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ORIGINAL RESEARCH PAPER

The contribution of yield components in determining the productivity of winter wheat (*Triticum aestivum* L.)

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Abstract

The aim of the present study was to determine the effect of different growth regulator rates and nitrogen fertilization levels on yield components and to evaluate their influence on winter wheat productivity. A field experiment with winter wheat 'Muza' was conducted at the Czesławice Experimental Farm, belonging to the University of Life Sciences in Lublin, Poland over the period 2004–2007. In this experiment, the effect of the studied factors on yield and its components was primarily dependent on weather conditions during the study period.

An increase in nitrogen rate from 100 to 150 kg ha^{-1} in 2005 and 2007 had a significant effect on the increase in grain yield per unit area. In 2005, the grain yield rose through increased spike density (by 6.3%) and a higher number of grains per spike (by 1.6%). The 1000-grain weight decreased the grain yield per unit area (by 0.04 t ha^{-1}). In 2007, the higher yield of wheat fertilized with nitrogen at a rate of 150 kg N ha^{-1} was positively affected by all the three yield components. The statistical analysis of the results showed that the winter wheat grain yields were also significantly affected by the retardant rates applied depending on the year.

Keywords
winter wheat; nitrogen fertilization; retardant; yield; yield components

Introduction

In Poland and in many other countries, winter wheat belongs to crops of great economic importance, which results, among others, from its high yielding ability and the high value of its grain [1,2]. Due to the high soil, climate, and agronomic requirements of winter wheat, the grain yield obtained can be significantly differentiated by wheat growing conditions [3]. The yield components, which develop during ontogenesis, are the factors that determine the productivity of a winter wheat crop [4]. The contribution of each of these components in determining grain yield, though it is affected by the genetic properties of a particular cultivar, can change depending on growth and development conditions, in particular under the influence of habitat and agronomic factors [5]. The individual yield components develop at different growth stages and the conditions prevailing during these stages are directly translated into the quantitative parameters of these traits. This is evidence of complex interactions both between plants (the crop components) and between the grain yield components [6]. Intravarietal variation can be observed in the spike structure as well as in grain yield per spike and per plant [7]. In the research on wheat yield, it is important to know the relationships between grain weight per spike and the structural characteristics that determine it. In many studies, it has been reported that grain number per spike has a positive effect on yield [8,9]. Most frequently, number of spikes per unit area, 1000-grain weight, and biological yield are assumed to be the main yield components [6,10,11]. In the case of some cereal varieties, however, grain weight per spike and 1000-grain weight can affect yield more than number of spikes per unit area [12]. In the papers on both spring and winter wheat, the negative correlation between 1000-grain weight and number of grains per spike is generally emphasized [13]. Nevertheless, many authors indicate that a deterioration in the value of one yield trait can be compensated by a more beneficial effect of another trait, which can eliminate the decrease in yield within certain limits [14]. The correlations between the above-mentioned traits and relevant agronomic practices are the essential elements that determine grain yield [15]. On the other hand, it is necessary to determine the importance of individual yield contributing factors in order to achieve the desired economic effects [16,17].

The selection of the research problem was based on the needs to adapt wheat growing technology to the agronomic requirements of winter wheat. This allowed a research hypothesis to be formulated which assumed that a high and valuable winter wheat grain yield can be obtained with an appropriate level of nitrogen fertilization, adjuvant application, and different rates of plant growth regulators.

Material and methods

A field experiment was conducted at the Czesławice Experimental Farm (51°30′ N; 22°26′ E), belonging to the University of Life Sciences in Lublin, Poland over the period 2004–2007. It was located on grey-brown podzolic soil (sandy), designated as PWsp, slightly acidic (pH in 1-M KCl – 6.3–6.6), with high or very high availability of phosphorus, potassium, and magnesium. The experiment was set up as a split-split-plot design in three replicates, in 10-m^2 plots. The experimental design included a treatment without retardant (control treatment) and treatments with the following retardants: Antywylegacz Płynny 675 SL [chlormequat chloride (CC) – 675 g L^{-1}], Moddus 250 EC [trinexapac-ethyl (TE) – 250 g L^{-1}], and Cecefon 465 SL [chlormequat chloride – 310 g L^{-1} + ethephon (E) – 155 g L^{-1}], applied at the recommended rates and at rates reduced by 50 and 67%. The retardants were used at the following growth stages of winter wheat: CC at the 1st node stage (BBCH 31); TE and CC + E at the 2nd node stage (BBCH 32). The growth regulators were applied with the adjuvant Atpolan 80 EC (76% of SN 200 mineral oil) or without adjuvant.

