

RESPONSE OF SLOVAK WINTER DURUM WHEAT CULTIVARS TO AGROTECHNOLOGY LEVEL IN MALOPOLSKA CLIMATIC-SOIL CONDITIONS*

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Abstract. Three years of field research were performed aimed at an assessment of infestation by fungi, leaf area index (LAI), thousand grain weight (TGW) and yield of three durum wheat cultivars in intensive and moderate-intensive agrotechnology system. The analysis of diseases symptoms demonstrated the occurrence of a significant intensity of Fusarium head blight, leaf septoria nodorum blotch symptoms on the leaves and black molds. In lesser extent occurred Fusarium foot rot and eyespot as well as stripe rust, septoria nodorum blotch on ears and powdery mildew. Fusarium head blight was the main disease. The factors considerably affecting plant diseases, as well as the LAI, TGW and the yield, were climatic conditions of the cropping season and the intensity of the cultivation technology. Unfavorable weather conditions (low temperatures in winter and precipitation in spring) did not result in a reduction in LAI and TGW, but significantly reduced the yield. Season with low rainfall (390 mm during the wheat cycle) special in summer favored the quality of grain – it was stated the highest TGW. The application of intensive agrotechnology led to a limitation of the occurrence of most of fungal diseases and an improvement in the quantity and quality of the yield obtained. Generally, the level of the susceptibility of the examined cultivars to the diseases may be accepted as similar. The durum wheat cultivars being compared may be recommended for cultivation in the research region and regions with similar climatic conditions.

Key words: agrotechnology, durum wheat, fungal diseases, LAI, TGW, yield

INTRODUCTION

According to the Directorate-General for Agriculture and Rural Development of the European Union, durum wheat (*Triticum turgidum* var. *durum*) is cultivated in the EU on an area of near 2.5 million ha, and harvested 7–8 million t. Durum wheat provides the raw material for the pasta industry, one of most renowned cereals products, popular in diet all over the world [Sicignano et al. 2015]. They are traditional (Italy>Greece>France>Spain) and nontraditional (Hungary>Austria>Slovakia=Cyprus=Bulgaria=Germany) regions of durum wheat cultivation in EU. Lower plant productivity is often accepted in nontraditional areas; however, this is not a rule. The hardness of wheat is largely controlled by genetic factors but can also be affected by the environment and factors such as moisture, lipid and pentosan contents [Turnbull and Rahman 2002]. Several studies have confirmed that meteorological factors strongly affect wheat cultivation, modifying plant responses and determining the quality of production. In general, meteorological conditions such as temperature, sunshine and rainfall during grain filling can

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greatly affect the protein content and composition of wheat grains [Dalla Marta et al. 2011, Fois et al. 2011]. Some authors concluded that diseases and pests strongly decided about the quantity of yield and the quality of grains in durum wheat cultivation [Garcia del Moral et al. 2003, Labuschagne et al. 2009, Royo et al. 2004, 2006, 2014]. This aspect is well recognized in traditional regions of cultivation.

Agronomic practices are important in yielding of all crops. In long-term evaluation Seddaiu et al. [2016] found that the most relevant factor influencing durum wheat yield in under Mediterranean conditions was N fertilization, which can cause yield increase by 30%. It is estimated that soil humidity and nitrogen are the factors most strongly affecting the level of the durum wheat grain yield [Arregui and Quemada 2008, Garrido-Lestache et al. 2005, Grahmann et al. 2014, Ladha et al. 2005]. New durum wheat cultivars have thermal requirements close to common wheat; however, the reproductive phase should proceed in high temperatures (but not higher than 35°C) and insulation conditions. *The xerophytic* character of durum wheat from traditional regions, resulting from morphological-anatomical plant conditions, has led to the fact that they are quite resistant to water deficiency, but despite this their water requirements are determined to be high. One of the cultivation requirements of durum is its good position in the crop rotation system. The lack of suitable crop rotation also favors plant infestation with other fungal diseases. It has been noted that durum wheat requires chemical protection, especially in more humid areas. Such practices delay the process of plant ageing, including flag leaves important as regards the yield, decrease infestation of vegetative parts and ears, cause lower contamination of the grain with mycotoxins, and above all cause an increased grain yield. However, no significant influence of plant protection practices was noted on the technological quality of durum wheat grain [Abad et al. 2004, Blandino et al. 2009, Gana et al. 2011, Lori et al. 2003]. Field cultivation of durum wheat should be very careful and conducted in optimum conditions and timing. Plant condition is also determined by the timing factors applied, sowing density, and above all proper fertilization. Durum wheat has a genetically conditioned high protein content and requires high nitrogen doses. As in the case of common wheat, nitrogen doses should be divided, and earlier application significantly affects protein content in the yield. Current breeding projects have contributed to the selection of shorter cultivars, and therefore nitrogen fertilization of durum wheat may be increased up to 150–200 kg N·ha⁻¹. This indicates the need for precise determination of the doses, but also climatic conditions favoring, or not, component assimilation. Also, balanced N/S doses are significant, which also crucially affects grain yield quality [Alvaro et al. 2008, Ciołek and Makarska 2004, De Vita 2007, Ercoli et al. 2011, 2013, Fois et al. 2009, Garrido-Lestache et al. 2005, Lopez-Bellido and Lopez-Bellido 2001]. Irrespective of the region of cultivation, proper levels and quality of production assure suitable selection of industrial, crop-forming and crop-protecting production means, and any omissions in this range result in a decrease in yield quantity and quality.

