

Effects of different *Rht-B1b*, *Rht-D1b* and *Rht-B1c* dwarfing genes on agronomic characteristics in wheat

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Summary

The value of different dwarfing genes in winter wheat breeding was studied using 6 near-isogenic lines carrying different *Rht* dwarfing genes over three years experiment. Results showed that both the *Rht-B1b* and *Rht-D1b* semi-dwarfing genes had significantly positive effects on kernel number and grain weight per spike, and had significantly negative effects on 1000-grain weight comparing to the tall line (*Rht-B1a*). The *Rht-B1c* dwarfing gene had a significantly negative effect on kernel number per spike, and had positive effect on 1000-grain weight. The combination of the *Rht-D1b* and *Rht-B1c* gene showed significantly negative effect on yield components. All of these 5 dwarfing or semi-dwarfing genotypes mentioned above had significantly negative effect on plant height and no significantly effect on the area of flag leaf, spikelets per spike and spike length.

Key words: Wheat (*Triticum aestivum* L.); Dwarfing gene; Near-isogenic line (NILs); Agronomic characteristics

Introduction

The effects of *Rht* dwarfing genes on increase of wheat grain yield and improvement of agronomic characteristics were studied by many people in the world (Flintham *et al.* 1997, Law *et al.* 1978, Youssefian *et al.* 1992). The enhancement of harvest index was caused by both *Rht-B1b* and *Rht-D1b* semi-dwarfing genes found by Snape, *et al.* (1984). Allan *et al.* (1989) found that near-isogenic lines with a single dose of Norin 10 (*Rht-B1b* and *Rht-D1b*) dwarfing genes had a mean yield 11% greater than the lines with both genes together. Norin 10 dwarfing genes had significantly positive effect on grain yield considered by many breeders (Li *et al.* 1995, Li *et al.* 1999, Pinthus *et al.* 1990, Pinthus *et al.* 1983). There were different views on the value of *Rht-B1c* Dwarfing gene in wheat breeding. Many people found that the same dwarfing gene had different effects on agronomic characteristics in different ecological conditions (Li *et al.* 1995, Richards 1992). The experiment was, therefore, conducted in Shijiazhuang of Hebei using 6 NILs to study the effects of different *Rht* dwarfing genes on wheat agronomic characteristics and to provide some information to breeding in similar ecological environments.

Materials and Methods

Genotypes: Near-isogenic lines carrying the *Rht-B1b*, *Rht-D1b*, *Rht-B1c*, *Rht-B1b+Rht-D1b* and *Rht-D1b+Rht-B1c* alleles were produced in the winter wheat background of Maris Huntsman (*Rht-B1a*), by M.D.Gale and Worland *et al.* at Plant Breeding Institute, Cambridge.

Environments and trial design: The Maris Huntsman isogenic lines (*HRht-B1a*, *HRht-B1b*, *HRht-D1b*, *HRht-B1c*, *HRht-B1b+Rht-D1b*, *HRht-D1b+Rht-B1c*) were grown in a space-plant field trial. The experiment was conducted at Institute of Cereal and Oil Crops, Hebei Academy of Agricultural and Forestry Sciences in the years of 1995, 1997 and 1998. Each line was sown in a separate plot of 1.2m X 0.8m (4rows, 20cm between rows, 133grains m⁻²) with randomized block design and three replicates. Nitrogen fertilizer was applied at a rate of 38-kg ha⁻¹ and 103.5kg just before sowing and before the start of stem elongation, respectively. Phosphate fertilizer was applied at a rate of 103kg ha⁻¹ just before stem elongation. Three to five times irrigation was conducted during the period of wheat plants development. Chemicals were applied to control aphids.

Characters test and data analysis: Ten plants were sampled randomly from each plot. Thirty plants of each line were used to score characteristics, i.e. plant height, spike length, kernel number per spike, grain-weight per spike, 1000-grain weight, flag leaf area and the second leaf area from top, and spikelets per spike. All variables measured for each genotype were subjected to analysis of variance procedures. Separate analysis was made for each year. Mean separation was conducted using the LSR.

Results

Effects on yield components of different *Rht* genes

Performance of yield components (kernel number and grain-weight per spike, 1000-grain weight, spikelets per spike) was showed in Table 1. Significance test of difference for yield components showed that all of them were significantly different at 0.05 level of probability. Effects difference on yield components of six lines were analyzed as follows:

Effect on Kernel number per spike: The result of three years experiment was similar. Both the *Rht-B1b* and *Rht-D1b* genes had significantly positive effect ($p < 0.01$ or < 0.05). The line carrying the *Rht-B1b+Rht-D1b* had more kernels than the *Rht-B1c* line and the *Rht-D1b+Rht-B1c* line. The *Rht-B1c* line had lower kernel number than *Rht-B1b*, *Rht-D1b*, *Rht-B1a* and *Rht-B1b+Rht-D1b* lines. The line with *Rht-D1b+Rht-B1c* had the least kernel number ($P < 0.05$ or 0.01) of all NILs.

