EFFECTS OF TWO HEIGHT REDUCING GENES ON YIELD AND ITS COMPONENTS IN A SEMI-HUMID ENVIRONMENT

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ABSTRACT

The influence of plant height on wheat performance depends on the environmental conditions. This study is an attempt to determine the effect of two of the most commonly used dwarfing genes on wheat performance in the semi-humid environment at Brasov, Romania. Height, yield and yield components were studied in 104 recombinant inbred lines (RIL) from a cross between semidwarf parents carrying different alleles at the *RhtB1* and *Rht8* loci, in 3 years at two planting dates. Average plant height of the genotypes was: *RhtB1a - rht8> RhtB1b - rht8> RhtB1a - Rht8> RhtB1b - Rht8.* The effects of the dwarfing alleles on yield were small. On an average at the normal planting date, lines carrying the *Rht8* alone yielded significantly less than tall lines and *RhtB1b* semidwarfs. At the late planting date, yield differences among RIL groups were small and not significant but, at both planting dates, the *RhtB1b* semidwarfs gave the highest average yield. The effects of the dwarfing genes on each of the yield components were generally small and not significant.

Key words: height reducing genes, semidwarf genes, wheat

INTRODUCTION

Wheat plant height is an important character, which can significantly influence not only lodging resistance, but also photosynthesis and assimilate distribution, therefore grain yield. Many researchers have studied the relationship between height and yield. Kertesz et al. (1991) found that in Hungary the moderate height reduction caused by the genes *Rht1* and *Rht2* reduced yield by 6%, while the strong height reduction caused by the genes *Rht1+Rht2* or *Rht3* reduced yield by 48 and 71% respectively. In California, Ehdaie and Waines (1994) found favourable pleiotropic effects of the genes *Rht1* and *Rht2*, which increased yield by 10-13% in spring wheat. Villareal and Rajaram (1992) also found that the semidwarfs carrying *Rht1* and *Rht2*, were superior to tall wheat in Mexico. Sip and Skorpik (1993) found that only the strong height reduction caused by *Rht3* had a negative influence on yield, while genes *Rht8*, *Rht1* and *Rht2*, had no effect on yield. In Romania, Saulescu et al. (1988) identified the height reducing genes present in Romanian semidwarf cultivars and suggested that *Rht1* was favored during selection under specific environmental conditions. By comparing yields of semidwarf and tall cultivars in 176 yield trials, Saulescu et al. (1994) found that *Rht1* carriers had an average yield advantage of 314 kg/ha. The yield increase associated with the *Rht1* dwarfing allele was smaller in Transylvania and in years with unfavourable conditions for plant emergence. All these results suggest that the effects of the dwarfing genes are dependent on the environmental conditions.

This study is an attempt to determine the effect of two of the most commonly used dwarfing genes, *RhtB1* and *Rht8*, on wheat performance in the semi-humid environment at Brasov, Romania.

MATERIAL AND METHODS

Height, yield and yield components were studied in 104 recombinant inbred lines (RIL) from a cross between winter wheat cultivars Sincron and F1054W. Sincron was selected from the cross Russalka/Aurora/3/ Mexique 50/ B21 // Aurora /4/ Zg4163-73 (Figure 1), as a long coleoptile, high-tillering semidwarf (Saulescu and Ittu, 1985). F1054W was selected from the cross Montana /3/ Mexique 50 / B21 // Aurora /4/ Lovrin 32, as a semidwarf, high yielding line.

