Plant Breeding 114, 497—500 (1995)

ISSN 0179-9541

The 1BL/1RS chromosome translocation effect on yield characteristics in a *Triticum aestivum* L. cross

R. L. Villareal, E. del Toro, A. Mujeeb-Kazi and S. Rajaram

International Maize and Wheat Improvement Center (CIMMYT), Lisboa 27, Apartado Postal 6-641, Deleg. Cuauhtemoc, 06600 Mexico, D.F., Mexico

With 4 tables

Received August 8, 1994/Accepted July 17, 1995
Communicated by B. S. Gill

Abstract

Comparisons involving 28 random F_2-derived F_6 wheat (*Triticum aestivum* L.) lines from the cross, 'Nacozari'/'Seri 82', suggested that advanced derivatives with the 1BL/1RS chromosome translocation possess superior agronomic performance in both full and reduced irrigation conditions when compared with 1B derivatives. This performance advantage was attributed to high grain yield, above-ground biomass at maturity, grains/spike, 1000-grain weight and test weight. The 1BL/1RS lines were shorter with delayed flowering and maturity. The superiority of the 1BL/1RS translocation group on grains/m^2 was expressed only under the full irrigation environment. Higher harvest index, longer spike-length and grain-filling period were detected only under reduced irrigation conditions. A significant grain yield relationship with test weight was detected only among the 1BL/1RS genotypes, indicating that they possess heavier and plumper grains than the 1B genotypes.

Key words: *Secale cereale*—*Triticum aestivum*—1BL/1RS translocation—yield components

The 1BL/1RS chromosome translocation containing the 1RS arm from rye has been incorporated globally into many hexaploid wheat (*Triticum aestivum* L.; 2n = 6X = 42; AABBDD) cultivars (Jahan et al. 1990, Lukaszewski 1990, Mettin et al. 1973, Zeller 1973), and to a limited extent in durum wheat (*T. turgidum* L.) 2n = 4X = 28, AABB (Friebe et al. 1987). In addition to protection of high-yield potential by resistance genes on the rye arm (McIntosh 1983), some researchers have perceived a yield increase associated with the 1BL/1RS translocation (Rajaram et al. 1983).

Trials conducted in Mexico comparing 10 high-yielding spring wheats, five with the 1BL/1RS translocation, and five with the normal 1B chromosome, demonstrated that genotypes with the 1BL/1RS chromosome translocation had higher above-ground biomass at maturity, 1000-grain weight, test weight and number of spikes/m^2. Although the 1BL/1RS cultivars appeared to have a slight advantage in grain yield, the observed difference was not significant (Villareal et al. 1991, 1994). In a similar study using F_3-derived F_6 and F_7 winter wheat lines from the 'Siouxland'/'Ram' cross, comparisons showed a 9% yield increase of 1BL/1RS genotypes over 1B genotypes (Moreno-Sevilla 1994). They attributed this trend to postanthesis stress tolerance of the 1BL/1RS genotypes which resulted in increased kernel weight. Recently, Carver and Rayburn (1994) reported 9–10% higher grain yield, 11–12% more aerial biomass, and 4–6% increase in kernel weight in 1BL/1RS over 1B near-isolines derived from two hard red winter-wheat populations.

Demonstration of the yield advantage of 1BL/1RS translocation in winter wheats has not been reported in spring wheats by evaluation of a stringent germplasm set. As about 50% of CIMMYT advanced high-yielding bread wheat lines possess the 1BL/1RS translocation, it is imperative that further investigations be conducted to verify this grain yield advantage of the 1BL/1RS germplasm. This study was conducted to determine the effect of 1BL/1RS on grain yield and yield components of advanced bread-wheat derivatives of 'Nacozari' (1B)/'Seri 82' (1BL/1RS) cross under five irrigations (optimum) and one irrigation (reduced) conditions throughout the growing cycle in northwest Mexico.

Earlier findings on CIMMYT 1BL/1RS wheats (Rajaram et al. 1983, Villareal et al. 1991, 1994) were based upon a genetically diverse set of 1BL/1RS and 1B cultivars. This study evaluates the translocation effects using random F_2-derived F_6 lines—a germplasm stringency that was not previously available.

