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## Effect of T1BL.1RS chromosome translocation on bread wheat grain yield and physiological related traits in a warm environment

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### ABSTRACT

The wheat (*Triticum aestivum* L.) - rye (*Secale cereale* L.) translocation T1BL.1RS was reported to increase the duration of the growth cycle and, in certain conditions, to enhance grain yield. It has been suggested that these effects depend on the environmental conditions and genetic background. In the present study, the effects of the 1BL.1RS translocation were analysed in a warm environment. The effect of the translocation on grain yield was negative under rainfed and nil under irrigated conditions. Under drought, the magnitude of yield reduction highly depended on the genetic recipient. The translocation was associated with higher leaf rolling and chlorophyll content. The effects of the modification of these traits on grain yield merits further investigation.

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

### INTRODUCTION

The translocation of the short arm of rye (*Secale cereale* L.) chromosome one (1RS) to the long arm of wheat chromosome 1B (1BL) was simultaneously and independently identified in Veery 'S' lines, derived from the winter bread wheat variety Kavkaz, by Merker (1982) and Mujeeb-Kazi (1982). The 1RS segment carries race-specific genes for resistance to leaf rust (*Lr26*), stem rust (*Sr31*) and powdery mildew (*Pm8*) (McIntosh, 1983; Zeller and Fuchs, 1983; Heun and Fischbeck, 1987). The translocation is actually present from 40% to currently 58% of the CIMMYT bread wheat germplasm (Rajaram et al., 1996; Mujeeb-Kazi, 2001) and in several winter wheat cultivars released in Europe, USA, China and Pakistan (Zeller and Fuchs, 1983; Lukaszewski, 1990; Jahan et al., 1990; Ter-Kuile et al., 1991). Wheat cultivars possessing the translocation occupy over five million hectares (Villareal et al., 1998).

Effect of T1BL.1RS translocation on yield under disease-free conditions is not clear. The presence of the translocation was found to be associated with higher grain yield, biomass, kernel weight and spike fertility in hard red winter wheats (Carver and Rayburn, 1994; Schlegel and Meinel, 1994; Moreno-Sevilla et al., 1995). Yield advantage was also noted in spring wheat by Villareal et al. (1995, 1998) and Singh et al. (1998). However, Mc Kendry et al. (1996) failed to detect a significant yield advantage of the translocation. Villareal et al. (1991, 1994) reported a

positive effect on biomass, tillering and grain weight associated with the T1B.1R translocation, with no significant difference in grain yield. Evaluation of the effects of the translocation has involved a limited number of wheat genotypes, and the influence of the genetic background has been poorly investigated. In addition, little information is available concerning T1BL.1RS effects on yield related physiological traits. Watanabe et al. (1994) did not find any difference between Condor1B and CondorT1BL.1RS for CO<sub>2</sub> assimilation, chlorophyll content, chlorophyll *a/b* ratio and rate of electron transport per unit chlorophyll. Watanabe and Komori (2001), by comparing wheat-rye addition lines and their parents, did not observe any major effect of rye chromosome 1R on photosynthetic rate. Finally, the evaluation of translocation effect was rarely realized under warm conditions although bread wheat cultivars carrying the T1BL.1RS translocation are grown in regions characterized by the occurrence of heat stress (e.g. Jahan et al., 1990). In the present study, evaluation of the agronomical and physiological effects of the T1BL.1RS translocation has been attempted on a wide genetic background and under warm conditions.

## MATERIAL AND METHODS

### *Plant material*

Seven CIMMYT bread wheats and their near-isogenic lines in which homozygous 1BL.1RS were substituted by 1B chromosomes were used in this study (Table 1). A detailed description of the methodology used to develop the genetic stocks is described elsewhere (Mujeeb-Kazi et al., 1996). Detection of 1B, 1BL.1RS heterozygotes from the homozygous 1B derivatives during each backcross of the heterozygote to the respective recurrent parent was made by combining C banding, *in-situ* hybridization and isoelectric focusing of glucose phosphate isomerase (William and Mujeeb-Kazi, 1993). Germplasm details are elucidated in Mujeeb-Kazi et al. (2001a, b).

