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MINERAL FERTILIZATION, FOLIAR APPLICATION AND VARIETIES AS A FACTORS INFLUENCING TRITICALE (X *Triticosecale* Witt.) PRODUCTIVITY

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Abstract

The aim of the study was to investigate the productive possibilities and the structural elements of the yield depending on the variety, the applied fertilizer rate and the import of foliar treatment for winter triticale. The study was conducted in 2019/2020-2020/2021. Colorit, Attila and Boomerang varieties were tested. Nitrogen fertilization was at rates: 0; 60 and 120 kg ha^{-1}. A foliar treatment was performed in the tillering and stem elongation phases. Mineral fertilization was a major impact on the values of all studied parameters and only for the number of grains per spike the variety has a stronger influence. The rate of 120 kg N ha^{-1} was the most productive for the observed traits. The foliar treatment was a stronger effect in the stem elongation phase, except for the plant height, where no differences were found between the two phases. Boomerang was the highest grain yield (45.0%), plant height (23.3%) and number of spikelet per spike (11.5%), Attila was the longest spike (23.4%), and Colorit was the highest number and heaviest grains per spike, 37.9% and 51.72%, respectively, compared to control.

Key words: *foliar application, mineral fertilization, triticale, varieties.*

INTRODUCTION

Although a new crop, the benefits of triticale production are enormous, and this is the reason for its adoption in more than 30 countries with an ever increasing acreage (Arough et al., 2016). Due to its biological properties and advancement in selection, production areas of triticale increase year by year, in recent years in the world triticale has been sawn on over 4 000 000 ha (Maričević et al., 2021). In Bulgaria the areas under triticale vary over the years. According to FAOSTAT, in 2000 the triticale areas were only 5 000 ha. By 2010, increased by over 50% - 11 010 ha. In 2018 they reached the highest values - 18 660 ha. According to the Ministry of Agriculture and Food in 2020 feld to 13 669 ha. Food security is a fundamental precondition for human well-being, and the agricultural and food sector is of major economic importance (Chervenkov & Slavov, 2021). However, negative changes in the environment, because of daily anthropogenic activity, are a continuous and irreversible process (Mitovska, Dimitrov & Chasovnikarova, 2021). In agriculture one of the biggest polluters is mineral fertilization. In commercial agriculture, the use of chemical fertilizers cannot be ruled out completely (Abo-Sedera et al., 2016). According Bielski et al. (2020) nitrogen fertilization was very important agronomy factor of winter triticale grain. However, investments can be reduced through deploying production technologies that are best suited to the cultivated crops and local conditions (Pawlak, 2021). One of the ways to reduce the use of mineral fertilizers is the treatment with foliar application. Foliar fertilizer application after soil fertilization is an effective method to increase to contents of trace elements in crops and crop yield, and to improve the soil environment (Niu et al., 2021). In fact, the purpose of foliar application is not to replace the mineral, but to correct specific physiological growth disorders caused by a deficiency of a particular element or group of elements. Szpunar-Krok et al. (2021) also emphasize that its most important function is in interventions to supplement nutrient deficiencies during the growing season in order to correct poor plant nutrition caused by intensive plant growth, drought, or agrotechnical errors. The authors added that the availability of macro- and micronutrients, such as Ca, S, Mg, K, N, P and Fe, is of key importance for the proper life processes of plant, which directly affects their growth and yield. The foliar application has a number of positive effects. Gamayunova et al. (2021) report that when fed with micro-fertilizers, plants become more resistant to adverse environmental conditions, pest and disease damage. The same authors point out that an important factor in increasing the yield and improving the quality of triticale grain is the use of fertilizing with micro-fertilizers. Through foliar treatment, the uptake of nutrients by plants is faster through the leaves than through the roots. Another positive quality of foliar fertilization is that the risk of leaching is reduced by applying direct treatment to the leaves.In addition, the use of foliar application as a cheap method may be recommended (Nasiru & Najafi, 2015). Timely, directed and correct impact on the processes of the root and foliar nutrition affected the course of formation and the amount of the crop (Shchuklina et al., 2021).

There is no scientific research in Bulgaria on the effect of Lactofol O foliar fertilizer on triticale. Due to the growing interest and the tendency to increase the areas of triticale, we set a goal to study the productive possibilities and the structural elements of the yield depending on the variety, the applied mineral fertilizer rate and the import of foliar treatment.