The aim of this study was an assessment of the health status and selected parameters such as leaf area index, thousand grain weight and yield, of three Slovak durum wheat cultivars in two different agronomic conditions in south-eastern Poland region cultivated during the three-year field experiment.

MATERIALS AND METHODS

The field experiment (cropping seasons: 2008/2009, 2009/2010, 2010/2011) were conducted in Prusy village near Krakow (Poland, 50°06' N, 20°04' E). Slovak winter durum wheat Istrodur, IS Pentadur and Riveldur cultivars were examined and the applied agrotechnology level

(a moderate-intensive level marked as A1 and an intensive level marked as A2) was the random sub-block method applied in four replications. The plot size was 10 m². The previous crop in season 2008/2009 was horse bean (*Vicia faba* L.), while in subsequent seasons it was potato (*Solanum tuberosum* L.). Soil cultivation was performed according to proper agrotechnology rules. 80 kg P₂O₅ and 150 kg K₂O·ha⁻¹ was applied prior to sowing. Grain was treated with tebuconazol in dose 3 g for 100 kg. The first nitrogen dose was applied in the Zadoks Growth Stage (GS) 27–29 (Zadoks et al. 1974): 70 kg N·ha⁻¹ in A1 and 80 kg N·ha⁻¹ in technology A2. The second dose, the same for both levels (50 kg N·ha⁻¹), was applied in GS 33–34, while the third dose – 30 kg, was applied only to A2 in GS 45–47. Herbicidal treatments in both levels were administered in GS 25 using fenoxaprop-P-ethyl in dose 82.8 g·ha⁻¹ and dicamba/triasulfuron in dose 105.44 g/6.56 g·ha⁻¹. Fungicidal treatments were administered only in A2 in GS 32–33 using propiconazole/fenpropidine in dose 125g/450 g·ha⁻¹ and in GS 50–52 using propiconazole/cyproconazole in dose 125g/40 g·ha⁻¹. Foliar fertilization with microelements (9 l·ha⁻¹ Basfoliar 36 Extra, 1 l·ha⁻¹ YaraVita Zboże) was employed concurrently with the application of fungicidal agents only in A2 agrotechnology level. The difference between A1 and A2 agrotechnology levels associated mainly to the fungicide treatment and the higher dose of fertilization (N dose and microelements).

The weather conditions of the research seasons were characterized by high variability. Precipitations and mean daily temperatures are presented against the background of long-term data for the research area in Fig. 1.

