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Genetic Impact of Dwarfing Genes (Rht_1 and Rht_2) for Improving Grain Yield in Wheat

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Abstract: Dwarfing genes (Rht_1 and Rht_2) have been extensively used for enhancing the grain yield in bread wheat. Ten semi-dwarf wheat genotypes having either Rht_1 or Rht_2 dwarfing genes were evaluated at Nuclear Institute of Agriculture, Tandojam, for yield and yield components. Significant differences in grain yield and yield components were observed in genotypes under study showing effects of dwarfing genes. Genotype SI88123 (Rht_1) had medium plant height (95.25 cm), higher number of tillers/plant (6.90), and the highest grain yield/plant (8.10 g). Sarsabz (Rht_1) with higher plant height (101.85 cm), reduced number of tillers per plant (3.55) and fertile spikes/plant had higher grain yield per spike (2.56 g). The short statured genotype SI8878 possessed significantly the highest number of grains/spike and considerably good yield/plant. Number of productive spikes established very high correlation with grain yield per plant in all the genotypes. The intensity of relationship varied from genotype to genotype.

Key words: Semi-dwarfing genes, grain yield, *Triticum aestivum* L

Introduction

The semi-dwarfing or reduced height genes Rht_1 (Rht-B1b) and Rht_2 (Rht-D1b) have been extensively exploited for developing high yielding varieties with reduced plant height and lodging resistance (Gale and Youssefian, 1985; Rebetzke and Richards, 2000). These genes reduced plant height by decreasing the sensitivity of reproductive and somatic tissues to endogenous gibberellin. The reduced cell elongation results in a decreased internode length, shorter plant height, shorter coleoptile length and smaller seedling leaf area (Keyes *et al.*, 1989; Hoogendoorn *et al.*, 1990; Beharev *et al.*, 1998; Worland *et al.*, 1998). The 'DARUMA' wheat grown in Japan around 1900 is considered to be a semi-dwarf type having short genes (Rht_1 and Rht_2) served as the framework for the "Green Revolution" in early sixties. The Norin 10 was then introduced in 1946 and used to develop Norin 10/Brevor 14 by Vogel *et al.* (1956) and was subsequently used by Borlaug (1968) and many others as a primary source of Rht_1 and Rht_2 genes.

Earlier wheat breeders believed that the taller cultivars have higher yield potential as compared to short statured ones as they possess higher biomass and have a larger source to contribute to the final sink of grain yield (Briggle and Vogel, 1968). However, with the induction of semi-dwarfing genes into tall wheat varieties, the theories have been changed. The semi-dwarfing genes Rht_1 and Rht_2 have been known to modify the plant ideotype by changing its cell size and number, root weight, coleoptile length, leaf size, harvest index, grain yield, yield components, protein content, disease reaction and gibberellic acid (GA) insensitivity (Gale and Youssefian, 1985; Loskutova, 1998). There are twenty major Rht dwarfing wheat genes. Of these, 16 are GA-sensitive, in contrast to Rht_1 and Rht_2 (Konzak, 1987).

This study is aimed to see the genetic impact of dwarfing genes (Rht_1 and Rht_2) for improving grain yield in wheat genotypes developed at Nuclear Institute of Agriculture (NIA), Tandojam.

Materials and Methods

Ten semi-dwarf spring wheat (*Triticum aestivum* L.) genotypes, namely WRS01, SI8878, SI8887, SI88123, SI88126, SI88155, SI88171, SI88231, Soghat 90 and Sarsabz were seeded at experimental farm, Nuclear Institute of Agriculture, Tandojam in the fall of 1993-94. A Randomized Complete Block Design (RCBD) was used and each plot consisted six rows 5.0 m in length and 30 cm distance between rows. Twenty plants at random, from 4 central rows were selected for agronomic studies. Traits measured on each plot were:

(I) plant height (cm); (ii) number of tillers per plant; (iii) number of productive spikes per plant; (iv) number of spikelets per spike; (v) number of grains per spike; (vi) number of grains per spikelet, calculated by dividing the number of seeds/spike by the number of spikelets/spike; (vii) grain yield per spike (g) and (viii) grain yield per plant (g). The parentage/pedigree of the genotypes is given in Table 1.

