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Comparative performance of bread wheat and hexaploid triticale cytoplasms

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Summary. Thirteen wheat-like advanced-generation triticale × wheat derivatives, having tetraploid wheat cytoplasm from triticale, were reciprocally crossed with three improved bread wheats, and the resulting F_1s were evaluated for determining the comparative performance of the bread wheat and triticale cytoplasms for different traits. Significant reciprocal differences in the mean performance were observed for days to heading, days to maturity, spikes/plant, flag-leaf area, peduncle length, plant height, spike length, grains/spike, 1,000-grain weight, grain yield and grain protein content, and most of them were in favour of hexaploid wheat cytoplasm. However, this superiority of the hexaploid cytoplasm was not universal for a particular trait, implying that the differences in the performance of the evaluated reciprocal crosses depended not solely on the cytoplasmic background, but also on the interplay of the specific genotype with the cytoplasm.

Key words: Wheat – Triticale – Cytoplasmic effects

Introduction

Although the nucleus normally assumes the major role in governing metabolic activities of the cell, its influence may be modified depending upon the cytoplasmic background. This phenomenon can have implications in intergeneric hybrids such as triticale, which combines, within a common cytoplasm, genomes of two distantly related species. Available evidence on the cytoplasmic relationship in *Triticeae* suggests that both hexaploid (6 ×) and tetraploid (4 ×) wheats originally derived their cytoplasms from a common source, probably the B-genome donor (Kihara 1968; Suemoto 1968). Nevertheless, it appears probable that through evolution, the 6 × -wheat cytoplasm has become modified to co-exist harmoniously with the 6 × nucleus (Kerber 1964). However, in the limited reports available, there is no consensus about the superiority of the 6 × wheat cytoplasm over the 4 × one. Keeping this in view, the present investigation was undertaken to ascertain the superior source of cytoplasm for use in the triticale × wheat hybridization programmes.

Materials and methods

Materials for the present investigation comprised 13 wheat-like advanced-generation (F_6 or F_7) D–R genome reconstituted lines (RL accessions), resulting from different triticale × wheat combinations, and having 4 × wheat cytoplasm acquired from triticale. During the winter of 1983–1984, these triticale × wheat derivatives were crossed reciprocally with three improved hexaploid wheat cultivars, viz. CPAN 1922, HB 618 and HD 2323.

The resulting 13 reciprocal F_1s and their parents were raised in a randomized block design with 3 replications during winter 1984–1985. Sowing was done in single-row plots, 1 m long, spaced at a distance of 25 cm, keeping a plant-to-plant distance of 5 cm. Data were recorded on 12 traits, viz. days to heading, days to maturity, spikes/plant, flag-leaf area (cm^2), peduncle length (cm), plant height (cm), spike length (cm), spikelets/spike, grains/spike, 1,000-grain weight (g), grain yield (g) and grain protein content (%). For comparing the performance of the 4 × and 6 × wheat cytoplasms for different characters, the data were subjected to the analysis of variance and the means were compared. Differences in the mean performance of the reciprocal crosses were attributed to the difference in the cytoplasms.

Results

On partitioning the total variability into its components, significant genotypic differences were observed for all the traits studied. Estimates of mean performance of the

Table 1. Mean performance of reciprocal crosses of D-R genome reconstituted lines with hexaploid wheat cultivars for different traits