**Table 1. List of genotypes studied, with their pedigree.**

<i>Lines</i>	<i>Translocation status</i>
Yaco/Glen//5*Yaco/3/3*Yaco	1B
Yaco/Glen//5*Yaco/3/3*Yaco	T1BL.1RS
Cno/Glen//5*Cno/3/3*Cno	1B
Cno/Glen//5*Cno/3/3*Cno	T1BL.1RS
Fink/Pvn//4*Fink/3/Fink/4/3*Fink	1B
Fink/Pvn//4*Fink/3/Fink/4/3*Fink	T1BL.1RS
Kauz/Pvn//4*Kauz/3/Kauz/4/3*Kauz	1B
Kauz/Pvn//4*Kauz/3/Kauz/4/3*Kauz	T1BL.1RS
Opata/Glen//6*Opata/3/3*Opata	1B
Opata/Glen//6*Opata/3/3*Opata	T1BL.1RS
Bow/Cno//7*Bow/3/3*Bow	1B
Bow/Cno//7*Bow/3/3*Bow	T1BL.1RS
Oci/Glen//7*Oci/3/3*Oci	1B
Oci/Glen//7*Oci/3/3*Oci	T1BL.1RS

(Glen = Glenson 81, Cno = Ciano 79, Pvn = Pavon 76, Bow = Bobwhite, Oci = Ocoroni)

*Experimental conditions*

The seven pairs of isolines were cultivated under drought conditions in 2000-2001 and under drought and irrigated conditions in 2001-2002, at the CIMMYT experimental station in Tlaltizapan (Central Mexico, 18°4'N, 99°1'W, 940m a.s.l.). Climate of this location is hot, sunny and dry during the wheat crop season, and representative of many warm-growing environments in the developing world (Reynolds et al., 1994). The experimental design was a randomized complete block with three replications. Cultivars were planted in 5.25 m<sup>2</sup> plots at the end of October. Sowing density was 10 g m<sup>-2</sup>. Maximal day temperature, provided by a Viasala HMP45C automatic sensor, was higher than 27°C for the entire growing cycle, and around 32°C during the grain filling period. Rainfall was 0 mm in 2000-2001 and 21.4 mm in 2001-2002. The crop was well-fertilized (200 kg N ha<sup>-1</sup> and 20 kg P ha<sup>-1</sup>). Drought and irrigated trials received 60 mm (at sowing) and 650 mm water, respectively. Weeds, pests and diseases were controlled.

*Agronomical and physiological measurements*

During both cropping seasons, yield and yield components were assessed. In 2001-2002, phenological traits, plant height, chlorophyll content, leaf rolling and grain carbon isotope discrimination were also recorded.

Grain yield and kernel weight were assessed at harvest. The number of grains per m<sup>2</sup> was calculated. Days to flowering, days to maturity and plant height were recorded on each plot. Leaf rolling (score: 1 = unrolled, 5 = fully rolled) was noted at anthesis, at 13:00 h, according to O'Toole (1982). Chlorophyll content (Chl) was estimated at anthesis on ten flag leaves per plot, using a portable chlorophyll meter (SPAD-502, Minolta, Tokyo, Japan). Carbon isotope discrimination ( $\Delta$ ) 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:  $\delta^{13}\text{C}(\text{‰}) = [(R \text{ sample}/R \text{ reference}) - 1] \times 1000$ , R being <sup>13</sup>C/<sup>12</sup>C ratio. The discrimination ( $\Delta$ ) was calculated using the following formula (Farquhar et al., 1989):  $\Delta (\text{‰}) = [(\delta\text{a} - \delta\text{p}) / (1 + \delta\text{p})] \times 1000$ , where  $\delta\text{p}$  is the  $\delta^{13}\text{C}$  of the samples and  $\delta\text{a}$ , the  $\delta^{13}\text{C}$  of the free atmospheric CO<sub>2</sub>, -8‰. Carbon discrimination of the grain was thereafter referred to as  $\Delta G_m$ .

**RESULTS**

For the first year experimentation, a significant negative effect of the translocation was noted on grain yield ( $F = 7.13$ ,  $P < 0.05$ ) and number of grains per square meter ( $F = 4.77$ ,  $P < 0.05$ ). Grain yield of T1BL.1RS lines was, in average, 18.5% lower than yield of 1B lines.