Table 1: Parentage/ pedigree and possible carrier of semi-dwarf genes

Genotypes	Parentage	Semi-dwarf genes
WRS01	(Maxipak x NIAB T-83) Beagles 'S' /Veerys	Rht_1
SI8878	Kauz 'S'	Rht_1
SI8887	PF704 / ALD 'S' // PAT72160/ ALD 'S' 3/ PEIN / S. -	
SI88123	URES / BOW 'S'	Rht_1
SI88126	URES / BOW 'S'	Rht_1
SI88155	FONG CHAN / 13/ TRT 'S' // VEE//9ht1	Rht_1
SI88171	DWL5023 / SWB 'S' // SNB 'S'	-
SI88231	KA "S" /NAG-	-
Soghat 90	PAVONht$_2$	Rht_1

Source: Singh *et al.* (1989)

Data were statistically analyzed and means were compared using Duncan's Multiple Range Test (Gomez and Gomez, 1983). Phenotypic correlation coefficients were worked out between grain yield and other traits in each genotype following Snedecor, (1956).

Results and Discussion

The analysis of variance showed significant ($P \leq 0.01$) mean squares for genotypes for all the characters, suggesting genetical differences among genotypes. The genotype SI8878 was the shortest (80.15cm) among all in plant height and had significantly the highest number of spikelets and grains/spike, which resulted in ultimate higher grain yield/plant (Table 2). This may not be true in every case as Pinthus and Levy (1983) reported that the presence of Rht_1 and Rht_2 genes caused no increase in grains/spike and the tall genotypes had the highest mean number of grains/spike. However, short statured wheat varieties are considered as a breeding prerequisite in many of the wheat growing countries of the world (Schillinger *et al.*, 1998). Genotypes SI88123 and SI88126 both having Rht_1 gene and plant height around 95 cm produced significantly more and fertile tillers per plant leading to higher grain yield/plant (8.10 and 6.78g, respectively) than other entries. These results suggested that increasing plant height up to certain extent may produce higher grain yield and support the idea of "tall dwarf" plant height model suggested by Gale and Law (1977). Busch and Rauch (1993) in their study on agronomic performance of tall versus short semi-dwarf lines did not found sufficient evidence to support the application of the "tall-dwarf" model in their hard red spring wheat germplasm. Culm length is controlled by polygenes as well as by the major Rht genes. Positive genotypic relationships between culm length and grain yield within the different Rht genes have been often reported (Pinthus, 1987). Interaction effects of the Rht genes and polygenes on culm length and grain yield of spring wheat

Table 2: Mean differences in eight agronomic traits of different wheat genotypes.

Genotypes	Plant height (cm)	No. of tillers/ plant	No. of spikes/ plant	No. of spikelets/ spike	No. of grains/ spike	No. of grains/ spikelet	Grain yield/ spike (g)	Grain yield/ plant (g)
WRS01	92.05cd	4.45bc	4.10cde	20.75e	45.20f	2.18e	1.44e	4.67b
SI8878	80.15e	4.95b	4.85bc	21.85cd	67.70a	3.10a	1.96cd	7.38a
SI8887	101.30a	4.45bc	4.40a	24.60a	56.35cd	2.29e	0.13bc	7.10a
SI88123	95.25b	6.90a	6.60a	23.25b	61.45bc	2.64bc	1.80d	8.10a
SI88126	95.80b	6.50a	5.70ab	23.45b	55.55cd	2.36de	1.74d	6.78a
SI88155	99.15a	3.85bc	3.65de	23.45b	65.10ab	2.78b	1.85d	4.93b
SI88171	92.10cd	4.85b	4.70bcd	19.70f	47.80ef	2.43cde	1.89cd	6.61a
SI88231	90.10d	4.30bc	4.00cde	22.25cd	53.40de	2.40cde	2.12bc	6.80a
Soghat 90	94.4bc	4.55bc	4.20cde	22.70bc	58.50cd	2.56bcd	2.33ab	7.60a
Sarsabz	101.85a	3.55c	3.40e	21.60de	57.95cd	2.69b	2.56a	6.96a

Means followed by same letters do not differ significantly at 5 percent level.