Cross	Days to heading	Days to maturity	Spikes/ plant	Flag-leaf area (cm^2)	Peduncle length (cm)	Plant height (cm)	Spike length (cm)	Grains/ spike	1000-grain weight (g)	Grain yield (g)	Grain protein content (%)
HD 2323 × RL 1	129.67	171.67	1.90	15.29	16.07	57.12	8.53	31.72	48.48*	2.99	9.59
RL 1 × HD 2323	130.00	170.33	1.98	15.20	18.63	60.17	8.11	33.77	45.48	3.08	9.44
HD 2323 × RL 2	131.00	167.67	2.99*	12.61	16.32	67.28	9.72	46.81	45.79*	6.31*	12.06
RL 2 × HD 2323	130.00	165.67*	2.34	13.96	23.52*	69.02	9.14	48.52	42.13	5.48	11.58
HD 2323 × RL 4	126.33	169.67	2.28	16.42*	32.60*	76.20	10.69	36.72	48.47	5.04	13.35*
RL 4 × HD 2323	122.67*	169.00	2.36	13.10	27.96	75.31	10.28	37.17	47.74	4.71	11.79
HD 2323 × RL 16	128.00*	171.33	2.50	12.83	24.76*	71.33	9.50	40.41	51.29	5.31*	7.78
RL 16 × HD 2323	130.00	171.67	2.38	13.34	19.55	64.48*	9.39	37.02	51.49	4.63	8.74
HB 618 × RL 2	134.00	169.33	2.01	13.19	14.66	64.11	9.18	46.02*	41.66	4.34*	10.26*
RL 2 × HB 618	134.67	168.67	2.33*	12.82	17.69	68.52	9.58	40.12	42.99	3.91	8.85
HB 618 × RL 3	135.67	168.67	2.41*	13.87	16.70	68.84	9.84	45.00	41.43	4.51*	10.05*
RL 3 × HB 618	136.00	168.67	2.09	14.95	16.07	68.17	9.76	45.56	40.33	3.87	7.96
HB 618 × RL 6	136.33	172.33	3.62*	16.18	16.95	61.52	10.40	43.94	48.98	7.52	9.92
RL 6 × HB 618	136.33	171.00	3.02	13.59	14.88	58.35	9.81	44.92	48.06	7.28	9.71
HB 618 × RL 13	131.00*	171.33	1.79	19.30	12.17	57.61	9.41	41.00*	50.09	3.91*	9.17
RL 13 × HB 618	135.33	170.67	1.78	20.42	13.41	57.70	9.39	34.02	48.76	3.16	9.48
HB 618 × RL 24	131.67*	171.00	2.23	14.58	16.47	65.20	9.97	43.08	47.02	4.22	8.89
RL 24 × HB 618	133.67	171.33	2.23	15.32	14.75	64.23	10.02	42.56	46.31	4.06	11.16*
HB 618 × RL 68	133.00*	172.67	2.34	15.66	11.71	64.12	9.85	43.94*	45.74	4.51*	10.93
RL 68 × HB 618	136.67	171.67	2.32	15.88	13.09	63.82	10.16	32.80	44.80	3.23	9.44
CPAN 1922 × RL 2	126.33	165.33	2.39	11.96	20.42	68.34	9.46	48.31	40.12	7.63	12.99
RL 2 × CPAN 1922	126.33	164.33	2.38	11.98	22.83	72.36	9.85	48.72	42.61	7.38	12.88
CPAN 1922 × RL 6	125.33	166.33*	3.62	11.98	25.45*	67.55	10.09	45.17	46.92	7.47	10.34*
RL 6 × CPAN 1922	123.33*	170.67	3.82	13.36	21.33	68.13	10.53	42.58	45.32	7.22	4.36
CPAN 1922 × RL 7	128.67	167.67*	3.57*	15.52*	33.51*	72.46	10.38*	38.78	52.09*	6.71	9.44
RL 7 × CPAN 1922	127.67	169.67	2.97	12.00	6.48	67.29*	9.32	41.53	47.71	6.20	9.28
CD at $p \leq 0.05$	1.27	1.82	0.30	3.18	3.12	4.90	0.73	4.91	2.68	0.62	1.50

* Significantly superior to its reciprocal counterpart

reciprocal crosses for different traits have been presented in Table 1.

Of the 13 reciprocal crosses studied, 6 exhibited significant reciprocal differences for days to heading, of which 4 crosses with the hexaploid cytoplasm – HD 2323 × RL 16, HB 618 × RL 13, HB 618 × RL 24 and HB 618 × RL 68 – were earlier in heading compared to their reciprocal counterparts. In contrast, the remaining two hybrids, HD 2323 × RL 4 and CPAN 1922 × RL 6, were significantly later in heading.

Superiority of the 6 × wheat cytoplasm for days to maturity was evident from the significantly earlier maturity of two crosses, CPAN 1922 × RL 6 and CPAN 1922 × RL 7, when compared to their counterparts with the 4 × cytoplasm. However, the maturity in HD 2323 × RL 2 was significantly delayed in comparison with its reciprocal.

The two cytoplasms were either on a par with each other or the 6 × one was relatively superior for spikes/ plant, in general. Combinations superior to their reciprocals were HD 2323 × RL 2, HB 618 × RL 3, HB 618 × RL 6 and CPAN 1922 × RL 7. The only cross delineating significant superiority of the 4 × cytoplasm was RL 2 × HB 618.

For flag-leaf area, all the reciprocal crosses, except HD 2323 × RL 4 and CPAN 1922 × RL 7, were on a par with each other. Both the exceptional crosses had significantly increased flag-leaf area, when compared to their reciprocal ones, evincing the pronounced manifestation of this trait under the 6 × cytoplasmic background.

Five crosses, viz. HD 2323 × RL 4, HD 2323 × RL 16, CPAN 1922 × RL 6, CPAN 1922 × RL 7 and HD 2323 × RL 2, showed reciprocal differences for peduncle length. The 6 × cytoplasm caused an increase in the peduncle length in all these crosses, except the last one where the opposite was true.