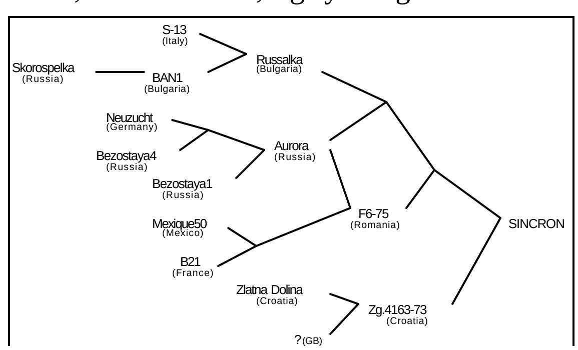

Figure 1. Genealogy of the winter wheat line Sincron

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The recombinant inbred lines were developed at the Agricultural Research & Development Institute of Fundulea using the following procedure (Ittu et al., 2000). From the F_2 population, 108 spikes were randomly harvested and the seed was planted in the field as F_3 head-rows. From F_3 to F_7, one spike was harvested from each head-row without any conscious selection and was used to plant the next generation. Seed from each $F_{7:8}$ head-row was bulked to produce the recombinant inbred lines. Parents were homogeneous, so sampling from parents was not considered necessary.

Polymorphism was found among the parents, and consequently among the recombinant inbred lines, for height-reducing genes *RhtB1* (previous designation *Rht1*) and *Rht8* (McIntosh et al., 1998). Classification of parents and RIL according to alleles at *RhtB1* and *Rht8* was based on plant height and on seedling response to exogenous gibberellic acid, as measured by the height of two-leaf seedlings grown in sterilized sand and watered with Austin nutrient solution supplemented with 50 mg kg^{-1} gibberellic acid (Gale and Gregory, 1977). Table 1 shows the alleles for the height reducing genes found in the parents Sincron and F1054W. Segregation patterns for the marker loci fit the expected 1:1 ratio ($0.25<P<0.90$, data not shown).

Table 1. Marker loci for height in winter wheat cross Sincron / F1054W

Gene	Chromosome location	Alleles present in Sincron	Alleles present in F1054W
RhtB1	4Ba	*RhtB1a*	*RhtB1b*
Rht8	2DL	*Rht8*	*rht8*

The 104 RIL were grown in the field on 5 m² plots without replications, with parents repeated 10 times, during 1995-1996, 1996-1997 and 1997-1998, at the Research and Development Institute for Potatoes and Sugar Beet Brasov, on a cambic chernozem.

The year 1995-1996 was dry at planting date, but excessive rainfall from November to the end of vegetation and temperatures below normal, caused reduced growth and low yields. The year 1996-1997 was moderately favourable for wheat, with dry autumn, but high rainfall during spring and relatively high temperatures (28.0-29.5°C) during grain filling. The year 1997-1998 was the most favourable, with good moisture at planting time, high rainfall in spring and normal temperatures.

Two planting dates were used each year, the recommended one, in the first days of October, and a late one, 2-3 weeks later.

Little spatial variation and no spatial trends were observed for yield or its components among replicated plots of the two parents. Therefore, all plots were treated as a population in which markers were completely randomized, and comparisons were made among subsets of lines with alternative alleles at each locus. A *t*-test, assuming equal variances was used to determine the significance of differences between average values of recombinant lines grouped according to the alleles of the marker genes. The significance of differences between means of individual lines and the mean of the most resistant parent was determined by a *t*-test, based on genotype x years interaction.

RESULTS AND DISCUSSION

Average plant height of RIL's carrying each combination of alleles of the dwarfing genes (*RhtB1a - rht8*, *RhtB1a - Rht8*, *RhtB1b - rht8* and *RhtB1b - Rht8*), in each of the three years of testing and averaged over the three years of testing are presented in table 2.

Each year and on average over the three years, at both planting dates, plant height was in decreasing order *RhtB1a - rht8*> *RhtB1b - rht8*> *RhtB1a - Rht8*> *RhtB1b - Rht8*. The dwarfing allele *Rht8* had a stronger height reducing effect than the dwarfing allele at the *RhtB1* locus.

Average yields of RIL's carrying each combination of alleles of the dwarfing genes, in each of the three years of testing, and averaged over the three years of testing, are presented in table 3. The results suggest that, under the environmental conditions of Brasov, the dwarfing genes had a relatively small effect on yield. Significant yield differences were only recorded in 1996 and 1998 at the normal planting date. In 1996 semidwarf lines with the dwarfing allele at the *RhtB1* locus were significantly superior to all the other RIL groups, while in 1998 the same lines, together with the tall ones were significantly superior to the among the *RhtB1b* carriers and among the tall lines (data not shown).

