ISSN 1644-0625
ISSN 2300-8504 (online)
www.agricultura.acta.utp.edu.pl

ACTA SCIENTIARUM POLONORUM

Acta Sci. Pol. Agricultura, 15(2) 2016, 49-63

NUTRITIONAL AND TECHNOLOGICAL CHARACTERISTICS OF COMMON AND SPELT WHEATS ARE AFFECTED BY MINERAL FERTILIZER AND ORGANIC STIMULATOR NANO-GRO®

Arkadiusz Stępień, Katarzyna Wojtkowiak,
Krzysztof Orzech, Artur Wiktorski
University of Warmia and Mazury in Olsztyn

Abstract. The effect of biostimulators on plants affects an increase in the level of plant resistance to stress factors which normally occurs in plants, while under non-stress conditions it affects better utilization of the genetically conditioned potential. Based on the field experiments conducted in the years 2011-2013 at the Experimental Station in Tomaszkowo, the effect of mineral fertilization and an organic plant growth stimulator, NANO-GRO®, was determined on the height of grain yield and its components, on the content of macro- and microelements and technological quality (protein and its fraction composition, starch, gluten, Zeleny index, hardness and bulk density) in the grain of common wheat and spelt. The combined application of basic mineral fertilization (NPK) with an organic growth stimulator, NANO-GRO®, had no effect on the grain yield and its components in common wheat and spelt, except increasing 1000 grain weight in spelt. Additional spraying of plants with preparation NANO-GRO® contributed to an increase in the content of P, Ca, Cu, Mn, Zn, a decrease in Mg content in spelt grain, an increase in the amount of Cu, Fe, and a decrease in Mg, Ca, Mn in wheat grain. It also caused an increase in the content of protein, gluten and Zeleny index, and a decrease in bulk density in common wheat grain. The content of starch increased in spelt grain, while the content of protein, gluten and grain hardness decreased. The amount of enzymatic proteins (albumins and globulins) increased in both cereals, while the amount of glutenins (as a result of a decrease in low molecular weight fractions, LMW) increased in spelt grain. An increase in gliadins was observed (ω, α/β, γ) as well as a decrease in the total glutenins (as a result of a decrease in LMW fractions) in common wheat grain. The use of the growth stimulator NANO-GRO® favorably affected the ratio of gliadins to glutenins in spelt grain.

Corresponding author: dr hab. inż. Arkadiusz Stępień, Department of Agroecosystems of University of Warmia and Mazury in Olsztyn, Pl. Łódzki 3, 10-718 Olsztyn,
email: arkadiusz.stepien@uwm.edu.pl

Key words: growth stimulator, macro- and microelements, protein fractions, yield structure

INTRODUCTION

Modern principles of fertilization should guarantee optimum plant nutrition, which would provide complete utilization of the yield-producing potential. From among agronomic treatments in an intensive plant cultivation technology, mineral fertilization including both macro- and microelements is the factor which affects the yield the most, as well as the chemical composition, and consequently the yield quality. Unbalanced mineral fertilization may deteriorate physical and chemical properties of the soil. Inappropriate application of mineral fertilizers, especially nitrogen, may cause a decrease in soil fertility through stimulation of acidification, disturbance of ion balance between elements, reduction in biological activity or induction of salinization [Adamiak *et al*. 2002, Wyszkowski and Sivitskaya 2014, Stępień and Wojtkowiak 2015].

In response to growing agronomic requirements, new solutions are being searched for aiming at providing plants with the most favorable conditions for growth and development, at least through reduction of bio- and abiotic stresses, and consequently increasing the yield and its quality. For this purpose, various types of biostimulators and growth regulators are used in agriculture [Jablonskytė-Raščė *et al.* 2013, Kotwica *et al.* 2014] as well as resistance stimulators [Koziara *et al.* 2006]. Also, microbial life is used when introducing bacterial vaccines [Kołodziejczyk *et al.* 2012, Stępień and Wojtkowiak 2013], algae extracts [Pacholczak *et al.* 2013], soil fertilizers [Sosnowski and Jankowski 2013] or preparations using nanotechnology [Jankowski *et al.* 2013, Parylak and Pytlarz 2015].

Preparation NANO-GRO® does not change the yield structure, nor does it provide any minerals necessary for growth, however it activates the protective mechanism in plants on a cellular level, stimulating them to produce natural growth hormones, i.e. auxins, gibberellins and cytokinins. This activity manifests itself in a quick growth and strong development of the aboveground part and the root system, and thus a greater soil penetration and better nutrient uptake [AGRARIUS 2015].

The aim of the study was evaluation of grain yields and their components, the content of macro- and microelements, technological quality (protein and its fraction composition, starch, gluten, Zeleny index, hardness and bulk density) in the grain of common wheat and spelt under the influence of mineral fertilization and an organic stimulator NANO-GRO®.

MATERIAL AND METHODS

The field experiment was conducted in the years 2011-2013 at the Experimental Station in Tomaszkowo (53°72’ N; 20°42’ E). The experiment was set up with a randomized block design in three replications, on a brown soil of a granulometric composition of light loam as Haplic Cambisol according to FAO [WRB 2014], complex 4, class IIIb. Physical and chemical properties of the soil for the cultivation of common wheat and spelt are presented in Table 1. Soil samples to determine physical and chemical properties were taken from the plough layer 0-30 cm, they were dried in a room temperature, and next screened through a 1 mm × 1 mm mesh sieve. In the collected soil samples, pH was determined with a potentiometric method in KCl solution of a concentration of 1 mol·dm^{-3}, organic carbon content with Tiurin's method, total nitrogen content with Kieldahl method, the content of available forms of phosphorus and potassium with Egner-Riehm's method, magnesium with Schachtschabel's method, and calcium with flame photometry. The content of available microelements in the soil (Zn, Cu, Mn and Fe) was extracted from the sorption complex with the use of HCl at a concentration of 1 mol·dm^{-3}.

Table 1. Physical and chemical soil properties before the experiment started (mean 2011-2012)
Tabela 1. Właściwości fizyczne i chemiczne gleby przed rozpoczęciem badań (średnia z lat 2011--2012)

Measured soil parameters – Parametry gleby	Values – Wartości	
	winter wheat pszenica ozima	winter spelt wheat pszenica ozima orkisz
Soil type – Typ gleby [WRB 2014]	*Haplic Cambisol*	*Haplic Cambisol*
Granulometric composition – Skład granulometryczny	loam – glina	loam – glina
pH in KCl	5.95	5.99
Organic C_{total} – $C_{ogółem}$ – organiczny, g·kg^{-1} DM	7.90	9.98
N_{total} – $N_{ogółem}$, g·kg^{-1} DM	0.95	0.95
P, mg·kg^{-1} DM	442	355
K, mg·kg^{-1} DM	187	265
Mg, mg·kg^{-1} DM	76.0	75.0
Mn, mg·kg^{-1} DM	202	192
Cu, mg·kg^{-1} DM	3.2	2.3
Zn, mg·kg^{-1} DM	7.5	7.8
Fe, mg·kg^{-1} DM	1900	1500

