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Influence of processing methods on biological value of winter triticale grain

Summary

The article presents the data of a three-year study on the increase in yield potential and biological value of winter triticale grain achieved through the foliar application of a mixture consisting of a natural growth regulator Ecosil and microelements (MicroStim – Boron, Copper). The object of the study is the Mikhas variety of winter triticale grain with selected processing methods. It was determined that the processing of winter triticale with the studied preparations led to an increase in grain yield of 4.4–5.8%, depending on the mineral nutrition background. The most effective was the use of these preparations on the mineral nutrition background N60+30+30, which led to an increase in the collection of crude protein by 4.1% per hectare. Fractional application of 120 kg of an active ingredient mineral nitrogen and a combined application of Ecosil and MikroStim – Boron, Copper made it possible to achieve 83.1 kg per hectare of extremely scarce, critical amino acids in the grain yield.

Keywords: *winter triticale, foliar additional fertilizing, mineral nitrogen, amino acids, natural regulators of growth and microelements, biological quality, crude protein*

Wpływ metod wytwarzania na wartość biologiczną pszenżyta ozimego

Streszczenie

W artykule przedstawiono wyniki trzyletnich badań nad wzrostem wydajności i wartości biologicznej ziarna pszenżyta ozimego uzyskanego poprzez nawożenie dolistne z zastosowaniem mieszaniny składającej się z naturalnego regulatora wzrostu Ecosil i mikroelementów (MicroStim - bor, miedź). Celem badań jest ocena wpływu zastosowania wybranych metod wytwarzania pszenżyta ozimego odmiany Mikhas. Stwierdzono, że wytwarzanie pszenżyta ozimego z zastosowaniem analizowanych preparatów doprowadziło do wzrostu wydajności ziarna rzędu 4,4-5,8%, w zależności od zastosowanego nawozu mineralnego. Najbardziej efektywne było zastosowanie preparatów mineralnych N60 + 30 + 30, które doprowadziły do zwiększenia zbiorów białka surowego w ilości 4,1% na hektar. Frakcyjne zastosowanie 120 kg aktywnego składnika azotu mineralnego i stosowanie Ecosil i MikroStim - bor, miedź umożliwiło osiągnięcie 83,1 kg na hektar, bez negatywnych zmian w składzie aminokwasowym ziarna.

Słowa kluczowe: *pszenżyto ozime, nawożenie dolistne, azot mineralny, aminokwasy, naturalne regulatory wzrostu i mikroelementy, jakość biologiczna, białko surowe*

Introduction

Triticale, a wheat-rye hybrid, is the first cereal crop created by man. It has several outstanding qualities and represents a new botanical variety. According to experts, it has become one of the leading grain crops and has large genetic diversity.

Agricultural producers in our republic should focus attention on winter triticale, which has large yield potential (Bulavina, 2002; Grib et al., 2002; Kochurko, 2002), increased protein volume (Bobodzhanov et. al, 1988; Bushuk, 1978), and a well-balanced amino acid composition (Fedorchuk, 1988) with high advantages for fodder. Due to the volume of fodder grain units, triticale is superior to the main fodder crops of barley and oats. The protein volume is 1-1.5% higher than that of wheat and 3-4% higher than that of rye (Komarov et al. 2004; Popov, 2012). Using this crop would make it possible to successfully solve problems of plant protein production, both in green mass and fodder grain.

Amino-acid composition is used as a biochemical criterion of the biological value of fodder and food products (Kuptsov and Shor, 2009; Kretovich, 1981). Until recently, the protein nutritional value of various types of fodder and diets was estimated by the amount of digestible protein, without considering protein quality, determined by the volume and ratio of essential amino acids. This, however, considerably reduced the efficiency of feeding. The biological role of essential amino acids comes from the fact that they are part of all major proteins of an animal's body, but they are not synthesized or replaced by other amino acids. They must be ingested with fodder. A dietary deficiency of one or more of them adversely affects the animal organism. According to many research results, the biological value of the protein in a type of grain is strongly influenced by the presence of lysine, tryptophan, threonine and methionine. The most important critical limiting amino acid is lysine, which is part of the complex proteins of the cell nucleus. A dietary deficiency of lysine impairs animal growth and protein deposition and leads to the development of anemia or other health problems (Turbin et al., 1975; Coct, 2006). The public livestock sector of the Republic of Belarus requires 6.3 million tons of fodder grain, using concentrated types of fodder (Golovach, 2009). Obtaining a high quality, environmentally friendly and balanced composition of amino acids in agricultural products, particularly feed grain, is now becoming urgent.

The acreage of winter triticale in the republic has stabilized in recent years at 500,000 hectares. According to this indicator, as reported by the FAO, Belarus is second in the world after Poland. Triticale provides 1.7–1.9 million tons of gross grain output in the republic (Grib, 2014).

