Effect of Ploidy Level and Chromosome Constitution on Crossability and Growth of F₁ Plants in Intervarietal Triticale Crosses

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One complete type octoploid and seven hexaploid triticale (*X Triticosecale* WITTMACK) lines or varieties, among which two were the complete and five were the substituted types, were used in reciprocal crosses. When the octoploid was used as a female parent, crossability, weight of 25 kernels and the percentage of the F₁ plants grown till maturity were superior to those from the reciprocal crosses, except the crossabilities in the cross with those substituted types which were Camel/Pato of 2D/2R, 4D/4R, 5D/5R, Camel of 2D/2R, 4D/4R and Beaver of 2D/2R substitution. In the reciprocal crosses of the substituted type with the complete type of hexaploid triticale, higher crossability was obtained when the former was used as a female except when the 2D/2R, 4D/4R substituted variety Welsh was used as female. When the substituted type was used as female the F₁ kernel weight was lower. F₁ seeds obtained from the crosses between either Camel/Pato or Welsh as female and the complete types Beagle and Currency as male had similar appearance to the kernel of wheat rather than that of triticale or rye. Similar results were also obtained in case of the reciprocal crosses between Camel/Pato and Welsh.

KEY WORDS: *X Triticosecale*, complete type, crossability, hexaploid triticale, octoploid triticale, reciprocal crosses, substituted type.

Introduction

Hybridization between octoploid and hexaploid triticale (*X Triticosecale* WITTMACK) is considered to be one of the most promising methods for development of highly fertile and productive secondary hexaploid triticale lines (BAEVA and LAZAROVA, 1975). Most of the improved secondary hexaploid triticale were obtained from octoploid triticale × hexaploid triticale (PISSAREV, 1966; KISS, 1966; JENKINS, 1969) and hexaploid wheat × hexaploid triticale crosses (GUPTA and PRIYADASHAN, 1982). MÜNTZING (1979) suggested that a larger population should be used in the earlier generations and the selection of individual plants should be exercised in further generations in order to produce or improve octoploid or hexaploid triticale with high yield are good characteristics.

KROLOW (1970) stated that the higher viability of the hybrid kernels produced by hexaploid wheat × diploid rye crosses, compared to the tetraploid wheat × diploid rye crosses, was not resulted from the action of specific genome but was due to the increase of the number of component genomes in wheat relative to the rye genome. Similar views had been given by OEHLER (1931) and PIENAAR (1973). The crossability of hexaploid and tetraploid wheat with rye (OETTLER, 1984), and that of interspecific crosses among wheat species (WAKAKUWA, 1934) showed clear differences due to the ploidy level of wheat species. Secondary hexaploid triticale lines and cultivars with various features such as short stem with high plant productivity (BAEVA, et al. 1985), winter hardiness, resistance to diseases, high protein and lysine content have been bred by hybridization among different ploidy level of triticales (PISSAREV and ZHILKINA, 1967; KISS, 1965; SHULYNDYN, 1975).

It has been suggested that the substitution triticales are inferior to complete triticales in

the following respects. The adaptation ability of the substitution varieties, particularly in suboptimal soil and weather condition, was lower (NACHIT and TAHIR, 1983; DRISCOLL, 1985). The 5D/5R substitution is especially interesting because it seems to be associated with significant yield decrease (SOWA, 1986). PILCH (1981) compared yield and adaptation of two complete types with the substitution type based on the limited sample and concluded that the

Table 1. One octoploid and seven hexaploid triticale lines used in this study

Line or varieties	Abbreviation	2n	Constitution of R-genome	Cytoplasm	Source	Year of introduction
TCL TIPO OCTO JUP- D.E/CIN-CNO × BGL [(ERA- CNO × GAL- LO) CML- PATOSEL] S-111						
Bv-82	OCT	56	complete	<i>T. aestivum</i>	CIMMYT	1982
Camel/Pato	C/P	42	2R, 4R, 5R chromosomes are substituted by 2D, 4D, 5D chromosomes	<i>T. aestivum</i>	Univ. Manitoba	1982
Camel	CML	42	2R, 4R chromosomes are substituted by 2D, 4D chromosomes	<i>T. aestivum</i>	Univ. Manitoba	1982
Welsh	WEL	42	2R, 4R chromosomes are substituted by 2D, 4D chromosomes	<i>T. aestivum</i>	Univ. Manitoba	1982
Bronco	BCO	42	2R, Chromosome is substituted by 2D chromosome	<i>T. turgidum</i>	Univ. Manitoba	1982
Beaver	BVR	42	2R, Chromosome is substituted by 2D chromosome	<i>T. aestivum</i>	Univ. Manitoba	1982
Beagle	BGL	42	chromosome complete	<i>T. turgidum</i>	Univ. Manitoba	1982
Currency	CNY	42	complete	<i>T. aestivum</i>	Univ. Sydney	1986

complete types were superior. The higher grain yield in lines of the complete R-genome than in the substitution lines was also observed by ZILLINSKY (1979). Recent study of SKOVMAND *et al.* (1985) showed a blurring of the phenotypes differences between the complete and the substitution types and suggested that the intercrossing of the two types will give more benefit to the genetic progress of the crop.

