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Effect of T1BL.1RS chromosome translocation on agronomic traits and transpiration efficiency in bread and durum wheat under drought conditions

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ABSTRACT

The T1BL.1RS translocation is reported to enhance grain yield, biomass, kernel weight and spike fertility in bread wheat. These effects of the translocation were evaluated, however, on a limited number of genotypes and the physiological effects of the translocation were barely studied. The aim of the present study was to evaluate the effects of T1BL.1RS on agronomical traits and transpiration efficiency (TE) in several bread and durum wheat cultivars grown under drought conditions. TE was evaluated from carbon isotope discrimination measurements.

Both bread and durum T1BL.1RS lines had longer spikes. Bread wheat T1BL.1RS lines flowered later, had lower harvest index, and grain weight. Durum wheat T1BL.1RS lines had lower number of spikes than their 1B counterparts. However, the T1BL.1RS translocation did not have any effect on grain yield. There was no effect of the T1BL.1RS translocation on grain carbon isotope discrimination, indicating that T1BL.1RS and 1B lines did not differ for TE.

Key-words: bread wheat (*Triticum aestivum* L.), durum wheat (*Triticum durum* Desf.), near isogenic lines, T1BL.1RS translocation, drought, transpiration efficiency, yield.

INTRODUCTION

The 1BL.1RS wheat (*Triticum aestivum* L.) - rye (*Secale cereale* L.) translocation is present in almost 58% of the CIMMYT spring bread wheat germplasm (Mujeeb-Kazi, 2001) and in many winter wheat cultivars worldwide (Zeller and Fuchs, 1983; Lukaszewski, 1990; Jahan et al., 1990; Ter-Kuile et al., 1991). More recently, the translocation has been transferred to durum wheat (*Triticum durum* Desf.) (Friebe et al., 1987). Bread wheat varietal releases possessing the translocation occupy over five million hectares (Villareal et al., 1998).

Under disease-free conditions, the presence of the translocation was reported to enhance grain yield, kernel weight and spike fertility in winter bread wheat (Carver and Rayburn, 1994; Schlegel and Meinel, 1994; Moreno-Sevilla et al., 1995) and spring bread wheat (Villareal et al., 1995, 1998; Singh et al., 1998). However, McKendry et al. (1996) failed to detect a significant yield advantage of the translocation. Comparing genetically diverse spring bread wheat cultivars, Villareal et al. (1994) reported a positive effect on biomass, tillering and grain weight associated with the T1BL.1RS translocation, but no significant difference in grain yield. Information concerning the effect of the T1BL.1RS translocation in durum wheat is scarce. Villareal et al. (1997), using 'Altar' as durum wheat recipient, reported a yield advantage of the translocation only under reduced irrigation. In a study carried out under four Mediterranean environments and also using 'Altar' germplasm developed by Mujeeb-Kazi et al. (2000), Zarco-Hernández et al. (2000) found that the effect on yield was either positive or negative, according to the environment and, on an average, not significant. The aim of the present study was to evaluate the effects of the translocation on agronomical traits and transpiration efficiency (TE) under drought conditions and on wider bread and durum wheat genetic backgrounds.

MATERIAL AND METHODS

Plant material

The study involved eleven bread wheat and five durum wheat genotypes and their near-isogenic lines in which homozygous 1BL.1RS and 1B chromosomes were substituted by 1B and 1BL.1RS chromosomes. A detailed description of the methodology used to develop the genetic stocks is described elsewhere (Mujeeb-Kazi et al., 1996). Bread wheats with T1BL.1RS homozygous and durum wheats with 1B homozygous were categorized as "extracted", according to Mujeeb-Kazi et al. (1996). In bread wheat, each genotype was represented by two or three homozygous lines for chromosome 1B substitution and the same number of homozygous lines for T1BL.1RS. In durum wheat each genotype was represented by either one or three homozygous lines for chromosome 1B substitution and the same number of homozygous lines for T1BL.1RS. There were 60 bread wheat and 18 durum wheat lines in total. The list of material is given in Table 1. Specific details of these germplasms are described in Mujeeb-Kazi et al. (2001a,b).