Materials and Methods

Plant materials: The test material was derived from a cross between 'Nacozari' (homozygous for 1B) and 'Seri 82' (homozygous for 1BL/1RS). The F_1 hybrids were grown in 1990. Five-hundred F_2 plants were space-planted about 0.1 m apart within 10-m rows. At maturity, about 200 individual spikes were selected randomly from the population and advanced to the F_3. Ten seeds from each individual F_2 spike were space-planted in the field about 0.1 m apart in rows 1 m long with 0.25 m between rows. One spike per F_3 plot was harvested and advanced to F_4 and similarly further to F_5 generation. The F_5 plants were grown in 1991 in a double row of 2 m to produce sufficient seed for yield evaluations. F_5 plots homogeneous for height and maturity were bulk-harvested and cytologically analysed (Jahan et al. 1990) resulting in identification of 14 lines, each homozygous for 1BL/1RS and 1B.

Field experiments: Two yield trials were designed to evaluate the effect of 1BL/1RS under optimum irrigation (OIYT) and reduced irrigation (RIYT) at the Mexican Institute of Forestry, Agriculture and Livestock Agricultural Research Center for Northwest (CIANO; 27° 20′N, 105° 55′W, elevation 40 m above sea level), Sonora, Mexico during the 1991–92 and 1992–93 wheat seasons. The trials were sown in late November and matured during April.

One-hundred and fifty kilograms N/ha (in ammonium sulphate) and 40 kg P/ha (in tri-superphosphate) were applied prior to sowing the trials. For both experiments, the test material was arranged in a randomized complete-block design with three replicates. Each plot consisted of eight rows, 20 cm apart and 5 m long, and was machine-sown at a seeding rate of 120 kg/ha. The trials were surface-irrigated just after sowing. The irrigation of OIYT was continued until the latest maturing entry reached physiological maturity (a total of five irri-

Table 1: Partitioning of mean squares for groups of 1B and 1BL/1RS F_2-derived F_6 lines from the cross of *Triticum aestivum* L. cvs Nacozari/Seri 82, under two irrigation practices during the 1991–92 and 1992–93 crop cycles; YR, year; IP, irrigation practice

Source	df	Grain Yield	Above-ground Biomass	1000-grain Weight	Test Weight	Plant Height	Days to Flowering
Year	1	5657359**	44503369**	150**	352**	1788**	9956**
Irrigation practice	1	66895553**	632999746**	880**	140**	407**	37**
YR × IP	1	4109940**	28729937**	644**	14**	4781**	418**
Reps (YR × IP)	8	239743	5309396**	2*	2**	12*	8**
Genotypes	27	758359**	9123824**	72**	22**	426**	214**
1B vs. 1BL/1RS	(1)	581134*	6163842*	15**	143**	754**	89**
Among 1B	(13)	770547**	10222961**	65**	21**	118**	296**
Among 1BL/1RS	(13)	798261**	8252414**	83**	21**	709**	143**
YR × Genotypes	27	513357**	3992282**	5**	3**	15**	27**
YR × (1B vs. 1BL/1RS)	(1)	292227	1723012	1	1	6	8**
YR × Among 1B	(13)	512745**	3778514*	4*	5**	14**	33**
YR × Among 1BL/1RS	(13)	530979**	4380609**	6**	2**	17**	22**
IP × Genotypes	27	597574**	3551742**	9**	3**	12**	4**
IP × (1B vs. 1BL/1RS)	(1)	70499	477840	1	6**	24	1
IP × Among 1B	(13)	546992**	3438287*	8**	3**	8	5**
IP × Among 1BL/1RS	(13)	688700**	3901653**	9**	3**	15*	3**
YR × IP × Genotypes	27	396049**	3501715**	6**	2**	19**	4**
YR × IP × (1B vs. 1BL/1RS)	(1)	115774	7698327*	2	6**	11	1
YR × IP × Among 1B	(13)	571225**	3119185*	5**	2**	24**	3**
YR × IP Among 1BL/1RS	(13)	242432**	3561428**	7**	1*	15*	5**
Error	216	144634	1590223	1	0.4	6	1

*, **Significant at the 0.05 and 0.01 levels of probability, respectively

gations). Weed growth was restricted by the use of a selective herbicide, Puma(Fenoxaprop-Ethyl = Ethyl (*R*)-2-[4[(6-chloro-2-benzoxazolyl) oxy] phenoxy] propanoate, 2.5 l/ha; Hoechst AG, Germany). A fungicide, Folicur (Tebuconazole = α-tertiari-butil-α- (*p*-chlorofenetil)-1H-1,2,4-triazole-1 ethanol, 0.5 l/ha; Bayer AG, Germany), was applied to control leaf rust. Insect control was not required.