The present investigation was conducted to examine the effect of ploidy level and chromosome constitution on crossability, the characters of F_1 seeds and the percentage of F_1 plants grown till maturity through the intervarietal hybridization of octoploid and hexaploid triticales.

Materials and Methods

Description of an octoploid line, two complete type and five substitution type varieties in hexaploid triticales used in this study is given in Table 1.

After chromosome examination of the root-tip cells of the germinated seed, one plant with the genuine chromosome number for each parental line or variety was planted to a pot with 14.4cm in diameter and 14cm in depth, which was filled with sandy loam, perlite and organic matters (2:1:1 by volume). Half to 1gm and 2 to 3gm of urea and the compound fertilizer were applied respectively before the plant was planted.

Twenty to forty florets per spike were emasculated about two days before inflorescence. The emasculated spikes were covered with cellophane bags to prevent accidental outcrossing. When the stigmas of most of the emasculated florets were feathery and receptive, male parent anthers which were about to dehisce were removed individually from the spikes and brush on the stigmas of the emasculated florets. Spikes were bagged after the pollination. After harvest, the number of florets with seed was recorded separately for each cross. The crossability in each cross combination was shown by the percentage of the florets with seeds. Weight of 25 kernels obtained by the pollination was measured.

All the seeds obtained from the crosses were allowed to germinate on the blotting paper in the germination box. After germination the seedlings were transferred individually into a pot that was prepared similarly to the parental plants. Chromosome counting of root-tip cells of the F_1 seedlings were not carried out. All the plants were grown in the glasshouse under natural condition. The number of F_1 plants that grew till maturity was also scored and shown by the percentage to the number of seeds obtained by the cross.

Corrected Chi-square test was used to compare the crossability and the percentage of F_1 plants grown till maturity in the individual reciprocal crosses and paired t test was used to compare the 25-kernel weight of the F_1 hybrid seeds in reciprocal crosses among octoploid, complete and substituted hexaploid triticales.

Results

I. Reciprocal crosses between octoploid and hexaploid triticales

(i) Crossability

In 14 combinations of the reciprocal crosses between octoploid and hexaploid triticales, four combinations out of seven in which octoploid triticales was used as a female parent showed

significantly superior and one showed significantly inferior crossability to the reciprocals. Crossing of two complete type hexaploid triticales Beagle and Currency to octoploid triticales as female resulted in the crossabilities of 51.4% and 32.9%, which were significantly higher than the scores of 28.4% and 9.8% obtained by the reciprocal crosses. Such significant differences were also found in the cross combinations with two varieties Welsh and Bronco out of five substituted hexaploid triticales. On the contrary, however, in the cross with the variety Camel the crossability of the octoploid as female was significantly lower than in the reciprocal crosses (Table 2).

(ii) Morphological characters of the F_1 seeds

All hybrid seeds were poorer in appearance than those of male or female parents (Fig. 1). Most of the hybrid seeds obtained from the cross between the octoploid female and the hexaploid male parent were better and more uniform than the seeds obtained from the reverse crossing (Table 2 and Fig. 1). The variation of the seed size was larger in the hybrid seeds obtained from both the complete and the substitution type hexaploid as a female parent crossed with the octoploid triticales. When the hexaploid triticales variety Camel/Pato of 2D/2R, 4D/4R, 5D/5R substitution type was crossed with the octoploid, the character of F_1 seeds looked much more like that of wheat rather than of triticales or rye (Fig. 1).

(iii) 25-kernel weight and the percentage of plants grown till maturity

In the cross between octoploid as female and hexaploid as male, 25-kernel weight was significantly superior to those in the reciprocal crosses (Table 2, 3). More than 76% of the hybrid plants obtained from the former crosses were grown till maturity while the plants obtained by the latter crosses ranged from 22.2 to 58.1%, and a correlation coefficient of $r=0.812$ (d.f.=12, $p<0.01$) was obtained between the seed weight and the percentage of plants grown till maturity (Table 2).

II. Reciprocal crosses among different levels of the substitution type in hexaploid triticales

(i) Crossability

In reciprocal crosses among different levels of D/R substitution lines in hexaploid triticales, three combinations out of seven where the complete type was used as male, showed significantly superior crossability to those of the reciprocals, while opposite result was obtained from the reciprocal crosses between complete type variety Currency and Welsh of 2D/2R, 4D/4R, substituted type. In three other combinations there were no significant differences in crossability between the reciprocal crosses (Table 4).

Reciprocal crosses between two D/R substitution lines Camel/Pato and Welsh showed the crossability of 50.5% in the former used as female and 34.6% in the latter as female parent. There was significant difference between them at the 5% level (Table 4). In the reciprocal crosses between two complete type varieties Beagle and Currency, significantly higher crossability of 47.6% was obtained when Beagle was the female parent compared with 29.4% in the reversed cross.

