment of the effect of nitrogen fertilization rates on the studied parameters.

RESULTS AND DISCUSSIONS

A proportional increase of barley grain yield with foliar nitrogen application was observed in 2024 compared to the control (Table 2). Grain yield was higher by 26.8% or 959 kg.ha^{-1}, compared to the unfertilized control, in the variant treated with 30 liters per hectare of liquid fertilizer. The values obtained when fertilizing barley with 10 and 20 L.ha^{-1} were relatively close and they had not been mathematically proven. Treatment with 20 liters per hectare of foliar fertilizer increasea grain yield by 70 kg.ha^{-1}, compared to the norm of 10 L.ha^{-}

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[1]. In the experimental year 2025, grain yield was also proven to be higher in the fertilized variants compared to the control.

Table 2

Barley productivity (kg.ha^{-1}) depending on foliar fertilization

Fertilization	2024 year	% to N_0	2025 year	% to N_0
Grain				
N_0	3583 c*	100	4330 c	100
N-10 L	4194 b	117.1	5098 b	117.7
N-20 L	4264 b	119.0	5378 a	124.2
N-30 L	4542 a	126.8	4990 b	115.2
Average	4146		4949	
Straw				
N_0	5419 b	100	6257 b	100.0
N-10 L	5744 b	106.0	6730 a	107.6
N-20 L	5651 ab	104.3	6762 a	108.1
N-30 L	5900 a	108.9	6779 a	108.3
Average	5679		6632	
Grain+Straw				
N_0	9002 c	100	10587 c	100
N-10 L	9938 b	110.4	11828 b	111.7
N-20 L	9915 b	110.1	12140 a	114.7
N-30 L	10442 a	116.0	11769 b	111.2
Average	9824		11581	

*Values with identical letters within each column and plant part are not significantly different at $p<0.05$ according to Duncan's multiple range test.

A high positive effect of application of 20 L.ha^{-1} on the barley productivity was found, in which the grain was 24.2% higher compared to the control. The grain yield obtained in the foliar fertilization variants of 10 L.ha^{-1} and 30 L.ha^{-1} was close, exceeding the unfertilized control by 15.2% – 17.7%. Foliar application of nitrogen for both experimental years showed better results compared to the control variant and the yield increase was at least 15.2%. Straw yield for the two experimental years did not change significantly, even at different doses of foliar nitrogen application. Its variation was from 4.3% (N-10 L in 2024) to 8.9% (N-30 L in 2024). In 2024, foliar fertilization at rates of 10 L and 20 L per hectare did not significantly increase straw yield compared to the control. The effect of the studied variants of foliar nitrogen application had been proven compared to unfertilized plants in 2025, but there were no significant differences between the studied rates of 10, 20 and 30 L.ha^{-1}. The application of foliar fertilizer NitroTOP NG in doses of 10, 20 and 30 liters per hectare had been proven to increase the total yield of barley grain+straw in both experimental years. In 2024, the best result was obtained in the variant 30 L.ha^{-1}, which exceeded the control in productivity by 16.0%. The effect of foliar fertilization with rates of 10 and 20 L.ha^{-1} was similar, which increased the yield of grain+straw by 10.4%-10.1% compared to N_0 variant. The highest effect on the total productivity of barley in the experimental 2025 year was demonstrated in the fertilizing rate of 20 L.ha^{-1}, which exceeded the control by 14.7%. The application of an increased dose of foliar fertilizer of 30 L.ha^{-1} did not increase the grain+straw yield and the productivity of barley was very close to that of the variant with 10 L.ha^{-1} foliar fertilizer.

The grain yield harvest index in the experimental year 2024 had higher values in the variants treated with foliar fertilizer compared to the control (Table 3). Increased values of GHI (0.430 - 0.435) were found in the variants treated with 20 and 30 liters per hectare of liquid nitrogen. Foliar fertilization of barley in rates of 10 L.ha^{-1} and 20 L.ha^{-1} demonstrated a proven

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positive effect on the grain yield harvest index in the experimental year 2025. The highest value (0.443) was demonstrated with application of 20 L.ha^{-1} foliar fertilizer. Grain yield harvest index of the variant 30 L.ha^{-1} decreased, but was still higher than the control variant.