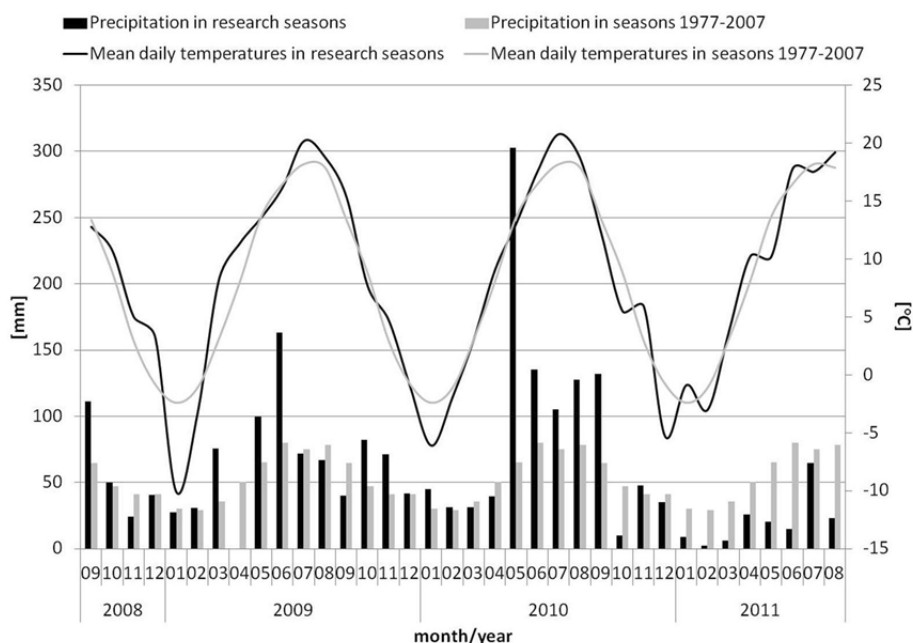


Fig. 1. Weather conditions in the research area observed in the cropping seasons against the background of long-term data

Evaluation of diseases occurrence on plants was examined in GS 68–70 with respect to pathogens causing diseases of stem-base and leaves. Ears were examined in turn in GS 86–88. Twenty randomly selected plants from each plot were subject to a visual assessment by the graphical scale method: 4° for the stem-base diseases and 7° for leaves and ears diseases, where 1° is no symptoms and 4° or 7° are symptoms on the area $\geq 50\%$ of plants part. The results were recalculated according formula:

$$DI = \frac{\sum_i^i (n \cdot v)}{i \cdot N} \cdot 100 [\%]$$

where:

n – number of plants in grade of scale;

v – grade of scale;

i – the highest grade of scale;

N – number of plants in evaluation.

The leaf area index, thousand grain weight and grain yield were also subject to assessment. Measurement of assimilation area was performed in GS 52–55 using SunScan Canopy Analysis System apparatus (Delta T).

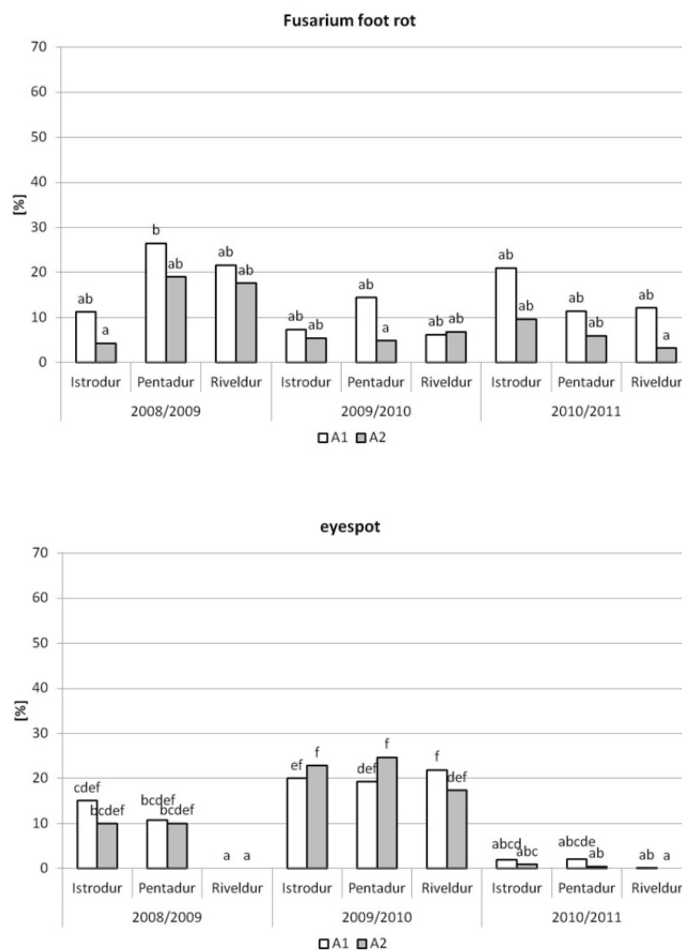
Results were analyzed statistically using Duncan's test at a significance level of $p=0.05$. All calculations were carried out using the STATISTICA 10.0 (StatSoft, Inc., USA) software package.

RESULTS AND DISCUSSION

The analysis of plant infestation by fungi demonstrated a significant intensity of the occurrence of the following diseases: stem-base – Fusarium foot rot (caused by *Fusarium spp.*) and eyespot (*Oculimacula spp.*), leaf diseases – powdery mildew (*Blumeria graminis*), septoria nodorum blotch symptoms on the leaves (*Phaeosphaeria nodorum*), stripe rust (*Puccinia striiformis*), and ear diseases – black molds (*Alternaria spp.*, *Cladosporium spp.*, *Stemphylium spp.*, *Epicoccum spp.*), Fusarium head blight (*Fusarium spp.*) and septoria nodorum blotch (*P. nodorum*).