MATERIALS AND METHODS

The study was conducted in 2019/2020-2020/2021 growing seasons at the Field Crops Institute, Chirpan, Bulgaria (42°11′58″N, 25°19'27″E). A three-factor experiment was carried out using the random block method in four replications with the size of each plot of 10 m^2 after sunflower predecessor. Sowing was done with 550 germinating kernels. Three Bulgarian winter triticale varieties were tested: Colorit (standard variety); Attila and Boomerang (factor C). Fertilization with ammonium nitrate was performed in tillering phase, at rates: 0; 60 and 120 kg ha^{-1} (factor A). Fertilization with triple superphosphate was performed pre-sowing as a background in rate of 60 kg ha^{-1}.

A single foliar treatment at a dose of 6000 ml ha^{-1} was performed in the tillering (treatment 1) and stem elongation (treatment 2) phases (factor B). The treatment was performed manually, early in the morning.The foliar fertilizer (Lactofol O) contains: 21% nitrogen, including nitrate (7.5%), ammonium (4%) and amide (10%); 5% phosphorus; 10% potassium; trace elements - boron (0.02%), copper (0.014%), iron (0.25%), manganese (0.002%), molybdenum (0.002%) and zinc (0.018%). The unfertilized and untreated with mineral and foliar fertilizer variant for Colorit was used as a control.

Statistical analysis was performed by three-factors dispersion using ANOVA and the smallest mean error $p< 0.001\%$.

The soil was classified as Pellic vertisols. The soil analysis showed an organic matter content in the range of 2.4-2.9%; the soil reaction was 6.0-6.5 pH; the content of total N was 0.09%, and the presence of phosphorus and potassium - 5 ppm and 32 ppm, respectively.

Table 1 showed the meteorological conditions during the triticale vegetation for the studied period and the multi-year period. The two observed vegetation periods were a higher sum of temperatures compared to the multi-year period. With regard to precipitation, an increase in the values of the studied years was also observed compared to the 93-year period.

Table 1. Temperature sum and rainfall during the triticale vegetation for 2019/21 and multy-yearperiod

Year	Mounths								Σ
	XI	XII	I	II	III	IV	V	VI	
Temperature sum, Σ˚C									
1928-20	216.0	63.6	-3.6	58.6	191.9	355.3	507.7	624.9	2014
2019/20	336	111	45	154	257	314	516	615	2348
2020/21	197	181	99	126	162	309	524	616	2214
Rainfall, mm									
1928-20	46.9	51.7	43.7	37.7	39.2	44.2	60.5	65.5	389
2019/20	82	22	2	56	67	62	50	63	404
2020/21	7	70	109	26	39	84	35	43	413

RESULTS AND DISCUSSIONS

The analysis of the total dispersion showed that the mineral fertilization was influenced to the greatest extent by more than the parameters (Table 2).

The strongest impact was observed in lenght spike (LS) - 79.621%, followed by number of spiklet per spike (NSS) - 51.26%, grain yield (GY) - 49.01%, grain weight (GW) - 43.83%, plant height (PH) - 39.44%, respectively. Foliar application was a significant effect on most indicators, except for PH.

The variety was the most effective on number of grain per spike (NGS), and showed 57.84% of the total variation. Factor C was unproven only for LS. The conditions of the year were also of great importance for most parameters, but for GY (40.58%) were of the greatest importance. No proven interaction between the factors was observed.

From the independent action of the factors only the mineral fertilization was a proven effect for all studied parameters (Table 3). The effect of foliar application was a stronger of treatment 2 than treatment 1. No significant difference was observed only in PH. The variety was a strong impact on most traits, except LS. Proven higher values were observed only at the plant height of Attila and Boomerang, and the grain yield of Boomerang compared to the control (Colorit). Proven lower values compared to the Colorit standard were NSS, NGS and GW.

Table 2. Effect of mineral fertilization, foliar application and varieties on triticale yield and yield components (mean squares - % of total)

Source of variance	df	Grain yield, kg ha^{-1}	Plant height, cm	Lenght spike, cm	Number of spiklet per spike	Number of grain per spike	Grain weight, g
Replicate	1	40.58***	3.26*	0.47	6.98***	2.85**	19.33***
A	2	49.01***	39.44***	79.62***	51.26***	27.05***	43.83***
B	2	2.02**	0.85	4.16**	2.80*	4.40**	7.29***
C	2	2.67**	17.14***	0.52	21.71***	57.84***	13.58***
AxB	4	0.18	0.50	1.12	2.05	0.23	0.30
AxC	4	1.06	0.43	4.35*	1.58	0.30	0.38
BxC	4	0.37	0.33	0.33	0.36	0.01	0.04
AxBxC	8	0.10	0.91	1.40	1.61	0.55	0.54
Error	26	4.01	37.14	8.04	11.66	6.77	14.73
VC, %	-	4.88	5.43	3.05	2.78	7.60	9.22