DM – dry matter – sucha masa

The following fertilization variants were used in the experiment:

1) without fertilization – control,
2) NPK – on all plots nitrogen fertilization was used at a rate of 90.0 kg·ha^{-1} with dosage division: into soil 54.0 kg·ha^{-1} (urea 46%) at tillering stage (BBCH 22--23), and foliar application of 36.0 kg·ha^{-1} N (10% urea solution) at the shooting stage (BBCH 30-31). Triple superphosphate (46%) at a rate of 30.2 kg·ha^{-1} P, and potassium salt (56%) at a rate of 83.1 kg·ha^{-1} K before sowing,
3) NPK + NANO-GRO® – application of mineral fertilizers as in the variant „NPK" + preparation NANO-GRO® at the shooting stage (BBCH 30-31). NANO-GRO® at a rate of 8 granules, dissolved in 300 dm^3·ha^{-1} of water were applied foliarly. NANO-GRO® is an organic growth stimulator, in the form of oligosaccharide granule of a size of ~4mm containing sulphates of the following elements: Fe, Co, Al, Mg, Mn, Ni, Ag in nanomolar concentrations (10^{-9} moles). NANO-GRO® has been registered by the Ministry of Agriculture and Rural Development as an organic plant growth stimulator, Decisions S-8/09, S-8a/10, S-8b/11 NANO-GRO® [AGRARIUS 2015].

The plot size was 6.25 m^2, with the plot area for harvest being 4.0 m^2, and the forecrop was winter triticale. Winter spelt cv Szwabenkorn and winter wheat cv Boomer were sown at a density of 5.50 million grains·ha^{-1}, with row spacing of 12 cm. Tillage treatments included skimming carried out just after harvesting the forecrop. In order to cover post-harvest residues, pre-sowing ploughing was conducted as well as harrowing before sowing winter wheat. Right before sowing, on all plots a seeder-cultivator unit was used in order to mix fertilizers and to prepare the soil for sowing. In wheat and spelt cultivation, weeds were controlled with the use of herbicides (in 2011: Mustang Forte 195 SE 1.0 $dm^3 \cdot ha^{-1}$ and Puma Universal 069 WG 1.2 $dm^3 \cdot ha^{-1}$; in 2012: Atlantis 12 OD 0.45 $dm^3 \cdot ha^{-1}$ + Sekator 125 OD 0.15 $dm^3 \cdot ha^{-1}$) in spring after the start of wheat vegetation (BBCH 21-29). No protection against pests or diseases was carried out.

Weather conditions in the growing seasons of 2011/2012 and 2012/2013 as well as the means from the years 1998-2010 are presented in Table 2. From the data it follows that at the time of the start of vegetation (April) 2012, the amount of rainfall exceed over twice the average rainfall totals for the long-term period. Over the study years, in May (the start of ear formation), rainfall totals were similar. In June 2012 (the end of ear formation) the amount of rainfall exceeded the amount of rainfall by 40% when compared with 2013. In July (the stage of grain filling) the amount of rainfall over the years was similar, although it significantly exceeded the means from the long-term period (on average by 39%). Mean air temperatures in the growing season of common wheat and spelt did not differ significantly from the means from the long-term period and from this plant's requirements.

During the course of research, every year the grain was harvested, dried and cleaned. The yield height was determined, while the samples were collected and subjected to chemical analysis of the content of macro- and microelements. The grain was mineralized in the acid mixture of HNO_3 and $HClO_4$ (4:1). The content of Cu, Zn, Mn and Fe was determined in the extract and mineralisate with the use of atomic absorption spectrometry, ASA, with Hitachi Z-8200 atomic absorption spectrophotometer. Phosphorus was determined with vanadium-molybdenic method, while potassium and calcium with atomic emission spectrometry (ESA), and magnesium with atomic absorption spectrometry (ASA) in the material previously mineralized in H_2SO_4 with an addition of H_2O_2 as an oxidizer.

Wet gluten content, bulk density, Zeleny index and grain hardness were determined with the use of NIR System Infratec 1241 Analyzer (Foss, Hillerod, Denmark), which takes measurements of transmission waves from the near-infrared region (570-1050 nm).

The total nitrogen was determined with Kjeldahl method and calculated for the protein content (N·5,75). Quantitative and qualitative characteristics of protein were determined with RP-HPLC technique developed by Wiesser *et al.* [1998]. Albumins were extracted with distilled water, globulins with NaCl and $HKNaPO_4$ mixture, gliadins with 60% ethanol and glutelins in the mixture of 50% propanol-1+2 mol·L^{-1} urea + tris HCl (pH 7.6) and 1% DTE (dithiothreitol) in the presence of nitrogen. Determinations were carried out with Hewlett Packard 1050 HPLC system. Detection of protein fractions was conducted with the wavelength of 210 nm, and their identification consisted in an analysis of spectra and retention time of complete proteins. Research results are presented in mAUs (milliabsorbance units). The results in this paper are the means from two years (2012-2013).

Table 2. Weather conditions in 2011-2013 and the multi-annual average of 1981-2010
Tabela 2. Warunki pogodowe w latach 2011-2013 na tle średnich z lat 1981-2010

Year Rok	Month – Miesiąc												
	September wrzesień	October październik	November listopad	December grudzień	January styczeń	February luty	March marzec	April kwiecień	May maj	June czerwiec	July lipiec	August sierpień	September –August wrzesień – sierpień
	Temperature – Temperatura, ºC												Mean – Średnia
2011/2012	14.1	8.3	3.1	2.3	-1.7	-7.5	3.0	7.8	13.4	15.0	19.0	17.7	7.9
2012/2013	13.5	7.4	4.9	-3.5	-4.6	-1.1	-3.5	5.9	14.8	17.5	18.0	17.4	7.2
1981/2010	12.8	8.0	2.9	-0.9	-2.4	-1.7	1.8	7.7	13.5	16.1	18.7	17.9	7.9
	Rainfall – Opady, mm												Sum – Suma
2011/2012	67.5	29.5	14.1	25.8	61.8	27.7	24.1	73.1	51.7	103.2	121.0	45.1	644.6
2012/2013	45.7	68.5	45.2	11.8	44.1	22.6	18.1	28.5	54.5	61.2	121.9	37.6	559.7
1981/2010	56.9	42.6	44.8	38.2	36.4	24.2	32.9	33.3	58.5	80.4	74.2	59.4	581.8

For statistical calculations, one-way analysis of variance was used, which was in accordance with the mathematical model of the experimental design of randomized blocks. Beside basic statistical parameters, statistically uniform groups were determined with Duncan's test, with the significance level of α = 0.05. To conduct statistical calculations and analyses, program Excel was used as well as statistical package Statistica 10.0 PL.

RESULTS AND DISCUSSION

No unidirectional effect of weather conditions was found on the yield components and nutritive or technological value of the grain of wheat or spelt (Tables 3-7).

