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YIELDS OF WINTER TRITICALE UNDER THE INFLUENCE OF NITROGEN FERTILISATION AND FUNGICIDE APPLICATION

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K e y w o r d s: triticosecale, grain yield, yield components, nitrogen doses, antifungal plant protection.

A b s t r a c t

This research encompassed the results of a three-year (2009–2011) field experiment conducted at the Research Station in Bałcyny near Ostróda. The first order factor was nitrogen fertilisation (kg N·ha^{-1}): 30, 60, 90, 120 and 150. The second order factor was the level of protection against fungal diseases: seed dressing, seed dressing + one application of fungicides, seed dressing + two applications of fungicides. The aim the researches was analyzing production output, expressed by grain yield and its components, as affected by different levels of nitrogen fertilisation (the yield forming factor) and protection against pathogens (the yield protecting factor). Statistical analysis of the results showed that the grain yield was significantly affected by the year of the trial, nitrogen fertilisation, fungicidal treatment and interaction of the first and second order factors. The yield structure were significatly influenced by the year of the experiment (1.000 grains weight, ears number m^2), nitrogen fertilisation (1.000 grains weight, grain number per ear), fungicial treatment (1.000 grains weight, grain weight per ear). Calculated regression equation between the dose of nitrogen and grain yield shows that the maximum yield of grain in a field experiment with the variety 'Gniewko' can be achieved at 145 kg N·ha^{-1}. The highest yield obtained (in all research years) from objects with full protection against pathogens.

PLONOWANIE PSZENŻYTA OZIMEGO POD WPŁYWEM NAWOŻENIA AZOTEM I OCHRONY FUNGICYDOWEJ

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S ł o w a k l u c z o w e: pszenżyto, plon ziarna, komponenty plonu, dawki azotu, przeciwgrzybowa ochrona roślin.

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Abstrakt

Materiał badawczy stanowiły wyniki trzyletniego (2009–2011) doświadczenia polowego zlokalizowanego w Zakładzie Produkcyjno-Doświadczalnym w Bałcynach k. Ostródy. Czynnikiem pierwszego rzędu było nawożenie azotem (kg $N \cdot ha^{-1}$): 30, 60, 90, 120, 150. Czynnik drugiego rzędu stanowił poziom ochrony przed chorobami grzybowymi: zaprawa nasienna, zaprawa nasienna + jeden zabieg ochronny, zaprawa nasienna + dwa zabiegi ochronne. Celem badań było poznanie efektów produkcyjnych – wyrażonych plonem ziarna i jego strukturą – pod wpływem zróżnicowanego poziomu nawożenia azotem (czynnik plonotwórczy) i ochrony przed patogenami (czynnik plonochronny). Analiza statystyczna wyników wykazała, iż na plon ziarna istotnie oddziaływały lata badań, nawożenie azotem, ochrona przeciwgrzybowa oraz interakcja czynników pierwszego i drugiego rzędu. Na elementy struktury plonu istotny wpływ miały lata badań (masa 1000 ziarn, liczba kłosów na m^2), nawożenie azotem (masa 1000 ziarn, liczba ziarn w kłosie), ochrona przeciwgrzybowa (masa 1000 ziarn, masa ziarna z kłosa). Z zastosowanego w doświadczeniu rachunku regresji wynika, iż optymalna dawka azotu dla pszenżyta odmiany „Gniewko" kształtuje się na poziomie 145 kg $N \cdot ha^{-1}$. We wszystkich latach badań najwyższy plon otrzymano z obiektów z pełną ochroną przeciwgrzybową.

Introduction

Triticale fields are a distinguishing feature of the Polish agriculture, a large producer of cereal grains in the EU. The total acreage cropped with triticale in Poland corresponds to about 27% of the farmland under this crop in the whole world. European agriculture also appreciated this strain of cereal. Over the last ten years, the triticale total acreage has increased by 26.8%, which clearly shows that the species is gaining importance.