The symptoms of stem-base disease complexes were noted with an intensity ranging from trace to in excess of 20% (Fig. 2, Table 1). Cropping season significantly affected symptom intensity. In the case of Fusarium foot rot, plants in season 2008/2009 were significantly the most infested, and the mean infestation index exceeded 15%. This was a season of quite high levels of atmospheric precipitation, especially in May and June (Fig. 1). In turn, eyespot was the most intensive (mean index over 20%) in season 2009/2010 – which was a season of very intensive spring-summer precipitation. The application of intensive agrotechnology significantly limited the intensity only of the occurrence of Fusarium foot rot. The susceptibility of the cultivars to Fusarium foot rot was similar. The Riveldur cultivar appeared to be significantly more resistant to eyespot compared to the Istrodur and IS Pentadur cultivars.

Powdery mildew, septoria nodorum and stripe rust were observed on leaves (Fig. 2, Table 1). Powdery mildew either was observed with a very low intensity or was not even identified in some sites. Atmospheric conditions did not affect the intensity of powdery mildew. The intensity of cultivation agrotechnology demonstrated a significant influence, with higher levels causing lower degrees of infestation, and in numerous cases no symptoms were observed at all. Despite the observed different intensities of mildew occurrence on the tested cultivars (the highest number of symptoms being in Istrodur), statistical analysis of the results demonstrated the differences noted had no significance. Septoria nodorum was a disease which was observed

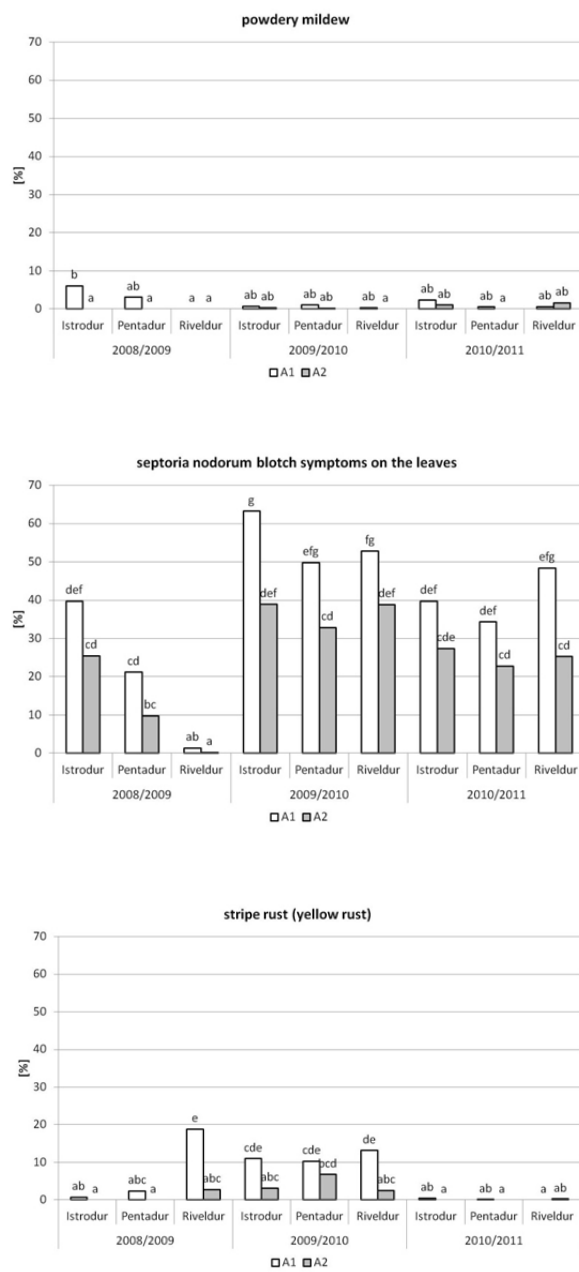


abbreviation: A1=moderate-intensive; A2=intensive

Means marked by the same letter in figure are not statistically different according to the Duncan test ($p=0.05$)

Fig. 2. Individual Index of durum wheat infestation by fungi, which is the cause of diseases (%) for cultivars, experiment seasons and level of agrotechnology