Winter wheat ‘Muza’, was sown after vetch grown for seed. Tillage for wheat was done following good agricultural practices. Before sowing the crop under study, phosphorus and potassium fertilizers were applied at the following amounts: 40 kg P ha^{-1} and 110 kg K ha^{-1}. Fertilization with nitrogen as ammonium nitrate and urea was applied at the rates of 100 and 150 kg of nutrient per ha at two times: the 1st dose, 60 or 95 kg, at the beginning of plant growth (BBCH 29), whereas the 2nd dose, 40 or 55 kg, at the 3rd internode stage (BBCH 33). The whole experiment was sprayed with the herbicides Apyros 75 WG (sulphonylurea – 20 g ha^{-1}) and Starane 250 EC (fluroxypyr 250 g L^{-1} – 0.6 L ha^{-1}) at the full tillering stage (BBCH 29–30). Alert 375 SC (a.i. flusilazole 125 g L^{-1} + carbendazim 250 g L^{-1}) at a rate of 1 L ha^{-1} and Tilt Plus 400 EC (a.i. propiconazole 125 g L^{-1} + fenpropidin 275 g L^{-1}) at a rate of 1 L ha^{-1} were used against fungal diseases. The wheat was sown in the third 10-day period of September at a seeding density of 500 germinating seeds per 1 m^2. Before sowing, seeds were treated with Dividend 030 FS (a.i. difenoconazole 30 g L^{-1}) at a rate of 300 mL of the seed dressing per 100 kg of seed.

The study evaluated the effect of the investigated factors on changes in the value of yield components and their contribution to the differences in grain yield per unit area between pairs of experimental treatments. In the case of cereals, the main yield components include the following: spike density per unit area, number of grains per spike, and 1000-grain weight. The calculation formulas proposed by Rudnicki [18] were used for this purpose. Evaluation of the contribution of individual components to a difference in yield is justified when the difference in yield per unit area between two treatments being compared has been proven statistically.

To evaluate the differences between mean values of the treatments, Tukey's test was used at a significance level of $\alpha = 0.05$. To determine the relationship between winter wheat grain yield and retardant rates, simple correlation coefficients were calculated and a simple linear regression analysis was performed. The calculations were made using Statistica 10 software.

The growing seasons in the period 2004–2007 varied in rainfall intensity and distribution as well as in temperature compared to the long-term means (Tab. 1). The first season (2004/2005) was very warm and wet, in particular during the spring and summer growth period. In the second season (2005/2006), adverse soil moisture conditions prevailed at the time of sowing and at the beginning of fall growth of winter wheat. The last year of the study (2006/2007) was characterized by the lowest rainfall. Compared to the long-term mean, it was lower by 54.8 mm. On the other hand, the mean temperature for the whole growing season was higher by 2.4°C.

Results

Contribution of the yield components to wheat productivity

In the experiment in question, an increase in nitrogen rate from 100 to 150 kg ha^{-1} had a significant effect on increasing grain yield per unit area in 2 out of 3 years of the study (2005 and 2007). In 2005, an increased nitrogen fertilization level was conducive to a higher winter wheat yield by 0.86 t ha^{-1}, i.e., by 9.1% (Tab. 2). The grain yield rose due to the increased spike density (by 0.60 t ha^{-1}, i.e., 6.3%) and higher number of grains per spike (by 0.15 t ha^{-1}, i.e., 1.6%). On the other hand, the 1000-grain weight decreased the grain yield per unit area (by 0.04 t ha^{-1}). As a result, the higher yield of wheat fertilized at the rate of 150 kg N ha^{-1}, compared to the rate of 100 kg N ha^{-1}, was primarily determined by the spike density (84.0%) and to a lesser extent by the number of grains per spike (21.6%). In 2007, all the three yield components also had a positive effect on the higher yield of wheat fertilized with nitrogen at the rate of 150 kg N ha^{-1}. The spike density had the greatest percentage contribution (45.8%). In 2007, the number of grains per spike and the 1000-grain weight contributed to the grain yield in 40.9% and 13.3%, respectively (Tab. 2).