Triticale was designed in order to obtain a species which combines wheat;s good quality of grain yield with the tolerance to abiotic and biotic stresses, i.e. a plant suitable for cultivation in unfavorable conditions, where the yielding of typical cereals is somewhat limited (OETTLER 2005, EREKUL and KÖHN 2006, UGARTE et al. 2007, ESTRADA-CAMPUZANO et al. 2008, VILLEGAS et al. 2010, ESTRADA-CAMPUZANO et al. 2012).

Triticale possesses a broad spectrum of use. Although it is primarily grown as animal fodder (MCGOVERIN et al. 2011), triticale is also a useful feedstock for bioethanol production, and a promising resource for making biogas (GOWDA et al. 2011). According to PELTONEN-SAINO et al. (2009), in the near future, winter cereals will be grown in northern countries on a larger acreage than today.

One of the major agrotechnical factors which affect grain yield and enable farmers to take advantage of the high production potential of cereals is mineral fertilisation, especially nitrogen nutrition (GIUNTA and MOTZO 2004, GIBSON et al. 2007, LESTINGI et al. 2010, ZEČEVIC et al. 2010). JAŚKIEWICZ (2011) claims that yields close to the maximum yielding capacity of a cultivar are achievable only when the agrotechnical requirements of a given cultivar are satisfied, hence the need to determine the response of cultvars to basic agrotechnical conditions.

Bearing in mind the above considerations, the present investigations were undertaken, in which the winter triticale cultivar 'Gniewko' was examined, with the aim of analyzing production output, expressed by grain yield and its components, as affected by different levels of nitrogen fertilisation (the yield forming factor) and protection against pathogens (the yield protecting factor).

Material and Methods

Results of a controlled field experiment, carried out at the Research Station in Bałcyny, Poland (N=53°35'49''; E=19°51'20,3'') were analyzed. The experiment was set up in a random, split-plot design, with four replications. The first order factor was nitrogen fertilisation (kg N·ha^{-1}): A-30, B-60, C-90 (60+30), D-120 (90+30), E-150 (90+60). Doses of nitrogen equal 30 and 60 kg N:ha^{-1} were applied in early spring (BBCH 27). Higher doses (90, 120, 150 kg·ha^{-1}) were applied on two dates: in the resumed plant growth (BBCH 27 and BBCH 38). Phosphorus and potassium fertilisation was applied before sowing in the total amounts of 30 kg P·ha^{-1} and 75 kg K·ha^{-1}. The second order factor was the level of plant protection against fungal diseases: a-seed dressing, b-seed dressing + one application of fungicide, c-seed dressing and two applications of fungicide. The seed dressing preparation was Baytan Universal 094 FS (*active ingredient triadimenol + imazalil + fuberidazole)*. The first fungicidal treatment comprised the spraying of plants with the preparation Input 460 EC in a dose of 1 l·ha^{-1} *(spiroxamine + prothioconazole)* during the first node phase (BBCH 31). The second application of a fungicide took place in the full phase of earing (BBCH 58), when the preparation Prosaro 250 EC *(tebuconazole + prothioconazole)* in a dose of 0.6 l·ha^{-1} was applied. Weeds were controlled by a single autumn spray of a mixture of herbicides (Boxer 800 EC 2 l·ha^{-1} – a.i. *prosulfocarb*, Glean 75 WG 5 g·ha^{-1} – a.i. *chlorosulfuron*, Legato 500 SC 0.5 l·ha^{-1} – a.i. *diflufenican*). The soil was classified as representing the soil valuation class III a, complex 2 (good wheat complex) (Table 1). Phosphorus content was determined by colorimetric method according to PN-R-04023:1996. Potassium content was determined by flame photometry according to PN-R-04022:1996. Magnesium content was determined by ASA according to PN-R-04020:1996. Total nitrogen was determined by colorimetric method according to PB 29 ed. 2. During the three-year research period, winter triticale was preceded by winter oilseed rape. Dressed seed material was sown at the density of 450 germinating kernels per 1 m^2. The results were submitted to analysis of variance in a Statistica®10 software package. Tukey's test at the significance level of 0.05 was run to evaluate the significance of differences and Pearson correlation coefficients were computed.