According to some research, triticale protein contains more threonine and phenylalanine than wheat protein (Ahmed and Mac-Donald, 1978). It has been reported that the volume of lysine, the first limiting amino acid in triticale, is also higher, and the use of triticale grain in agricultural production can substantially increase the biological value of food products and fodder (Bosieva et al., 2011). In comparison with wheat, triticale grain contains a much higher level of free essential amino acids, such as valine and leucine, giving it more biological value than wheat (Goryanina, 2011). In addition, the amino acid composition of triticale grain is characterized by a high volume of glutamic acid, proline and aspartic acid (Shulyndin et al., 1985).

The most effective and fastest impact on the volume of grain protein comes from applying nitrogen fertilizers (Gladkovsky and Pugach, 1999). Mineev noted that "the results of a fertilizer efficiency study of this or that crop can be considered complete and recommended to production if they were followed by a series of studies on their influence on product quality" (Mineev and Trashkova, 1978).

There have not been sufficient studies on the genetic features of different varieties of triticale, as well as selection, technological and other biological aspects that could be changed by intensification elements, like the application of micro fertilizers and growth regulators and their potential use in the production of various types of fodder (Drobutko, 2013; Verevkina, 2004; Serazhetdinov and Terekhov, 2012).

The aims of this research were to study the impact of the application of natural growth regulators and microelements on the nutritive value of grain protein and the volume of critical essential amino acids and to determine the impact on the discussed rates as a result of the foliar application of a mixture consisting of a natural growth regulator and microelements on two mineral nitrogen backgrounds.

The following tasks were set out to achieve the research aims:

– establish the efficiency of a combined application of natural growth regulators and microelements for the Mikhas variety of winter triticale in the conditions of the southern area of the Republic of Belarus on cultivated sod-podzolic, sandy-loam soil;

– determine the influence of frequency rates of a combined application of natural growth regulators and microelements on two mineral nitrogen backgrounds (90 and 120 $kg \cdot ha^{-1}$) on winter triticale grain quality;

– determine the influence of these techniques on the volume of essential amino acids in winter triticale grain.

The focus of the research was the Mikhas variety of winter triticale crops and the grain quality of winter triticale, using different processing methods: timing and the rate of usage of a combined application of a natural growth regulator Ecosil and microelements in a chelated form (MicroStim – Boron, Copper). Ecosil (5% aqueous emulsion a. e. triterpene acids) is a natural plant growth regulator with a fungicidal effect. The active ingredient is a natural amount of triterpene acids, including neutral isoprenoids and low-polar mono- and sesquiterpene compounds. Microstim – Boron, Copper is water-soluble concentrate, prepared from chelates of copper and boron in an organic-mineral form. The composition includes ($g \cdot dm^{-3}$): 65 of nitrogen, 40 of boron, 40 of copper, 6 of humic substances.

Material and Methods

The experimental field of separate structural subdivisions at "Lyakhovichi State Agrarian College" Institution of Education at the "Baranovichi State University" was used to conduct the field experiments, which included 6 study variants from 2011–2014. The experiment was conducted in quadruple, the placement of variants was randomized, the total area per allotment was 40 m^2, and the control area was 25 m^2. The soil type at the site was sod-podzolic, sandy, spread by a moraine, with the following agrochemical indicators: the volume of humus – 2.7%, mobile forms of phosphorus (P_2O_5) – 200, potassium (K_2O) – 276 $mg \cdot kg^{-1}$, pH (KCl) – 5.86. The preceding plants at the site were annual grasses for green fodder. Soil treatment and care of the crops was done according to industry regulations; the set up and implementation of the experiment were carried out with standard techniques. Phosphorus (P)-potassium (K) fertilizers were introduced at a rate of P 60 ($kg \cdot ha^{-1}$) and K 90 ($kg \cdot ha^{-1}$) in the form of superphosphate and chloride potassium. Seeds had been previously treated with the Skarlet preparation, micro-emulsion (0,4 $dm^3 \cdot t^{-1}$). Spring care consisted of chemical weeding with herbicide Ballerina (0,4 $dm^3 \cdot ha^{-1}$) and double additional fertilizing with nitrogen: early-spring N60 ($kg \cdot ha^{-1}$) Carbamide-ammonia mixture and a second application during the first shoot stage N30 ($kg \cdot ha^{-1}$) in the form Carbamide-ammonia mixture. At the "flag-leaf" stage 37–39 additional foliar fertilizing was done on separate variants according to the research plan at a rate of 30 $kg \cdot ha^{-1}$. The combined application of growth regulators and microfertilizers solutes was introduced manually with a backpack sprayer at the end of the tillering stage 27-29 and at the "flag-leaf" stage 37-39. The estimation of the yield was performed by continuous allotting.