Table 3. Grain yield and yield components of winter wheat and winter spelt
Tabela 3. Plon ziarna i element składowe plonu pszenicy ozimej i pszenicy ozimej orkisz

Yield and yield components Plon i jego składowe	Fertilization treatment Wariant nawozowy			Year of research Rok badań	
	without fertilization bez nawożenia	NPK*	NPK + NANO-GRO®	2012	2013
Winter wheat – Pszenica ozima					
Grain yield, Mg·ha^{-1} Plon ziarna	$6.50^{b} \pm 1.94$	$7.12^{ab} \pm 1.33$	$7.31^{a} \pm 1.58$	$5.58^{b} \pm 0.79$	$8.37^{a} \pm 0.52$
Ear length, mm Długość kłosa	$62.24^{a} \pm 5.80$	$66.65^{a} \pm 6.99$	$66.73^{a} \pm 4.15$	$67.67^{a} \pm 6.44$	$62.74^{b} \pm 2.70$
Number of grains per ear Liczba ziaren z kłosa	$24.64^{b} \pm 4.24$	$32.59^{a} \pm 5.55$	$31.44^{a} \pm 3.71$	$31.29^{a} \pm 6.38$	$27.82^{a} \pm 4.95$
Weight of grains per ear, g Masa ziaren z kłosa	$0.95^{b} \pm 0.18$	$1.17^{a} \pm 0.20$	$1.18^{a} \pm 0.11$	$1.12^{a} \pm 0.23$	$1.08^{a} \pm 0.15$
Weight of 1000 grains, g Masa tysiąca ziaren	$38.08^{b} \pm 2.81$	$38.67^{ab} \pm 2.79$	$39.14^{a} \pm 2.48$	$36.24^{b} \pm 0.79$	$41.01^{a} \pm 0.75$
Winter spelt wheat – Pszenica ozima orkisz					
Grain yield, Mg·ha^{-1} Plon ziarna	$5.55^{a} \pm 1.85$	$5.47^{a} \pm 2.08$	$5.39^{a} \pm 1.86$	$3.81^{b} \pm 0.70$	$7.13^{a} \pm 0.52$
Ear length, mm Długość kłosa	$80.68^{a} \pm 10.69$	$84.67^{a} \pm 10.23$	$84.79^{a} \pm 8.85$	$91.66^{a} \pm 4.85$	$75.09^{b} \pm 4.03$
Number of grains per ear Liczba ziaren z kłosa	$22.30^{a} \pm 5.57$	$22.62^{a} \pm 5.72$	$25.38^{a} \pm 6.01$	$19.10^{b} \pm 1.82$	$27.76^{a} \pm 4.60$
Weight of grains per ear, g Masa ziaren z kłosa	$0.82^{a} \pm 0.23$	$0.84^{a} \pm 0.18$	$0.87^{a} \pm 0.26$	$0.66^{b} \pm 0.09$	$1.02^{a} \pm 0.15$
Weight of 1000 grains, g Masa tysiąca ziaren	$39.84^{a} \pm 0.58$	$39.29^{b} \pm 0.29$	$40.17^{a} \pm 0.27$	$38.79^{b} \pm 0.57$	$40.75^{a} \pm 0.46$

* in variants "NPK" and "NPK + NANO-GRO®" the same mineral NPK fertilization (90 kg·ha^{-1} N, 30.2 kg·ha^{-1} P, 83.1 kg·ha^{-1} K) was used – w wariantach "NPK" i "NPK+ NANO-GRO®" stosowano takie samo nawożenie nawozami mineralnymi NPK (90 kg·ha^{-1} N, 30,2 kg·ha^{-1} P, 83,1 kg·ha^{-1} K)

means in rows (separately for fertilization variants and years) followed by the same letter do not differ significantly (α < 0.05) – średnie w wierszach (oddzielnie dla wariantów nawozowych i dla lat) oznaczone tą samą literą nie różnią się istotnie (α < 0,05)

±SD – standard deviation – odchylenie standardowe

Table 4. Content of macronutrients in the grain of winter wheat and winter spelt, g·kg^{-1} of DM.
Tabela 4. Zawartość makroelementów w ziarnie pszenicy ozimej i pszenicy ozimej orkisz, g·kg^{-1} s.m.

Macroelement Makroelement	Fertilization treatment Wariant nawozowy			Year of research Rok badań	
	without fertilization bez nawożenia	NPK*	NPK + NANO-GRO®	2012	2013
Winter wheat – Pszenica ozima					
P	$3.4^{a} \pm 0.05$	$3.4^{a} \pm 0.06$	$3.4^{a} \pm 0.02$	$3.4^{a} \pm 0.04$	$3.4^{a} \pm 0.04$
K	$5.0^{a} \pm 0.60$	$5.6^{a} \pm 0.76$	$5.0^{a} \pm 0.18$	$5.1^{a} \pm 0.64$	$5.3^{a} \pm 0.33$
Mg	$1.2^{ab} \pm 0.02$	$1.3^{a} \pm 0.09$	$1.1^{b} \pm 0.07$	$1.2^{a} \pm 0.11$	$1.2^{a} \pm 0.11$
Ca	$0.4^{b} \pm 0.03$	$0.6^{a} \pm 0.09$	$0.4^{b} \pm 0.01$	$0.4^{a} \pm 0.11$	$0.5^{a} \pm 0.09$
Winter wheat spelt – Pszenica ozima orkisz					
P	$4.0^{a} \pm 0.09$	$3.8^{b} \pm 0.05$	$4.0^{a} \pm 0.10$	$3.9^{a} \pm 0.10$	$3.8^{a} \pm 0.13$
K	$4.8^{ab} \pm 0.09$	$5.0^{a} \pm 0.50$	$4.6^{b} \pm 0.08$	$5.0^{a} \pm 0.30$	$4.6^{a} \pm 0.21$
Mg	$1.3^{a} \pm 0.05$	$1.3^{a} \pm 0.09$	$1.2^{b} \pm 0.03$	$1.3^{a} \pm 0.08$	$1.3^{a} \pm 0.05$
Ca	$0.4^{a} \pm 0.02$	$0.3^{b} \pm 0.05$	$0.4^{a} \pm 0.04$	$0.4^{a} \pm 0.06$	$0.4^{a} \pm 0.07$

* in variants "NPK" and "NPK + NANO-GRO®" the same mineral NPK fertilization (90 kg·ha^{-1} N, 30.2 kg·ha^{-1} P, 83.1 kg·ha^{-1} K) was used – w wariantach "NPK" i "NPK+ NANO-GRO®" stosowano takie samo nawożenie nawozami mineralnymi NPK (90 kg·ha^{-1} N, 30,2 kg·ha^{-1} P, 83,1 kg·ha^{-1} K)
means in rows (separately for fertilization variants and years) followed by the same letter do not differ significantly ($\alpha < 0.05$) – średnie w wierszach (oddzielnie dla wariantów nawozowych i dla lat) oznaczone tą samą literą nie różnią się istotnie ($\alpha < 0,05$)
±SD – standard deviation – odchylenie standardowe

Table 5. Content of micronutrients in the grain of winter wheat and winter spelt, mg·kg^{-1} of DM.
Tabela 5. Zawartość mikroelementów w ziarnie pszenicy ozimej i pszenicy ozimej orkisz, mg·kg^{-1} s.m.