Table 1

Soil properties

Specification	Vegetation period		
	2008/2009	2009/2010	2010/2011
Soil type	lessives typical		
Soils pecies	medium clay		
Soil pH (1 M KCl)	6.5	6.4	6.5
Soil valuation class	R – IIIa		
Soil suitability complex	good wheat		
Content of nutrients (mg/kg of soil)			
– P	77.4	69.8	73.8
– K	176.7	164.9	157.2
– Mg	92.0	97.0	95.0
– N_{min} (0-90 cm)	19.4	18.5	17.2

Results and Discussion

The three years when the field experiments were conducted were highly varied in the weather conditions, especially in the distribution of rainfalls during the growing season (Figure 1). This had a direct impact on the growth and development of winter triticale. In the analyzed seasons, the early autumn plant growth was accompanied by rainfall shortages and temperatures higher

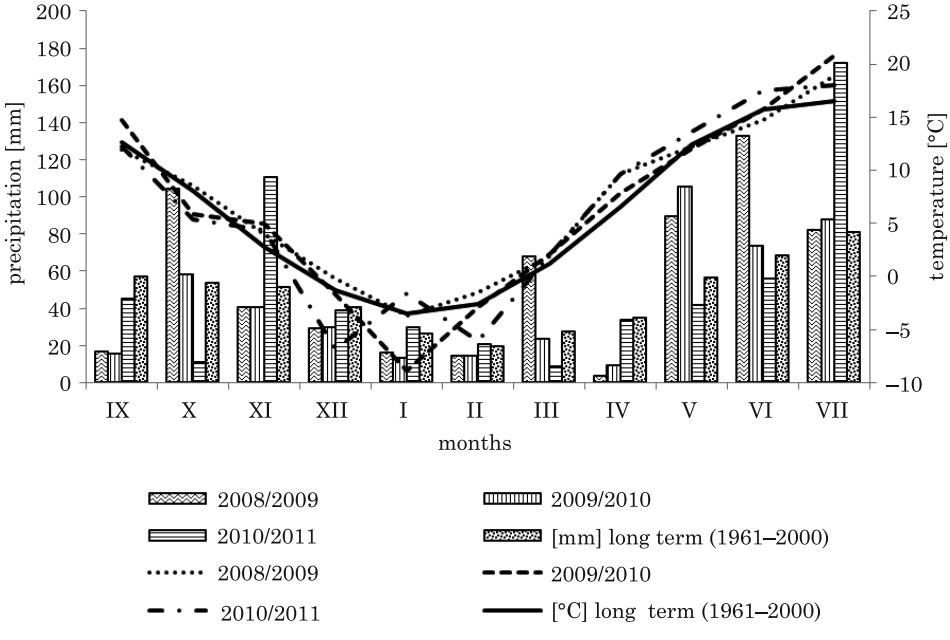

Fig. 1. Rainfall and temperature distribution during the growing seasons

than multi-annual average. In the growing seasons of 2009 and 2010, April was a very dry and warm month, while May was wet. Air temperatures higher than the average occurred in July, which was favorable for the plants as it helped the grain and straw to dry properly. Triticale harvest was particularly troublesome in 2011, when the rainfall in July was as much as 211% higher than the multi-year mean.

