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YIELD OF WINTER DURUM WHEAT (*Triticum durum* Desf.) LINES IN CONDITION OF DIFFERENT PROTECTION LEVEL OF PLANTS

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Abstract. The paper deals with evaluating the yield and yield structure elements of winter durum wheat lines (*Triticum durum* Desf.) under conditions of varied levels of chemical protection. The field experiments were carried out in 2006-2008 on the Experimental Farm Felin, University of Life Sciences, Lublin. Examinations involved 3 lines of durum wheat (STH 716, 717, 725) achieved from Plant Breeding Station in Strzelce as well as common wheat Tonacja cv. for comparison. The second factor consisted of 2 levels of chemical protection: I – minimum (seed dressing Oxafun T 75 DS/WS and herbicide Chwastox Trio 540 SL); II – complex (seed dressing, herbicides Puma Uniwersal 069 EW and Chwastox Trio 540 SL, fungicide Alert 375 SC, growth regulator Stabilan 750 SL and insecticide Decis 2,5 EC). Obtained results allowed for concluding that when comparing with minimum protection, the increase in wheat grain yields by 1.08 $t \cdot ha^{-1}$ was recorded on complex-protected treatments, regardless of compared lines and varieties. Lower yield of durum wheat as compared to common wheat resulted first of all from lower spike density per area unit. A positive influence of chemical protection on spike number and grain number per spike was observed. Durum wheat lines were characterized by high grain vitreousness.

Key words: yield structure elements, winter breeding lines, chemical protection, grain yield, durum wheat, *Triticum durum*

INTRODUCTION

Besides common wheat (*Triticum aestivum* L.), durum wheat (*Triticum durum* Desf.) is of the largest economic importance of all the other species. World production of durum wheat grain amounts to 32-34 million tons and shows an upward tendency [Matuz and Beke 1996, Rachoń and Szumiło 2006]. Because of its high quality, that is a large amount of yellow pigment, a good qualitative composition of glutenous proteins, a high vitreousness and hardness of endosperm, the grain of this species of wheat

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achieves high prices and is a sought after product on the international market [Dexter et al. 1982, Chaurand 1996, Rachoń and Szumiło 2002]. Until recently, durum wheat cultivation was concentrated mainly in dry and warm regions where water deficit and prolonged high temperatures during grain formation limit the possibility of common wheat cultivation. In recent years, growing interest in cultivation of this crop has been observed also in other regions including such European countries as Hungary, Germany, Austria and Poland [Aufhammer and Federolf 1995, Tokes and Bagyinka 1996, Rachoń 2001]. Most frequently grown cultivars of durum wheat are the spring forms. They are characterized by a good quality but a low yield level. In the 1960s, 2 spring cultivars were registered in Poland, i.e. Puławska Twarda and Hela. In recent years, breeding works have been undertaken on winter forms, being more productive than the spring ones, although generally having slightly worse quality parameters – a lower content of protein and gluten and a poorer vitreousness of grain [Zalewski and Bojarczuk 2004, Rachoń et al. 2009].

The extensive chemical protection of wheat crop brings an effect in the form of an increase in grain yield and improvement of most parameters determining its quality. However, intensive cultivation technology is not always economically justified [Kwiatkowski et al. 2006]. In this connection, research was undertaken aimed at comparison of the yield of new winter durum wheat breeding lines in conditions of varying chemical protection.

The research hypothesis assumed that breeding lines of winter durum wheat subjected to the complex crop cultivation, as compared with the minimal plant protection, yield higher and give grain of a better quality.

MATERIAL AND METHODS

A field study was conducted over 2006-2008 on the Experimental Farm Felin (51°22' N, 22°64' E) of the University of Life Sciences in Lublin. The experimental field was situated on grey-brown podsolic soil formed from loess soils, with a granulometric composition of medium loam, classified as the good wheat complex, soil quality class II. It is characterized by a high abundance in nutrients: P – 76, K – 119 and Mg – 5.55 (in $mg \cdot 100\ g^{-1}$ soil), and its pH in the solution of KCl is 6.3.