In 2001-2002, and under irrigated conditions, the effect of the T1BL.1RS translocation on yield was not significant (Table 1), even when tested separately for each pair of isolines. T1BL.1RS lines were on average 1.5 day later than 1B lines. Under drought conditions, T1BL.1RS lines were also later (around 1 day) than 1B lines and were 1.5 cm shorter. A significant negative correlation was noted ( $r = 0.58$ ,  $P < 0.05$ ) between days to flowering and grain yield. A significant negative effect of the translocation was noted on grain yield. The average yield of T1BL.1RS lines was 16.8% lower, compared to 1B lines.

**Table 1. Effect of the 1BL.1RS translocation on agronomical and physiological traits (cropping season 2001-2002).**

Environments and traits	Mean		<i>F</i> -test (G)	<i>F</i> -test (T)	<i>F</i> -test (GxT)
	T1BL.1RS	1B			
<i>Rainfed conditions</i>					
Grain yield (t ha <sup>-1</sup> )	0.79	0.95	1.09ns	4.83*	1.09ns
Grains m <sup>-2</sup>	2746.1	3357.0	2.47ns	7.66*	1.59ns
Kernel weight (mg)	28.63	28.05	8.68***	0.81ns	0.49ns
Chl (SPAD)	50.83	49.55	24.77***	18.49***	2.03ns
Leaf rolling	3.48	2.85	3.35*	11.25**	0.75ns
$\Delta G_m$ (‰)	15.07	15.28	-	0.48ns	-
<i>Irrigated conditions</i>					
Grain yield (t ha <sup>-1</sup> )	3.76	3.71	1.08ns	0.05ns	0.61ns
Grains m <sup>-2</sup>	10415.4	10307.3	2.57ns	0.72ns	0.18ns
Kernel weight (mg)	36.30	35.98	2.36ns	0.23ns	1.14ns
Chl (SPAD)	46.85	45.54	30.38***	10.71**	0.52ns
Leaf rolling	2.21	1.57	9.73***	16.20**	0.80ns
$\Delta G_m$ (‰)	17.93	17.78	-	0.84ns	-

(G), genotype effect; (T), translocation effect; Chl, chlorophyll content (SPAD values);  $\Delta G_m$ , carbon isotope discrimination of the mature grain; \*, \*\*, \*\*\* indicate significance at  $P = 0.05$ , 0.01 and 0.001, respectively.

The genotype x translocation effect was not significant. When tested separately for each pair of isolines, translocation effect on yield was significant only in Ciano 79 background (-35.9%). The presence of the translocation was also associated with lower number of grains per square meter and kernel weight. The number of grains per square meter was strongly correlated to grain yield ( $r = 0.92$ ,  $P < 0.001$ ).

Carbon isotope discrimination of the grain ( $\Delta G_m$ ) was associated with grain yield in both drought and irrigated environments (Fig. 1). No effect of the translocation was noted, however, on this trait. The presence of the T1BL.1RS translocation was associated with higher chlorophyll content, under both drought and irrigated conditions. The effect of the translocation on chlorophyll content was particularly high in Ciano 79 and Ocoroni backgrounds (+5.1% and 4.9%, respectively). No correlation was found between chlorophyll content and grain yield ( $r = 0.12ns$  and  $r = -0.31ns$  under drought and irrigated conditions, respectively). Leaf rolling score was significantly higher under drought (3.1) than under irrigation (1.8), and higher in lines carrying the 1BL.1RS translocation. By considering separately the 1B and T1BL.1RS lines, we found that leaf rolling had a negative effect on yield within 1B lines and a positive effect within T1BL.1RS lines (Fig. 2).

## DISCUSSION

Results on agronomical traits for the seven pairs of near-isogenic lines indicate that T1BL.1RS translocation has no effect on grain yield under irrigated conditions. These results agree with those of McKendry et al. (1996) and Villareal et al. (1991, 1994) and differ from those of Carver