Table 3: Correlation coefficient (r) of seven different agronomic traits with grain yield/plant (g) of wheat genotypes.

Genotypes	Plant height (cm)	No. of tillers/ plant	No. of fertile tillers/plant	No. of spikelets/ spike	No. of grains/ spike	No. of grains/ Spikelet	Grain yield/ spike (g)
WRS 01	0.314n.s	0.697***	0.696***	0.116n.s	0.379n.s	0.320n.s	0.571**
SI8878	0.179n.s	0.875***	0.889***	0.087n.s	0.342n.s	0.303n.s	0.267n.s
SI8887	0.311n.s	0.739***	0.729***	0.393n.s	0.468*	0.306n.s	0.490*
SI88123	0.542*	0.754***	0.863***	0.017ns	0.129n.s	0.131n.s	0.357n.s
SI88126	0.343n.s	0.643**	0.615**	-0.034n.s	0.144n.s	0.209n.s	0.279n.s
SI88155	0.170n.s	0.538*	0.613**	-0.101n.s	0.384n.s	0.409n.s	0.510*
SI88171	0.480*	0.966***	0.959***	0.284n.s	0.620**	0.528**	0.789***
SI88231	0.493*	0.809***	0.929***	0.229n.s	0.074n.s	-0.044n.s	0.359n.s
Soghat 90	0.4408*	0.660**	0.765***	0.305n.s	0.481*	0.519*	0.456*
Sarsabz	0.533*	0.821***	0.857***	0.440*	-0.064n.s	0.138n.s	0.243n.s

*,**,*** denote correlation coefficient values significant at 5, 1 and 0.1% levels, respectively.

were also illustrated by Beharev *et al.* (1988). They found no beneficial effect on grain yield attributable to the Rht alleles *per se* which indicate the possible advantage of selecting for tall polygenes within the semi-dwarf group. Sarsabz had the maximum plant height (101.85 cm) and minimum number of spikes, but significantly higher main spike yield (2.56 g) than other entries. Because Sarsabz headed earlier and had long grain filling duration, there was more conversion of source into sink, hence produced more heavier seeds as compared to other genotypes. SI8887 with comparable plant height to Sarsabz had significantly the highest number of spikelets per spike. Two genotypes WRS01 and SI88171 were inferior to all for most of the traits. The local check variety Soghat 90 (Rht_2) with medium plant height (94.4 cm), gave the highest main spike yield (2.33 g) followed by Sarsabz (2.56 g). Sarsabz, SI8887 and SI88155 having statistically similar plant height were significantly taller than the remaining genotypes. These results agreed with Gale and Youssefian, (1985), Richards (1992), Beharev *et al.* (1998).

Genotype SI88123 had the highest plant yield which was mainly contributed by the higher number of spikes/plant. An increased number of spikes per unit area often results in high grain yield (Bingham, 1972; Villareal *et al.,* 1992). Grain yield of wheat has been continuously increasing by genetic improvements and increased agronomic inputs. Selection for reduced plant height has resulted in lodging resistance cum better utilization of chemical fertilizers. Semi-dwarf spring cultivars having lodging resistance also do not require vernalization (Busch and Rauch, 1993).