Table 1. List of material used in the study (at each entry correspond a group of homozygous lines for 1B and a group of homozygous lines for T1BL.1RS. The number in parenthesis indicates, for each entry, the number of homozygous lines of each group)

Bread wheats	*Durum Wheats*
Glen/Cno79//4*Glen/3/3*Glen (2)	Laru//Cndo/Vee/3/3*Laru/4/4*Laru (3)
Spb/Pvn//4*Spb/3/2*Spb (2)	Croc1//Cndo/Vee/3/7*Croc1 (1)
Yaco/Glen//5*Yaco/3/3*Yaco (3)	Dverd2//Cndo/Vee/3/7*Dverd2 (1)
Cno79/Glen//5*Cno79/3/3*Cno79 (3)	Pardo//Cndo/Vee/3/3*Pardo/4/4*Pardo (1)
Fink/Pvn//4*Fink/4/3*Fink (3)	Bia//Cndo/Vee/3/4*Bia/4/4*Bia (3)
Kauz/Pvn//4*Kauz/3/Kauz/4/3*Kauz (3)	
Mrl/Buc//Seri/3/4*Mrl/Buc/4/Mrl/Buc/5/3*Mrl/Buc (3)	
Opata/Glen//6*Opata/3/3*Opata (2)	
Bow/Cno79//7*Bow/3/3*Bow (3)	
Oci/Glen//7*Oci/3/3*Oci (3)	
Esda/Glen//7*Esda/3/3*Esda (3)	

Experimental conditions

All extracted lines and their substituted counterparts were cultivated in 2000-2001 under reduced moisture conditions at the CIMMYT experimental station in Ciudad Obregon (Sonora, Mexico, 27°3' N, 109°1' W, 38m a.s.l.). Soil in Ciudad Obregon is a coarse sandy clay mixed montmorillonitic type Calciorthid. Climate is sunny and dry during the wheat crop season. Prior to sowing, 150 kg N ha^{-1} (as ammonium sulfate) and 40 kg P. ha^{-1} (as tri-superphosphate) were applied. The trial was seeded at the beginning of December. Seeding rate was 120 kg ha^{-1}. The crop received about 250 mm of water after germination. Diseases and weeds were chemically controlled. The trial was arranged in a randomized complete block design with three repetitions. Plots consisted in eight rows, 20 cm apart and 5 m long.

Agronomical and physiological measurements
Days to heading, flowering and maturity as well as plant height and spike length were recorded on each plot. Grain filling period was calculated by taking the difference between days to physiological maturity and flowering. Grain yield and kernel weight were assessed at harvest. The number of grains per square meter was calculated. Harvest index was evaluated on a random sample of 50 culms. Biomass was evaluated as the ratio of grain yield to harvest index. The number of spikes per square meter was calculated by dividing biomass by culm mass and the number of grains per square meter by dividing grain yield by kernel weight. The ratio of the number of grains per square meter to the number of spikes per square meter provided the number of grains per spike. Test weight was recorded using an electronic hectoliter balance.
Carbon isotope discrimination (Δ) was determined on the mature grain. For each line, a 10 g grain sample was collected at maturity and ground to a fine powder. Carbon isotope composition was determined using an isotope mass spectrometer (Isotope Services, Inc., Los Alamos, NM, USA) as $\delta^{13}C(‰) = [(R\ sample/R\ reference-1) \times 1000]$, R being $^{13}C/^{12}C$ ratio. The standard error was 0.1‰. The discrimination (Δ) was calculated as $\Delta\ (‰) = [(\delta a - \delta p) / (1 + \delta p)] \times 1000$, where δp is the $\delta^{13}C$ of the samples and δa, the $\delta^{13}C$ of the free atmospheric CO_2, -8‰. Carbon discrimination of grain at maturity was thereafter referred to as ΔG_m.