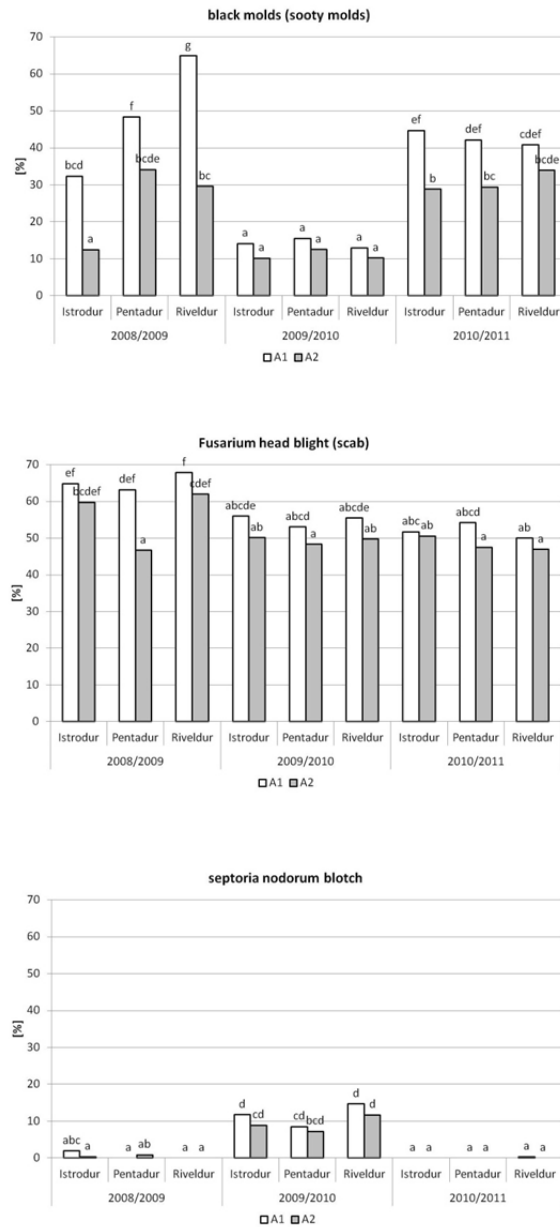
with the highest infestation on leaves – in some cases, the index exceed 60%. All experimental factors differentiated the intensity of septoria occurrence. Seasons with very intense precipitation, i.e. 2009/2010, appeared to be characterized by the highest occurrence of septoria. Cultivation using an intensive level of agrotechnology caused a statistically significant limitation in septoria occurrence compared to moderate-intensive technology. Istrodur appeared to be the most susceptible cultivar. Stripe rust occurrence was strongly differentiated and depended on all experimental factors. In the humid season of 2009/10, rust intensity was statistically significantly the highest. The very low levels of precipitation observed in season 2010/2011 did



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cont. Fig. 2. Individual Index of durum wheat infestation by fungi, which is the cause of diseases (%) for cultivars, experiment seasons and level of agrotechnology

Table 1. The mean Index of durum wheat infestation by fungi, which are the cause of diseases observed on plants material (%)

Disease Pathogen	Means for factor									
	Cropping season			Cultivar			Level of agrotechnology			
	2008/ 2009	2009/ 2010	2010/ 2011	Istrodur	IS Pentadur	Riveldur	A1 (moderate- intensive)	A2 (intensive)		
Fusarium foot rot/ <i>Fusarium</i> spp.	15.9 b*	7.3 a	9.9 ab	9.2 a	12.8 a	10.4 a	14.0 b	7.9 a		
Eyespot/ <i>Oculimacula</i> spp.	5.2 b	21.0 c	0.7 a	9.9 b	9.2 b	2.5 a	7.3 a	6.2 a		
Powdery mildew/ <i>Blumeria graminis</i>	0.5 a	0.3 a	0.8 a	1.2 a	0.4 a	0.2 a	1.2 a	0.1 a		
Septoria nodorum blotch symptoms on the leaves/ <i>Phaeosphaeria nodorum</i>	12.5 a	46.0 c	32.7 b	38.8 b	27.5 a	22.2 a	36.8 b	22.2 a		
Stripe rust/ <i>Puccinia striiformis</i>	2.0 b	7.3 c	0.1 a	1.2 a	1.7 a	3.9 b	4.1 b	0.8 a		
Black molds/ <i>Alternaria</i> spp., <i>Cladosporium</i> spp. and others	36.1 b	12.5 a	36.5 b	22.6 a	29.4 b	30.6 b	34.0 b	21.4 a		
Fusarium head blight/ <i>Fusarium</i> spp.	60.8 b	52.1 a	50.1 a	55.5 a	52.2 a	55.4 a	57.4 a	51.3 a		
Septoria nodorum blotch/ <i>P. nodorum</i>	0.2 a	10.3 b	0.0 a	2.0 a	1.2 a	1.8 a	1.9 a	1.4 a		

*Means marked by the same letter for disease are not statistically different according to the Duncan test (p=0.05)

not favor rust development. Also, in the case of this disease, intensive cultivation technology contributed to the limitation of rust symptoms. Riveldur appeared to be significantly the most susceptible cultivar.