Phenotypic correlations between plant yield (y) and other yield components (x) were computed in each genotype. In general, all the genotypes had similar trend, however, the intensity of this relationship varied (Table 3). The significant positive correlations between plant height and yield were observed in five genotypes viz.; SI88123, SI88231, SI88171, Soghat 90 and Sarsabz. Number of tillers/plant and number of productive spike/plant showed very strong correlations with grain yield in all the genotypes. Three genotypes SI8887, SI88171 and Soghat 90 showed significantly positive correlations for number of grains per spike and grain yield. Main spike yield exhibited positive correlation with plant yield; however, it was significant only in genotypes, viz. WRS01, SI8887, SI88155, SI88171 and Soghat 90. The yield is a polygenic phenomenon and depends on its associated components. Spikes per unit area is one of the important yield components and is considered as the pleiotropic effect of Norin 10 genes (Gale and Youssefian, 1984; Kertesz *et al.,* 1991). Highly significant positive correlation between plant height and grain yield per plant in genotype SI88123, established higher grain yield than the remaining genotypes. All the measured traits in SI88171 and Soghat 90 had positive correlations with yield per plant showing visible effects of semi-dwarf genes on yield. The Norin 10 dwarfing genes, Rht_1 (Rht-B1b) and Rht_2 (Rht-D1b), reduced plant height and increase grain yield by altering the proportion of dry matter allocated to the grain (harvest index), and by reducing plant lodging, especially with increasing environmental yield potential (Waddington *et al.,* 1986; Slafer *et al.,* 1994; Rebetzke and Richards, 1999).

The 'Norin 10' based semi-dwarf wheats have been extensively used in the development of high yielding cultivars at global level. The results showed that number of tillers per plant possessed very strong positive correlation with grain yield per plant, while the extent of correlation between plant height and grain yield varied among the genotypes. The maximum grain yield was produced by the genotypes SI88123 and Soghat 90, which also exhibited significantly positive correlation between plant height and grain yield. The presence of dwarfing genes prevent excessive plant height, while minor gene variation for height could be exploited to select for taller, high yielding semi-dwarfs. Plant height being more heritable than yield, selection for taller plants in a given semi-dwarf population may serve as a useful selection criteria in early generations where huge segregating population is involved.

References

Beharev, A., A. Cahaner and M. J. Pinthus, 1998. Genetic correlations between culm length, grain yield and seedling elongation within tall (rht_1) and semi-dwarf (Rht_1) spring wheat (*Triticum aestivum* L.). Europ. J. Agron., 9: 35-40.

Beharev, A., M. J. Pinthus and A. Cahaner, 1988. Interaction effects of Rht dwarfing alleles and polygenes on culm length and grain yield of spring wheat. In: (Miller, T.E. and Koebner, R.M.D., eds.), Proc. 7th Int. Wheat Genet. Symp., Cambridge, UK, pp: 1047-1050.

Bingham, J., 1972. Physiological objectives in breeding for grain yield in wheat. In Proc. 6th Eucarpia Congress, Cambridge, U. K. 16-29.

Borlaug, N. E., 1968. Wheat breeding and its impact on world food supply. In: (Finlay, K.W. and Shepherd, K.W., eds.) Proc. 3rd Int. Wheat Symp. (Australian Aca. Sci.), pp:1-36.

Briggle, L.W. and O. A. Vogel, 1968. Breeding short-statured, disease resistant wheats in the United States. Euphytica, 17: 107-130.

Busch, R. H. and T. L. Rauch, 1993. Agronomic performance of tall versus short semi-dwarf lines of spring wheat. Crop Sci., 33: 941-943.

Gale, M. D. and C. N. Law, 1977. The identification and exploitation of Norin-10 semi-dwarfing genes. In: Plant Breeding Institute Cambridge Ann. Rep. 1976, UK, pp: 21-35.

Gale, M. D. and S. Youssefian, 1984. Pleiotropic effects of the Norin-10 dwarfing genes. Rht_1 and Rht_2, and interactions in response to chlorequat. In: (*Sakamoto, S.* ed.,) Proc. 6th Int. Wheat Genet. Symp., Kyoto, Japan, pp: 271- 277.

Gale, M. D. and S. Youssefian, 1985. Dwarfing genes in wheat. In: (*Russell, G.E.,* ed.), Progress in Plant Breeding,I. Butterworths, London, 1-35.

Gomez, K. A. and A. A. Gomez, 1983. Statistical Procedures for Agricultural Research. (2nd Edition), John Wiley and Sons, New York.

