

# Effect of Reduced Height Genes (*Rht*) on Components of the Root System in Bread Wheat

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**Abstract:** It is accepted that there is an interaction between dwarfing genes and the overall size of a plant because of the gene's interaction with gibberellic acid pathways. The main **objective** of this project was to determine the effect of four stem dwarfing genes (*Rht1*, *Rht2*, *Rht3* and *rht*) on components of the root system in near-isogenic lines of Maringa and Nainari 60.

The working **hypothesis** was that since the *Rht* genes affect the plant hormone gibberellic acid (GA3) metabolic pathway (Spielmeyer et al. 2004), these genes will also dwarf or affect root characters, as well as shoot characters, and this may in turn affect water and nutrient uptake and grain yield in these wheat lines.

**Introduction:** Agricultural geneticists and crop physiologists rarely study plant roots because of the difficulty of extracting them from field or pot soil containing organic matter. This project aims to study the effect of the reduced height genes (*Rht*) that were used to dwarf wheat stems in the green revolution, on root size and other root characters in bread wheat. There are few reports of such studies in the literature, and few using isogenic lines of wheat (*Triticum aestivum* L.) relevant to California growing conditions. 'Nainari 60' bread wheat is a tall (*rht*), spring cultivated variety (cultivar) released by the International Maize and Wheat Improvement Center, (CIMMYT) at Ciudad Obregon, Sonora, Mexico, to be grown in northwest Mexico and southwest USA. 'Maringa' bread wheat is an old, tall (*rht*) spring cultivar from southern Brazil which has similar growing conditions to Southern California. 'Nainari 60' was one of the earliest wheats released in 1960 by Dr. Norman Borlaug during the green revolution to be grown in irrigated conditions (Borlaug 1968). Both cultivars lodged (fell down) when too much irrigation water and fertilizer was applied to the fields, and this reduced grain yield. To overcome lodging, Borlaug introduced the dominant reduced height genes *Rht1*, *Rht2* and *Rht3* that dwarf the stems, into tall, recessive Nainari *rht/rht*, which allowed the plants to be grown with high water and fertilizer input. This prevented stems from lodging and increased grain yield considerably. Later, the same was done to dwarf the stems of Maringa wheat. Thus there are two near-isogenic series in Maringa and Nainari 60 where lines differ only by the dominant genes *Rht1*, *Rht2*, *Rht3* or the recessive allele *rht*. Near-isogenic lines are lines of wheat that are nearly genetically identical except for the gene which carries the trait being studied. The effect of these genes on shoot characters and root dry matter has been studied (Ehdaie and Waines, 1994, 1996). But, no one has studied the effect of these dwarfing genes on components of the root system, which include: length of longest root, number of roots greater than 30 cm, total root length greater than 30 cm, shallow root biomass (less than 30 cm), deep root biomass (greater than 30 cm), and total root biomass.

**Expected Results:** We expected the tall *rht/rht* lines to have a greater and longer root system than the dwarf *Rht3/Rht3* lines, and the semi-dwarf genotypes to be intermediate. Previous

studies (Ehdaie and Waines, 1996) demonstrated that mature Maringa *rht/rht* had taller stems than mature Nainari 60 *rht/rht* by 29cm. We expected the 45 day old Maringa isogenic lines to have a larger root system than the Nainari 60 isogenic series, if root characters reflect shoot characters at this early stage of plant growth. The length of the longest root may be similar in each line, but the total length of all seminal roots longer than 30 cm may be significantly different among lines. Genotypes with a larger root system may take up more water and fertilizer than those with small root systems.

**Results:** The effect of the high temperatures in spring and summer on the plants may have had a role in root production because it was offseason for normal planting of these wheat cultivars. However, since the experiment was repeated in both spring and summer producing consistent data, the offseason heat had little or no effect on the expression of reduced height genes. A summary of the results is reported in Table 1.

**Table 1. Maringa and Nainari 60 near-isogenic lines for plant height evaluated for root traits in sand-tube experiments.**