Microelement Mikroelement	Fertilization treatment Wariant nawozowy			Year of research Rok badań	
	without fertilization bez nawożenia	NPK*	NPK + NANO-GRO®	2012	2013
Winter wheat – Pszenica ozima					
Cu	$1.53^{c} \pm 0.32$	$2.08^{b} \pm 0.38$	$2.85^{a} \pm 0.22$	$2.13^{a} \pm 0.53$	$2.18^{a} \pm 0.75$
Mn	$31.43^{c} \pm 1.47$	$35.70^{a} \pm 2.83$	$34.40^{b} \pm 1.08$	$35.09^{a} \pm 2.60$	$32.60^{b} \pm 2.01$
Fe	$54.73^{b} \pm 9.59$	$53.60^{c} \pm 4.19$	$58.00^{a} \pm 1.40$	$51.40^{b} \pm 12.5$	$59.40^{a} \pm 10.10$
Zn	$25.00^{b} \pm 8.78$	$29.54^{a} \pm 3.05$	$29.70^{a} \pm 1.30$	$24.51^{b} \pm 5.85$	$31.64^{a} \pm 1.72$
Winter wheat spelt – Pszenica ozima orkisz					
Cu	$2.37^{c} \pm 1.18$	$3.65^{b} \pm 0.10$	$4.04^{a} \pm 0.06$	$3.00^{b} \pm 1.29$	$3.71^{a} \pm 0.28$
Mn	$43.23^{a} \pm 5.16$	$41.80^{b} \pm 1.48$	$43.60^{a} \pm 0.84$	$44.04^{a} \pm 3.24$	$41.71^{b} \pm 2.50$
Fe	$57.80^{a} \pm 5.01$	$58.10^{a} \pm 2.11$	$59.00^{a} \pm 0.82$	$53.20^{b} \pm 2.61$	$63.43^{a} \pm 8.33$
Zn	$33.13^{b} \pm 2.32$	$33.41^{b} \pm 3.14$	$35.98^{a} \pm 0.85$	$33.47^{a} \pm 3.37$	$34.87^{a} \pm 3.15$

* in variants "NPK" and "NPK + NANO-GRO®" the same mineral NPK fertilization (90 kg·ha^{-1} N, 30.2 kg·ha^{-1} P, 83.1 kg·ha^{-1} K) was used – w wariantach "NPK" i "NPK+ NANO-GRO®" stosowano takie samo nawożenie nawozami mineralnymi NPK (90 kg·ha^{-1} N, 30,2 kg·ha^{-1} P, 83,1 kg·ha^{-1} K)
means in rows (separately for fertilization variants and years) followed by the same letter do not differ significantly ($\alpha < 0.05$) – średnie w wierszach (oddzielnie dla wariantów nawozowych i dla lat) oznaczone tą samą literą nie różnią się istotnie ($\alpha < 0,05$)
±SD – standard deviation – odchylenie standardowe

Table 6. Physical and chemical parameters of winter wheat and winter spelt
Tabela 6. Właściwości fizyczne i chemiczne ziarna pszenicy ozimej i pszenicy ozimej orkisz

Trait Cecha	Fertilization treatments Wariant nawozowy			Year of research Rok badań	
	without fertilization bez nawożenia	NPK*	NPK + NANO-GRO®	2012	2013
Winter wheat – Pszenica ozima					
Content of protein, % Zawartość białka	9.90^{c} ± 0.88	10.60^{b} ± 0.37	10.80^{a} ± 0.37	9.94^{b} ± 0.64	10.92^{a} ± 0.19
Content of starch, % Zawartość skrobi	71.18^{a} ± 0.71	70.75^{b} ± 1.27	70.57^{b} ± 1.11	69.93^{b} ± 0.58	71.73^{a} ± 0.30
Content of gluten, % Zawartość glutenu	21.32^{c} ± 1.01	22.67^{b} ± 0.23	23.18^{a} ± 0.29	22.13^{b} ± 1.35	22.64^{a} ± 0.39
Zeleny index Wskaźnik Zeleny'ego	20.73^{c} ± 6.54	24.90^{b} ± 3.67	26.47^{a} ± 3.05	20.05^{b} ± 4.10	28.01^{a} ± 1.31
Hardness Twardość ziarna	25.78^{b} ± 6.49	30.83^{a} ± 5.14	29.97^{a} ± 6.71	23.53^{b} ± 3.80	34.19^{a} ± 1.92
Density, kg·hl^{-1} Gęstość objętościowa	74.77^{c} ± 3.87	75.32^{a} ± 3.53	75.12^{b} ± 3.67	71.70^{b} ± 0.42	78.43^{a} ± 0.11
Winter wheat spelt – Pszenica ozima orkisz					
Content of protein, % Zawartość białka	12.45^{b} ±0.38	13.37^{a} ± 0.10	12.70^{b} ± 0.69	12.81^{a} ± 078	12.87^{a} ± 0.35
Content of starch, % Zawartość skrobi	66.58^{b} ± 2.28	66.87^{b} ± 1.62	67.83^{a} ± 1.89	65.38^{b} ± 1.00	68.80^{a} ± 0.50
Content of gluten, % Zawartość glutenu	27.48^{b} ± 0.46	30.22^{a} ± 2.35	28.03^{b} ± 3.26	30.07^{a} ± 2.76	27.09^{b} ± 0.87
Zeleny index Wskaźnik Zeleny'ego	39.13^{b} ± 8.04	41.18^{a} ± 9.55	38.17^{b} ± 6.35	32.23^{b} ± 0.81	46.75^{a} ± 2.61
Hardness Twardość ziarna	45.35^{ab} ± 12.88	48.08^{a} ± 13.25	43.98^{b} ± 6.43	36.09^{b} ± 3.60	55.51^{a} ± 4.54
Density, kg·hl^{-1} Gęstość objętościowa	80.10^{a} ± 0.31	79.60^{b} ± 0.16	79.60^{b} ± 0.12	74.59^{b} ± 0.32	84.95^{a} ± 1.15

* in variants "NPK" and "NPK + NANO-GRO®" the same mineral NPK fertilization (90 kg·ha^{-1} N, 30.2 kg·ha^{-1} P, 83.1 kg·ha^{-1} K) was used – w wariantach "NPK" i "NPK+ NANO-GRO®" stosowano takie samo nawożenie nawozami mineralnymi NPK (90 kg·ha^{-1} N, 30,2 kg·ha^{-1} P, 83,1 kg·ha^{-1} K)
means in rows (separately for fertilization variants and years) followed by the same letter do not differ significantly ($\alpha < 0.05$) – średnie w wierszach (oddzielnie dla wariantów nawozowych i dla lat) oznaczone tą samą literą nie różnią się istotnie ($\alpha < 0,05$)
±SD – standard deviation – odchylenie standardowe

In the growing season 2011/2012 winter wheat and winter spelt were only characterized by a greater ear length. In the growing season 2012/2013 compared with the first year of study, an increase by 50.0% was observed in grain yield, by 13.2% in 1000 grain weight in wheat, and by 87.1% in the grain yield, by 45.3% in the grain number per ear, by 52.2% in grain weight per ear, and by 5.1% in 1000 grain weight in spelt (Table 3). Such differences over the years may result from a strong influence of weather conditions. Higher temperatures in the period of intensive growth in 2013 (April and May on average by 2^{o}C) combined with an optimum rainfall contributed to an increase in growth intensity, and consequently to higher yields and improvement in the yield components.

