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INTERRELATIONS BETWEEN HEIGHT OF WINTER WHEAT GENOTYPES AND RESISTANCE TO FUSARIUM HEAD BLIGHT (FHB)

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ABSTRACT

The relationship between plant height and resistance to fusarium head blight (FHB) has a genetic basis. It is believed that the genes controlling FHB resistance and those that affect the plant height are associated, or the genes for the lower stem promote sensitivity to FHB by pleiotropy. The aim of this study was to determine possible correlations between AUDPC for types of resistance to FHB and plant height of wheat genotypes. Spearman correlation coefficient demonstrated by high negative significance between height of genotypes and AUDPC for total amount of resistance (AUDPC) (r = - 0.77) and between height of genotypes and AUDPC for Type I resistance (r = -0.81). The correlation between height of genotypes and AUDPC for Type II resistance (r = 0.14), and between the height of genotypes and AUDPC for Type III resistance (r = -0.18) was not statistically significant.

Key words: plant height, types of resistance to FHB, *Triticum aestivum*.

INTRODUCTION

Wheat breeders give great attention to the final height of wheat genotypes, firstly in order to achieve the best balance between grain yield potential and lodging resistance. Also it is proven that levels of resistance to fusarium head blight (FHB), as leading grain yield and quality reducing disease worldwide, may also be affected by plant height. Relationship between plant height and resistance to FHB has a genetic basis, according to Hilton et al., (1999). They believe that genes controlling resistance to FHB and those that affect the plant height are associated, or the genes for the lower stem promote sensitivity to FHB by pleiotropy. The presence of genes for dwarf growth *Rht1* and *Rht2* increased the sensitivity to FHB.

Mao et al. (2010) confirmed negative associations of *Rht-B1*, *Rht-D1* and *Rht8* with FHB resistance. The findings of Dvojković et al. (2010) indicate the presence of gene *Rht8* in most Croatian genotypes. Draeger et al. (2007) believe that most genotypes having *Rht-D1b* alleles for semi-dwarfing growth are generally highly susceptible to FHB. In the UK the majority of winter wheat genotypes have alleles for the growth of dwarf *Rht-D1b* on chromosome 4D, and most of all genotypes are susceptible to FHB. As the most resistant genotype was detected Soissons, which has alleles *Rht-B1b* (known as *Rht1*), cited by Srinivasachary et al. (2009).

The most frequently used height reducing genes with strong effect on plant height shortening in the most breeding programs over the world are *Rht-B1b* (*Rht1*) and *Rht-D1b* (*Rht2*) (Cadalen et al., 1998). Worland et al. (2001) stated that these genes failed to combine height reductions with grain yield increases in southern European environments, but this statement was not always confirmed.

Wheat cultivars grown in southern Europe mainly possess short semi-dwarf stem, controlled by dwarfing genes derived from Japanese cultivars Akakomugi (*Rht8*), and at lower extent from cultivar Saitama 27 (*Rht-B1d*; *Rht1*) (Worland and Petrovic, 1988; Jošt and Jošt, 1989; Worland et al., 1998; Ganeva et al., 2005; Dvojković et al., 2010). The objective of this study was to investigate possible interrelations between different types

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of resistance to FHB and plant height of wheat genotypes.

MATERIAL AND METHODS

In total 24 genotypes were used for FHB resistance testing in 2007/08 and 2008/09 at the experimental field of IFA-Tulln (Austria) and in 2008/09 at the experimental field of Agricultural Institute Osijek (Croatia). 20 genotypes originated from the Croatia, of which 17 from the Agricultural Institute Osijek (Srpanjka, Zitarka, Golubica, Super Zitarka, Janica, Lucija, Alka, Lela, Pipi, Katarina, Renata, Aida, Seka, Felix, U1, Tena, Osjecanka) and three genotypes (Zlatna Dolina, Divana, Sirban Prolifik) originated from other breeding centers. Genotypes Soissons and Renan originate from France, and genotype Libellula from Italy. These genotypes were sown in field trials in Tulln (Austria) and Osijek (Croatia). Tulln (40º20'N, 16º4'E) is located 30 km west of Vienna. The soil type is meadow-chernozem. The average temperatures during growing season 2007/08 were 7.3ºC and sum of percipitation was 401.4 mm and in 2008/09 were 7.6 °C and sum of percipitation was 579.3 mm. Plot size was 1 m^2. In Croatia the field trial was set up at Agricultural Institute Osijek (45º32'N, 18º44'E). The soil type is eutric cambisol. The average annual precipitation in growing season in year 2008/09 was 367.8 mm and the average annual temperature was 10.76ºC. Genotypes were sown in eight row plots of 7 m length and 1.08 m wide in October at a sowing rate of 330 seeds/m^2. Spray inoculations were performed individually for each genotype at flowering (Zadok's scale 65) (Zadoks et al., 1974) using a hand sprayer. Two days later inoculation was repeated. General resistance (percentage of diseased spikelets in the plot), scored at day 22 after first inoculation in Tulln and Osijek, and Type I resistance (resistance to initial infection assedssed by the percentage of diseased ears) in Tulln and the area under the disease progress curve (AUDPC) were calculated. In the greenhouse experiment Type II resistance (resistance to spread of symptoms, Bai and Shaner, 1994.) and Type III resistance (resistace to DON, Lemmens et al., 2005), and the area under the disease progress curve (AUDPC) were calculated. At both locations (Osijek, Tulln) the height of the genotypes of wheat was measured, not taking into account the awns.