Data analysis
Separate randomized complete block analyses were performed for yield and yield components. Translocation, genotype and genotype x translocation effects were tested by using the PROC procedure of SAS. Translocation effect was also tested separately for each genotype. The variation of yield and agronomical traits was evaluated for each genotype within each chromosome group (homozygous for 1B or T1BL.1RS). Genotypes were classified for each trait by Duncan. Phenotypic correlations (r) between yield and carbon isotope discrimination were calculated on means by Pearson Correlations.

RESULTS

Genotype effect was highly significant for most traits (Tables 2 and 3). In bread wheat, T1BL.1RS lines had longer spikes (+1.9%), but a lower harvest index (-4.6%), plant height (-2.8%) and kernel weight (-2.1%) than their counterparts. They headed later and had shorter grain filling period. Genotype x translocation was significant for these traits, except for harvest index. In durum wheat, the translocation had significant effect on spikes per square meter (-11.1%) and test weight (-1.5%). As in bread wheat, the translocation resulted in longer spikes (+5.0%), but lower harvest index (-7.0%) and plant height (-7.0%). There was no effect of the translocation on grain yield, either in bread or durum wheat. In both species, highly significant genotype effect was observed for the carbon isotope discrimination of the grain (ΔG_m). The T1BL.1RS translocation however did not affect ΔG_m values. Highly significant correlation was noted between ΔG_m and grain yield in both bread and durum wheat (Fig. 1 and 2). When tested separately for each genotype, the translocation effect was significant for ΔG_m values only in the 'Fink' (bread wheat) background (F = 8.61, $P<0.05$). ΔG_m was slightly higher in the Fink1BL.1RS (14.88‰) than in its counterpart (14.41‰).

Table 2. Effect of the 1BL.1RS translocation on agronomical and physiological traits in bread wheat (cropping season 2000-2001)

Traits	Means		*F*-test (G)	*F*-test (T)	*F*-test (G x T)
	T1BL.1RS	1B			
Grain yield (kg ha^{-1})	3485.2	3494.1	10.00***	0.03ns	0.72ns
Biomass (kg ha^{-1})	8847.7	8475.6	9.93***	2.43ns	0.91ns
Harvest index	0.398	0.417	33.92***	20.85***	0.76ns
Grain per square meter	9381.7	9209.2	18.07***	0.43ns	1.18ns
Spikes per square meter	273.0	274.0	13.14***	0.06ns	1.91ns
Grains per spike	34.54	34.47	13.15***	0.06ns	0.96ns
Kernel weight (mg)	37.61	38.41	68.49***	7.26*	3.46**
Test weight (g)	79.5	79.4	8.86***	0.32ns	0.77ns
Plant height (cm)	70.2	72.2	15.50***	7.02*	3.01**
Spike length (cm)	11.48	11.27	95.57***	6.09*	2.39*
Days to heading (days)	83.0	81.8	51.52***	6.35*	3.21**
Days to maturity (days)	123.5	123.4	65.76***	0.14ns	5.52***
Grain filling period (days)	40.5	41.5	17.82***	8.41**	1.94ns
Grain Δ (‰)	14.93	14.83	13.24***	1.21ns	0.88ns

(G), genotype effect; (T), translocation effect; *, **, *** indicate significance at P = 0.05, 0.01 and 0.001, respectively.

Table 3. Effect of the 1BL.1RS translocation on agronomical and physiological traits in durum wheat (cropping season 2000-2001)