Results and discussion

Weather conditions during the research were close to mean annual rates. The analysis of winter triticale cenosis productivity (tab. 1) revealed that depending on the degree of intensification by means of crop cultivation technology, up to 72.4 c/ha was generated in certain years.

In our experiments, a one-time combined application of Ecosil and Microstim – Boron, Copper in the first shoot stage 30–32 of crop development with a background of 90 kg of mineral nitrogen significantly increased triticale grain yield by

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2.5 c/ha (tab. 1). A double use of these preparations also contributed to productivity growth of 0.9 c/ha.

Fractional application of 120 kg of mineral nitrogen as an active ingredient on the crops of winter triticale significantly increased grain yield from 4.9 c/ha to 63.0 c/ha. The application of a mixture of preparations of Ecosil and MikroStim – Boron, Copper at the first shoot stage 30-32 increased the productivity of the crops and provided a three years' average of 64.7 c/ha of winter triticale grain yield. The double use of these preparations led to a slight change in growth of 1.1 c/ha, which is statistically unreliable.

The greatest increase in the grain yield in our study with a three years' average on a background of high doses of mineral nitrogen applied was observed in variant 6, where the studied preparations Ecosil, Microstim – Boron, Copper were applied twice during the growing season at the tillering and "flag-leaf" stages, resulting in 7.7 c/ha for variant 1 and 2.8 c/ha for variant 4.

Table 1. Grain productivity of the Mikhas variety of winter triticale, (2012–2014), c/ha

Tabela 1. Wydajność Ziarno odmiany Mikhas pszenżyta ozimego, (2012–2014), c/ha

No.	Variant	Timing of Preparation Applications			Grain yield				± to back-ground 1, [c/ha]	± to back-ground 2, [c/ha]
		Stages of development by the BBCH code	Ecosil	Mikrostim, Boron, Copper	2012	2013	2014	Three year average		
1	**Background 1-Control**		—	—	55.4	56.8	62.2	58.1	-	
2	**Background 1+ Microstim – Boron, Copper + Ecosil**	Stage 27-29	+	+	57.9	59.1	64.7	60.6	2.5	
3	**Background 1+ Microstim – Boron, Copper + Ecosil (twice)**	Stage 27-29+ Stage 37-39	+	+	59.7	58.7	66.2	61.5	3.4	
4	**Background 2**	—	—	—	58.6	61.6	68.8	63.0	4.9	-
5	**Background 2 +Microstim – Boron, Copper + Ecosil**	Stage 27-29	+	+	59.8	63.0	71.2	64.7	6.6	1.7
6	**Background 2+ Microstim – Boron, Copper + Ecosil (twice)**	Stage 27-29+ Stage 37-39	+	+	60.2	64.8	72.4	65.8	7.7	2.8
7	**LSD (P<0.05)**				2.41	2.32	2.45	2.39		

**Background 1-N60 (tillering stage 20-22) + N30 (first shoot stage 30-32)*

**Background 2- N60 (tillering stage 20-22) + N30 (first shoot stage 30-32) + N30 ("flag-leaf" stage 37-39)*

The next step of our research was to study the protein productivity and feeding value of winter triticale grain using various cultivation intensifiers. The protein volume in winter triticale grain is an essential criterion in assessing the quality of the crop yield. The quantitative volume in the grain of these plants is an inherited trait. However, it is not stab and varies within certain limits for each variety depending on the cumulative effects of different factors: conditions of cultivation, soil fertilizing, soil and air humidity, temperature, lodging, disease, etc. Over the years of the study the protein volume in the Mikhas variety of winter triticale grain (tab. 2) variant 1 (N60 the tillering stage 20-22 + N30 at the first shoot stage 30-32) amounted to an average of 14.5%.

An additional application of 30 kg of mineral nitrogen in the flag-leaf phase in comparison with the variants in background 1 contributed to the intensification of the process of the outflow of plastic substances from the vegetative parts of the plants into the seeds and increased protein synthesis in triticale, increasing the analyzed parameter by 0.9% (three years' average). The application of preparations of Ecosil and MicroStim – Boron, Copper on winter triticale crops slightly decreased the volume of crude protein.

Table 2. Volume of crude protein in the Mikhas variety of winter triticale grain (2012–2014)

Tabela 2. Objętość białka surowego w ziarnie pszenżyta ozimego odmiany Mikhas (2012–2014)

No.	Variant	Protein volume, %			
		2012	2013	2014	Three year average
1	**Background 1-Control**	14.5	14.8	14.3	14.5
2	**Background 1+ Microstim – Boron, Copper + Ecosil**	14.6	14.7	14.4	14.5
3	**Background 1+ Microstim – Boron, Copper + Ecosil (twice)**	14.6	14.2	14.1	14.3
4	**Background 2**	15.9	15.4	15.0	15.4
5	**Background 2 +Microstim – Boron, Copper + Ecosil**	15.3	14.9	14.7	15.0
6	**Background 2+ Microstim – Boron, Copper + Ecosil (twice)**	15.0	14.5	14.2	14.6
7	***LSD (P<0.05)***	0.33	0.52	0.44	0.44

The percentage of protein does not reflect the true ability of the genotype to synthesize in these conditions. The assessment of a variety is the collected protein per hectare (tab. 3). In the variants with the application of N60 at the tillering stage 20-22 + N30 at the first shoot stage 30-32, the protein collected in the winter triticale grain yield ranged from 7.26 to 7.58 c/ha.