The number of ears per 1 m^2 of a field depended on the growing season (Table 2). The highest value of this trait was recorded in 2010. Significantly fewer ears per land unit were determined in 2011, by 9%. Nitrogen fertilisation as well as fungicidal treatments did not have any influence on the value of this yield component. A tendency was noticed for a higher number of ears per square meter on a field fertilized with growing nitrogen doses. The way triticale was protected against pathogens was not significant relative to the ears density. The number of ears per 1 m^2 tended to be higher on the treatments where seed dressing was accompanied by one or two applications of fungicides; it was the lowest on the treatments with seed dressing alone. In another experiment, JAŚKIEWICZ (2011) reported that the intensity of triticale chemical protection against pathogens did not differentiate significantly the number of ears per 1 m^2. In turn, Wróbel and Jabłoński (2004) as well as ADAMIAK et al. (2008) claimed that a triticale protection technology had a significant effect on the number of ears per 1 m^2, and triticale on a treatment with a double application of fungicides grew the most dense field cover in terms of the number of ears.

The grain number in ear was significantly conditioned by the nitrogen fertilisation level. As the amount of applied nitrogen increased, the above yield trait achieved a higher value. However, it was not until the application of 90 kg $N \cdot ha^{-1}$ that the number of grains per ear in winter triticale increased significantly. The highest dose of 150 kg $N \cdot ha^{-1}$ had a positive effect on the number of grains per ear, but the difference was not significant. The current results confirm the reports by DOPKA (2006). In our experiment, the grain number in ear was higher on treatments with the highest level of protection against diseases but without significant difference. ADAMIAK et al. (2008) verified experimentally that the application of fungicides improves the quality parameters of ear. In contrast, this yield structure component was not modified significantly by various protection technologies in the research conducted by WRÓBEL and JABŁOŃSKI (2004) or JAŚKIEWICZ (2011).

Nitrogen fertilisation did not play any larger role in the formation of grain weight per ear. Similar results were reported by DOPKA (2006). Statistical analysis showed that the second experimental factor, such as the way triticale was protected against pathogens, had a significant effect on that trait. The grain weight per ear tended to increase as the intensity of fungicidal protection

Table 2

Grain yield and yield components of winter triticale as affected by year, N fertilisation and protection method

Treatment	Yield (t·ha^{-1})				1000 grain weight (g)				Grain number in ear				Grain weight per ear	Ear number m^2			
	2009	2010	2011	mean	2009	2010	2011	mean	2009	2010	2011	mean	2009–2011 mean	2009	2010	2011	mean
N rate (kg·ha^{-1})																	
30	8.46	8.36	7.06	7.96	36.9	38.9	43.0	39.6	37.4	37.1	36.6	37.0	1.35	608	643	508	586
60	8.84	8.68	8.00	8.51	34.9	38.2	39.9	37.7	38.6	36.1	38.2	37.6	1.36	612	651	589	617
90	9.03	9.07	8.57	8.89	36.2	39.5	43.2	39.6	39.2	38.9	39.8	39.3	1.41	650	653	597	633
120	9.11	9.26	8.97	9.11	34.6	36.7	39.0	36.7	42.3	39.9	40.6	40.9	1.44	648	660	605	638
150	9.25	9.39	9.23	9.29	34.0	36.2	40.6	36.9	40.2	41.6	43.0	41.6	1.40	661	678	662	667
Protection method																	
a	8.49	8.21	8.13	8.28	33.5	35.7	39.4	36.2	39.4	38.6	38.7	38.9	1.34	639	613	609	620
b	8.94	8.92	8.33	8.73	35.4	38.0	41.4	38.3	38.7	39.6	39.3	39.2	1.38	645	655	602	634
c	9.39	9.72	8.64	9.25	37.0	40.0	42.7	39.9	40.4	38.0	40.9	39.8	1.47	623	707	570	633
mean	8.94	8.96	8.37	–	35.3	37.9	41.2	–	39.5	38.7	39.6	–	1.39	636	657	592	–
HSD (0.05)																	
Year (Y)	0.18				1.8				n.s.				n.s.	21.3			
Nitrogen (N)	0.22				2.3				1.5				n.s.	n.s.			
Protect. method (P)	0.18				1.7				n.s.				0.07	n.s.			
YxN	0.40				n.s.				n.s.				n.s.	n.s.			
YxP	0.31				n.s.				n.s.				n.s.	n.s.			
NxP	n.s.				n.s.				n.s.				n.s.	n.s.			
YxNxP	n.s.				n.s.				n.s.				n.s.	n.s.			