Traits	Means		*F*-test (G)	*F*-test (T)	*F*-test (G x T)
	T1BL.1RS	1B			
Grain yield (kg ha^{-1})	2803.2	3067.6	7.09**	4.55ns	1.29ns
Biomass (kg ha^{-1})	7878.6	8029.2	2.94ns	0.24ns	0.42ns
Harvest index	0.357	0.384	4.78*	5.62*	0.40ns
Grain per square meter	5550.7	6186.9	10.64**	3.44ns	1.94ns
Spikes per square meter	184.8	207.9	4.46*	7.01*	1.25ns
Grains per spike	30.2	30.4	1.16ns	0.42ns	0.79ns
Kernel weight (g)	51.0	50.2	118.14***	1.43ns	8.24**
Test weight (g)	78.4	79.6	5.17*	8.76*	2.62ns
Plant height (cm)	75.9	81.6	171.44***	22.62**	1.18ns
Spike length (cm)	8.32	7.92	16.55***	18.55**	3.98*
Days to heading (days)	77.1	76.1	375.73***	5.18ns	7.08**
Days to maturity (days)	116.9	116.2	117.92***	1.28ns	1.21ns
Grain filling period (days)	39.8	40.1	4.34*	0.00ns	0.27ns
Grain Δ (‰)	15.26	15.22	9.55**	0.40ns	0.27ns

(G), genotype effect; (T), translocation effect; *, **, *** indicate significance at P = 0.05, 0.01 and 0.001, respectively.

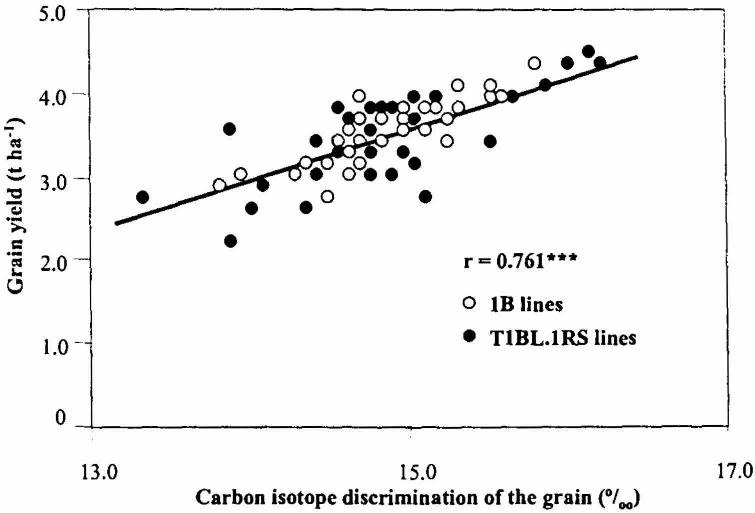

Fig. 1. Relationship between carbon isotope discrimination of the grain and grain yield among the tested bread wheat entries.

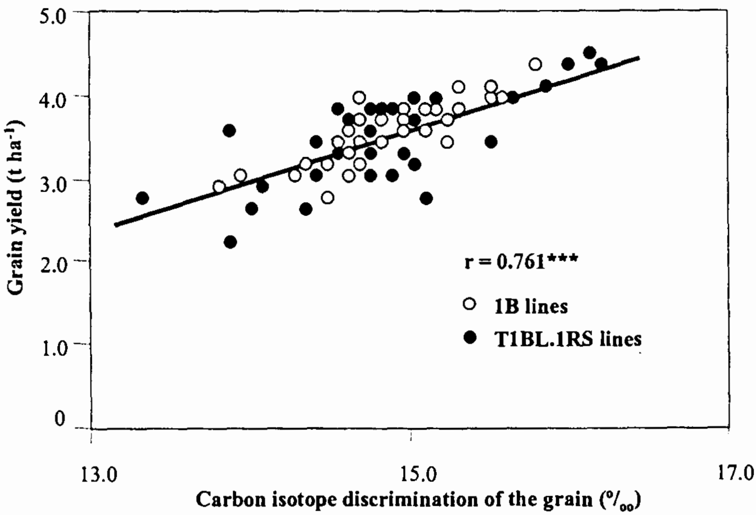

Fig. 2. Relationship between carbon isotope discrimination of the grain and grain yield among the tested durum wheat entries.