The reduction in the retardant rate to 1/3 of the recommended rate caused, depending on the year of the study, a reduction or an increase in grain yield per unit area (Tab. 3). This factor was found to have a significant effect in 2 years of the study. In 2006, the effect of the reduction in the rates of the individual retardants on grain yield was negative, while in 2007 it was positive (Tab. 3). In 2006, all the main yield components had a negative contribution to the grain yield per unit area. Spike density in the treatments with the retardants under study had the strongest effect on the reduction in grain yield (a 51.0–81.0% contribution). In the case of the treatments with Cecefon 465 SL, the number of grains per spike also had a high contribution to the reduction in grain yield (42.5%). Under the conditions in 2007, two yield component traits – spike density (32.1–46.8%) and number of grains per spike (42.3–60.4%) – had the greatest effect on increasing grain yield. In the case of the treatments with Antywylegacz 675 SL and Cecefon 465 SL, the contribution of the number of grains per spike was higher than that of spike density. The 1000-grain weight had a relatively low contribution to the increase in grain yield per unit area (7.5–12.1%).

Relationship of winter wheat grain yield and its components to retardant rates

The winter wheat grain yields were significantly affected by the retardant rates applied. The regression equations describing this relationship are shown in Tab. 4, while the trend graphs in Fig. 1–Fig. 3. In 2005 and 2007, the grain yield was found to increase

Tab. 1 Weather conditions at the Experimental Station.

Year	Month IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	Total/ Mean
Precipitation (mm)													
2004/2005	21.1	26.1	65.5	15.8	34.8	35.4	42.2	21.2	146.9	48.0	55.8	46.2	559.0
2005/2006	23.1	4.2	24.6	55.7	16.1	24.4	47.4	26.1	68.1	23.2	26.6	202.5	542.0
2006/2007	10.1	31.0	43.7	22.7	83.7	23.8	32.6	16.4	46.4	85.1	70.0	31.4	496.9
1951–2005	51.6	40.1	38.1	31.5	22.7	25.6	26.3	40.2	57.7	65.7	83.5	68.6	551.7
Air temperature (°C)													
2004/2005	12.5	9.8	2.8	1.1	−0.7	−4.0	−1.1	8.4	13.0	15.6	19.8	17.0	7.8
2005/2006	14.7	8.7	2.7	−1.3	−8.2	−4.6	−2.0	8.5	13.3	16.9	21.1	17.4	5.8
2006/2007	15.1	9.8	4.7	2.5	2.0	−2.0	5.7	8.2	14.9	18.2	18.8	18.8	9.7
1951–2005	12.6	7.8	2.5	−1.4	−3.5	−2.7	1.1	7.4	13.0	16.2	17.8	17.1	7.3

Tab. 2 Effect of yield components on the differences in yield per unit area between nitrogen rates in 2005 and 2007.

Yield and yield components	2005					2007				
	nitrogen rate (kg N ha^{-1})		effect of yield components			nitrogen rate (kg N ha^{-1})		effect of yield components		
			contribution		share (%)			contribution		share (%)
	100	150	t ha^{-1}	%		100	150	t ha^{-1}	%	
Grain yield (t ha^{-1})	9.41	10.27	-	-	-	7.37	8.18	-	-	-
Number of spikes per 1 m^2	584	622	0.60	6.3	84.0	534	554	0.30	4.0	45.8
Grain number per spike	34.2	34.8	0.15	1.6	21.6	32.8	33.9	0.27	3.7	40.9
1000-grain weight (g)	43.0	42.8	−0.04	−0.4	−5.6	44.6	45.1	0.08	1.1	13.3
Total	-	-	0.71	7.5	100.0	-	-	0.65	8.8	100.0

when the rates of all the retardants had been reduced. In 2006, this relationship was opposite – a reduction in retardant rates was accompanied by a decrease in winter wheat grain yield. The effect of the retardants was similar and was confirmed in the trend line throughout the study years.

The varied response of winter wheat to the retardant rates applied was certainly dependent on weather conditions. In 2005 and 2007, the air temperature was higher than the long-term mean, while in 2006 its value was lower. Therefore, it can be indicated that in the warmer growing seasons the reduced retardant rates were more effective during the period of crop protection treatments. The full (standard) retardant rates were more effective in the season characterized by a temperature lower than the long-term mean air temperature.

Discussion

In the experiment under discussion, the effect of the studied factors on yield and its components was dependent on weather conditions (including mainly temperature and the amount and distribution of rainfall) during the study period. Many authors stress that the values of yield components are substantially dependent on weather

Tab. 3 The effect of yield components on the difference in yield per unit area between the extreme rates of retardants in 2006 and 2007.