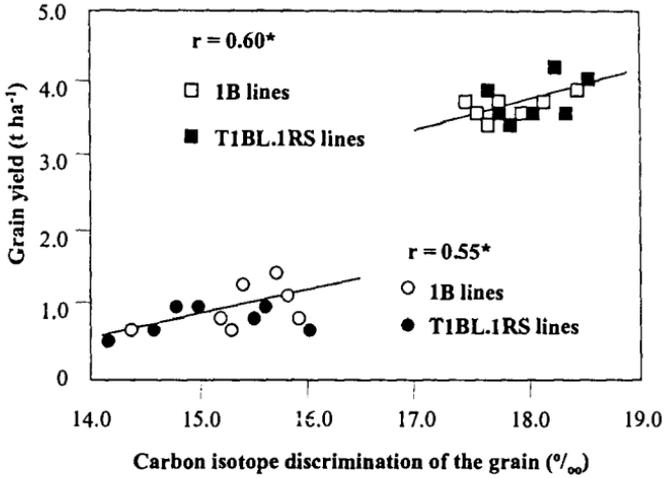


Fig. 1. Relationship between grain carbon isotope discrimination and grain yield in 2001-2002

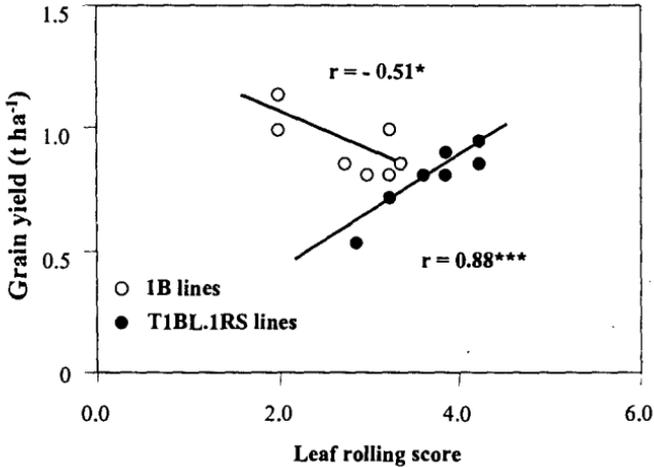


Fig.2. Relationship between leaf rolling and grain yield within T1BL.1RS and 1B lines, under drought conditions, in 2001-2002.

and Rayburn (1994), Schlegel and Meinel (1994), Villareal et al. (1995) and Moreno-Sevilla et al. (1995), who found a positive effect of 1BL.1RS ranging between 4 and 10%. Discrepancies between these results are likely to be due to differences in the testing environments and genetic material used (Singh et al., 1998). The significant negative effect of the translocation on grain yield, noted in the present study, had not been previously reported. It is probably related to the strong heat and drought stress experienced by the crop. Differences were found among genetic backgrounds for the magnitude of the translocation effects on grain yield. The most negative effect was noted for Ciano 79. The delay in flowering and reduction in plant height associated with the translocation were less than those reported by McKendry et al. (1996) and Villareal et al. (1998). This is likely to be due to a strong reduction of variation in phenology among genotypes, as a consequence of the shortening of the growth cycle by heat stress (-45% and -19%, compared to the studies mentioned above, respectively).

The presence of the T1BL.1RS translocation was associated with higher chlorophyll content (+2.9%) under both drought and irrigated conditions, suggesting that chlorophyll loss and premature leaf senescence induced by heat stress (Al-Khatib and Paulsen, 1984) were less in T1B.1R lines. This result disagrees with Watanabe et al. (1994) who did not find any difference between Condor1B and CondorT1BL.1RS for chlorophyll content. This is probably due, again, to differences in environmental conditions and genetic background. In our experiment, the effect of T1BL.1RS differed with the recipient cultivar. As for grain yield, the largest difference for chlorophyll content between the 1B and T1BL.1RS lines was found in Ciano 79 background. The opposite effects of the translocation on chlorophyll content and yield, as well as the lack of correlation between these two traits within the fourteen lines indicate that, in our conditions, higher chlorophyll content was not associated with yield advantage. This suggests that photosynthetic activity was maintained despite heat induced chlorophyll loss in 1B lines. Low level of chlorophyll in 1B lines could represent a mechanism of heat avoidance, reducing light absorption of the leaves and thus mitigating the heating effects of strong light, as revealed in barley by Havaux and Tardy (1999).

Leaf rolling is induced by loss of turgor and poor osmotic adjustment (Hsiao et al. 1984), but represents an important drought and heat avoidance mechanism (O'Toole and Chang, 1978). Higher leaf rolling in T1BL.1RS lines could have delayed chlorophyll degradation by light and heat stress. Moreover, the absence of T1BL.1RS effect on  $\Delta G_m$ , a trait strongly related to stomatal conductance (Morgan et al., 1993), suggested that T1BL.1RS and 1B lines have maintained similar transpiration rates during their growth cycle.