Traits measured from each plot were: (1) days to flowering, number of days from crop emergence until 50% anthesis; (2) plant height (cm), using three measurements in the plot from the ground to the tip of the spike (excluding awns); (3) spike length (cm), using three measurements from the base of the spike to the tip of the highest spikelet (awns excluded); (4) days to physiological maturity, recorded when the green colour was completely lost from 50% of the spikes in the plot; (5) grain yield (kg/ha), grain weight from an interior 5.0 m^2 portion, excluding border rows and 0.5 m of all rows at the end of each plot; (6) test weight (kg/hl), was recorded, using an electronic hectolitre balance for each entry; and (7) 1000-grain weight (g), determined from two dried 250-grain samples from each plot.

At physiological maturity, about 2 weeks before combine-harvest, a random sample of 50 spike-bearing culms was harvested at ground level from each plot. The spike number, grain and total weights were determined on this sample so that calculations could give harvest index (%) and grains/spike. Using the total plot grain yield, biomass (t/ha), spikes/m^2 and grains/m^2 were calculated; spikes/m^2 were estimated by dividing plot grain yield by grains/spike multiplied by grain weight.

Data analysis: Analysis of variance was performed on a total of 28 lines (14 1BL/1RS and 14 1B) across two irrigation practices and two wheat production cycles. Entry effects and their interactions with year and irrigation conditions were partitioned as shown in Table 1. Of these, the key comparisons are: (1) among chromosome classes, because it indicates if the chromosome translocation affects a trait; (2) lines within each chromosome group, because it indicates if there is variability within each group; and (3) chromosome group interaction with the environment, i.e. year × (1B versus 1BL/1RS), irrigation practice × (1B versus 1BL/1RS), and year × irrigation practice × (1B versus 1BL/1RS). Total variation among 1B or among 1BL/1RS inbred lines was partitioned assuming a completely random model. Average performance in a specific irrigation environment was equally of interest to average performance across environments; the data in each irrigation practice were therefore analysed separately. The general means of the 1BL/1RS and 1B genotypes were subjected to orthogonal contrast comparisons (Table 2). Mean comparisons utilized the least significant difference (LSD) estimates. Tables 3 and 4 summarize the mean comparison between the two chromosome groups under full and reduced irrigation practices, respectively (SAS Institute 1988).

Results

Mean air temperatures, [calculated as (mean maximum + mean minimum) ÷ 2], during the 1991–92 and 1992–93 wheat seasons were 18.5°C and 18.9°C, respectively, compared with the long-term average 17.1°C at CIANO. Minor lodging was observed during the 1991–92 crop season. Production management was optimum for weed, disease and bird control, and at no time during either cropping season were these factors a constraint on yield.

Combined analysis of variance showed significant variation between years, irrigation practice, and genotypes for all traits (Table 1) except for the effect of irrigation practice on harvest

Table 2: Means for the 1B and 1BL/1RS F_2-derived F_6 lines from the cross 'Nacozari'/'Seri 82', under two irrigation practices during the 1991–92 and 1992–93 crop cycles

Plant characteristic	1BL/1RS	1B	F-test
Grain yield (kg/ha)	5605	5374	*
Above-ground biomass (t/ha)	13.9	13.4	*
Harvest index (%)	40.2	39.8	ns
Spikes/m^2	351	354	ns
Grains/m^2	14990	14778	ns
Grains/spike	43.9	41.6	**
1000-grain weight (g)	38.62	38.20	**
Test weight (kg/hl)	79.0	78.3	**
Plant height (cm)	90.2	93.2	**
Spike length (cm)	10.5	10.5	ns
Days to flowering	80.0	79.0	**
Physiological maturity (day)	121.8	120.6	**
Grain-fill period (day)	41.8	41.6	ns

*, **Significant at the 0.05 and 0.01 levels of probability, respectively; ns, Not significant