Yield and yields components	Year	CC (L ha^{-1})		Effect of yield components			TE (L ha^{-1})		Effect of yield components			CC + E (L ha^{-1})		Effect of yield components		
				contribution		share (%)			contribution		share (%)			contribution		share (%)
		2.00	0.67	t ha^{-1}	%		0.40	0.13	t ha^{-1}	%		2.00	0.67	t ha^{-1}	%	
Grain yield (t ha^{-1})	2006	7.55	7.03	-	-	-	7.43	6.82	-	-	-	7.62	6.97	-	-	-
Number of spikes per 1 m^2		577	492	−0.42	5.5	81.0	531	500	−0.45	6.1	74.0	531	496	−0.33	4.3	51.0
Grain number per spike		36.7	36.2	−0.05	0.7	8.6	36.4	36.8	−0.09	1.2	14.9	38.6	36.5	−0.28	3.7	42.5
1000-grain weight (g)		36.6	36.0	−0.05	0.7	10.4	36.7	37.0	−0.07	0.9	11.1	37.7	37.4	−0.04	0.5	6.5
Total		-	-	−0.52	6.9	100.0	-	-	−0.61	8.2	100.0	-	-	−0.65	8.5	100.0
Grain yield (t ha^{-1})	2007	6.85	8.39	-	-	-	6.92	8.28	-	-	-	7.04	8.44	-	-	-
Number of spikes per 1 m^2		501	571	0.49	7.2	32.1	505	593	0.64	9.2	46.8	525	580	0.56	8.0	40.3
Grain number per spike		29.4	36.5	0.93	13.5	60.4	32.0	37.1	0.57	8.3	42.3	32.0	35.9	0.67	9.5	47.6
1000-grain weight (g)		44.8	46.4	0.12	1.8	7.5	44.0	46.0	0.15	2.2	10.9	44.6	46.1	0.17	2.4	12.1
Total		-	-	1.54	22.5	100.0	-	-	1.36	19.7	100.0	-	-	1.40	19.9	100.0

conditions and on soil nutrient availability [15,19]. Ahmadizadeh et al. [20] and Hannachi et al. [21] showed that aboveground biomass and harvest index were the most important yield variables to be considered under drought conditions. Chrzanowska-Drożdż [22] and Fageria et al. [23] showed that the variation in winter wheat yield and its components was more dependent on different rates of nitrogen and dates of nitrogen application than on the varietal properties and weather conditions during the study period. In our experiment, the increase in nitrogen rate from 100 to 150 kg ha^{-1} had a significant effect on increasing grain yield per unit area in 2 out of 3 years of the study (2005 and 2007).

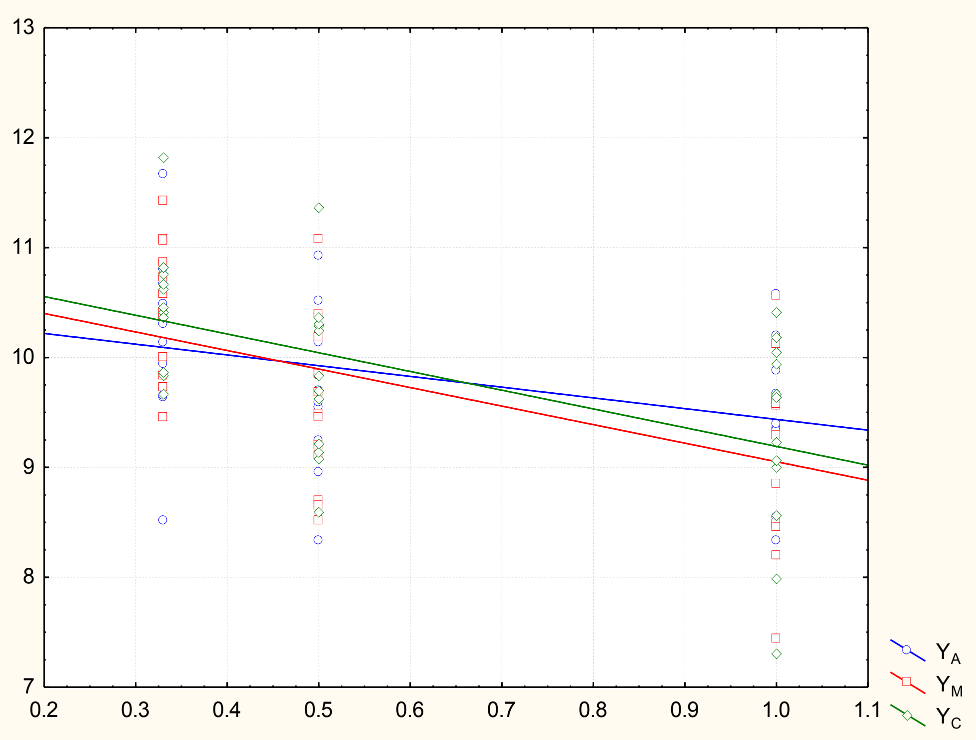
Mądry et al. [24] emphasize that the cereal yield components are strictly related to each other. Deterioration in the value of one yield component trait can be compensated by a high value of another trait and this can reduce a decrease in grain yield. In the study by Weber and Biskupski [25], the higher yields of winter wheat ‘Kobiera’ and ‘Satyna’, compared to the other cultivars, resulted from the increased number of spikes per unit area as well as from the increased weight and number of grains per spike. In 2007, all the three yield components also had a positive effect on the higher yield of wheat fertilized with nitrogen at the rate of 150 kg N ha^{-1}, but the spike density had the greatest percentage contribution. The divergent opinions on the strength of the relationship between cereal grain yield and its components are revealed [3]. In the study by Brzozowska et al. [15], the high spike density per unit area resulted primarily in a decrease in the number of grains per spike and in medium grain filling. On the other hand, Ali et al. [26] revealed that grain yield per plant had a strong and positive genotypic correlation with number of productive tillers per plant and number of grains per spike with maximum direct effects.