Root Trait	Spring 2006 Planting		Summer 2006 Planting	
	Maringa <i>rht, Rht1, Rht2, Rht3</i>	Nainari 60 <i>Rht Rht2, Rht3</i>	Maringa <i>rht, Rht1 Rht2, Rht3</i>	Nainari 60 <i>rht Rht2,Rht3</i>
Number of roots > 30 cm	Similar <sup>1</sup> (range: 12-15)	Similar <sup>1</sup> (range: 8-9)	Similar <sup>1</sup> (range: 12-14)	Similar <sup>1</sup> (range: 8-11)
Longest root (cm)	Similar <sup>1</sup> (range: 87-96)	Similar <sup>1</sup> (range: 78-85)	Similar <sup>1</sup> (range: 83-92)	Similar <sup>1</sup> (range: 79-82)
Total root length > 30 cm	Similar <sup>1</sup> (range: 665-880)	Similar <sup>1</sup> (range: 410-445)	Similar <sup>1</sup> (range: 595-723)	Similar <sup>1</sup> (range: 450-518)
Shallow root biomass (g/plant)	Mar 1 = Mar 2 > mar > Mar 3 (1.01, 1.03, 0.73, 0.48 respectively)	Nai 2 > Nai 3 > nai (0.64, 0.37, 0.28 respectively)	Mar 1 = mar = Mar 2 > Mar 3 (0.57, 0.48, 0.47, 0.40 respectively)	Similar <sup>1</sup> (range: 0.23-0.30)
Deep root biomass (g/plant)	Mar 1 = Mar 2 > mar > Mar 3 (0.28, 0.26, 0.19, 0.12 respectively)	Similar <sup>1</sup> (range: 0.070-0.14)	mar = Mar 2 = Mar 1 > Mar 3 (0.13, 0.11, 0.09, 0.06 respectively)	Similar <sup>1</sup> (range: 0.05-0.06)
Total root biomass (g/plant)	Mar 1 = Mar 2 > mar > Mar 3 (1.29, 1.29, 0.92, 0.60 respectively)	Nai 2 > Nai 3 = nai (0.77, 0.45, 0.35 respectively)	Mar 1 = mar = Mar 2 > Mar 3 (0.66, 0.60, 0.58, 0.46 respectively)	Similar <sup>1</sup> (range: 0.29-0.36)

<sup>1</sup> The term "Similar" implies the presence of variance, but no statistical difference.

**Key:**

mar = Maringa containing genotype *rht/rht*  
Mar 1 = Maringa containing genotype *Rht1/Rht1*  
Mar 2 = Maringa containing genotype *Rht2/Rht2*  
Mar 3 = Maringa containing genotype *Rht3/Rht3*  
nai = Nainari 60 containing genotype *rht/rht*  
Nai 2 = Nainari 60 containing genotype *Rht2/Rht2*  
Nai 3 = Nainari 60 containing genotype *Rht3/Rht3*

This table shows that there is no evidence that semi-dwarfing genes *Rht1* and *Rht2* in both Maringa and Nainari 60 reduced root traits. There were small differences in the biomass of different lines. However, these differences do not show a decreased biomass in the dwarf lines. The dwarfing gene *Rht3* consistently reduced shallow and deep root biomass only in Maringa. Plants were assumed to be equal if they were within 15% of each other in value. Anything outside of that range shows a statistically significant variance.

**Discussion:** The experimental results do not support our original hypothesis that the root length and biomass of the plants with genetically dwarfed shoots would also be reduced compared with the roots of the plants with tall shoots. In some cases, plants with either *Rht1* or *Rht2* genes increased root traits compared to tall plants. In one case *Rht3* reduced deep root weight in Maringa. However, overall the conclusion is that the *Rht* genes have little or no effect on root characteristics. For most of the cases, the difference between the lines was not significant, but did not show any support of the hypothesis or our expected results. This suggests we can breed for wheat plants with semi-dwarf stems but with large root systems. It is obvious that the previously accepted theory that dwarfing genes decrease cell size and thus dwarf the plant, is false. We see this in the fact that it had little or no effect on the root structure. Breeding programs could be introduced in order to combine a semi-dwarf shoot plant with a high biomass of root tissue. This would produce better water use efficiency and ultimately lead to increased grain yield. This trait would be important in developing countries where subsistence agriculture is used. Water is not always in ready supply and chemical fertilizers to increase yield are very expensive. A line of wheat could, theoretically, be developed in order to aid in a low irrigation and low chemical nutrition conditions.

**Materials and Methods:** Four near isogenic lines were available in Maringa: tall *rht/rht*, semi-dwarf *Rht1/Rht1*, semi-dwarf *Rht2/Rht2* and dwarf *Rht3/Rht3*. In Nainari 60, only three lines were available: tall *rht/rht*, semi-dwarf *Rht2/Rht2* and dwarf *Rht3/Rht3* (Hoogendorn et al. 1988). We also included 'Pavon 76,' a local wheat check, to make up eight experimental lines. These lines were grown in silica sand #30 in root tubes (80cm long, 10 cm in diameter) which allowed the sand medium to be washed free from the roots at the end of the experiment. The sand was purchased from Ace Hardware Store in Rubidoux, California. The sand was contained in a polyethylene tube which was sealed at one end, with two drainage holes covered with filter paper. This was sleeved inside a rigid PVC pipe standing in a hog-wire support system. Each PVC tube and sand culture contained one seedling transplanted after germination to assure seedlings of uniform shoot and root size. There were four replications, and the eight test lines were randomized within each replication. At the end of 45 days, each sleeve was drawn from the PVC pipe and supported on a wire mesh tray in a plastic tub half filled with water. The

polyethylene sleeve was cut lengthwise and opened up into a sheet without damaging the roots. The sand was gently washed free from the roots in a water bath with a stream of water. When all the sand was washed from the roots, the seedling roots longer than 30cm were counted and their lengths measured.

Other root characters measured included: length of the longest root, dry weight of roots longer than 30 cm (deep root), dry weight of roots from 0 - 30 cm (shallow root), total root dry weight, blade area of the longest leaf (blade length x maximum blade width x 0.78) for each line, and shoot dry weight. The data were subjected to analysis of variance and means were compared using the LSD test.

### **References:**

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