Inoculum

To produce macroconidia of *F. culmorum* (isolate IFA 104), a mixture of wheat and oat grain (3 : 1 by volume) was soaked in water overnight in 250 ml glass bottles, then water was decanted and seeds autoclaved. After adding the *Fusarium* strain, the seeds were kept for 2 weeks at 25°C in the dark. Concentration of conidial suspension was $2{,}5\text{x}10^4$ ml^{-1} (Snijders and Van Eeuwijk, 1991). For experiment in Croatia concentration was raised to $10\text{x}10^4$ ml^{-1}. The aggressiveness test was done in a Petri-dishes as described by Lemmens et al. (1993) (data not shown). Tubes small aliqouts of inoculum were frozen at -80°C until use.

Statistic alanalysis

Analysis of variance and correlation analysis were calculated using SAS/STAT, a version 9.1.2., PROC GLM and PROC CORR Spearman procedure. For AMMI1 models software IRRISTAT 5.0 (Irristat for Windows ©, 2005) was used.

AUDPC calculation of a (modified by Shaner and Finney in 1977):

$$\text{AUDPC} = \sum_{i=1}^{n} \{[(Yi + Yi - 1)/2] * (Xi - Xi - 1)\}$$

Yi - the percentage of visibly infected spikelets (*Yi*/100) at the ith observation;

Xi - the day of the ith observation;

n - total number of observations.

RESULTS AND DISCUSSION

Analysis of variance for the height of genotypes showed statistically significant differences between genotypes and environments, and for interaction genotype*environment (Table 1). At both locations (Osijek and Tulln) the tallest genotypes were U1 (134 cm), Sirban Prolifik

(133 cm), Tena (96 cm) and Bezostaja (94 cm). Lowest height was found in genotypes Srpanjka (56 cm), Renata (60 cm) Seka (62 cm) and Katarina (64 cm) (Figure 1).

Spearman correlation coefficient determined a high negative significance between the height of genotype and AUDPC for general resistance (r=-0.77), and the height of genotype and AUDPC for Type I resistance (r=-0.81). There was no statistically significant correlation between genotype height and AUDPC for Type II resistance (r=0.14) and between genotype height and AUDPC for Type III resistance (r=-0.18) (Table 2). Shortest genotypes in two years of experiments in Tulln were Srpanjka (51.5 cm), Renata (55.1 cm) and Seka (57.5 cm), and the tallest genotypes were Sirban Prolifik (135.3 cm) and U1 (133.3 cm) (Figures 2 - 5). Although some genotypes have the same height, the differences in resistance may be different, which we can explain with the potential possession of resistance genes.

Table 1. Analysis of variance for the height of winter wheat genotypes in three environments (2007/08 and 2008/09 in Tulln and 2008/09 in Osijek)

Source of variability	Plant height			
	Degrees of freedom	Mean square	F-value	P
Genotype	23	2329.19	216.72***	<.0001
Replication	1	16.67	1.55ns	0.2170
Environment	2	5680.26	528.52***	<.0001
Genotype* Environment	46	42.42	3.95***	<.0001
Error	71	10.75		