There is a high possibility to affect yield components through appropriate agronomic practices, under the influence of which they change to a different degree and often in different directions [22,27]. The reduction in the retardant rate to 1/3 of the recommended rate caused, depending on the year of the study, a reduction or an increase in grain yield per unit area. The varied response of winter wheat to the retardant rates applied was certainly dependent on weather conditions. Many authors indicate that the effect of yield components on yield quantity cannot be unambiguously determined and a precise determination of optimal crop parameters is difficult due to the specific properties of cultivars and different habitat conditions [18,29,30]. Singh and Chaudhary [31] suggested that if the correlation coefficient between a causal factor and the effect (i.e., grain yield) is almost equal to its direct

Tab. 4 Regression equations describing the effect of reduced retardant rate on grain yield of winter wheat.

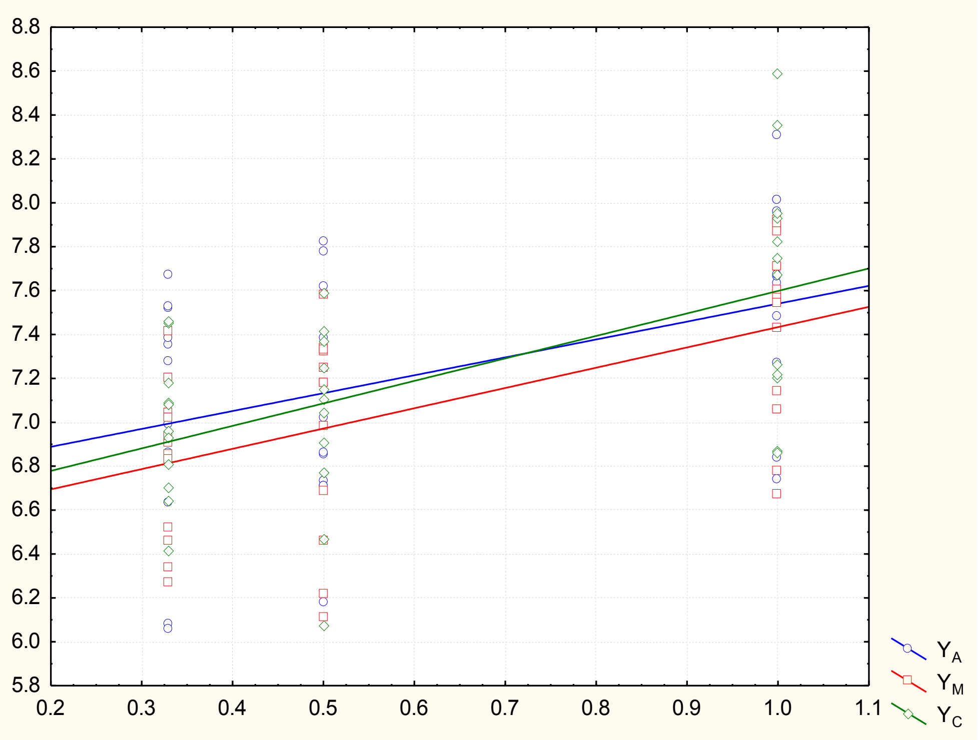
Year	Retardant	Regression equation	Coefficient	
			correlation (r)	determination (r^2)
2005	Antywylegacz Płynny 675 SL	$Y_A = 10.4149 - 0.9797x^*$	−0.37	0.14
	Moddus 250 EC	$Y_M = 10.7387 - 1.6868x^*$	−0.52	0.28
	Cecefon 465 SL	$Y_C = 10.8962 - 1.7051x^*$	−0.54	0.29
2006	Antywylegacz Płynny 675 SL	$Y_A = 6.7254 + 0.8150x$	0.43	0.18
	Moddus 250 EC	$Y_M = 6.5096 + 0.9241x$	0.54	0.29
	Cecefon 465 SL	$Y_C = 6.5738 + 1.0247x$	0.56	0.32
2007	Antywylegacz Płynny 675 SL	$Y_A = 9.1322 - 2.2833x$	−0.72	0.52
	Moddus 250 EC	$Y_M = 8.9261 - 2.0301x$	−0.68	0.46
	Cecefon 465 SL	$Y_C = 9.3051 - 2.2894x$	−0.71	0.50