Table 3: The effect of the 1BL/1RS chromosome translocation on yield characteristics of 28 random F_2-derived F_6 lines (14 1BL/1RS and 14 1B) from the cross of *Triticum aestivum* L. cvs 'Nacozari'/'Seri 82', under optimum irrigated condition during the 1991–92 and 1992–93 crop cycles

Plant characteristic	1BL/1RS	1B	Mean Difference	CV (%)
Grain yield (kg/ha)	6266	6006	260*	6.0
Above-ground biomass (t/ha)	15.2	14.7	0.5*	9.0
Harvest index (%)	41.3	40.7	0.6 ns	7.2
Spikes/m²	373	377	4.0 ns	11.5
Grains/m²	15906	15634	272*	5.8
Grains/spike	44.3	42.6	1.7**	9.7
1000-grain weight (g)	40.19	39.87	0.32*	2.9
Test weight (kg/hl)	79.8	78.8	1.0***	0.9
Plant height (cm)	91.6	94.1	2.5***	2.4
Spike length (cm)	9.9	10.1	0.2 ns	4.9
Days to flowering	80.3	79.4	0.9**	2.9
Physiological maturity (day)	126.1	125.5	0.6 ns	1.9
Grain-fill period (day)	45.8	46.1	0.3 ns	4.9

*, **, *** Significant at the 0.05, 0.01 and 0.001 levels of probability, respectively; ns, Not significant

index and grains/spike (not shown). The year by genotype, irrigation practice by genotype, and year by irrigation by genotype interactions were also significant for all traits except on irrigation practice by genotype interaction on spike length and spikes/m².

The genotype variation was partitioned into sources representing specific differences between chromosome classes (1B versus 1BL/1RS), and among inbreds within each chromosome group. Significant differences were found between chromosome classes for grain yield, above-ground biomass a maturity, grains/spike, 1000-grain weight, test weight, plant height, days to flowering, and physiological maturity (see Tables 1 and 2). The 1BL/1RS genotypes were higher-yielding, had increased aerial biomass yield at maturity, number of grains/spike, heavier grains and test weight, were shorter and took longer to flower and mature physiologically than 1B lines. Genotypes within the 1BL/1RS and 1B chromosome classes showed significant variations for all traits. Hence, genetic diversity exists among the genotypes within both chromosome groups.

The year by among-chromosome-class interaction was significant for spike length and days to flowering. Moreover, interactions between irrigation practice and chromosome group was significant for test weight, spike length, physiological maturity, and grain-filling period. Year by irrigation practice by chromosome group interactions were significant for above-ground biomass and test weight. These interactions were mainly due to changes in magnitude and a few reversals in order.

Optimum irrigation yield trial experiment

The 1BL/1RS lines yielded 4.3% better ($P < 0.05$) than the 1B lines (see Table 3). The highest (6747 kg/ha) and the lowest (5264 kg/ha) yielding entries were both 1B genotypes (not shown). The overall mean grain yield of the entries across two years was 6136 kg/ha. A combined analysis across years under full irrigation practice revealed a nonsignificant chromosome class × year interaction for grain yield. A coefficient of variation of 6.0% indicated satisfactory experimental precision. Above-ground biomass yields of the 1BL/1RS translocation lines were superior to those of the homozygous 1B lines ($P < 0.05$; Table 3). There were no harvest index differences between the two groups. Coefficients of variation were 9.0% and 7.2% for above-ground biomass and harvest index, respectively. There was no year × translocation group interaction for these characters.

Primary yield component analyses detected more grains/m², grains/spike and 1000-grain weight for the 1BL/1RS lines (Table 3). Test weight comparisons suggested ($P < 0.001$) that grains of the 1BL/1RS cultivars were plumper. However, when spike number/m² and spike length were compared, no significant differences were found. Across years of testing, year × chromosome class interaction for the above characters were nonsignificant. The 1BL/1RS genotypes were 2.7% shorter and flowered 0.9 day later than the 1B homozygous lines. Spike length, days to physiological maturity and grain-filling-period characteristic comparisons among the two groups were not