***,**,* = significant at P<0.001; 0.01 and 0.05;
ns = nonsignificant (P>0.05)

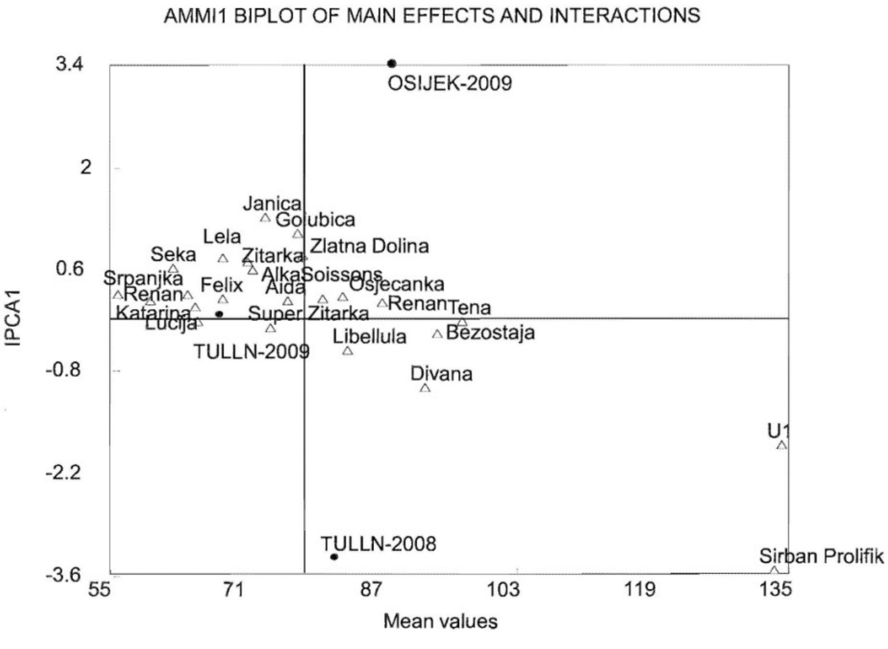

Figure 1. AMMI model of studied winter wheat genotypes for their height (2007/08 and 2008/09 in Tulln and 2008/09 in Osijek)

Table 2. Spearman correlation coefficient height and AUDPC for different types of resistance of winter wheat genotypes measured in Tulln in 2007/08 and 2008/09

Trait	AUDPC for Type I resistance	AUDPC for Type II resistance	AUDPC for Type III resistance	AUDPC for general resistance
Plant height	-0.81**	0.14	-0.18	-0.77**

**p≤0.01; *p≤0.05

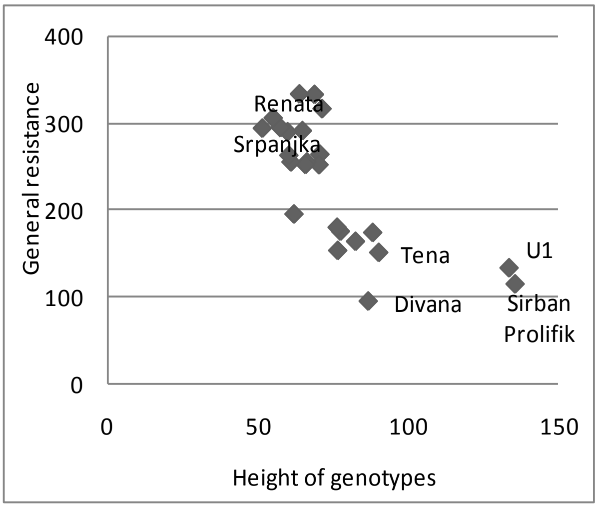

Figure 2. Relationship between AUDPC for general resistance and height of genotypes

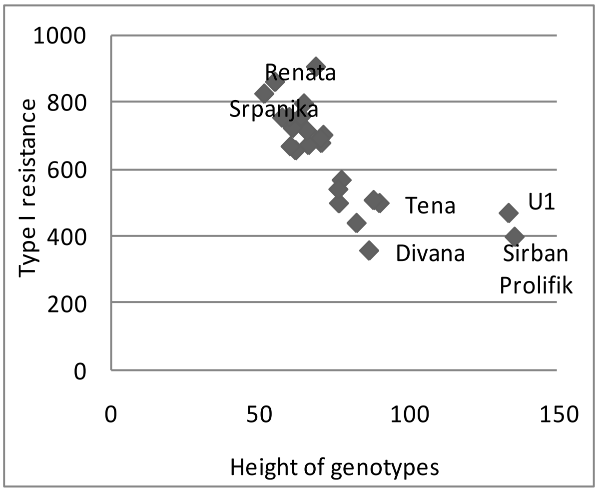

Figure 3. Relationship between AUDPC for Type I resistance and height of genotypes