* Full retardant rate = 1.



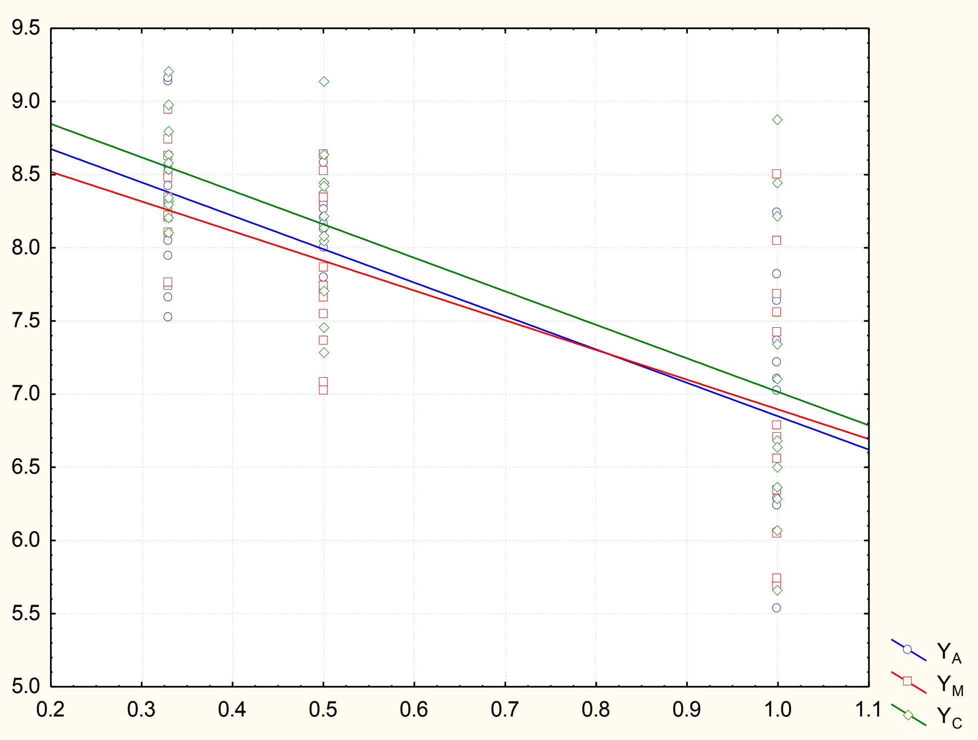
Retardant rate (1 = full rate). Treatment: Y_A with Antywylegacz Płynny 675 SL, Y_M with Moddus 250 EC, Y_C with Cecefon 465 SL.

Fig. 1 The effect of reduced retardant rate on grain yield of winter wheat in 2005.



Retardant rate (1 = full rate). Treatment: Y_A with Antywylegacz Płynny 675 SL, Y_M with Moddus 250 EC, Y_C with Cecefon 465 SL.

Fig. 2 The effect of reduced retardant dose rate on grain yield of winter wheat in 2006.



Retardant rate (1 = full rate). Treatment: Y_A with Antywylegacz Płynny 675 SL, Y_M with Moddus 250 EC, Y_C with Cecefon 465 SL.

Fig. 3 The effect of reduced retardant dose rate on grain yield of winter wheat in 2007.

effect, then the correlation explains the true relationship and direct selection through this trait will be effective.

Conclusions

The values of the winter wheat yield components were significantly dependent on weather conditions during the study period. Increased nitrogen fertilization had a significant yield-increasing effect in 2 out of 3 years of the study. In 2005, the winter wheat grain yield was primarily determined by spike density and number of grains per spike (TGW decreased the yield), whereas in 2007 all the three yield components positively influenced the productivity of winter wheat. The retardant rates applied significantly affected the winter wheat grain yield. This effect varied depending on the year.