Effect on Grain-weight per spike: The results in 1995 were identical to that in 1997. The *Rht-B1b* and *Rht-D1b* genes had significantly positive effect ($P < 0.01$ or 0.05) on grain-weight per spike comparing with the tall line (*Rht-B1a*). There were no differences between the *Rht-B1a* and *Rht-B1c* lines in 1995. The *Rht-B1a* line was significantly higher than the *Rht-B1c*, *Rht-D1b+Rht-B1c* and *Rht-B1b+Rht-D1b* lines in 1997 and 1998. The *Rht-D1b+Rht-B1c* line had the lowest grain-weight per spike in three years experiment.

Effect on 1000-grain weight: In the experiment of three years, the 1000-grain weight of *Rht-D1b* and *Rht-B1b +Rht-D1b* lines was significantly lower than that of *Rht-B1a* genotypes. This is partly identical to that the *Rht-B1b*, *Rht-D1b* and *Rht-B1c* genotypes had significantly negative effect on 1000-grain weight found by Pinthus *et al.* (1990). There was no difference between *Rht-D1b* and *Rht-B1b +Rht-D1b* genotypes. The *Rht-B1c* line had significantly positive effect comparing to the *Rht-D1b* and *Rht-B1b+Rht-D1b* genes and there was no difference between the *Rht-B1c* line and the tall line at 0.05 levels in both 1995 and 1997. The *Rht-B1a* line had highest 1000-grain-weight and the *Rht-D1b+Rht-B1c* line had the lowest 1000-grain-weight in 1998 and there were no differences among other four lines.

Table 1. Performance of major agronomic characteristics of different dwarfing genotypes in three years

Genotypes	Kernels per spike			Grain weight per spike(g)			1000-grain weight(g)			Spikelets per spike		
	95	97	98	95	97	98	95	97	98	95	97	98
<i>Rht-B1a</i>	22.50	34.23	35.7	0.68	1.38	0.9	30.22	40.4	25.1	20.7	22.2	21.4
<i>Rht-B1b</i>	31.35	47.83	37.2	0.94	1.74	0.82	29.98	36.2	22.2	21.4	22.7	22.2
<i>Rht-D1b</i>	38.18	49.23	37.7	0.89	1.75	0.81	23.31	35.8	21.5	20.7	21.7	22.7
<i>Rht-B1c</i>	24.19	22.43	10.4	0.74	0.96	0.22	30.59	43.3	21.3	21.3	24.7	23.6
<i>Rht-B1b+Rht-D1b</i>	28.8	25.10	20.3	0.62	0.90	0.44	21.52	36.2	21.8	21.4	24.4	23.8
<i>Rht-D1b+Rht-B1c</i>	17.8	6.07	10.7	0.52	0.21	0.19	29.21	33.6	17.9	21.9	24.2	22.9

Genotypes	Plant height(cm)			Spike length(cm)			Area of flag leaf (cm ²)			Area of the second leaf from top (cm ²)		
	95	97	98	95	97	98	95	97	98	95	97	98
<i>Rht-B1a</i>	88.3	100.7	103.2	10.5	10.2	10.8	43.4	41.4	61.3	37.0	43.7	53.5
<i>Rht-B1b</i>	71.0	81.7	75.3	11.5	10.7	12.0	43.2	50.9	61.5	46.6	45.7	50.0
<i>Rht-D1b</i>	73.0	77.7	74.8	10.9	10.3	12.8	44.5	40.8	54.0	46.0	42.0	51.9
<i>Rht-B1c</i>	39.3	41.7	38.6	11.3	10.2	12.6	45.7	43.5	58.0	37.7	40.9	52.0
<i>Rht-B1b+Rht-D1b</i>	47.3	47.3	47.1	11.5	11.4	13.3	39.2	44.0	59.9	35.2	40.8	51.2
<i>Rht-D1b+Rht-B1c</i>	28.7	35.3	35.4	11.3	11.2	11.7	41.7	42.3	59.7	39.2	40.3	52.6

* Yield components may be affected by hot-wind during the late stage of wheat development

Effect on Spiklets per spike: There were no significantly differences between genotypes in 1995. Both the *Rht-B1c* and *Rht-B1b+Rht-D1b* gene lines had more spiklet number per spike than the *Rht-B1b*, *Rht-D1b* and *Rht-B1a* lines both in 1997 and 1998, and there were no significantly differences between *Rht-B1c* and *Rht-B1b+Rht-D1b* or among *Rht-B1b*, *Rht-D1b* and *Rht-B1a* lines .

Effects of the *Rht* genes on other agronomic characteristics

Effects of genotypes on flag leaf area, the area of the second leaf from top and plant height were highly significant compared to replicates error at 0.05 or 0.01 level of probability. Effects of the *Rht* genes on spike length were not significant. Thus it can be seen that environments affected the difference between genotypes of spike length. Youssefian (1992) found that spike length was not affected by *Rht-B1b*, *Rht-D1b* and *Rht-B1c* genes. This agrees to our results.