Two crosses, HD 2323 × RL 16 and CPAN 1922 × RL 7, displayed significant increase in plant height in comparison to their reciprocals having 4 × cytoplasm, whereas the remaining crosses did not show significant reciprocal differences for this trait.

For spike length, the cross combination of CPAN 1922 with RL 7 exhibited a significant difference in favour of the 6 × wheat cytoplasm. In all the remaining reciprocal crosses, the manifestation of this trait remained unaltered under the two cytoplasmic backgrounds.

None of the 13 reciprocal F_1s displayed significant differences for spikelets/spike.

Superiority of the 6 × cytoplasm was evident from three crosses, viz. HB 618 × RL 2, HB 618 × RL 13 and HB 618 × RL 68, which had higher number of grains per spike when compared to the respective reciprocal. However, there were no reciprocal differences in the rest of the crosses.

Performance of most of the reciprocal crosses remained at par for 1,000-grain weight. However, the cross combinations of HD 2323 with RL 1 and RL 2, and of CPAN 1922 with RL 7 displayed significantly increased grain weight in favour of the 6 × wheat cytoplasm.

Six of the 13 reciprocal crosses had significantly higher grain yield in the 6 × wheat cytoplasmic background. These crosses were HD 2323 × RL 2, HD 2323 × RL 16, HB 618 × RL 2, HB 618 × RL 3, HB 618 × RL 13 and HB 618 × RL 68. In the rest of the cases, there were no statistical differences between the reciprocal crosses.

Five crosses – HD 2323 × RL 4, HB 618 × RL 2, HB 618 × RL 3, CPAN 1922 × RL 6 and HB 618 × RL 24 – deviated significantly from their reciprocal counterparts for grain protein content. In the first four crosses, the 6 × cytoplasm was superior to the 4 × one, whereas the opposite was true in the last cross.

Discussion

Although opinions differ on the role of cytoplasm in heredity per se, there is no disagreement about the fact that cytoplasm is an essential component of the living cell for the action of nuclear genes. A cell functions as an entity and a harmonious relationship between the nucleus and cytoplasm is essential for the smooth operation of the various developmental processes. Differences in the performance of cytoplasms may be explained by the plasmon-sensitive hypothesis of Renner and Kupper (1921), according to which maternal cytoplasm provides an inevitable substrate for the paternal genes and can also modify the expression of genes for producing a deviant phenotype.

The wheat-like derivatives resulting from triticale × wheat hydridization, involved in the reciprocal crosses with bread wheat under study, were alloplasmic as these had the cytoplasm of triticale contributed, in turn, by the durum wheat involved in its synthesis. Of the 13 reciprocal hybrids studied, significant differences were observed in only a few crosses for different traits, i.e. 3 each for 1,000-grain weight, grains/spike and days to maturity, 2 for plant height and flag-leaf area, 1 for spike length, and none for spikelets per spike. However, for the rest of the traits, the number of reciprocal hybrids showing significant differences were 5 or 6. Most of the desirable reciprocal differences observed were caused by the 6 × wheat cytoplasm. The significantly higher grain yield under the 6 × cytoplasmic background appears to be primarily due to the increased number of spikes/plant in HB 618 × RL 3, increased grain number in HB 618 × RL 13 and HB 618 × RL 68, and grain weight in HD 2323 × RL 2.

In the available literature, conflicting reports are available regarding the superiority of 6 × or 4 × wheat cytoplasm for different traits. Sisodia and McGinnis (1970) and Hsam and Larter (1974a, b) advocated the superiority of the 6 × wheat cytoplasm. On the other hand, Merker (1973) and Roupakias and Kaltsikes (1977) found no significant differential effect of the 6 × and 4 × cytoplasms on meiosis. Interestingly, the parents used by Roupakias and Kaltsikes (1977) were the same as used by Hsam and Larter (1974a, b), but the results obtained were contradictory. Recently, Khodabandeh (1985) found no significant difference in the two types of cytoplasm on fertility under the glasshouse conditions; however, the 6 × cytoplasm was somewhat superior under field conditions. Such cytoplasmic differences as observed by him might be due to environmental factors.

In most of the studies, including the present one, the number of crosses exhibiting significant differences was so small that no generalized conclusion can be drawn. Although most of the differences observed in the present investigation for the traits under study were in favour of the 6 × cytoplasm, in a few cases the 4 × cytoplasm exhibited the superiority for the same trait. Thus, the superiority of the 6 × cytoplasm, as observed in the present investigation for different traits, is not universal. Possibly the performance of the evaluated 6 × germplasm did not depend solely on the cytoplasmic background, but also on the interplay of the specific cross-combination with the cytoplasm. The present study also implies that generalization for the relative performance of the two cytoplasms for different traits, made by some other workers based on a small number of crosses, is questionable.

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