## CONCLUSION

Under a combination of drought and heat stressed conditions, a negative effect of T1BL.1RS was noted on grain yield. This result has important practical consequences, since T1BL.1RS translocation is present in many cultivars grown under drought and heat stress. No effect was found when the crop was irrigated.

The nil or negative effect of the translocation may be partially due to a longer growing cycle. The difference in earliness between T1BL.1RS and 1B being limited in this environment, other causes necessitate to be investigated. Higher leaf rolling in T1BL.1RS lines may have limited chlorophyll degradation. It could reflect, however, a lower osmotic adjustment capacity compared to 1B lines, that merits further investigation.

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## REFERENCES

- Al-Khatib K., Paulsen G.M. 1984. Mode of high temperature injury to wheat during grain development. *Plant Physiol.* 61: 363-368.
- Carver B.F., Rayburn A.L. 1994. Comparison of related wheat stocks possessing 1B or 1RS.1BL chromosomes: agronomic performance. *Crop Sci.* 34: 1505-1510.
- Farquhar G.D., Ehleringer J.R., Hubick K.T. 1989. Carbon isotope discrimination and photosynthesis. *Ann. Rev. of Plant Physiol. and Plant Mol. Biol.* 40: 503-537.
- Havaux M., Tardy F. 1999. Loss of chlorophyll with limited reduction of photosynthesis as an adaptive response of Syrian barley landraces to high-light and heat stress. *Aust. J. Plant Physiol.* 26: 569-578.
- Heun M., Fischbeck G. 1987. Identification of wheat powdery mildew resistance genes by analysing host-pathogen interactions. *Plant Breeding* 98: 124-129.
- Hsiao, T.C., O'Toole J.C., Yambao E.B., Turner N. C. 1984. Influence of osmotic adjustment on leaf rolling and tissue death in rice. *Plant Physiol.* 75: 328-333.
- Jahan Q., Ter-Kuile N., Hashmi N., Aslam M., Vahidy A.A., Mujeeb-Kazi A. 1990. The status of the 1B/1R translocation chromosome in some released wheat varieties and the 1989 candidate varieties of Pakistan. *Pak. J. Bot.* 22: 1-10.
- Lukaszewski A.J. 1990. Frequency of 1RS/1AL and 1RS/1BL translocations in the United States wheats. *Crop Sci.* 30: 1151-1153.
- McIntosh R.A. 1988. The role of specific genes in breeding for durable stem rust resistance in wheat and triticale. In N.W. Simmonds and S. Rajaram (eds.), *Breeding strategies for resistance to rusts of wheat*, CIMMYT, Mexico, pp. 1-9.
- McKendry A.L., Tague D.N., Miskin K.E. 1996. Effect of 1BL.1RS on agronomic performance of soft red winter wheat. *Crop Sci.* 36: 844-847.
- Merker A. 1982. "Veery" - a CIMMYT spring wheat with 1B/1R chromosome translocation. *Cereal Res. Comm.* 10: 105-106.
- Moreno-Sevilla B., Baenziger P.S., Peterson C.J., Graybosch R.A., McVey D.V. 1995. The 1BL/1RS translocation: agronomic performance of F3-derived lines from a winter wheat cross. *Crop Sci.* 35: 1051-1055.
- Morgan J.A., LeCain D.R., McCaig T.N., Quick J.S. 1993. Gas exchange, carbon isotope discrimination and productivity in winter wheat. *Crop Sci.* 33: 178-186.
- Mujeeb-Kazi A. 1982. Wheat Improvement. CIMMYT Report, 78-87.
- Mujeeb-Kazi A., William M.D.H.M., Islam-Faridi M.N. 1996. Homozygous 1B and 1BL/1RS chromosome substitutions in *Triticum aestivum* and *Triticum turgidum* cultivars. *Cytologia* 61: 147-154.
- Mujeeb-Kazi A. 2001. Intergeneric hybrids in wheat: current status. In P. Hernandez, M.T. Moreno, J.I. Cubero and A. Martin (eds.), *International Triticeae IV Symposium*. Cordoba, Spain, pp. 261-264.