Flag leaf area: There was no difference between genotypes in 1995. The *Rht-B1b* semi-dwarfing gene had the highest flag leaf area in 1997 and 1998. Both the *Rht-B1b* and *Rht-B1a* line with bigger areas than *Rht-D1b* in 1998. There was no significantly difference between any other two lines in 1997 and 1998.

The second leaf from top: The *Rht-B1b* and *Rht-D1b* semi-dwarfing genes had significantly positive effects, and there was no difference between the *Rht-B1b+Rht-D1b*, *Rht-B1c*, *Rht-D1b+Rht-B1c* and *Rht-B1a* lines in 1995. The differences between genotypes in 1997 and 1998 were not significant but it also showed that the areas of the *Rht-B1b* line were bigger than others in 1997.

Plant height: The differences between genotypes were significant except that between the *Rht-B1b* and *Rht-D1b* lines in three-year trial. The order of the height was *Rht-B1a* > *Rht-B1b* = *Rht-D1b* > *Rht-B1b+Rht-D1b* > *Rht-B1c* > *Rht-D1b+Rht-B1c* (Table 1). So, it can be seen that different *Rht* genes or different combinations of the *Rht* genes all had significant effects. Therefore, they can be used by breeders according to different breeding objectives.

Discussion

In this experiment both the *Rht-B1b* and *Rht-D1b* genes had significantly positive effects on grain yield. In a review of researches on various dwarfing genes of wheat by Gale *et al.* (1985), numerous studies were cited confirming the superiority of the cultivars carrying the *Rht-B1b* or *Rht-D1b* genes over *Rht-B1a* cultivars in their yielding ability (Gale *et al.* 1985). The principal contribution to yield was mostly attributed to the increase of grain number per spike. Similarly in their analyses of random lines and NILs, they found that *Rht-B1b* and *Rht-D1b* had a positive effect on grain number per ear, and a decrease in grain size was also found. The negative effect on grain size, however, was generally less than the positive effect on spikelet fertility, resulting in an overall increase of grain yield.

The difference in yielding ability between *Rht-B1b* and *Rht-D1b* genes was not significant in our study. It agrees to the finding of Gale *et al.* (1985). There was no yield difference between the *Rht-B1b* and *Rht-D1b* genes also were found by Allan (1989), Fischer *et al.* (1990) and Hoogendoorn *et al.* (1988). Villareal *et al.* (1992) found, however, that the *Rht-B1b* line gave higher yield potential than the *Rht-D1b* lines ($P < 0.05$). Pinthus *et al.* (1984) found that the overall mean yield of the *Rht-B1b* semi-dwarfing lines was significantly higher than that of the *Rht-D1b* lines.

Grain yield of the *Rht-B1b+Rht-D1b* line was lower than both the *Rht-B1b* and *Rht-D1b* lines in this experiment. This was identical to the finding of Allan (1989). Fischer *et al.* (1990) found, however, that there was a yield superiority of the *Rht-B1b+Rht-D1b* dwarfs over the *Rht-B1b* or the *Rht-D1b* groups. Later on, Villareal *et al.* (1992) found that the yield difference between *Rht-B1b* and *Rht-B1b+Rht-D1b* line was not significant. Thus it can be considered that the differences of parental background and environment may be the main sources of the differences between these studies.

That the *Rht-B1c* gene had negative effect on wheat grain yield was considered by a lot of breeders. Flintham *et al.* (1983) found, however, that the decrease of biomass of *Rht-B1c* gene was similar to that of *Rht-B1b* and *Rht-D1b* lines, and there was no negative effect on grain yield in the comparison of 16 randomized lines. The effects of *Rht-B1c* on grain number and grain size was identical to that of *Rht-B1b* and *Rht-D1b* genes. Zhang *et al.* (1995) found that the *Rht-B1c* gene had a positive effect on the rate of photosynthesis and chlorophyll content, but had a negative effect on the duration of high value of photosynthesis rate. Wang *et al.* (1995) reported that advanced lines or plants developed using the *Rht-B1c* line as a parent and

those lines had higher grain yield and resistant to lodging. According to our result, both *Rht-B1c* and *Rht-D1b+Rht-B1c* genotypes had negative effect on grain yield because they had very dwarf plant and had significantly lower biomass than *Rht-B1b* and *Rht-D1b* lines. Although the grain size of *Rht-B1c* line was large, there were not enough material sources for the development of grains. In addition, the effects of dry-hot wind at the late stage of wheat development caused the premature senility of the plant so that grain filling cannot be guaranteed. So, there was lower maturing spike rate and grain yield was seriously affected. Therefore, there was a low value of *Rht-B1c* gene only in the ecological environment like Hebei. However, it cannot be denied that *Rht-B1c* was good parent for shortening plant height. The combination of *Rht-B1c* gene and other dwarfing genes had a high value in improvement of plant height of the line with other ideal characters or in the breeding for improvement of grain size.

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