Table 4: The effect of 1BL/1RS chromosome translocation on yield characteristics of 28 random F_2-derived F_6 lines (14 1BL/1RS and 14 1B) from the cross of *Triticum aestivum* L. cvs Nacozari/Seri 82, under reduced irrigation condition during the 1991–92 and 1992–93 crop cycles

Plant characteristic	1BL/1RS	1B	Mean difference	CV (%)
Grain yield (kg/ha)	4945	4743	202*	9.8
Above-ground biomass (t/ha)	12.6	12.1	0.5*	10.4
Harvest index (%)	39.2	39.0	0.2*	7.4
Spikes/m²	329	331	2.0 ns	11.8
Grains/m²	14074	13922	152 ns	10.0
Grains/spike	43.5	40.6	2.9*	10.7
1000-grain weight (g)	37.05	36.53	0.52*	4.7
Test weight (kg/hl)	78.2	77.8	0.4**	1.3
Plant height (cm)	88.9	92.4	3.5***	3.9
Spike length (cm)	11.1	10.9	0.2**	5.1
Days to flowering	79.8	78.6	1.2***	2.0
Physiological maturity (day)	117.6	115.8	1.8***	2.1
Grain-fill period (day)	37.9	37.2	0.7*	4.9

*, **, *** Significant at the 0.05, 0.01 and 0.001 levels of probability, respectively; ns, Not significant

significantly different ($P > 0.05$). Very good coefficients of variation were calculated in all cases and no year × translocation class interactions were detected for these characters.

Reduced irrigation yield trial experiment

Under the reduced irrigation condition, the genotypes possessing the 1BL/1RS chromosome translocation yielded 4.2% better than the 1B homozygous lines ($P < 0.05$; Table 4). The year × chromosome group interaction for grain yield was nonsignificant. The coefficient of variation was 9.8% for the two-year experiment.

There was no significant year × translocation class interaction for above-ground biomass yield and harvest index. Biomass yield of 1BL/1RS cultivars was 4.1% greater than 1B cultivars. Similarly, the 1BL/1RS translocation group possessed a significantly higher harvest index than the 1B lines ($P < 0.05$). Among the yield components studied, the advantages of the 1BL/1RS genotypes over the 1B lines existed only for grains/spike, 1000-grain weight, test weight and spike length. No significant differences were detected for spikes/m^2 and grains/m^2 between the translocation groups.

The 1BL/1RS translocation material was 3.5 cm shorter than the 1B cultivars ($P < 0.001$), flowered later, took longer to reach physiological maturity and had a longer grain-filling period than the 1B lines. Low coefficients of variation (indicative of precision) were obtained for the above phenological characters.

Discussion

Twenty-eight individual random F_2-derived F_6 lines from a 1B × 1BL/1RS cross were used to avoid confounding the effect of the chromosome translocation with cultivar background. Genotype adaptation was measured across environments and in two contrasting irrigation conditions. Comparison of the translocation groups suggested that the 1BL/1RS chromosome translocation enhances agronomic performance in both optimum and reduced irrigation conditions. This advantage was attributed to high grain yield, above-ground biomass yield at maturity, grains/spike, 1000-grain weight and test weight. The 1BL/1RS cultivars were also shorter and later to flower and mature. These conform with the earlier findings of Moreno-Sevilla (1994) that utilized F_3-derived F_6 and F_7 lines of winter wheats, Carver and Rayburn (1994) who studied two winter wheat populations and Villareal et al. (1991, 1994) who used high-yielding spring wheat cultivars. A yield superiority of the 1BL/1RS genotypes were also detected in both environments studied, thereby supporting the reported wide adaptability of 1BL/1RS wheats of CIMMYT origin (CIMMYT 1986, Rajaram et al. 1983). The superiority of the translocation group on grains/m^2 was expressed only under the optimum irrigation condition. Similarly, higher harvest index, longer spike length, and grain-filling period were observed only under limited irrigation. The 1BL/1RS genotypes matured later across irrigations and reduced irrigation environments.

Correlation among the productivity components (data not presented), showed strong association between grain yield and biomass, spikes/m^2, grains/m^2, and 1000-grain weight among genotypes within both chromosome groups. Significant grain yield relationship with test weight was detected only among the 1BL/1RS genotypes, indicating that they possess heavier and plumper grains than the 1B genotypes. This is probably one of the principal components contributing to differences among chromosome classes for grain yield. Furthermore, the strong association between grains/m^2 and grains/spike and the negative association of grains/m^2 and 1000-grain weight found only within the 1B chromosome group indicates that genotype in this chromosome class have smaller grains and hence lower grain yield.