dose. In our studies, the weight of grain was from 1.34 g in the treatment with seed dressing alone up to 1.47 g in the treatment with complete protection. A significant increase in the weight of grains from a single ear was observed between these two types of treatments. This finding is confirmed by the experiment of ADAMIAK et al. (2008). On the other hand, JAŚKIEWICZ (2011) did not verify any statistical significance of different levels of triticale protection versus the weight of grains per ear.

The statistical analysis proved that the 1.000 grains weight was significantly affected by the year of experiment, nitrogen fertilisation and fungicidal protection. The lowest 1.000 grains weight was noted in the first year of the research (35.3 g), while the highest one was achieved in the third year (41.2). The references indicate that the 1.000 grains weight of triticale ranges from 35 to 55 g (EREKUL and KÖHN 2006, KOZAK et al. 2007). Nitrogen nutrition affected this trait adversely, but this effect was not unidirectional. In general, the 1,000 grains weight was decreasing as the doses of nitrogen fertiliser increased. The most robust grain was harvested from the treatment which had received the lowest nitrogen fertilisation. Significantly lower values of the 1,000 grains weight were recorded on the treatments given 120 kg $N \cdot ha^{-1}$ than from the ones supplied 30 kg $N \cdot ha^{-1}$. However, the highest dose of nitrogen resulted slightly higher increase of the 1.000 grains weight. SAMBORSKI et al. (2008) also showed that the highest dose of nitrogen had a negative effect on the 1.000 grains weight. In the study by ALARU et al. (2004), a dose of nitrogen above 60 $kg \cdot ha^{-1}$ did not have any significant influence on the 1.000 grains weight. MUT et al. (2005) observed a significant increase of the 1.000 grains weight under the influence of nitrogen fertilisation. In our research, the robustness of grains depended significantly also on the protection of plants from diseases. The highest 1.000 grains weight was recorded under complete protection. Lower weight of 1.000 grains was determined on treatments with a single application of fungicide. Significantly less robust grains were harvested from treatment where seed dressing was the only form of protection against pathogens. The results reported by WRÓBEL and JABŁOŃSKI (2004) coincide with the above information. Contrary results are presented by ADAMIAK et al. (2008), who did not record any significant effect of disease prevention methods on the mass of 1.000 grains.

Our statistical analysis of the results demonstrated a significant effect of the year of the experiments on the yields of winter triticale. The year 2011 was the least favorable for the winter triticale grain yield. Triticale produced significantly higher yields in 2009 and 2010 (Table 2). Among the most important factors affecting grain yields, BIBERDŽIĆ et al. (2013) mentioned the climate. The difference in grain yields between the best and the worst year was 6.6%. In the growing seasons of 2008/2009 and 2009/2010, in response to the