Table 7. The protein fractions in the grain of winter wheat and winter spelt, mAUs – milliabsorbance units
Tabela 7. Frakcje białka w ziarnie pszenicy ozimej i pszenicy ozimej orkisz, mAUs – milliabsorbance units

Feature – Cecha		Fertilization treatment – Wariant nawozowy			Year of research – Rok badań	
		without fertilization bez nawożenia	NPK	NPK + NANO-GRO®	2012	2013
Winter wheat – Pszenica ozima						
Albumins and globulins – Albuminy i globuliny		$16887^{b} \pm 15$	$17012^{b} \pm 10$	$17763^{a} \pm 155$	$16914^{b} \pm 419$	$17528^{a} \pm 291.0$
Gliadins – Gliadyny	ω	$2221^{b} \pm 36$	$2101^{c} \pm 31$	$2531^{a} \pm 36$	$2096^{b} \pm 195$	$2472^{a} \pm 153$
	α/β	$17263^{b} \pm 42$	$16601^{c} \pm 71$	$19487^{a} \pm 204$	$16733^{b} \pm 1315$	$18835^{a} \pm 1240$
	γ	$11725^{c} \pm 17$	$12067^{b} \pm 87$	$13337^{a} \pm 32$	$11490^{b} \pm 735$	$13262^{a} \pm 112$
	Σ gliadins – Σ gliadyn	$31209^{b} \pm 64$	$30770^{c} \pm 68$	$35355^{a} \pm 267$	$30320^{b} \pm 2196$	$34569^{a} \pm 2870$
Σ Glutenins – Σ Gluteniny	HMW	$7769^{b} \pm 84$	$8772^{a} \pm 39$	$8809^{a} \pm 95$	$7037^{b} \pm 513$	$9863^{a} \pm 489$
	LMW	$20716^{c} \pm 97$	$23275^{a} \pm 205$	$21477^{b} \pm 55$	$19794^{b} \pm 1145$	$23852^{a} \pm 1652$
	Σ glutenins – Σ glutenin	$28486^{c} \pm 179$	$32047^{a} \pm 217$	$30287^{b} \pm 49$	$26831^{b} \pm 1550$	$33715^{a} \pm 1980$
Gliadins: glutenins ratio – Stosunek gliadyny: gluteniny		$1.10^{b} \pm 0.005$	$0.96^{c} \pm 0.007$	$1.17^{a} \pm 0.011$	$1.13^{a} \pm 0.091$	$1.03^{b} \pm 0.056$
Winter wheat spelt – Pszenica ozima orkisz						
Albumins and globulins – Albuminy i globuliny		$18232^{c} \pm 45$	$18554^{b} \pm 17$	$19126^{a} \pm 115$	$19741^{a} \pm 398$	$17533^{b} \pm 154$
Gliadins – Gliadyny	ω	$1685^{b} \pm 13$	$1895^{a} \pm 83$	$1686^{b} \pm 41$	$1614^{b} \pm 107$	$1896^{a} \pm 98$
	α/β	$24198^{b} \pm 363$	$25426^{a} \pm 111$	$23554^{c} \pm 176$	$23723^{b} \pm 859$	$25063^{a} \pm 765$
	γ	$15935^{c} \pm 27$	$18557^{a} \pm 21$	$17986^{b} \pm 13$	$17155^{b} \pm 119$	$17830^{a} \pm 543$
	Σ gliadins – Σ gliadyn	$41818^{c} \pm 377$	$45878^{a} \pm 134$	$43217^{b} \pm 136$	$42486^{b} \pm 1801$	$44789^{a} \pm 2531$
Σ Glutenins – Σ Gluteniny	HMW	$12036^{a} \pm 76$	$11399^{b} \pm 59$	$10698^{c} \pm 268$	$10912^{b} \pm 600$	$11843^{a} \pm 327$
	LMW	$29171^{c} \pm 156$	$30451^{b} \pm 196$	$32018^{a} \pm 440$	$30471^{a} \pm 1266$	$30623^{a} \pm 1456$
	Σ glutenins – Σ glutenin	$41207^{c} \pm 148$	$41851^{b} \pm 189$	$42715^{a} \pm 171$	$41383^{b} \pm 676$	$42465^{a} \pm 1615$
Gliadins: glutenins ratio – Stosunek gliadyny: gluteniny		$1.02^{b} \pm 0.010$	$1.10^{a} \pm 0.005$	$1.01^{b} \pm 0.001$	$1.03^{a} \pm 0.042$	$1.05^{a} \pm 0.022$

* in variants “NPK” and “NPK + NANO-GRO®” the same mineral NPK fertilization (90 $kg \cdot ha^{-1}$ N, 30.2 $kg \cdot ha^{-1}$ P, 83.1 $kg \cdot ha^{-1}$ K) was used – w wariantach “NPK” i “NPK + NANO-GRO®” stosowano takie samo nawożenie nawozami mineralnymi NPK (90 $kg \cdot ha^{-1}$ N, 30,2 $kg \cdot ha^{-1}$ P, 83,1 $kg \cdot ha^{-1}$ K)

means in rows (separately for fertilization variants and years) followed by the same letter do not differ significantly ($\alpha < 0.05$) – średnie w wierszach (oddzielnie dla wariantów nawozowych i dla lat) oznaczone tą samą literą nie różnią się istotnie ($\alpha < 0,05$)

±SD – standard deviation – odchylenie standardowe

Grain of winter spelt cv Schwabenkorn compared with the grain of winter wheat cv Boomer, irrespective of the used fertilization, contained more microelements. In the first year of research, a higher content of Mn (by 7.6%) was found in wheat grain and (by 5.6%) in spelt grain (Table 5). In the following year of research, also a higher content of Fe by 15.6% was found, and Zn by 29.1% in wheat grain, and Cu by 23.7%, Fe by 19.2% in spelt grain.

In the second year of research, in the grain of wheat and spelt, starch content increased (by 2.6% and by 5.2%, respectively), as well as bulk density (by 9.4% and by 13.9, respectively), Zeleny index (by 39.6% and by 45.1%, respectively) and grain hardness (by 45.3% and by 53.8%, respectively) (Table 6). Wheat grain from the second year of research (2013) was characterized by a higher content of protein (by 9.9%) and gluten (by 2.3%). Among the analyzed quality traits in the first year of research, a significantly higher (by 11.0%) gluten content was found in spelt grain.