References

1. Akbar M, Muhammad T, Tayyab J, Muhammad A. Evaluation of exotic wheat germplasm for seed yield and its components under rain fed conditions. Sarhad Journal of Agriculture. 2001;17(4):511–513.
2. Singh BN, Vishwakarma SR, Singh VK. Character association and path analysis in elite lines of wheat (*Triticum aestivum* L.). Plant Archives. 2010;10(2):845–847.
3. Podolska G, Sułek A, Stankowski S. Number of ears per area unit – main factor of winter wheat yielding (review). Acta Scientiarum Polonorum Agricultura. 2002;1(2):5–14.
4. Singh SP, Diwivedi VK. Character association and path analysis in wheat (*Triticum aestivum* L.). Agricultural Science Digest. 2002;22(4):255–257.
5. Sainis JK, Shouche SP, Bhagwat SG. Image analysis of wheat grains developed in different environments and its implications for identification. J Agric Sci. 2006;144:221–227. http://dx.doi.org/10.1017/S0021859606006010
6. Khan AS, Ashfaq M, Asad MA. A correlation and path coefficient analysis for some yield components in bread wheat. Asian J Plant Sci. 2003;2(8):582–584. http://dx.doi.org/10.3923/ajps.2003.582.584
7. Leilah AA, Al-Khateeb SA. Statistical analysis of wheat yield under drought conditions. J Arid Environ. 2005;61(3):483–496. http://dx.doi.org/10.1016/j.jaridenv.2004.10.011
8. Aycicek M, Yildirim T. Path coefficient analysis of yield and yield components in bread wheat (*Triticum aestivum* L) genotypes. Pak J Bot. 2006;38:417–424.
9. Dogan R. The correlation and path coefficient analysis for yield and some yield components of durum wheat (*Triticum turgidum* var. *durum* L.) in west Anatolia conditions. Pak J Bot. 2009;41(3):1081–1089.
10. Ługowska B, Banaszak Z, Wójcik W, Grzmil W. Zależność plonu ziarna pszenicy ozimej o skróconym źdźble od jego składowych. Biuletyn Instytutu Hodowli i Aklimatyzacji Roślin. 2004;231:5–10.
11. Mollasadeghi V, Imani AA, Shahryari R, Khayatnezhad M. Classifying bread wheat genotypes by multivariable statistical analysis to achieve high yield under after anthesis drought. Middle East J Sci Res. 2011;7(2):217–220.
12. Samborski S, Kozak M, Mądry W, Rozbicki J. Pierwotne cechy rozwojowe w analizie składowych plonu. Cz. II. Zastosowanie dla plonu ziarna pszenżyta ozimego. Fragmenta Agronomica. 2005;4(88):84–97.
13. Podolska G, Krasowicz S. Efektywność produkcyjna i ekonomiczna uprawy pszenicy ozimej w zależności od czynników agrotechniki. Folia Universitatis Agriculturae Stetinensis. 2008;266(8):133–140.
14. Pržulj N, Momcilovic V. Characterization of vegetative and grain filling periods of winter wheat by stepwise regression procedure. I. Vegetative period. Genetika. 2011;43(2):349–359. http://dx.doi.org/10.2298/GENSR1102349P