subsequently higher nitrogen doses up to 90 kg N·ha^{-1}, the grain yield increased significantly. The response of triticale to nitrogen was slightly different in the final year of the experiment. A significant increase in grain yield was noticed following the application of 120 kg N·ha^{-1}. MUT et al. (2005) obtained the highest grain yield of triticale supplied with a dose of nitrogen equal 180 kg·ha^{-1}. A dose of nitrogen above 60 kg·ha^{-1} in the study by ALARU et al. (2004), and a dose above 66 kg·ha^{-1} in the experiment by GIBSON et al. (2007) did not affect significantly the volume of grain yield. In our trials, a the highest increase in grain yields (by 0.55 t·ha^{-1}) was observed after an application of just 60 kg N·ha^{-1}. Raising the nitrogen fertilisation level to 90 kg·ha^{-1} caused significantly higher grain yields. The highest yield was harvested from treatments fertilised with 150 kg N·ha^{-1}, the difference was significant versus the 90 kg·ha^{-1} dose. MAŁECKA et al. (2004) reported that the grain yield from winter triticale increased significantly as the nitrogen fertilisation was gradually elevated to 120 kg·ha^{-1}. Its further increase did not cause a significant difference in the volume of grain yields. In the trial run by DOPKA (2006), the effects of 100 and 150 kg N·ha^{-1} were similar. SAMBORSKI et al. (2008) demonstrated a yield-stimulating effect of nitrogen at a dose rising up to 80 kg N·ha^{-1}, with an average yield increase of 21%, and following the application of 170 kg N·ha^{-1}, when a 9.2% yield increase occurred. The technology used to protect triticale from fungal diseases was another factor which strongly differentiated the yield. The weakest yield stimulating effect was produced by seed dressing. Triticale from the treatments with seed dressing and a single application of fungicide yielded significantly better. The highest yield was harvested from the treatments with full protection against fungi. On average, triticale protected by seed dressing alone yielded by 0.45 t·ha^{-1} (5.5%) worse than the same crop given seed dressing and a single spraying of fungicide. Two applications of fungicide in a growing season significantly increased the yield compared with treatments with a single treatment (0.52 t·ha^{-1}, i.e. 6% higher yield).

The influence of the antifungal protection on the yield of winter triticale differed between the years, which was confirmed by the interactions of years and levels of fungicide application. This effect was most distinct in the second year of the experiment, when an increase in grain yields from treatments with complete protection versus the ones with the lowest plant protection input was 1.51 t·ha^{-1}. WRÓBEL and JABŁOŃSKI (2004) recorded the highest yield from treatments with the complete fungicide application. When the protection against fungal diseases had been completely abandoned, the yield decreased by 15%. In the study by ADAMIAK et al. (2008), the yield was 7–16% higher, depending on a cultivar, following a double application of chemicals against fungal pathogens. In our study, an interaction between the years and level of

antifungal protection was determined. ALARU et al. (2009) concluded that the strongest influence on yield and yield structure was produced by the year of an experiment, followed by a cultivar and a division of the nitrogen fertilisation dosage.

Grain yields of winter triticale varieties 'Gniewko' were very high. Yield variability was fairly narrow range. The reason could be the cultivation of triticale after a very good forecrop and high content of mineral nitrogen in the soil. From the calculated regression equation between the dose of nitrogen and grain yield, which is a second-degree curve, it follows that the maximum yield of grain in a field experiment with the variety 'Gniewko' can be achieved at 145 kg N·ha^{-1} (Figure 2).

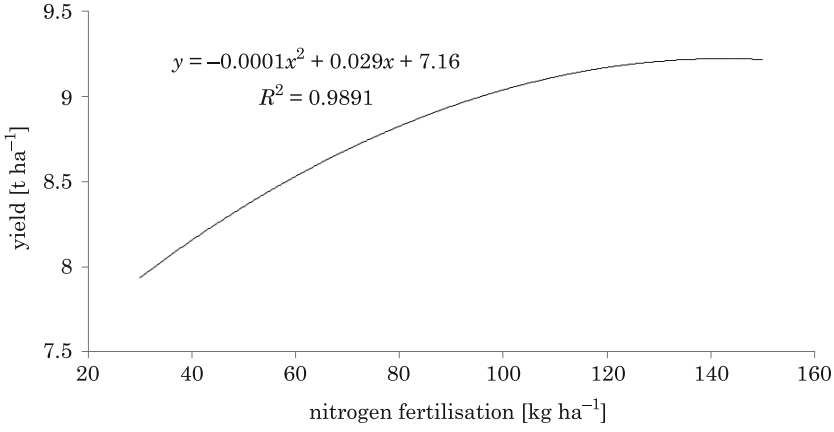

Fig. 2. Regression curve of grain yield (y) of winter triticale cv. „Gniewko" depending on nitrogen fertilisation dose (x)