Table 3

Grain yield harvest index of barley depending on foliar fertilization

Fertilization	2024 year	2025 year
N_0	0.398 c*	0.409 b
N-10 L	0.422 b	0.431 a
N-20 L	0.430 a	0.443 a
N-30 L	0.435 a	0.424 ab
Average	0.421	0.427

*Values with identical letters within each column are not significantly different at p<0.05 according to Duncan's multiple range test.

The studied foliar fertilization with NitroTOP NG did not have a significant effect on the hectoliter weight of barley grain (Table 4). The values of this indicator during the two experimental years varied within narrow limits with average values of 64.2 - 64.4 kg.hl^{-1}. The mass of 1000 grains also did not differ significantly between the two growing seasons. The average values obtained were 43.9 g in 2024 and 46.2 g in 2025. In 2025, a positive effect of foliar fertilization with 20 and 30 L.ha^{-1} on the mass of 1000 grains was found, which was higher by 1.4 - 1.6 g compared to the N_0 variant.

Table 4

Test weight (kg.hl^{-1}) and weight of 1000 grains (g) of barley depending on foliar fertilization

Fertilization	Test weight		Weight of 1000 grains	
	2024 year	2025 year	2024 year	2025 year
N_0	64.4 ns**	63.7 ns	43.6 ns	45.3 b*
N-10 L	64.6	63.8	43.8	45.8 b
N-20 L	64.3	64.5	43.9	46.9 a
N-30 L	64.4	65.0	44.2	46.7 a
Average	64.4	64.2	43.9	46.2

*Values with identical letters within each column are not significantly different at p<0.05 according to Duncan's multiple range test.
**Not significantly different at p<0.05 according to Duncan's multiple range test.

Table 5

Grain protein concentration (%) and yield (kg.ha^{-1}) of barley depending on foliar fertilization

Fertilization	Grain protein concentration		Grain protein yield	
	2024 year	2025 year	2024 year	2025 year
N_0	9.8 b*	10.6 b	351.1 c	459.0 c
N-10 L	10.0 b	10.8 b	419.4 b	550.6 b
N-20 L	9.4 c	11.2 ab	400.8 b	602.3 a
N-30 L	10.6 a	11.8 a	481.5 a	588.8 a
Average	9.9	11.1	414.2	550.2

*Values with identical letters within each column are not significantly different at p<0.05 according to Duncan's multiple range test.

The percentage of crude protein of barley grain in 2024 harvest year varied within relatively narrow limits from 9.8% in the unfertilized control to 10.6% at a rate of 30 L.ha^{-1} and the values corresponded to barley with brewing qualities. (Table 5). The concentration of grain protein in the experimental 2025 increased with the doses of foliar nitrogen treatment: from 10.6% in the N_0 variant to 11.8% in the 30 L.ha^{-1} treatments. A mathematically proven effect

on the concentration of protein in the grain compared to the control was established only with the application of 30 L.ha^{-1} of foliar fertilizer. In the experimental year 2025, higher crude protein yield was obtained in all variants of the study. This increase compared to 2024 was due to the increased levels of grain yield and the distribution of precipitation and average monthly temperatures. A rate of 30 L.ha^{-1} foliar nitrogen leaded to the highest grain protein yield of 481.5 kg.ha^{-1} in 2024. In 2025, foliar fertilization with 20 and 30 L.ha^{-1} had been proven to lead to high grain protein yields of 588.8-602.3 kg.ha^{-1}.

CONCLUSIONS

Application of 10, 20 and 30 L.ha^{-1} of NitroTOP NG foliar fertilizer proven increased the grain and grain+straw yields of malting barley, compared to the unfertilized control. A rate of 30 L.ha^{-1} was highly effective under drought conditions in 2024 and the obtained grain and grain+straw yields exceeded the control by 26.8% and 16.0%, respectively. In 2025, the highest productivity (5378 kg grain and 12140 kg grain+straw.ha^{-1}) was established in treatment of 20 L.ha^{-1}. Foliar nitrogen application slightly affected the test weight of barley grain. Fertilizer rates of 20 and 30 L.ha^{-1} had a positive effect on the mass of 1000 grains in 2025. The concentration of grain protein in both experimental years met the conditions for brewing qualities, with its content averaging 9.9% in 2024 and 11.1% in 2025. Only the rate of 30 L.ha^{-1} of foliar fertilizer NitroTOP NG proven increased a grain protein concentration compared to the N_0 variant during the study period.

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