The first experimental factor was 3 winter lines of durum wheat (STH 716, 717, 725) and one cultivar of common wheat (Tonacja). The second factor was 2 levels of chemical protection: I – minimal protection (seed dressing Oxafun T 75 DS/WS at a rate of $200\ g \cdot 100\ kg^{-1}$ of grain and the herbicide Chwastox Trio 540 SL at a rate of $2\ dm^3 \cdot ha^{-1}$), II – complex protection (seed dressing, herbicides Puma Uniwersal 069 EW at a rate of $1.2\ dm^3 \cdot ha^{-1}$ and Chwastox Trio 540 SL at a rate of $2\ dm^3 \cdot ha^{-1}$, fungicide Alert 375 SC at a rate of $1\ dm^3 \cdot ha^{-1}$, growth regulator Stabilan 750 SL at a rate of $1.8\ dm^3 \cdot ha^{-1}$ and insecticide Decis 2.5 EC at a rate of $250\ cm^3 \cdot ha^{-1}$). The minimal chemical crop cultivation applied in the experiment involved preventive plant protection against pathogenic fungi (in the form of seed dressing) and the most prevalent dicotyledonous weeds. A higher level of chemicalization, in turn, (complex protection) involved additionally pesticides commonly used in conditions of the intensive cultivation of winter wheat. Lines of durum wheat were obtained from the Plant Breeding Station in Strzelce. The experiment was conducted in the randomized complete block design with 4 replications in the field after winter rape. The area of plots for harvesting amounted to $10\ m^2$.

Tillage was typical of the ploughing system. 26 kg P·ha^{-1} and 66 kg K·ha^{-1} were applied preplant. Nitrogen fertilization was performed as top-dressing after starting of growth (70 kg N·ha^{-1}) and at the third nod stage (30 kg N·ha^{-1}). Wheat was sown at the following dates: 22nd September 2005, 21st September 2006 and 24th September 2007. Sowing rate amounted to 500 grains per 1 m^2. Biometric measurements were carried out after obtaining full grain maturity. Spike density per 1 m^2 was calculated before harvesting. Grain yield, the number and weight of grains per spike and 1000 grain weight were determined after the harvesting. Grain test weight according to standard PN-73/R-74007, grain uniformity according to BN-69/9131-02 and grain vitreousness according to PN-70/R-74008 were also estimated. The results were statistically worked out using the analysis of variation, evaluating the significance of differences with Tukey's test.

Precipitation distribution and average air temperatures during the growth of winter cereals were presented in Table 1. In the three-year experimental cycle, October was characterized by considerable precipitation deficiencies, and in March and May their total amounts exceeded the long-term standards. The first year of research was characterized mainly by low air temperatures in the period from January to March, warm and dry July and humid August. During the season 2006/2007, the lowest total precipitation and the highest temperature were recorded, exceeding the long-term average for each month – from September to August. In the last growing season of the research, September was humid, while a low precipitation level was recorded in June. In the years of research, the long and warm autumn allowed good growing of plants before entering winter dormancy. The winters, however, were mild, which had a favourable effect on plant wintering.

Table 1. Rainfalls and air temperatures according to the Meteorological Observatory at Felin
Tabela 1. Opady i temperatury powietrza wg Obserwatorium Meteorologicznego w Felinie