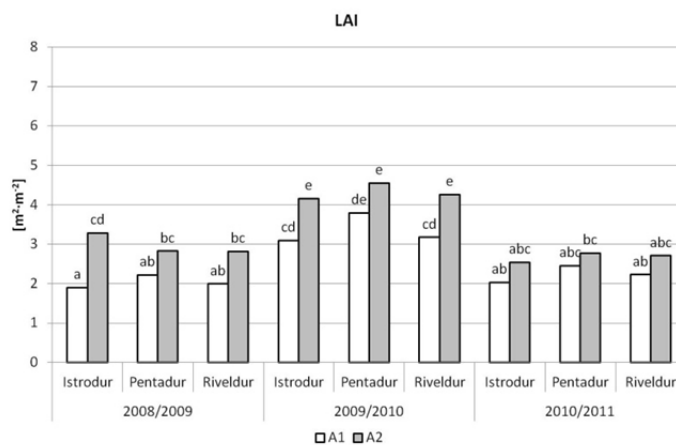
Black molds, Fusarium head blight and septoria nodorum blotch were noted on the ears (Fig. 2., Table 1). Their intensity may be determined as being high. Black mold was dependent on cultivation season, agrotechnology level and cultivar. Seasons rich in atmospheric precipitations (2009/2010) did not favor its development. Wheat cultivation using moderate-intensive technology favored a statistically significant intensification of black molds. Istrodur cultivar appeared to be least susceptible to black molds. Fusarium head blight appeared to be a disease which infested ears to the highest degree – in all cases, the index exceeded 50%. In the first research season, Fusarium head blight was the most intensive – the mean infestation index for the season exceeded 60%. Two subsequent research seasons were characterized by a similar index, i.e. about 50%. In the sites where the most intensive agrotechnology was used, ear infestation caused by Fusarium head blight was significantly lower. The cultivars were characterized by similar susceptibility. The symptoms of septoria nodorum blotch on the ears occurred with the highest intensity in the research season 2009/2010. The mean index of ear infestation caused by this disease was very low in other years. Septoria nodorum blotch, like eyespot, appeared to be a disease, the occurrence of which was not affected by the agrotechnology level applied. Also, it was the cultivar that was the factor which did not differentiate plant ear infestation in a significant manner.

The influence of the applied experimental factors on the LAI index, TGW and grain yield was also subject to assessment (Fig. 3–5, Table 2). The leaf area index (Fig. 3) was significantly differentiated in the research seasons and was dependent on the cultivation technology applied. Significantly the highest LAI was noted in season 2009/10 when it was 3.84 m²·m⁻². In the other two seasons, this index was at a very similar level – about 2.5 m²·m⁻². A significantly higher LAI was obtained when using an intensive cultivation technology compared to a moderate-intensive one. The LAI index for the three examined wheat durum cultivars did not differ statistically significantly. All experimental factors significantly affected the TGW level of durum wheat grain (Fig. 4). The heaviest grain was obtained in season 2010/11, when mean TGW was nearly 52 g. In seasons 2008/09 and 2009/10, TGW was lower, at a level of 45.4 g and 48.5 g, respectively, and the difference was also significant statistically. The level of cultivation technology intensity determined grain quality. The higher level of nitrogen fertilization and fungicidal practices

Table 2. The mean leaf area index (LAI), thousand grain weight (TGW) and yield detected in experiment

Parameter	Means for factor							
	Cropping season			Cultivar			Level of agrotechnology	
	2008/ 2009	2009/ 2010	2010/ 2011	Istrodur	IS Pentadur	Riveldur	A1 (moderate- intensive)	A2 (intensive)
LAI (m ² ·m ⁻²)	2.5 a	3.8 b	2.5 a	2.8 a	3.1 a	2.9 a	2.5 a	3.3 b
TGW (g)	45.4 a	48.5 b	51.9 c	50.9 c	45.3 a	49.6 b	46.1 a	51.1 b
Yield (t·ha ⁻¹)	6.9 c	3.8 a	4.8 b	5.2 b	6.0 c	4.3 a	4.5 a	5.8 b