Resistance to leaf rust and powdery mildew derived from 1RS has been overcome in Europe (Bennett 1984, Zeller and Hsam 1984) and Mexico (S. Rajaram pers. comm.) and may be breaking down in other areas. It is unlikely that this resistance breakdown will curtail the future diversification of the 1BL/1RS wheat as its yield advantage and agronomic attributes continue to exhibit unusual productivity (Villareal et al. 1991, 1994, Carver and Rayburn 1994, Moreno-Sevilla 1994).

Acknowledgements

The authors thank CIMMYT bread wheat and wide crosses programme field staff for their contributions to the field experiments and Martha Larios for typing the manuscript.

References

Bennett, F. G. A., 1984: Resistance to powdery mildew in wheat: A review of its use in agriculture and breeding programs. Plant Pathol. **33**, 279—300.

Carver, B. F., and A. L. Rayburn, 1994: Comparison of related wheat stocks possessing 1B or 1RS.1BL chromosomes: agronomic performance. Crop Sci. **34**, 1505—1510.

CIMMYT, 1986: Veery 'S': Bread Wheats for Many Environments. CIMMYT, Mexico, D.F., Mexico.

Friebe, B., F. J. Zeller, and R. Kunzmann, 1987: Transfer of the 1BL/1RS wheat-rye-translocation from hexaploid bread wheat to tetraploid durum wheat. Theor. Appl. Genet. **74**, 423—425.

Jahan, Q., N. Ter-Kuile, N. Hashmi, M. Aslam, A. A. Vahidy, and A. Mujeeb-Kazi, 1990: The status of the 1B/1R translocation chromosome in some recent varietal releases and in the 1989 national uniform wheat yield trials (NUWYT) in Pakistan. Pak. J. Bot. **22**, 1—10.

Lukaszewski, A. J., 1990: Frequency of 1RS. 1AL and 1RS. 1BL translocations in United States wheats. Crop Sci. **30**, 1151—1153.

McIntosh, R. A., 1983: A catalogue of gene symbols for wheat. Proc. 6th Intern. Wheat Genet. Symp. 1983, Plant Germplasm Inst., Kyoto, 1197—1255.

Mettin, D., W. D. Blüthner, and G. Schlegel, 1973: Additional evidence on spontaneous 1B/1R wheat-rye substitutions and translocations. Proc. 4th Intern. Wheat Genet. Symp. 1973, Columbia, Missouri, 179—184.

Moreno-Sevilla, B., 1994: Effect of the 1BL/1RS translocation on yield components and grain yield in hard red winter wheat in Nebraska. PhD. Thesis, Univ. of Nebraska, Lincoln, USA.

Rajaram, S., C. E. Mann, G. Ortiz-Ferrara, and A. Mujeeb-Kazi, 1983: Adaptation, stability and high yield potential of certain 1B/1R CIMMYT wheats. Proc. 6th Intern. Wheat Genet. Symp. 1983, Plant Germplasm Inst, Kyoto, 613—621.

SAS Institute, 1988: SAS/STAT Users Guide. Release 6.03 ed. SAS Institute, Inc., Cary.

Villareal, R. L., S. Rajaram, and E. del Toro, 1991: The effect of chromosome 1B/1R translocation on the yield potential of certain spring wheats (*Triticum aestivum* L.). Plant Breeding **106**, 77—81.

——, A. Mujeeb-Kazi, S. Rajaram, and E. del Toro, 1994: Associated effects of chromosome 1B/1R translocation on agronomic traits in hexaploid wheat. Breed Sci. **44**, 7—11.

Zeller, F. J., 1973: 1B/1R wheat-rye chromosome substitutions and translocations. Proc. 4th Intern. Wheat Genet. Symp. 1973, Columbia, Missouri, 209—221.

——, and S. L. K. Hsam, 1984: Broadening the genetic variability of cutivated wheat by utilizing rye chromatin. Proc. 6th Intern. Wheat Genet. Symp. 1983, Plant Germplasm Inst., Kyoto, Japan, 161—173.