Year – Rok	Month – Miesiąc												IX–VIII
	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	
	Rainfalls – Opady, mm												Sum Suma
2005/2006	18.0	8.6	21.7	54.5	15.7	26.7	47.0	30.3	59.5	37.9	6.8	198.3	525.0
2006/2007	11.0	14.2	41.2	18.6	51.5	22.3	30.2	17.4	81.5	87.8	87.0	37.6	500.3
2007/2008	129.8	17.7	31.1	14.9	36.2	17.8	64.8	55.8	101.6	25.9	77.1	45.0	617.7
Mean for Średnia z lat 1951-2000	52.1	40.3	39.1	31.5	21.7	24.8	25.8	40.6	58.3	65.8	78.0	69.7	547.7
	Air temperature – Temperatura powietrza, °C												Mean Średnia
2005/2006	14.9	8.8	2.7	-0.8	-7.6	-4.3	-1.0	8.7	13.6	16.9	21.9	17.4	7.6
2006/2007	15.8	10.1	5.3	3.0	2.6	-1.6	6.2	8.7	15.0	18.1	19.2	18.4	10.1
2007/2008	13.0	7.6	1.0	-1.2	0.4	2.2	3.4	9.3	12.8	17.7	18.3	19.3	8.7
Mean for Średnia z lat 1951-2000	12.9	7.9	2.5	-1.4	-3.6	-2.8	1.0	7.5	13.0	16.5	17.9	17.3	7.4

RESULTS AND DISCUSSION

Winter wheat is a cereal crop which responds intensely to chemical protection measures [Jończyk 1999, Kulig et al. 2001, Blecharczyk et al. 2003, Lipa 2004, Kwiatkowski et al. 2006]. In the study carried out, the significant growth of winter wheat grain yield in conditions of full chemical protection was observed as compared with the minimal protection (Table 2). Irrespective of the lines and cultivar compared, this growth over the years 2006-2008 amounted on average to 1.08 $t \cdot ha^{-1}$. Of durum wheat lines, the lowest growth was observed for line STH 716 – 8.17%. Lines STH 717 and STH 725 showed a more intense reaction and the growth in yield of those lines amounted to 20.6% and 21.2%, respectively. The cultivar of common wheat yielded higher by 16.08%. A study by other authors [Jończyk 1999, Kwiatkowski et al. 2006] confirmed the yield-protecting effect of complex chemical protection. The average grain yield of the tested lines of durum wheat, 5.82 $t \cdot ha^{-1}$, should be regarded as good. However, as compared with common wheat, it constituted only 66% of its yield. Seibel and Stewart [1997] report that to ensure the crop profitability, durum wheat should reach a yield at a level of at least 70% of common wheat yield. Rachoń and Szumiło [2006], conducting a study of spring forms in a 10 – year cycle, obtained a yield accounting for 72.4% yield of common spring wheat. Differences in particular years were within the range 57.3-86.1% and were dependent on climate conditions. From the analysis of variation coefficients it follows that line STH 716 was characterized by the highest yield variation (24.9%), whereas the other lines of durum wheat and the cultivar of common wheat were more stable in this respect (14.2-15.0%). A higher yield of common wheat resulted mostly from a greater spike density per area unit (Table 2). Spike density per 1 m^2 for lines of durum wheat ranged from 403 to 460 and was significantly smaller as compared with common wheat (658). Many authors [Podolska and Mazurek 1999, Kulig et al. 2001] report that the number of spikes, as the basic yield structure element, is to the largest extent correlated with the yield height.

Table 2. The grain yield and number of spikes of winter wheat
Tabela 2. Plon ziarna i liczba kłosów pszenicy ozimej

Lines and cultivar Linie i odmiana (I)	Yield of grain – Plon ziarna $t \cdot ha^{-1}$				Number of spikes per 1 m^2 Liczba kłosów na 1 m^2			
	Protection – Ochrona (II)		Mean Średnia	CV %	Protection – Ochrona (II)		Mean Średnia	CV %
	M	C			M	C		
STH 716	5.14	5.66	5.40	24.9	382	424	403	22.7
STH 717	5.54	6.68	6.11	15.0	428	472	450	11.7
STH 725	5.38	6.52	5.95	14.2	442	478	460	12.0
Tonacja	8.04	9.58	8.81	14.9	600	715	658	16.4
Mean – Średnia	6.03	7.11	–		463	522	–	
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:								
I	1.050				104.1			
II	0.547				54.3			
interaction – interakcji								
I × II	ns – ni				ns – ni			