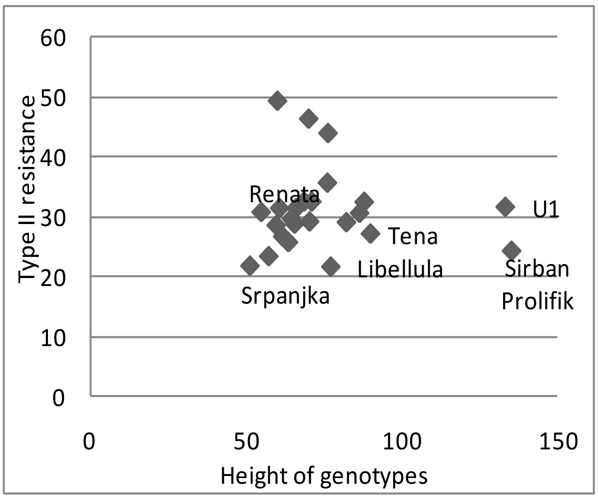

Figure 4. Relationship between AUDPC for Type II resistance and height of genotypes

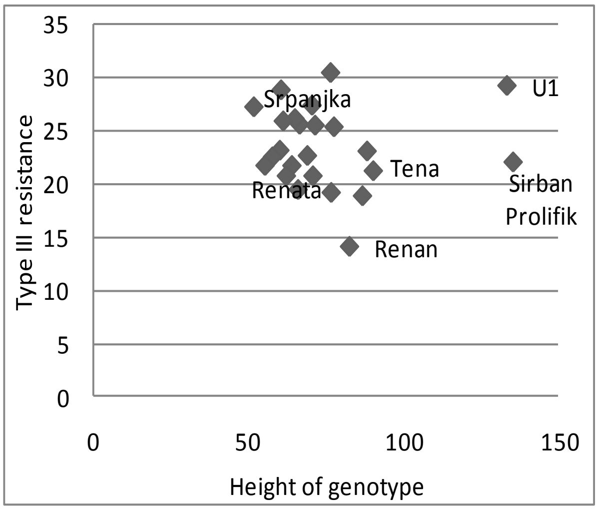

Figure 5. Relationship between AUDPC for Type III resistance and height of genotypes

In this study, plant height was significantly negatively correlated with AUDPC for FHB incidence (Type I resistance), and AUDPC for general resistance. The lowest AUDPC for initial infection and general resistance had older wheat genotype (Divana; 87 cm), which belongs to class of taller genotypes in Croatia. AUDPC for FHB (Type II resistance) and AUDPC for DON resistance (Type III resistance) showed no significant correlation with plant height. This would mean that shorter genotypes tended to have more infection with *Fusarium* species. Similar results were found in previous studies (Mesterhazy, 1995; Hilton et al., 1999; Buerstmayr et al., 2000; Somers et al., 2003). In natural infections taller genotypes have their spikes at a greater distance from the primary inoculum sources (such as crop residues), and is considered that artificial infection should reduce effect of plant height. The negative correlation between AUDPC for FHB symptoms and plant height in this study could be attributed to genetic effects and/or the influence of microclimate. Even in the presence of irrigation, spikes of taller plants could dry more quickly and thus could be exposed to less moisture than the spikes of shorter genotypes.

Handa and Ban (2008) identified QTL called QFhs.kibr-2D involved in Type I and Type II resistance and controlling the accumulation of DON-a, which was closely associated with SSR loci Xgwm261 and semi-dwarfing alleles *Rht8*. Most of investigated genotypes posses *Rht8* (indicated by Dvojković at el., 2010), so it is possible that also they have similar QTLs. Research should further go in the direction to introduce *Rht1* and *Rht2* genes in Croatian breeding material, for which is believed to be associated with *Fusarium* resistance. Such an approach would more clearly elucidate the complex relationship of *Rht* genes with *Fusarium* resistance. Buerstmayer et al. (2000) and Haberle et al. (2009) concluded however that, although there is a significant negative correlation between visual FHB symptoms and plant height, it is possible to control the breeding process to select genotypes with shorter stems, which also have high FHB resistance.

CONCLUSIONS

Significant negative correlations between plant height and AUDPC for Type I resistance and between plant height and AUDPC for general resistance were observed. We can conclude that genotypes which have higher plant height have better resistance to FHB. Results of this reserach could be useful in improving resistance to FHB in wheat genotypes.

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