Hoogendoorn, J., J. M. Rickson, and M. D. Gale, 1990. Differences in leaf and stem anatomy related to plant height of tall and dwarf wheat. J. Pl. Physiol., 136: 72-77.

Kertesz, Z., J. E. Flintham, and M. D. Gale, 1991. Effects of Rht dwarfing genes on wheat grain yield and its components under Eastern European conditions. Cereal Research Communications, 19: 297- 304.

Keyes, G. J., D. J. Paolillo, and M. E. Sorrells, 1989. The effects of dwarfing genes Rht_1 and Rht_2 on cellular dimensions and rate of leaf elongation in wheat. Ann. Bot., 64: 683-690.

Konzak, C. F., 1987. Mutations and mutation breeding. In: (Heyne, E.C., ed.) Wheat and Wheat Improvement. American Society of Agronomy, Madison, W.I., pp: 428-443.

Loskutova, N. P., 1998. The influence of Rht_{1-5}, Rht_{8-9} and Rht_{13} genes on morphological characters and yield productivity of wheat. In: (*Slinkard, A.E.,* ed), Proc. 9th Int. Wheat Genet. Symp., University Extension Press. University Saskatchewan, Saskatoon, pp: 283-284.

Pinthus, M. J. and A. A. Levy, 1983. The relationship between the Rht_1 and Rht_2 dwarfing genes and grain weight in *Triticum aestivum* L. spring wheat. Theor. Appl. Genet., 66: 153-157.

Pinthus, M. J., 1987. Yield, grain weight and height relationships in two random samples of early semi-dwarf genotypes of spring wheat (*Triticum aestivum* L.). Plant Breeding, 99: 34-40.

Rebetzke, G. J. and R. A. Richards, 1999. Genetic improvement of early vigour in wheat. Aust. J. Agric. Res., 50: 291-301.

Rebetzke, G. J. and R. A. Richards, 2000. Gibberellic acid-sensitive dwarfing genes reduce plant height to increase kernel number and grain yield of wheat. Aust. J. Agric. Res., 51: 235-245.

Richards, R. A., 1992. The effects of dwarfing genes in spring wheat in dry environments. I. Agronomic characteristics. Aust. J. Agric. Res., 43: 517-527.

Schillinger, W. F., E. Donaldson, R. E. Allan, and S.S. Jones, 1998. Winter wheat seedling emergence from deep sowing depths. Agron. J., 90: 582-586.

Slafer, G. A., E. H. Satorre, and F. H. Andrade, 1994. Increases in grain yield in bread wheat from breeding and associated physiological changes. In: (*Slafer, G.A.,* ed.), Genetic Improvement of Field Crops. Marcel Dekker Inc., New York, pp: 1-68.

Singh, R. P., R. L. Villareal, S. Rajaram, and E. Del Toro, 1989. Cataloguing dwarfing genes Rht_1 and Rht_2 in germplasm used by the bread wheat breeding programme at CIMMYT. Cereal Research communications., 17: 273-279.

Snedecor, G. W., 1956. Statistical Methods. The Iowa State University Press, Ames, Iowa, U.S.A.

Villareal, R. L., S. Rajaram, and E. Del Toro, 1992. Yield and agronomic traits of Norin-10 derived spring wheats adapted to North Western Mexico. J. Agron. and Crop Sci., 168: 289-297.

Vogel, O. A., Jr. Craddock, C. E. Muir, E. H. Everson and C. R. Rohde, 1956. Semi-dwarf growth habit in winter wheat improvement for the Pacific Northwest. Agron. J., 48: 76-78.

Waddington, S. R., J. K. Ransom, M. Osmanzai, and D. A. Saunders, 1986. Improvement in the yield potential of bread wheat adapted to North-west Mexico. Crop Science, 26: 698-703.

Worland, A.J., V. Korzun, M. S. Roder, M.W. Ganal and C. N. Law, 1998. Genetic analysis of the dwarfing gene Rht_8 in wheat. Part II. The distribution and adaptive significance of allelic variants at the Rht_8 locus of wheat as revealed by microsatellite screening. Theoretical and Applied Genetics, 96: 1110-1120.