M – minimal protection – ochrona minimalna
C – complex protection – ochrona kompleksowa
CV – coefficient of variation – współczynnik zmienności
ns – ni – not significant – nieistotne

Application of complex chemical protection, irrespective of the cultivars and lines compared, significantly modified some yield structure elements of wheat (Tables 2, 3, 4). Significant increase in the number of spikes per 1 m^2 (on average by 59) and the number of grains per spike (on average by 2.7) were observed, whereas no significant differences were observed in respect of 1000 grain weight and grain weight per spike. Analysed quality characteristics, i.e. grain test weight, grain uniformity and vitreousness, indicated a slight growth at complex protection. However, it was within the margin of error (Tables 4 and 5).

Table 3. Number and weight of grains per spike of winter wheat
Tabela 3. Liczba i masa ziaren z kłosa pszenicy ozimej

Lines and cultivar Linie i odmiana (I)	Number of grains per spike Liczba ziarn z kłosa				Weight of grains per spike, g Masa ziarn z kłosa			
	Protection – Ochrona (II)		Mean Średnia	CV %	Protection – Ochrona (II)		Mean Średnia	CV %
	M	C			M	C		
STH 716	28.4	30.3	29.3	12.8	1.387	1.454	1.421	10.4
STH 717	35.1	38.1	36.6	8.8	1.447	1.606	1.527	6.2
STH 725	28.2	33.1	30.7	10.0	1.397	1.533	1.465	9.6
Tonacja	33.0	34.2	33.6	6.6	1.549	1.584	1.567	7.7
Mean – Średnia	31.2	33.9	–		1.445	1.544	–	
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:								
I	4.72				ns – ni			
II	2.46				ns – ni			
interaction – interakcji								
I × II	ns – ni				ns – ni			

For explanations see Table 2 – objaśnienia w tabeli 2

Table 4. Weight of 1000 grains and test weight of winter wheat
Tabela 4. Masa 1000 ziaren i gęstość ziarna pszenicy ozimej

Lines and cultivar Linie i odmiana (I)	Weight of 1000 grains – MTZ g				Test weight – Gęstość ziarna w stanie zsypnym, kg·m^{-3}			
	Protection – Ochrona (II)		Mean Średnia	CV %	Protection – Ochrona (II)		Mean Średnia	CV %
	M	C			M	C		
STH 716	47.7	48.4	48.1	6.9	717	716	716	6.9
STH 717	41.7	42.9	42.3	6.6	757	765	761	5.5
STH 725	49.0	49.6	49.3	9.8	782	792	787	7.4
Tonacja	46.1	47.0	46.5	3.2	769	777	773	4.0
Mean Średnia	46.1	47.0	–		756	763	–	
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:								
I	4.51				28.8			
II	ns – ni				ns – ni			
interaction – interakcji								
I × II	ns – ni				ns – ni			

For explanations see Table 2 – objaśnienia w tabeli 2

Of the durum wheat lines compared, STH 716 and STH 725 were characterized by the best formed grain (TGW 48.1 g and 49.3 g, respectively) – Table 4. Those lines had a significantly higher 1000 grain weight as compared with line STH 717 (42.3 g), and a better grain uniformity (95.3 and 94.0%) – Table 5. However, no differences were observed in values of those parameters when comparing lines of durum wheat with the cultivar of common wheat. Only the grain vitreousness of the tested winter lines of durum wheat was considerably higher (75.0-81.1%) in relation to the grain of common winter wheat (38.9%). Similarly, the grain of spring forms of durum wheat is more vitreous than that of common wheat [Szwed-Urbaś 1993, Zwingelberg 1996, Rachoń and Szumiło 2002, Woźniak 2005].