15. Brzozowska I, Brzozowski J, Hruszka M. Plonowanie i struktura plonu pszenicy ozimej w zależności od sposobu pielęgnacji i nawożenia azotem. Acta Agrophysica. 2008;11(3):597–611.
16. Harasim A, Matyka M. Ważniejsze elementy technologii produkcji wpływające na poziom plonowania pszenicy ozimej oraz ich zmiana w ujęciu długookresowym. Pamiętnik Puławski. 2005;140:59–68.
17. Noworolnik K. Effect of some soil properties on yielding of winter wheat and winter barley. Acta Agrophysica. 2008;12(2):477–485.
18. Rudnicki F. Wyznaczanie wpływu poszczególnych elementów plonowania na różnice plonów między obiektami doświadczalnymi. Fragmenta Agronomica. 2000;3(67):53–65.
19. Nouri-Ganbalani A, Hassanpanah D, Nouri-Ganbalani G. Effects of drought stress condition on the yield and yield components of advanced wheat genotypes in Ardabil. Journal of Food, Agriculture and Environment. 2009;7:228–234.
20. Ahmadizadeh M, Nori A, Shahbazi H, Aharizad S. Correlated response of morpho-physiological traits of grain yield in durum wheat under normal irrigation and drought stress conditions in greenhouse. Afr J Biotechnol. 2011;10(85):19771–19779.
21. Hannachi A, Fellahi ZEA, Bouzerzour H, Boutekrabt A. Correlation, path analysis and stepwise regression in durum wheat (*Triticum durum* Desf.) under rainfed conditions. Journal of Agriculture and Sustainability. 2013;3(2):122–131.
22. Chrzanowska-Drożdż B. Reakcja pszenicy ozimej na dawki i terminy stosowania azotu. Część I. Rozwój i plonowanie pszenicy ozimej w zależności od dawki i terminu stosowania azotu. Zeszyty Naukowe Akademii Rolniczej we Wrocławiu. 2001;80:257–270.
23. Fageria N, Baligar V, Li Y. The role of nutrient efficient plants in improving crop yields in the twenty first century. J Plant Nutr. 2008;31:1121–1157. http://dx.doi.org/10.1080/01904160802116068
24. Mądry W, Gozdowski D, Rozbicki J, Pojmaj M, Samborski S. Związki między plonem ziarna a jego składowymi w populacji rodów hodowlanych pszenżyta ozimego w trzech stacjach doświadczalnych. Biuletyn Instytutu Hodowli i Aklimatyzacji Roślin. 2007;245:77–94.
25. Weber R, Biskupski A. Influence of seeding density and seeding date on the characters of yield structure components and the yield of winter wheat cultivars on light soil. Acta Scientiarum Polonorum Agricultura. 2007;6(3):77–85.
26. Ali Y, Atta BM, Akhter J, Monneveux P, Lateef Z. Genetic variability, association and diversity studies in wheat (*Triticum aestivum* L.) germplasm. Pak J Bot. 2008;40(5):2087–2097.
27. Theobald CM, Roberts AMI, Talbot M, Spink JH. Estimation of economically optimum seed rates for winter wheat from series of trials. J Agric Sci. 2006;144:303–316. http://dx.doi.org/10.1017/S0021859606006289
28. Harasim E, Wesołowska-Trojanowska M. Wpływ nawożenia azotem na plonowanie i jakość technologiczną ziarna pszenicy ozimej. Pamiętnik Puławski. 2010;152:77–84.
29. Klimont K. Wpływ herbicydów na wartość siewną i skład chemiczny ziarna pszenicy ozimej i jarej, jęczmienia jarego, pszenżyta jarego. Biuletyn Instytutu Hodowli i Aklimatyzacji Roślin. 2007;243:57–67
30. Sokoto MB, Abubakar IU, Dikko AU. Correlation analysis of some growth, yield, yield components and grain quality of wheat (*Triticum aestivum* L.). Nigerian Journal of Basic and Applied Sciences. 2012;20(4):349–356.
31. Singh RK, Chaudhary BD. Biometrical methods in quantitative genetic analysis. New Delhi: Kalyani Publisher; 1979.

Udział elementów struktury plonu w kształtowaniu wydajności pszenicy ozimej (*Triticum aestivum* L.)

Streszczenie

Celem badań było określenie wpływu zróżnicowanych dawek regulatorów wzrostu i poziomu nawożenia azotem na elementy plonowania oraz ocena ich oddziaływania na wydajność pszenicy ozimej. Eksperyment polowy z uprawą pszenicy ozimej odmiany 'Muza' przeprowadzono w Gospodarstwie Doświadczalnym Czesławice, należącym do Uniwersytetu Przyrodniczego w Lublinie, Polska, w latach 2004–2007. W niniejszym doświadczeniu wpływ badanych czynników na plon i jego składowe zależny był głównie od warunków meteorologicznych, występujących w poszczególnych latach badań.

Zwiększenie dawki azotu ze 100 do 150 kg ha^{-1} w 2005 i 2007 roku istotnie wpływało na zwiększenie plonu ziarna z jednostki powierzchni. W 2005 roku przyrost plonu ziarna następował poprzez zwiększoną obsadę kłosów (o 6.3%) i zwiększoną liczbę ziaren w kłosie (o 1.6%). Masa 1000 ziaren obniżała plon ziarna z jednostki powierzchni (o 0.04 t ha^{-1}). W 2007 roku o większym plonie pszenicy nawożonej azotem w dawce 150 kg N ha^{-1} decydowały dodatnio wszystkie trzy elementy struktury plonu. Plony ziarna pszenicy ozimej istotnie kształtowały stosowane dawki retardantów, ale efekt ich stosowania różnił się w latach badań.