DISCUSSION

In bread wheat, no effect of T1BL.1RS was detected on grain yield in either of the eleven backgrounds studied. This result is in agreement with Villareal et al. (1994) and Mc Kendry et al. (1996) and disagrees with Carver and Rayburn (1994), Schlegel and Meinel (1994), Moreno-Sevilla et al. (1995), Villareal et al. (1995, 1998) and Singh et al. (1998). The differences between extracted and substituted lines for harvest index, thousand kernel weight, plant height, spike length, days to heading and grain filling period observed in this study, were also reported by Villareal et al. (1998). The increase in spike length was not associated with higher number of grains per spike, resulting in lower spike compaction. There was a significant effect of the translocation on kernel weight, while Dhaliwal et al. (1987) and McKendry et al. (1996) did not find any effect of T1BL.1RS on this trait. The difference in earliness between 1B and T1BL.1RS lines was not significant and much lower than reported by Villareal et al. (1998). No difference in heading date between T1BL.1RS and non-rye isolines was noted by Carver and Rayburn (1994), and McKendry et al. (1996). As postulated by Villareal et al. (1998), phenological differences associated with the translocation may be genetic background specific. This hypothesis is confirmed by the highly significant genotype x translocation interaction noted for days to heading and maturity, indicating that the ranking for earliness highly differed between the two translocation groups. The reduction in plant height associated with the translocation agrees with Villareal et al. (1994), Moreno-Sevilla et al. (1995) and Mc Kendry et al. (1996) but not with Villareal et al. (1998), who did not detect plant height differences between 1B and T1BL.1RS in 'Seri' lines. Carver and Rayburn (1994) noted an increased height associated with the T1BL.1RS translocation in 'Chisholm' background and no difference in 'Arkan' background. The significant genotype x translocation interaction noted for plant height also suggests an important background effect for this trait.

In durum wheat, no significant difference was found between extracted and substituted lines for grain yield. This result is in good accordance with Zarco-Hernández et al. (2000). These authors reported, as observed in the present study, a lower number of spikes per square meter in T1BL.1RS lines while Villareal et al. (1997) did not detect any effect of the translocation on this trait. Effect of the translocation on harvest index and plant height was negative in the present study and not significant in Villareal et al. (1997). The positive effect of the translocation on grain weight reported by Villareal et al. (1997) and Zarco-Hernández et al. (2000) was not found here. We observed, however, as did Villareal et al. (1997), a significant and positive effect of the translocation on spike length. As in bread wheat, the longer spike was not associated with higher number of grains *per* spike, thus leading to a lower spike compaction.

Effect of the T1BL.1RS on physiological traits has been rarely analyzed. Watanabe et al. (1994) did not find any difference between Condor1B and CondorT1BL.1RS for CO_2 assimilation, chlorophyll and nitrogen content and chlorophyll *a/b* ratio. Watanabe and Konori (2001) did not observe any effect of the rye chromosome 1R on photosynthetic rate. The absence of T1BL.1RS effect on grain carbon isotope discrimination (ΔG_m) suggested that T1BL.1RS and 1B lines did not differ for transpiration efficiency (TE) and stomatal conductance (Morgan et al., 1993; Merah et al., 2001). Interestingly, translocation effect on ΔG_m was significant only in the latest line ('Fink') that also showed a translocation effect on biomass ($F = 15.81$, $P<0.05$). The significant correlation between (ΔG_m) and grain yield, registered in the current study, confirms previous data from Merah et al. (2001).

CONCLUSIONS

Discrepancies in the T1BL.1RS effect on grain yield have been attributed by several authors to differences in testing environment and genetic background (Singh et al., 1998; Zarco-Hernández et al., 2000). In the present study that involved eleven bread wheat and five durum wheat near isogenic genotypes, yield gains related to T1BL.1RS were not apparent in any background tested, suggesting that environmental conditions strongly influence yield effects of the translocation. In the present environmental conditions, modifications that could have led to positive effects on yield, such as a longer spike, were compensated in bread wheat by later flowering leading to shorter grain filling period and lower grain weight. Durum wheat also had longer spikes, but spike density was reduced. The lack of effect of the translocation on ΔG_m, together with previous results from Watanabe et al. (1994) and Watanabe and Konori (2001) suggest a lack of effect of the translocation on photosynthesis related traits.

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