A - mineral fertilization; B - foliar application; C – variety

Table 3. Independent action of mineral fertilization, foliar application and varieties on triticale average for test period

variant		Grain yield, kg ha^{-1}	Plant height, cm	Lenght spike, cm	Number of spiklet per spike	Number of grain per spike	Grain weight, g
Mineral fertilization							
No fetilizer		5139.4	110.4	11.2	30.0	55.4	2.21
N_{60}		6336.0***	120.9***	12.5***	31.9***	64.4***	2.63***
N_{120}		6870.8***	124.4***	13.1***	33.1***	71.8***	3.09***
Foliar application							
no treatment		5946.8	117.4	12.1	31.5	60.3	2.46
Treatment 1		6094.6^{NS}	118.9^{NS}	12.2^{NS}	31.4^{NS}	64.5*	2.65**
Treatment 2		6304.8**	119.4^{NS}	12.5***	32.1*	66.8***	2.82***
Variety							
Colorit		6078.3	113.3	12.3	32.2	77.3	2.92
Attila		5929.7^{NS}	119.7***	12.3^{NS}	30.5^{000}	53.9^{000}	2.46^{000}
Boomerang		6338.2*	122.7***	12.2^{NS}	32.3^{NS}	60.4^{000}	2.55^{000}
SD	*5%*	*204.5*	*2.5*	*0.3*	*0.6*	*3.3*	*0.11*
	1%	*276.4*	*3.2*	*0.4*	*0.8*	*4.5*	*0.15*
	0.1%	*368.7*	*4.2*	*0.5*	*1.1*	*6.0*	*0.20*

NS - no significant; *, **, *** significant at P = 5%, P = 1% and P = 0.1%; treatment 1 - foliar application in tillering; treatment 2 - foliar application in stem elongation

GY ranged from 4853 kg ha^{-1} (Boomerang) to 7384 kg ha^{-1} (Boomerang) and the average of all variants was 6115 kg ha^{-1} (Table 4). The varieties reacted differently to the nitrogen fertilization. This implies genotypes differ in absorption, and utilization of N depends on the environment (Belete et al., 2018). Boomerang showed that it is the most responsive to fertilization. Kucukozdemir et al. (2021) reported that, in addition to the genetic yields potential of a variety, the environmental conditions in which the plants are grown are also influence the yield. As far as foliar application treatment 2 was concerned, it was a stronger effect compared to treatment 1. Comparing the effect of mineral fertilizer rates, the N_{120} dose was a greater effect on GY than N_{60}. This result confirms the study of Wojtokowiak et al. (2015).

The authors reported the N_{120} rate as optimal. The complex action of N_{120} + treatment 2 was the strongest effect and increased GY as follows: Boomerang (45.0%), Colorit (35.6%) and Attila (33.7%). For all three varieties, plant height varied under the action of mineral fertilization. Fortunato et al. (2019) reported that with increasing fertilizer rate, the PH also increased.

The lowest value was accounted for Colorit at N_0 (103.9 cm). The tallest plants were registred for Boomerang when fertilized with N_{120}+treatment 1 (131.4 cm).

No differences in height were found with respect to foliar application introduced during the different phases.Zoz et al. (2012) confirmed that foliar fertilization of molybdenum had no proven effect on PH in wheat.

LS of the studied varieties varied from 10.3 cm (Boomerang) to 13.7 cm (Attila). The longest spike, on average for the test period, was observed for Attila, from the variant N_{120} + treatment 2, which exceeded the control by 23.4%. With a minimum difference of 0.1 cm was Boomerang. Foliar fertilizer applied in the stem elongation (treatment 2) showed a stronger effect than treatment 1. Saleen et al. (2020) also reported a positive effect of boron on LS in wheat. Again in wheat Yadav et al. (2021) reported an increase in LS under the action of $ZnSO_4$.

NSS ranged from 28.4 (Attila) to 34.1 (Boomerang) (Table 5). The highest values were obseved in fertilization with 120 kg N ha^{-1} for Boomerang, with 11.8% more than the control. The foliar application for all three varieties was a greater effect in treatment 2. In contrast to our results, Hadi et al. (2020) reported that foliar application in bread wheat with Zn and Fe had a greater effect in the tillering than in the booting phase.