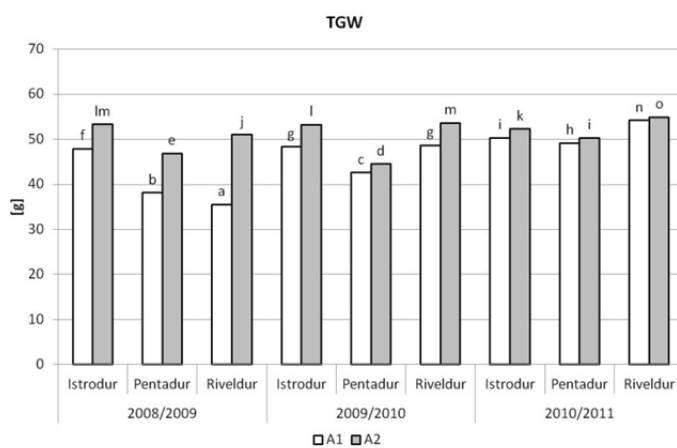
*Means marked by the same letter for parameter are not statistically different according to the Duncan test (p=0.05)



abbreviation: A1=moderate-intensive; A2=intensive

Means marked by the same letter in figure are not statistically different according to the Duncan test ($p=0.05$)

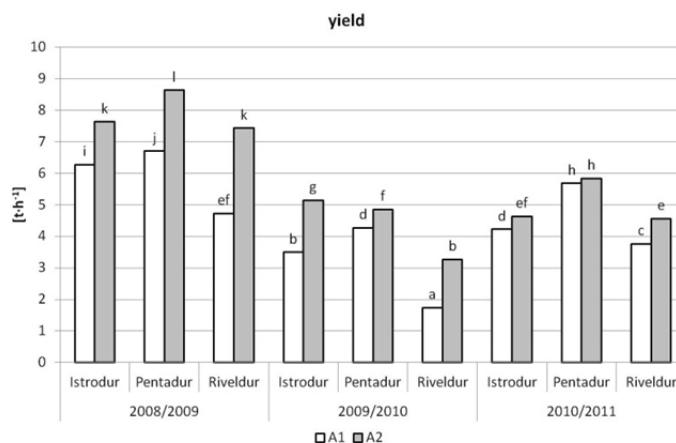
Fig. 3. Individual leaf area index (LAI) ($m^2 \cdot m^{-2}$) detected in experiment



abbreviation: A1=moderate-intensive; A2=intensive

Means marked by the same letter in figure are not statistically different according to the Duncan test ($p=0.05$)

Fig. 4. Thousand grain weight (TGW) (g) detected in experiment



abbreviation: A1=moderate-intensive; A2=intensive

Means marked by the same letter in figure are not statistically different according to the Duncan test ($p=0.05$)

Fig. 5. Yield ($t\cdot ha^{-1}$) detected in experiment

when using an intensive technology allowed significantly higher TGW to be obtained compared to technology with lower outlays on industrial production processes. The heaviest grain was formed by the Istrodur cultivar (TGW 50.9 g), slightly worse was the Riveldur cultivar (TGW 49.6 g), and the lightest was noted in the case of the IS Pentadur cultivar (TGW 45.3 g). The differences between the cultivars were significant statistically.

The highest yield (Fig. 5), i.e. $6.9 t\cdot ha^{-1}$, was obtained in the first experimental season, 2008/09. The lowest yield of durum wheat was obtained in season 2009/2010, which was unfavorable due to precipitation. The yield in this case was only $3.8 t\cdot ha^{-1}$. A yield of an average level of $4.78 t\cdot ha^{-1}$ was noted in the season in which the best quality grain was obtained, i.e. 2010/2011. Wheat cultivation according to intensive technology caused an increase in the yield obtained. The best, in terms of yield, was the IS Pentadur cultivar, in which the yield was nearly $6 t\cdot ha^{-1}$.

The factors considerably determining plant health status, leaf area index, quality and quantity of the yield of the examined durum wheat cultivars were weather conditions during the cropping season and the intensity of the cultivation agrotechnology applied. It should be emphasized that atmospheric factors noted during the research period were quite differentiated and they may be determined as untypical ones with respect to long-standing data. The first two cropping seasons were abundant in precipitation (especially the second one), and the last season was exceptionally dry (Fig. 1). The application of fungicidal plant protection and higher nitrogen fertilization in the intensive technology favored a limitation of the occurrence of most fungal diseases, as well as an increase in the quantity and quality of the yield obtained compared to moderate-intensive technology. Evaluating the quality of grain and flour produced from durum wheat, Spychaj et al. [2011] noted that, apart from the obtained yield increase, agrotechnology intensification profitably affects the values of most of the examined quality features. Similar results in Polish field conditions were obtained by Makowska et al. [2008] and Rachoń et al. [2012]. Intensive chemi-