Table 5. Grain uniformity and vitreousness of winter wheat
Tabela 5. Wyrównanie i szklistość ziarna pszenicy ozimej

Lines and cultivar Linie i odmiana (I)	Grain uniformity – Wyrównanie ziarna %				Grain vitreousness – Szklistość ziarna %			
	Protection – Ochrona (II)		Mean Średnia	CV %	Protection – Ochrona (II)		Mean Średnia	CV %
	M	C			M	C		
STH 716	95.5	95.1	95.3	3.0	75.7	76.8	76.2	11.7
STH 717	78.3	82.0	80.2	13.1	73.1	77.0	75.0	12.6
STH 725	94.1	94.0	94.0	3.4	78.7	83.5	81.1	18.1
Tonacja	90.4	90.6	90.5	3.8	37.7	40.2	38.9	62.3
Mean Średnia	89.6	90.4	—		66,3	69.4	—	
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:								
I	8.29				22.74			
II	ns – ni				ns – ni			
interaction – interakcji I × II	ns – ni				ns – ni			

For explanations see Table 2 – objaśnienia w tabeli 2

CONCLUSIONS

1. As compared with the minimal protection, application of complex plant protection against mono and dicotyledonous weeds, lodging, fungal diseases and pests resulted in an increase in grain yield on average by 1.08 $t \cdot ha^{-1}$ in three-year period, irrespective of the lines and cultivars compared.
2. Mean grain yield of the tested winter lines of durum wheat – 5.82 $t \cdot ha^{-1}$ – can be regarded as good; however, as compared with common wheat, it accounted for only 66% its yield.
3. Lower yield of durum wheat in comparison with common wheat resulted mainly from a smaller spike density per area unit.
4. Positive effect of chemical protection on spike number and grain number per spike was observed.
5. Winter breeding lines of durum wheat were characterized by a high vitreousness of grain.

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PLONOWANIE OZIMYCH LINII PSZENICY TWARDEJ (*Triticum durum* DESF.) W WARUNKACH ZRÓŻNICOWANEGO POZIOMU OCHRONY ROŚLIN

Streszczenie. W pracy dokonano oceny plonowania i elementów struktury plonu 3 linii ozimych pszenicy twardej *Triticum durum* Desf. w warunkach zróżnicowanego poziomu ochrony chemicznej. Badania polowe przeprowadzone w latach 2006-2008 objęły linie STH 716, 717 i 725, które otrzymano w Stacji Hodowli Roślin w Strzelcach i odmianę pszenicy zwyczajnej Tonacja. Stosowano 2 poziomy ochrony chemicznej: I – ochrona minimalna (zaprawa nasienna Oxafun T 75 DS/WS i herbicyd Chwastox Trio 540 SL), II – ochrona kompleksowa (zaprawa nasienna, herbicydy Puma Uniwersal 069 EW i Chwastox Trio 540 SL, fungicyd Alert 375 SC, regulator wzrostu Stabilan 750 SL i insektycyd Decis 2,5 EC). W porównaniu z ochroną minimalną na obiektach chronionych kompleksowo otrzymano wzrost plonu ziarna pszenicy o 1,08 $t \cdot ha^{-1}$, niezależnie od porównywanych linii i odmian. Średni plon ziarna badanych linii pszenicy twardej – 5,82 $t \cdot ha^{-1}$ należy uznać za dobry, jednak w porównaniu z pszenicą zwyczajną stanowił tylko 66% jej plonu. Niższe plonowanie pszenicy twardej w porównaniu z pszenicą zwyczajną wynikało przede wszystkim z niższej obsady kłosów na jednostce powierzchni. Stwierdzono korzystne oddziaływanie ochrony chemicznej na liczbę kłosów oraz liczbę ziarn z kłosa. Linie pszenicy twardej wyróżniały się wysoką szklistością ziarna.

Słowa kluczowe: elementy struktury plonu, linie hodowlane ozime, ochrona chemiczna, plon ziarna, pszenica twarda, *Triticum durum*

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