In the first year of research, the content of structural proteins (albumins and globulins) was lower (by 3.6%) in wheat grain and higher (by 12.6%) in spelt grain (Table 7). In the second year, the grain of wheat and spelt was characterized by a higher content of gluten proteins (gliadins ω, α/β, γ and glutenins LMW and HMW). The growing season 2011/2012 influenced increase in the ratio of gliadins to glutenins (1.13) in wheat grain. Weather conditions had a significant effect on the accumulation of the protein content and its composition [Daniel and Triboi 2000, Buczek and Bobrecka-Jamro 2015, Wojtkowiak *et al.* 2015]. According to Buczek and Bobrecka-Jamro [2015], a higher content of protein (14.5%) and gluten (30.5%) was obtained in the period which was characterized by a temperature similar to the one from the long-term period, and by a moderate rainfall. According to Daniel and Triboi [2000], excessive rainfall and thermal stress cause not only variation in the protein content, but they also deteriorate mechanical resistance of gluten, which is under these conditions affected by a higher rate of the synthesis of gliadins than glutenins. In our studies, huge oscillation in temperatures in the growing season 2011/2012 at the time of protein accumulation (June – July) vegetation of wheat and spelt may have had a negative effect on its content.

Increase in the cereal yield under the effect of mineral fertilization is well documented, however its effectiveness is not always satisfactory. In most studies, an increase in the effectiveness of fertilizing wheat along with an increase in fertilization is estimated to be 60-90 kg·ha N [Podolska *et al.* 2015, Andruszczak *et al.* 2011]. In our studies, when compared with just mineral fertilization (NPK), no significant effect of the applied spraying with growth stimulator NANO-GRO® was observed on the yield and its components in wheat and spelt, except an increase (by 2.2%) in 1000 grain weight in spelt (Table 3). When compared with the plot without fertilization, spraying with NANO-GRO® preparation applied together with mineral fertilizers (NPK + NANO-GRO®) contributed to a significant increase in the grain yield in common wheat (by 12.5%), grain number per ear (by 27.6%), grain weight per ear (by 24.2%) and 1000 grain weight (by 2.8%) (Table 3). Moreover, mineral fertilization alone (NPK) caused an increase in the grain number per ear and grain weight per ear in wheat by 32.6% and by 23.2%, respectively.

Plant supplementation as a response to various types of abiotic stresses, such as: low temperature, drought, excessive moisture, salinity, presence of heavy metals, phytotoxicity of pesticides and fertilizers, may be obtained when using dedicated stimulators. According to Kotwica *et al.* [2014] biostimulator Asahi SL based on active substances from the nitrophenol group used for spraying plants, causes an increase in the height of yield components and grain yield in winter wheat, irrespective of the duration of monoculture and weather conditions over the years of research. In the studies of Dolijanović *et al.* [2013], spelt supplemented with a microbiological preparation Slavol gave higher yields. According to Jablonskytė-Raščė *et al.* [2013] application of bioactivator Ekoplant, Biokal and Terra Sorb caused an improvement in plant biometric indices such as: stem weight, ear length and grain number per wheat ear.

Grain of common wheat and spelt is a rich source of nutrients [Biel *et al.* 2010, Svečnjak *et al.* 2013, Rachoń *et al.* 2015, Stępień and Wojtkowiak 2015]. According to Żuk *et al.* [2015] spelt grain (cv Roter and Speltz), compared with an average content of elements in the common wheat grain, contained a much higher amount of nitrogen (by 18-24%), copper (by 33-56%), iron (by 18-31%), and zinc (by 4-27%). In our studies, spelt grain, compared with common wheat grain, was characterized by a higher content of P and Mg, a lower content of K, and a similar one of Ca (Table 4).

An application of growth stimulator NANO-GRO® and mineral fertilizers (NPK) contributed to an increase in the content of P (by 5.3%) and Ca (33.3%) in spelt grain. Among the analyzed fertilization variants in common wheat, application of mineral fertilizers NPK affected an increase in the calcium content in the grain by 50%. An additional application of spraying with NANO-GRO® preparation together with mineral fertilizers decreased the content of Mg in wheat grain by 15.4%, and the content of Mg in spelt grain by 7.7%, compared with the content of Mg in experimental plants with mineral fertilization (NPK). An application of mineral fertilizers (NPK) in winter spelt affected an increase in K in the grain, compared with the content determined in the grain from the plot without fertilization (statistically insignificant) and from the plot with NPK+ NANO-GRO®

Mineral fertilization NPK, compared with the plot without fertilization contributed to a significant increase in Cu, Mn and Zn in wheat grain by 35.9%, 13.6% and 18.2%, respectively (Table 5). Mineral fertilization NPK together with preparation NANO-GRO®, compared with the plot with mineral fertilization (NPK), increased the content of Cu and Fe by 37.0% and 8.2%%, respectively, while it decreased the content of Mn (by 3.6%). Mineral fertilization NPK compared with the control, caused a significant increase in the content of Cu (54.0%), and a decrease in Mn (by 3.3%) in spelt grain. An application of NPK + NANO-GRO® at the stage BBCH-30-31, compared with the application of mineral fertilizers (NPK), caused an increase in Cu (10.7%.), Mn (4.3%) and Zn (7.7%).

When comparing the results of our studies (Table 6) with the studies of Rachoń *et al.* [2013], both the grain of wheat and spelt were characterized by a lower content of protein and gluten, and a higher content of starch. In our studies, application of mineral fertilizers (NPK), compared with the variant without fertilization, affected an increase in the content of protein, gluten, Zeleny index and hardness, and a decrease in the content of starch in the grain of common wheat and spelt (Table 6). The beneficial effect of nitrogen on the grain yield and flour strength traits (protein content, the amount of gluten, sedimentation index) is confirmed by the studies of Zecevic *et al.* [2010], Jablonskytė-Raščė *et al.* [2013], and Podolska *et al.* [2015].

According to Stankowski *et al.* [2008], nitrogen fertilization had a minimal effect on technological traits of the common wheat grain. An application of NANO-GRO® along with mineral fertilizers (NPK) caused a significant increase in the content of protein, gluten and Zeleny index, and a decrease in bulk density in common wheat grain. In spelt grain, the content of starch increased, while the content of protein, gluten, Zeleny index and grain hardness decreased. According to Jablonskytė-Raščė *et al.* [2013], application of a bio-activator alone (Biokal 01) did not affect unequivocally the grain quality of common wheat and spelt.

In the studies of Buczek and Bobrecka-Jamro [2015], an increase in the production intensity causes an improvement in quality traits in the grain, as well as accumulation of a more valuable fraction of reserve proteins, glutenins, and a smaller amount of gliadins and albumins and globulins. In our studies, in spelt grain under the effect of mineral fertilization NPK, the content of structural and gluten proteins increased, except glutenins HMW (Table 7). An application of mineral fertilization (NPK) with a NANO-GRO® stimulator contributed to an increase in the amount of albumins and globulins (by 3.1%), and low-molecular fractions, LMW (by 5.1%), which affected the final total of glutenins.