Differences in the number of emerged plants and in the number of spikes per unit area were

Table 2. Average plant height of recombinant inbred lines, grouped according to the alleles of the dwarfing genes *RhtB1* and *Rht8*

Alleles of the dwarfing genes	Plant height (cm)							
	1996		1997		1998		Average	
	Normal planting date	Late planting date	Normal planting date	Late planting date	Normal planting date	Late planting date	Normal planting date	Late planting date
RhtB1a - rht8	65.7 a	56.0 a	90.5 a	87.0 a	94.4 a	90.0 a	83.2 a	77.5 a
RhtB1b - rht8	65.2 a	53.0 a	81.8 ab	79.0 b	86.4 b	83.0 b	77.8 b	71.5 b
RhtB1a - Rht8	54.9 b	47.0 b	77.1 b	73.0 c	79.6 c	79.0 b	70.5 c	66.4 c
RhtB1b - Rht8	48.8 b	43.0 b	64.8 c	65.0 d	69.0 c	69.0 c	60.9 d	58.8 d

Values from the same column, followed by the same letters, are not significantly different at P<5%.

Table 3. Average grain yield of recombinant inbred lines, grouped according to the alleles of the dwarfing genes *RhtB1* and *Rht8*

Alleles of the dwarfing genes	Grain yield (kg/ha)							
	1996		1997		1998		Average	
	Normal planting date	Late planting date	Normal planting date	Late planting date	Normal planting date	Late planting date	Normal planting date	Late planting date
RhtB1a - rht8	3781 b	2789 a	4145 a	4381 a	5834 a	5405 a	4587 a	4192 a
RhtB1b - rht8	4374 a	2572 a	4524 a	4739 a	5604 a	5462 a	4834 a	4258 a
RhtB1a - Rht8	3533 b	2500 a	4237 a	4585 a	5086 b	5065 a	4282 b	4050 a
RhtB1b - Rht8	3555 b	2553 a	4673 a	4897 a	4767 b	4430 a	4332 ab	3960 a

Values from the same column, followed by the same letters, are not significantly different at P<5%.

Rht8 carriers. On the average at the normal planting date, only the lines carrying the *Rht8* alone yielded significantly less than the tall lines and the *RhtB1b* semidwarfs. At the late planting date, yield differences among RIL groups were small and not significant.

Despite the small effects of the dwarfing alleles on yield, it should be noted that, at both planting dates, the *RhtB1b* semidwarfs gave the highest average yield. It is also worth mentioning that the highest yielding individual lines were found small and not significant in all years and at both planting dates (Tables 4 and 5).

Knowing that the *RhtB1b* allele produces a significant reduction in coleoptile length (Allan et al., 1961; Saulescu et al., 1994), it is obvious that under conditions found at Brasov coleoptile length did not influence seedling emergence and number of spikes.

The number of grains per spike was similar in all RIL groups, with the exception of the semidwarfs carrying the allele *Rht8*, which had significantly smaller spikes in 1996 at normal planting date, in 1998 at late planting and on average (Table 6).

Average weight of 1000 grains was not significantly influenced by the dwarfing alleles (Table 7). However, there was a tendency for the semidwarfs carrying the *RhtB1b* allele to have larger grains, at both planting dates.

Table 4. Average number of emerged plants/m² in recombinant inbred lines, grouped according to the alleles of the dwarfing genes *RhtB1* and *Rht8*

Alleles of the dwarfing genes	Number of emerged plants/m²							
	1996		1997		1998		Average	
	Normal planting date	Late planting date	Normal planting date	Late planting date	Normal planting date	Late planting date	Normal planting date	Late planting date
RhtB1a - rht8	251 a	213 a	423 a	428 a	386 a	400 a	353 a	347 a
RhtB1b - rht8	243 a	204 a	413 a	431 a	386 a	423 a	347 a	352 a
RhtB1a - Rht8	255 a	202 a	429 a	410 a	374 a	397 a	353 a	336 a
RhtB1b - Rht8	220 a	175 a	517 a	400 a	368 a	379 a	368 a	318 a

Values from the same column, followed by the same letters, are not significantly different at P<5%.