cal plant protection, with respect to the minimum, and a higher N dose led to the production of durum wheat grain of better physical and technological features. An increase in the thousand grain weight caused by protection intensification was noted in the studies of Ciolek and Makarska [2004], i.e. from 2.5 g to 4.0 g. In this study, we obtained an 5 g increase in TGW. This proves the crucial effect of protection and fertilization practices on the quality of durum wheat grain. Despite the higher than normal susceptibility of the Istrodur cultivar to leaf septoria, this study suggests that only this cultivar may be assessed as highly profitable in terms of yield. In terms of quantity, Istrodur, gave the best yield on a moderate level, compared to the other cultivars. Generally, the cultivars used in the study may be considered to have similar levels of susceptibility to stem base diseases. The Riveldur cultivar appeared to be more susceptible than other cultivars to strip rust, but was in turn less infested with eyespot. Moreover, the Istrodur cultivar was characterized by lower infestation by black molds. The symptoms of other diseases observed in the study were on a poorly differentiated level, and the differences observed were not significant statistically. It may be concluded that the durum wheat cultivars examined in this study may be recommended for cultivation in the region the research was undertaken, as well as in regions with similar weather conditions. But very dangerous is large infestation by *Fusarium* head blight. Many authors assumed [Bottalico and Perrone 2002, Champeil et al. 2004, Parry et al. 1995] that the climate is the principal factor affecting the development of *Fusarium* head blight in cereals – humidity determines the severity and intensity of the disease, but drought in spring (before ear emergence) favours the development of symptoms infection. Our experiment also proved this. Intensive agrotechnology did not affect level of infestation. Is necessary to provide programs to protect durum wheat against fungi causing *Fusarium* head blight in favorable develop climatic conditions.

CONCLUSIONS

1. The occurrence of diseases in the examined cultivars of winter durum wheat cultivation, is dependent on the agrotechnology level applied and the weather conditions of the vegetation season.
2. Low temperatures in winter and precipitation in spring did not result in a reduction in LAI and TGW, but significantly reduced the yield. Season with low rainfall (390 mm during the wheat cycle) special in summer favoured the quality of grain – it was stated the highest TGW.
3. The application of intensive agrotechnology led to a limitation of the occurrence of most of fungal diseases and an improvement in the quantity and quality of the yield obtained.
4. Generally, the level of the susceptibility of the examined cultivars to the diseases may be accepted as similar. The durum wheat cultivars being compared may be recommended for cultivation in the research region and regions with similar climatic conditions.

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REAKCJA SŁOWACKICH ODMIAN PSZENICY TWARDEJ OZIMEJ NA POZIOM AGROTECHNIKI W WARUNKACH KLIMATYCZNO-GLEBOWYCH MAŁOPOLSKI

Synopsis. Wykonano trzyletnie badania polowe, których celem była ocena występowania chorób oraz ocena wskaźnika stopnia ulistnienia roślin (LAI), masy tysiąca ziaren (MTZ) i plonu trzech odmian pszenicy twardej ozimej, przy zastosowaniu intensywnego i umiarkowanego poziomu agrotechniki. Analiza objawów chorobowych wykazała występowanie w znacznym nasileniu fuzariozy kłosów, septoriozy liści oraz czernienia kłosów. W mniejszym nasileniu stwierdzono występowanie fuzaryjnej zgorzeli podstawy źdźbła i korzeni, łamliwości źdźbła zbóż i traw, rdzy żółtej zbóż i traw, septoriozy kłosów i mączniaka prawdziwego zbóż i traw. Główną chorobą była fuzarioza kłosów. Czynniki decydującymi w sposób znaczący o zdrowotności roślin oraz LAI, MTZ, jak i plonu były warunki pogodowe sezonu wegetacyjnego i poziom intensywności agrotechniki. Niekorzystne warunki pogodowe (niskie temperatury w zimie i opady na wiosnę) nie powodowały zmniejszenia LAI i MTZ, ale znacznie zmniejszyły plon. Sezon z niskimi opadami (390 mm) latem sprzyjał jakości ziarna – stwierdzono najwyższy MTZ. Zastosowanie intensywnej technologii uprawy powodowało ograniczenie występowania większości chorób grzybowych oraz poprawę ilości i jakości uzyskanego plonu. Ogólnie poziom podatności na choroby testowanych odmian można uznać za zbliżony. Porównywane odmiany pszenicy twardej można zalecać do uprawy w rejonie badań i rejonach o podobnych warunkach klimatycznych.

Słowa kluczowe: agrotechnika, pszenica twarda, choroby grzybowe, LAI, MTZ, plon

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