An application of the biostimulator NANO-GRO® together with mineral fertilizers (NPK) caused a decrease in the content of gliadins' fraction (ω, α/β, γ) and their total. Decrease in the content of gliadins, considered to be allergenic proteins, may indicate their positive effect, however, an appropriate content of these proteins determines the structure of gluten and usefulness in the bread-making process [Sherry 2009]. An increase in the content of gluten proteins in the grain under the effect of mineral or organic fertilization was confirmed in the studies of Stępień and Wojtkowiak [2013]. In our studies, as a result of mineral fertilization in common wheat, an increase was observed in the content of glutenins (HMW and LMW) and gliadins γ, and a decrease in the content of fractions α/β and ω, which has a significant effect on the total of gliadins. Addition of NANO-GRO® stimulator, compared with the plot fertilized only with mineral fertilizers (NPK), caused an increase in the content of albumins and globulins, gliadins (all fractions), and a decrease in the total of glutenins (as a result of a decrease in LMW fractions). Ratios of gluten proteins (gliadins to glutenins) confirm the high technological value of protein in spelt grain cv Schwabenkorn.

An application of mineral fertilizers (NPK), compared with the plot without fertilization, affected the deterioration in the ratio of gliadins to glutenins. As a result of the application of mineral fertilizers together with spraying with NANO-GRO®, a beneficial average ratio of gliadins to glutenins was obtained (1.01), which indicates a balance in the viscosity and elasticity traits of protein. Inverse correlations in the ratio of gliadins to glutenins was observed in common wheat grain as a result of fertilization or its lack. In our studies, the ratio of gliadins fraction to glutenins, both in the grain of common wheat and spelt, was lower than the values obtained by Gálova and Knoblochova [2001] (for spelt cv Schwabenkorn – 1.24), Stępien and Wojtkowiak [2013] (for winter wheat – 1.27) and Buczek and Bobrecka-Jamro [2015] (for wheat of population and hybrid cultivars – 1.38).

To sum up, based on the available literature and results of our studies, it may be concluded that in many cases a positive effect of biostimulators, including the preparation presented in the current paper, was observed on the condition of plants and the yield quality. NANO-GRO® activates physiological mechanisms in plants inducing responses manifesting themselves, among other things, in the growth and strong root development. This allows for intensification of mineral uptake from the soil, which in turn affects plant growth and yield quality. However, it also happens that after an application of biostimulators no positive effect is observed, or it is unstable over the years. Moreover, sometimes a negative effect is also observed. This may be caused by the correlation between fertilization, soil environment and changeability of weather conditions.

CONCLUSIONS

1. No unidirectional effect of weather conditions was found on the obtained research results. In the second year of research there were more favorable conditions for obtaining higher yields of good quality.

2. An application of mineral fertilization (NPK) with an organic growth stimulator, NANO-GRO®, had no effect on the grain yield and its components in common wheat and winter spelt, except increasing 1000 grain weight in spelt.

3. An additional application of spraying plants with preparation NANO-GRO® contributed to an increase in the content of P, Ca, Cu, Mn, Zn, and a decrease in the content of Mg in spelt grain, increasing the amount of Cu and Fe, and decreasing Mg, Ca and Mn in wheat grain.

4. The combined application of mineral fertilizers (NPK) with NANO-GRO® caused an increase in the content of protein, gluten and Zeleny index, and a decrease in bulk density in common wheat grain. In spelt grain, the content of starch increased, while the content of protein, gluten and grain hardness decreased.

5. An application of the growth stimulator NANO-GRO® increased the amount of enzymatic proteins (albumins and globulins) in both cereals, and favorably affected the ratio of gliadins to glutenins in the spelt grain.

REFERENCES

Adamiak, J., Stępień, A., Adamiak, E., Klimek, D. (2002). The impact of fertilization methods on the nutrient balance and changes of soil chemical features in crop rotation. Arch. Agron. Soil. Sci., 48, 435-443.

AGRARIUS. (2015). Stymulator wzrostu plonowania roślin NANO-GRO®, uwolnij siłę natury i zyskaj", http://www.agrarius.eu.

Andruszczak, S., Kwiecińska-Poppe, E., Kraska, P., Pałys, E. (2011). Yield of winter cultivars of pelt wheat (*Triticum aestivum* ssp. *spelta* L). cultivated under diversified conditions of mineral fertilization and chemical protection. Acta Sci. Pol. Agricultura, 10(4), 5-14, www.agricultura.acta.utp.edu.pl.

Biel, W., Hury, G., Maciorowski, R., Kotlarz, A., Jaskowska, I. (2010). Wpływ zróżnicowanego nawożenia azotem na skład chemiczny ziarna dwóch odmian orkiszu (*Triticum aestivum* ssp. *spelta*). Acta Sci. Pol., Zootechnica, 9(4), 5-14.

Buczek, J., Bobrecka-Jamro, D. (2015). Ocena wskaźników jakościowych ziarna pszenicy populacyjnej i mieszańcowej w zależności od technologii produkcji. Acta Agrophys., 22(3), 247-259.

Daniel, C., Triboi, E. (2000). Effect of temperature and nitrogen nutrition on the grain composition of winter wheat: effects on gliadin content and composition. J. Cereal Sci., 32, 45-56.

Dolijanović, Ž., Oljača, S., Kovačević, D., Dordević, S., Brdar, J. (2013). The effects of different fertilizers on spelt grain yield (*Triticum aestivumssp spelta*). Fourth International Scientific Symposium "Agrosym 2013", Jahorina, 506-510.

Gálová, Z., Knoblochová, H. (2001). Biochemical characteristics of five spelt wheat cultivars (*Triticum spelta* L.). Acta Fytotechnica et Zootechnica, 4, 85-87.

Jablonskytė-Raščė, D., Maikštėnienė, S., Mankevičienė, A. (2013). Evaluation of productivity and quality of common wheat (*Triticum aestivum* L.) and spelt (*Triticum spelta* L.) in relation to nutrition conditions. Zemdirbyste-Agriculture, 100(1), 45-56.

Jankowski, K., Deska, J., Truba, M., Jankowska, J. (2013). Impact on nano-gro stimulator on the seeds germination and growth kinetics of seedlings of selected grass and legumes species. Environmental Protection and Natural Resources, 24, 1(55), 23-26.

Kołodziejczyk, M., Szmigiel, A., Kulig, B. (2012). Plonowanie pszenicy jarej w warunkach zróżnicowanego nawożenia azotem oraz stosowania mikrobiologicznych preparatów poprawiających właściwości gleby. Fragm. Agron., 29(1), 60-69.

Kotwica, K., Jaskulska, I., Gałażewski, L., Jaskulski, D., Lamparski, R. (2014). The effect of tillage and management of post-harvest residues and biostymulant application on the yield of winter wheat in increasing monoculture. Acta Sci. Pol., Agricultura, 13(4), 65-76, www.agricultura.acta.utp.edu.pl.

Koziara, W., Sulewska, H., Panasiewicz, K. (2006). Effect of resistance stimulator application to some agricultural crops. J. Res. Appl. Agric. Engng., 51(2), 82-87.

Pacholczak, A., Szydło, W., Petelewicz, P., Szulczyk, K. (2013). The effect of AlgaminoPlant on rhizogenesis in stem cutting of *Physocarpus opulifolius* 'Dart's Gold' and 'Red Baron'. Acta Sci. Pol. Hortorum Cultus, 12(3), 105-116.