With increasing doesn't of applied mineral nitrogen of up to 120 kg. a. i./ha, the protein productivity of the crops also increased. The maximum collected protein per hectare of 8.35 c/ha in our study was achieved with variant 4, which is 15% higher than in the control variant. The double use of growth regulators and microelements had no advantage over the one-time use on both backgrounds of nutrition.

The use of fertilizers, growth regulators, and microelements affected not only the protein volume, but also the quality of the protein through changes in the amount of a particular fraction of amino acids. With an increase in protein volume in triticale grain, the amount of critically essential amino acids that limit the biological value of the protein (lysine, tryptophan, threonine and methionine) also increased (tab. 4). The experiments showed that there is a direct correlation (r = 0.82) between the volume of essential amino acids in the grains and the protein volume.

Table 3. Collection of crude protein with the grain yield of winter triticale, c/ha (2012-2014)

Tabela 3. Zbiór białka surowego z ziarna pszenżyta ozimego, c/ha (2012-2014)

No.	Variant	The collection of crude protein, c/ha			
		2012	**2013**	**2014**	**Three year average**
1	**Background 1-Control**	6.91	7.23	7.65	7.26
2	**Background 1+ Microstim – Boron, Copper + Ecosil**	7.27	7.47	8.01	7.58
3	**Background 1+ Microstim – Boron, Copper + Ecosil (twice)**	7.49	7.17	8.03	7.56
4	**Background 2**	8.01	8.16	8.88	8.35
5	**Background 2 +Microstim – Boron, Copper + Ecosil**	7.87	8.07	9.00	8.31
6	**Background 2+ Microstim – Boron, Copper + Ecosil (twice)**	7.77	8.08	8.84	8.23

Table 4. Collection of crude protein with the grain yield of winter triticale, c/ha (2012-2014)

Tabela 4. Zbiór białka surowego z ziarna pszenżyta ozimego, c/ha (2012-2014)

No.	Variant	Amino acid				The amount of critical amino acids	Gross yield, [kg·ha^{-1}]
		Lysine	**Methionine**	**Threonine**	**Tryptophan**		
1	**Background 1-Control**	0.441	0.228	0.435	0.145	1.249	72.6
2	**Background 1+ Microstim –Boron, Copper + Ecosil**	0.441	0.228	0.435	0.145	1.249	75.7
3	**Background 1+ Microstim – boron, copper + Ecosil (twice)**	0.436	0.225	0.430	0.144	1.235	76.1
4	**Background 2**	0.460	0.240	0.460	0.153	1.313	82.7
5	**Background 2 +Microstim – Boron, Copper + Ecosil**	0.452	0.235	0.449	0.150	1.285	83.1
6	**Background 2+ Microstim – Boron, Copper + Ecosil (twice)**	0.443	0.229	0.438	0.146	1.256	82.6

With increasing application doses of mineral nitrogen up to 120 kg/ha a. i. (background 2) the volume of lysine in the studied variety of winter triticale grain increased by 0.019g /100g. At the same time the percentage amount with regard to protein declined slightly. Here we have a frequently occurring inverse correlation between protein level and lysine volume. It has been determined that the combined application of a growth regulator and microelements (Ecosil and MikroStim – Boron, Copper) on the background of mineral nitrogen at high doses slightly reduced the overall output of critical amino acids per unit area compared to the background variants.

Conclusions

The conducted research made it possible to establish the impact of the combined application of growth regulations and microelements on crops of winter triticale in the conditions of the sod-podzolic sandy soils of the southeastern part of the Republic of Belarus.

The processing of the Mikhas variety of winter triticale with the preparation of Ecosil and microelements in an organic-mineral form led to an increase in grain yield of 4.4–5.8%, depending on the mineral nutrition background.

The most effective was the use of these preparations on the background of mineral nutrition N60 at the tillering stage 20-22 + N30 at the first shoot stage 30-32 + N30 at the “flag-leaf” stage 37-39, leading to an increase in crude protein collected from one hectare of 4.1%.

Fractional application of 120 kg of an active ingredient nitrogen and a combined application of preparations of Ecosil and MikroStim – Boron, Copper made it possible to achieve

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83.1 kg · ha^{-1} of extremely scarce, critical amino acids in the grain yield.

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