Table 3 shows the correlation coefficients between the grain yield and its components. Significant positive correlations were observed between yield and grain number in ear, 1000 grain weight and grain weight per ear, grain number in ear and grain weight per ear weight. Table 4 presents the correlation coefficients between the examined traits in the years of study. In the first research year by testing correlation coefficients between yield and 1000-grain weight (r=0.31*), grain weight per ear (r=0.32*), ear number m^{-2} (r=0,27*) positive and significant correlations were found. However, grain number in ear was significantly and positively correlated with grain yield only in the third year (r=0.47*). Table 4 shows the correlation coefficients between the analyzed traits, depending on studied fertilization and protection method treatments. Significant negative correlations were observed between yield and 1000-grain weight in the treatment 30 kg·ha^{-1} N (r=-0.47*), 'a' treatment

(r=-0.26) and 'c' treatment (r=-0.37*). Positive and strong correlations were observed between yield and grain number in ear in the treatment 'b' (r=0.33). The present results confirm the opinion of many authors that the traits analyzed and their correlations are genetically determined, but are strongly modified by the nutrient status of the environment and weather conditions (MÁRTON 2008, BOLTON 2009).

Table 3

Correlation coefficients between grain yield and its components (significant level (p)/ correlation coefficient (r))

Traits	Yield	1000 grain weight	Grain number in ear	Grain weight per ear	Ears number 1 m^2
Yield	1.00	p=0.09/-0.13	p=0.00/0.23*	p=0.17/0.10	p=0.25/0.09
1000 grain weight		1.00	p=0.59/0.04	p=0.01/0.20*	p=0.19/0.09
Grain number in ear			1.00	p=0.00/0.45*	p=0.83/-0.02
Grain weight per ear				1.00	p=0.29/0.08

* significant at 0.05

Table 4

Correlation coefficients between the yield components and year, nitrogen fertilisation and protection method

Specyfication	1000 grain weight	Grain number in ear	Grain weight per ear	Ears number m^2
Correlations between the examined traits				
2008/09	0.31*	0.16	0.32*	0.27*
2009/10	0.42*	0.15	0.10	0.21
2010/11	-0.20	0.47*	0.08	-0.09
Correlations between the traits analyzed in the N fertilisation				
30	-0.47*	0.13	-0.14	0.06
60	0.08	-0.00	0.17	-0.21
90	-0.07	-0.15	-0.02	0.27
120	-0.02	0.19	0.31	-0.03
150	0.32	-0.07	-0.31	0.09
Correlations between the traits analyzed in the protection method				
a	-0.26*	0.18	-0.15	-0.07
b	-0.25	0.33*	0.03	0.04
c	-0.37*	0.16	-0.02	0.22

* significant at 0.05

Conclusions

1. Effect of nitrogen fertilisation had significant influence on grain yield, 1000-grain weight and grain number in ear. Effect of antifungal protection method treatments on grain yield, 1000-grain weight and grain weight per ear.

The weather conditions in the research years were statistically significantly influence on yields, 1000 grain weight and ears number per m^2. Also, the effect of interaction of the year x fertilisation and year x protection method on the yield was significant.

2. Regression equation between the dose of nitrogen and grain yield shows that the maximum yield of grain in a field experiment with the variety „Gniewko" can be achieved at 145 kg $N \cdot ha^{-1}$. The highest yield obtained from objects with full antifungal protection.

3. The triticale grain yield was significantly positively correlated with grain number in ear (0.47). Significant positive correlations of 1000 grain weight, grain weight per ear and ears number m^2 in the first year and positive correlations of 1000-grain weight and grain number in ear in the second year and third year were determined.

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