Parylak, D., Pytlarz, E. (2015). Wykorzystanie biostymulatora Nano-Gro i międzyplonu ścierniskowego jako czynnika fitosanitarnego w monokulturowej uprawie pszenicy ozimej. Progress in Plant Protection, 55(2), 154-158.

Podolska, G., Rothkaehl, J., Górniak, W., Stępniewska, S. (2015). Wpływ nawożenia azotem i gęstości siewu a plon i wartość wypiekową pszenicy orkisz (*Triticum aestivum.* ssp. *spelta*) odmiany Rokosz. Ann. Univ. Mariae Curie-Skłodowska, Sect. E, 70(1), 93-103.

Rachoń, L., Szumiało, G., Brodowska, M., Woźniak, A. (2015). Nutritional value and mineral composition of grain of selected wheat species depending on the intensity of a production technology. J. Elem., 20(3), 705-715.

Rachoń, L., Szumiało, G., Kurzydłowska, I. (2013). Wpływ intensywności technologii produkcji na jakość ziarna pszenicy zwyczajnej, twardej, orkiszu i jednoziarnistej. Ann. Univ. Mariae Curie-Skłodowska, Sec. E, 68(2), 60-68.

Sherry, P. R. (2009). Wheat. Journal of Experimental Botany, 60(6), 1537-1553.

Sosnowski, J., Jankowski, K. (2013). Effect of soil fertilizer UGMAX on feed value of some grass species depending on their cuts. Acta Sci. Pol. Agricultura 12(1), 35-44, www.agricultura.acta.utp.edu.pl.

Stankowski, S., Smagacz, J., Hury, G., Błasik, S. (2008). Wpływ intensywności nawożenia azotem na jakość ziarna i mąki odmian pszenicy ozimej. Acta Sci. Pol. Agricultura, 7(3), 105--114, www.agricultura.acta.utp.edu.pl.

Stępień, A., Wojtkowiak, K. (2015). Effect of meat and bone meal on the content of microelements in the soil and wheat grains and oilseed rape seeds. J. Elem., 20(4), 999-1010.

Stępień, A., Wojtkowiak, K. (2013). Composition of gluten proteins in spring and winter wheat grain cultivated under conditions of varied fertilization. Acta Agric. Scand. B-S P, 63(7), 588-594.

Svečnjak, Z, Jenel, M, Bujan, M, Witali, D, Dragojević, I.V. (2013). Trace element concentrations in the grain of wheat cultivars as affected by nitrogen fertilization. Agr. Food Sci., 22, 445-451.

Wieser, H., Antes, S., Seilmeier, W. (1998). Quantitative determination of gluten protein types in wheat flour by reversed-phase high-performance liquid chromatography. Cereal Chem., 75, 644-650.

Wojtkowiak, K., Stępień, A., Konopka, I. (2015). Protein composition of spring triticale grain inthe conditions of diversified fertilization systems. Acta Sci. Pol. Agricultura, 14(2), 77-87, www.agricultura.acta.utp.edu.pl.

WRB (2014). World reference base for soil resources. International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. FAO, Rome.

Wyszkowski, M., Sivitskaya, V. (2014). Changes in the content of some micronutrients in soil contaminated with heating oil after the application of different substances. J. Elem., 19(1), 243-252.

Zecevic, V., Knezevic, D., Boskovic, J., Micanovic, D., Dozet, G. (2010). Effect of nitrogen fertilization on winter wheat quality. Cereal Res. Commun., 38, 243-249.

Żuk-Golaszewska, K., Kurowski, T., Załuski, D., Sadowska, M., Gołaszewski, J. (2015). Physio-agronomic performance of spring cultivars *T. aestivum* and *T. spelta* grown in organic farming system. Int. J. Plant Prod., 9 (2), 211-236.

ZMIANA WARTOŚCI ODŻYWCZEJ I TECHNOLOGICZNEJ ZIARNA PSZENICY ZWYCZAJNEJ I PSZENICY ORKISZ POD WPŁYWEM NAWOŻENIA MINERALNEGO I ORGANICZNEGO STYMULATORA NANO-GRO®

Streszczenie. Oddziaływanie biostymulatorów na rośliny wpływa na podwyższenie poziomu, naturalnie występującej u roślin, odporności na czynniki stresowe, a w warunkach bezstresowych na lepsze wykorzystanie genetycznie uwarunkowanego potencjału. Na podstawie badań polowych przeprowadzonych w latach 2011-2013 w Zakładzie Dydaktyczno-Doświadczalnym w Tomaszkowie określono wpływ nawożenia mineralnego i organicznego stymulatora wzrostu roślin NANO-GRO® na wysokość plonów ziarna i jego składowych, zawartość makro- i mikroelementów oraz jakość technologiczną (białko i jego skład frakcyjny, skrobia, gluten, wskaźnik Zeleny'ego, twardość i gęstość usypowa) ziarna pszenicy zwyczajnej i pszenicy orkisz. Łączne zastosowanie podstawowego nawożenia mineralnego (NPK) z organicznym stymulatorem wzrostu – NANO-GRO® nie miało wpływu na plon ziarna i jego składowe pszenicy zwyczajnej i orkiszu ozimego, z wyjątkiem zwiększenia masy tysiąca ziaren orkiszu. Dodatkowe zastosowanie opryskiwania roślin preparatem NANO-GRO® przyczyniło się do zwiększenia zawartości P, Ca, Cu, Mn, Zn, obniżenia zawartości Mg w ziarnie orkiszu, zwiększenia ilości Cu, Fe i zmniejszenia Mg, Ca, Mn w ziarnie pszenicy. Spowodowało także zwiększenie zawartości białka, glutenu oraz wskaźnika Zeleny'go, a zmniejszenie gęstości objętościowej w ziarnie pszenicy zwyczajnej. W ziarnie orkiszu wzrosła zawartość skrobi, a zmniejszyła się zawartość białka, glutenu i twardość ziarna. Zwiększyła się ilość białek enzymatycznych (albumin i globulin) w obu zbożach oraz ilość glutenin (jako efekt spadku frakcji niskocząsteczkowych – LMW) w ziarnie orkiszu. Stwierdzono zwiększenie gliadyn (ω, α/β, γ) oraz zmniejszenie sumy glutenin (jako efekt spadku frakcji LMW) w ziarnie pszenicy zwyczajnej. Użycie stymulatora wzrostu NANO-GRO® korzystnie wpłynęło na stosunek gliadyn do glutenin w ziarnie orkiszu.

Słowa kluczowe: frakcje białek, makro- i mikroelementy, struktura plonu, stymulator wzrostu

Accepted for print – Zaakceptowano do druku: 07.03.2016

For citation – Do cytowania:

Stępień, A., Wojtkowiak, K., Orzech, K., Wiktorski, A. (2016). Nutritional and technological characteristics of common and spelt wheats are affected by mineral fertilizer and organic stimulator NANO-GRO®. Acta Sci. Pol. Agricultura, 15(2), 49-63.