- Mujeeb-Kazi A., Cortes A., Rosas V., Cano S., Delgado R. 2001a. Registration of six isogenic T1BL.1RS chromosome translocation and six chromosome 1B durum germplasms. *Crop Sci.* 41: 595-596.
- Mujeeb-Kazi A., Cortes A., Rosas V., Cano S., Delgado R. 2001b. Registration of 17 isogenic chromosome 1B and 17 T1BL.1RS chromosome translocation bread wheat germplasms. *Crop Sci.* 41: 596-597.
- O'Toole J.C., 1982. Adaptation of rice to drought prone environments. In *Drought resistance in crops with emphasis on rice*. International Rice Research Institute, Manila, Philippines, pp. 195-213.
- O'Toole J.C., Chang T.T. 1978. Drought and rice improvement in perspective. IRRI Research Paper Series, No. 14, International Rice Research Institute.
- Rajaram S., Singh R.P., van Ginkel M. 1996. Approaches to breed wheat for wide adaptation, rust resistance and drought tolerance. In R.A. Richards et al. (eds.) *Proc. Wheat breeding Society Australia, 8<sup>th</sup> assembly*, Aust. Nat. University Canberra, Australia, pp. 2-30.
- Reynolds M.P., Balota M., Delgado M.I.B., Amani I., and Fischer R.A. 1994. Physiological and morphological traits associated with spring wheat yield under hot, irrigated conditions. *Aust. J. Plant Physiol.* 21: 717-730.
- Schlegel R., Meinel A. 1994. A quantitative trait locus (QTL) on chromosome arm 1RS of rye and its effects on yield performance of hexaploid wheat. *Cereal Res. Comm.* 22: 7-13.
- Singh R.P., Huerta-Espino J., Rajaram S., Crossa J. 1998. Agronomic effects from chromosome translocations 7DL.7Ag and 1BL.1RS in spring wheat. *Crop Sci.* 38: 27-33.
- Ter-Kuile N., Jahan Q., Hashmi N., Aslam M., Vahidy A.A., Mujeeb-Kazi A. 1991. 1B/1R translocation wheat cultivars detected by A-PAGE electrophoresis and C-banding in the 1990 National Uniform Wheat Yield Trial in Pakistan. *Pak. J. Bot.* 23: 203-212.
- Villareal R.L., Rajaram S., Mujeeb-Kazi A., Del Toro E. 1991. The effect of chromosome 1B/1L translocation on the yield potential of certain spring wheats (*Triticum aestivum* L.). *Plant Breeding* 106: 77-81.
- Villareal R.L., Mujeeb-Kazi A., Rajaram S., Del Toro E. 1994. Associated effects of chromosome 1B/1R translocation on agronomic traits in hexaploid wheat. *Breed. Sci.* 44: 7-11.
- Villareal R.L., Del Toro E., Mujeeb-Kazi A., Rajaram S. 1995. The 1B/1L translocation effect on yield characteristics in a *Triticum aestivum* L. cross. *Plant Breeding* 114: 497-500.
- Villareal R.L., Banuelos O., Mujeeb-Kazi A., Rajaram S. 1998. Agronomic performance of chromosomes 1B and T1BL.1RS near-isolines in the spring bread wheat Seri M82. *Euphytica* 103: 195-202.
- Watanabe N., Evans J.R., Chow H.S. 1994. Changes in the photosynthetic properties of Australian wheat cultivars over the last century. *Aust. J. Plant Physiol.* 21: 169-183.
- Watanabe N., Komori S. 2001. Effects of alien chromosome additions on photosynthesis in wheat. In Z. Bedö and L. Láng (eds.), *Wheat in a global environment*, Kluwer Academic Publishers, Dordrecht, Netherlands, pp. 511-516.
- William, M.D.H.M., Mujeeb-Kazi A. 1993. Rapid detection of 1B, 1BL/1RS heterozygotes in the development of homozygous 1BL/1RS translocation stocks of *Triticum turgidum* ( $2n = 4x = 28$ ). *Genome* 36: 1088-1091.
- Zeller F.J., Fuchs E. 1983. Cytology and disease resistance of a 1A/1R wheat and some 1B/1R wheat rye translocation cultivars. *Z. Pflanzenzüchtung* 90: 285-296.

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