Table 4. Grain yield (kg ha^{-1}), plant height (cm) and length spike (cm) average for test period

	variant	GY, kg ha^{-1}	% of control	PH, cm	% of control	LS, cm	% of control
Colorit	N_0	5093	100.0	103.9	100.0	11.1	100.0
	N_0+treatment1	5217^{NS}	102.4	104.3^{NS}	100.4	11.1^{NS}	100.0
	N_0+treatment2	5508^{NS}	108.2	107.1^{NS}	103.1	11.7^{NS}	105.4
	N_{60}	6152**	120.8	115.0**	110.7	12.5***	112.6
	N_{60}+treatment1	6185**	121.4	116.2**	111.8	12.5***	112.6
	N_{60}+treatment2	6342***	124.5	117.6***	113.2	12.6***	113.5
	N_{120}	6701***	131.6	117.2***	112.8	13.0***	117.1
	N_{120}+treatment1	6605***	129.7	119.0***	114.5	13.0***	117.1
	N_{120}+treatment2	6904***	135.6	119.8***	115.3	13.3***	119.8
Attila	N_0	4859^{NS}	95.4	108.8^{NS}	104.7	11.4^{NS}	102.7
	N_0+treatment1	4903^{NS}	96.3	114.4**	110.1	11.4^{NS}	102.7
	N_0+treatment2	5169^{NS}	101.5	114.2**	109.9	11.7^{NS}	105.4
	N_{60}	6020**	118.2	121.6***	117.0	12.5***	112.6
	N_{60}+treatment1	6172**	121.2	121.1***	116.6	12.5***	112.6
	N_{60}+treatment2	6266***	123.0	121.1***	116.6	12.7***	114.4
	N_{120}	6560***	128.8	126.3***	121.6	12.6***	113.5
	N_{120}+treatment1	6611***	129.8	122.8***	118.2	12.7***	114.4
	N_{120}+treatment2	6810***	133.7	126.9***	122.1	13.7***	123.4
Boomerang	N_0	4853^{NS}	95.3	111.4*	107.2	10.3^{NS}	97.8
	N_0+treatment1	5175^{NS}	101.6	114.1**	109.8	10.9^{NS}	98.2
	N_0+treatment2	5480^{NS}	107.6	115.7**	111.4	11.1^{NS}	100.0
	N_{60}	6237***	122.5	123.9***	119.3	12.5***	112.6
	N_{60}+treatment1	6769***	132.9	126.7***	121.9	12.4**	111.7
	N_{60}+treatment2	6883***	135.2	125.0***	120.3	12.5***	112.6
	N_{120}	7049***	138.4	128.6***	123.8	13.2***	118.9
	N_{120}+treatment1	7215***	141.7	131.4***	126.5	13.3***	119.8
	N_{120}+treatment2	7384***	145.0	128.1***	123.3	13.6***	122.5
SD	*5%*	*613.4*	*12.0*	*7.4*	*7.1*	*0.8*	*7.2*
	1%	*829.2*	*16.3*	*9.7*	*9.3*	*1.0*	*9.0*
	0.1%	*1106.1*	*21.7*	*12.5*	*12.0*	*1.4*	*12.6*

NS - no significant; *, **, *** significant at P = 5%, P = 1% and P = 0.1%; treatment 1 - foliar application in tillering; treatment 2 - foliar application in stem elongation

Table 5. Number of spiklet per spike, number of grain per spike and grain weight (g) average for test period