Table 5 . Average number of spikes/m² in recombinant inbred lines, grouped according to the alleles of the dwarfing genes *RhtB1* and *Rht8*

Alleles of the dwarfing genes	Number of spikes/m²							
	1996		1997		1998		Average	
	Normal planting date	Late planting date	Normal planting date	Late planting date	Normal planting date	Late planting date	Normal planting date	Late planting date
RhtB1a - rht8	507 a	311 a	582 a	668 a	673 a	669 a	587 a	549 a
RhtB1b - rht8	482 a	291 a	608 a	675 a	648 a	667 a	579 a	545 a
RhtB1a - Rht8	497 a	308 a	645 a	678 a	657 a	680 a	600 a	555 a
RhtB1b - Rht8	471 a	292 a	603 a	742 a	579 a	688 a	551 a	574 a

Values from the same column, followed by the same letters, are not significantly different at P<5%.

Table 6. Average number of grains/spike in recombinant inbred lines, grouped according to the alleles of the dwarfing genes *RhtB1* and *Rht8*

Alleles of the dwarfing genes	Number of grains/spike							
	1996		1997		1998		Average	
	Normal planting date	Late planting date	Normal planting date	Late planting date	Normal planting date	Late planting date	Normal planting date	Late planting date
RhtB1a - rht8	17 ab	21 a	19 a	16 a	30 a	30 ab	22 ab	22 a
RhtB1b - rht8	19 a	21 a	19 a	16 a	30 a	33 a	23 a	22 a
RhtB1a - Rht8	16 b	20 a	17 a	17 a	26 a	29 b	20 b	22 a
RhtB1b - Rht8	17 ab	20 a	20 a	16 a	31 a	31 ab	23 a	23 a

Values from the same column, followed by the same letters, are not significantly different at P<5%.

It is interesting to notice that, although at the level of each yield component the effects of the dwarfing genes are small and not significant, the small existing differences cumulate to produce more important differences in yield.

Table 7. Average weight of 1000 grains in recombinant inbred lines, grouped according to the alleles of the dwarfing genes *RhtB1* and *Rht8*

Alleles of the dwarfing genes	Weight of 1000 grains (g)							
	1996		1997		1998		Average	
	Normal planting date	Late planting date	Normal planting date	Late planting date	Normal planting date	Late planting date	Normal planting date	Late planting date
RhtB1a - rht8	47.1 a	44.5 a	40.9 a	43.6 a	45.2 a	46.1 a	44.4 a	44.7 a
RhtB1b - rht8	49.2 a	45.2 a	41.6 a	43.9 a	44.0 a	46.5 a	44.9 a	45.2 a
RhtB1a - Rht8	46.8 a	43.8 a	40.8 a	41.6 a	42.9 a	44.2 a	43.5 a	43.2 a
RhtB1b - Rht8	47.9 a	46.3 a	40.4 a	40.5 a	43.7 a	43.0 a	44.0 a	43.2 a

Values from the same column, followed by the same letters, are not significantly different at P<5%.

CONCLUSIONS

Average plant height was strongly affected by the dwarfing genes *RhtB1* and *Rht8*. On an average, lines carrying both genes were the shortest, followed by lines carrying only *Rht8*. Lines carrying only *RhtB1b* were significantly taller than lines with *Rht8*, but significantly shorter than lines without any dwarfing alleles.

The effects of the dwarfing alleles on yield were small. On an average at the normal planting date, lines carrying the *Rht8* alone yielded significantly less than tall lines and *RhtB1b* semidwarfs. At the late planting date, yield differences among RIL groups were small and not significant but, at both planting dates, the *RhtB1b* semidwarfs gave the highest average yield. The effects of the dwarfing genes on each of the yield components were generally small and not significant, but the small existing differences cumulated to produce more important differences in yield.

Results suggest that in the semi-humid environment at Brasov - Romania best results can be expected from *RhtB1b* semidwarfs and tall genotypes, while *Rht8* semidwarfs should be avoided.

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