Variant		NSS	% of control	NGS	% of control	GW, g	% of control
Colorit	N_0	30.5	100.0	65.5	100.0	2.32	100.00
	N_0+treatment1	30.3^{NS}	99.3	67.8^{NS}	103.5	2.41^{NS}	103.88
	N_0+treatment2	31.6^{NS}	103.6	69.5^{NS}	106.1	2.61^{NS}	112.50
	N_{60}	32.4*	106.2	72.0^{NS}	109.9	2.74^{NS}	118.10
	N_{60}+treatment1	32.2^{NS}	105.6	80.0**	122.1	3.00***	129.31
	N_{60}+treatment2	32.7*	107.2	81.7**	124.7	3.10***	133.62
	N_{120}	33.7**	110.5	83.6***	127.6	3.16***	136.21
	N_{120}+treatment1	33.1**	108.5	85.3***	130.2	3.43***	147.85
	N_{120}+treatment2	33.7**	110.5	90.3***	137.9	3.52***	151.72
Attila	N_0	28.4^{NS}	93.1	41.7^{NS}	63.7	1.92^{NS}	82.76
	N_0+treatment1	29.2^{NS}	95.7	47.1^{NS}	71.9	2.11^{NS}	90.95
	N_0+treatment2	29.4^{NS}	96.4	48.7^{NS}	74.4	2.23^{NS}	96.12
	N_{60}	30.5^{NS}	100.0	51.9^{NS}	79.2	2.32^{NS}	100.00
	N_{60}+treatment1	30.2^{NS}	99.0	55.1^{NS}	84.1	2.45^{NS}	105.60
	N_{60}+treatment2	31.4^{NS}	103.0	53.7^{NS}	85.2	2.53^{NS}	109.05
	N_{120}	31.5^{NS}	103.3	57.8^{NS}	88.2	2.61^{NS}	112.50
	N_{120}+treatment1	31.7^{NS}	103.9	61.6^{NS}	94.1	2.84**	122.41
	N_{120}+treatment2	32.2^{NS}	105.6	65.9^{NS}	100.6	3.15***	135.78
Boomerang	N_0	28.9^{NS}	94.8	46.8^{NS}	71.5	1.85^{NS}	79.74
	N_0+treatment1	30.6^{NS}	100.3	54.7^{NS}	83.5	2.16^{NS}	93.10
	N_0+treatment2	30.9^{NS}	101.3	56.7^{NS}	86.6	2.32^{NS}	100.00
	N_{60}	33.2**	108.9	58.4^{NS}	89.2	2.38^{NS}	102.59
	N_{60}+treatment1	32.2^{NS}	105.6	62.1^{NS}	94.8	2.54^{NS}	109.48
	N_{60}+treatment2	32.9*	107.9	62.9^{NS}	96.0	2.63^{NS}	113.36
	N_{120}	34.1***	111.8	65.0^{NS}	99.2	2.87**	123.71
	N_{120}+treatment1	33.7**	110.5	66.9^{NS}	102.1	2.96***	127.59
	N_{120}+treatment2	34.0***	111.5	70.3^{NS}	107.3	3.27***	140.95
SD	*5%*	*1.8*	*5.9*	*10.0*	*15.3*	*0.34*	*14.66*
	1%	*2.5*	*8.2*	*13.5*	*20.6*	*0.46*	*19.83*
	0,1%	*3.3*	*10.8*	*18.0*	*27.5*	*0.59*	*25.43*

NS - no significant; *, **, *** significant at P = 5%, P = 1% and P = 0.1%; treatment 1 - foliar application in tillering; treatment 2 - foliar application in stem elongation

Attila and Boomerang were significantly fewer NGS than Colorit and remained outside the statistical confidence limit. Colorit showedthe best results under the influence of N_{120} + treatment 2, exceeding the variant without fertilization by 37.9%. Tesfaye et al. (2021) confirm the results obtained in our study that the number of grains per spike was significantly influenced by the foliar treatment in bread wheat. Abdelsalam et al. (2019) observed the same trend under the influence of foliar nanofertilizers in bread wheat.

The heaviest grains were reported from Colorit (3.52 g) and the lightest from Boomerang (1.85 g). Treatmant 2 again was a stronger effect than treatment1. Parvin et al. (2020) also reported better results in the introduction of humic acid in the later stages of development than in the earlier ones. For the Boomerang variety, there was a confirmed effect only at the high rate of 120 kg N ha^{-1} alone and 120 kg N ha^{-1} with foliar application. Attila showed a significant increase only at 120 kg N ha^{-1} with foliar application. Meena et al. (2021) confirmed the effect of foliar application ($ZnSO_4$) on grain weight (GW) in bread wheat.

CONCLUSIONS

The results obtained from field experience give us reason to concluded that mineral fertilization was a major impact on the values of all studied parameters and only for the number of grains per spike the varietyhad a stronger influence.The influence of the variety was second in importance for all traits except the length spike.Foliar treatment was the least effect, but not confirmed for plant height.However, all three factors were a proven and significant impact.The rate of 120 kg N ha^{-1} was the most productive for the observed traits. Foliar treatment was a stronger effect in the stem elongation phase, except for plant height, where no differences were found between the two phases.Boomerang was the highest grain yield (45.0%), plant height (23.3%) and number of spikelet per spike (11.5%) compared tocontrol.Attila was the longest spike (23.4%).Coloritwas with the largest number and heaviest grains in spike, 37.9% and 51.72%, respectively.

Based on the results obtained from our study, we recommend that farmers fertilize with 120 kg N ha^{-1} in combination with foliar fertilizer, applied in the later stages of plant development of new, high-yielding varieties and hybrids of triticale.

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