(ii) Morphological characters of the F_1 seeds

The F_1 hybrid seeds were much poorer in morphological characters and less uniform in

Table 2. Seed sets, crossability, 25-kernel weight and the number of seeds germinated of the F₁ seeds and the percentage of the F₁ plants grown till maturity in the reciprocal crosses between the octoploid and the hexaploid triticales

Female parent	Male parent	No. of florets pollinated	No. of seeds obtained	Cross-ability	X_c^2	25-kernel weight (gr)	No. of seeds germinated	No. of plants grown till maturity	% of plants grown till maturity	X_c^2
OCT ¹⁾	C/P ¹⁾	296	20	6.8		0.626 ²⁾	19	18	90.0	11.98**
C/P	OCT	253	28	11.1	2.68	0.498	12	10	35.7	
OCT	CML	154	25	16.2	28.81**	0.879	20	19	76.0	11.32**
CML	OCT	67	35	52.2		0.465	12	10	28.6	
OCT	WEL	75	26	34.7	11.04**	0.611	25	24	92.3	6.86**
WEL	OCT	200	31	15.1		0.628	20	18	58.1	
OCT	BCO	116	33	28.5	17.07**	0.758	31	30	90.0	19.18**
BCO	OCT	252	27	10.7		0.382	20	9	33.3	
OCT	BVR	83	23	27.7	0.98	0.861 ³⁾	22	22	95.7	27.44**
BVR	OCT	101	36	35.6		0.553	9	8	22.2	
OCT	BGL	74	38	51.4	11.03**	0.791	35	33	86.8	25.87**
BGL	OCT	176	50	28.4		0.492	36	15	30.0	
OCT	CNY	82	27	32.9	24.98**	0.746	26	25	92.6	17.88**
CNY	OCT	277	27	9.8		0.488	18	9	33.3	

1) Abbreviations are followed by Table 1.

2) Converted from the weight of 20 kernels.

3) Converted from the weight of 23 kernels.

*, ** Significant at 5% and 1% levels respectively.

Fig. 1. Seeds of the parents and F_1 hybrids obtained by the reciprocal crosses between the octoploid and the hexaploid, and the complete and the substitution type hexaploid triticales. Abbreviation of each line and variety is followed by Table 1. The line or variety put on the left in each cross indicates the female parent.

Table 3. Comparison of 25-kernel weight of the F₁ hybrid seeds from the reciprocal crosses within each combination of three different triticales types

Comparison	d.f.	't' value
OCT. × HEXA. (SUBSTITUTION) and HEXA. (SUBSTITUTION) × OCT.	4	2.392*
OCT. × HEXA. (COMPLETE) and HEXA. (COMPLETE) × OCT.	1	13.592*
HEXA. (COMPLETE) × HEXA. (SUBSTITUTION) and HEXA. (SUBSTITUTION) × HEXA. (COMPLETE)	4	3.322*

*Significant at 5% level

seed size than those of the parents in 17 out of 18 combinations. An exception was found in the case of Beagle crossed with Currency, in which the F₁ seed characters including the seed size were as uniform as those of the parents. When Camel/Pato of 2D/2R, 4D/4R, 5D/5R substitution type and Welsh of 2D/2R, 4D/4R substitution type were used as female in the crosses with the complete types Beagle and Currency, all the hybrid seeds became shorter, and similar to the seed of wheat rather than of triticales or rye. Similar seed characters were also obtained from the reciprocal crosses between Camel/Pato and Welsh (Fig. 1).

(iii) 25-kernel weight and the percentage of plants grown till maturity

The opposite results were obtained in these characters to the crossability in the reciprocal crosses among different level of the D/R substitution lines in hexaploid triticales. When the complete type Beagle was crossed with the pollen of the various levels of substitution type Camel/Pato, and Beaver, 25-F₁-kernel weight and the percentage of the plants grown till maturity showed superiority to those obtained by the reciprocal crosses and the F₁ seed weight was positively correlated to the percentage of plants grown till maturity ($r=0.804$, d.f.=10, $p<0.01$). Slightly lower values in the percentage of plants grown till maturity were recorded when Currency was the female parent in the crosses with Camel/Pato and Welsh (Table 4). Because few seeds were obtained, 25-kernel weight was not recorded for the hybrid seeds from the cross of Beagle × Camel and Beagle × Bronco. All hybrid seeds obtained from the complete type female parents crossed with substitution types were significantly heavier in seed weight than those from the opposite crosses (Table 3, 4).

Discussion

It has been stated by OEHLER (1931), KROLOW (1970), PIENAAR (1973) and OETTLER (1984, 1985) that the ploidy level has a strong effect on crossability and seed characters in wheat-rye hybridization. They also showed that wheat of the higher ploidy level gave better results than wheat of the lower ploidy level in the cross with diploid rye. In this study, significantly higher crossabilities were obtained in the crosses of the octoploid triticales with the pollen

Table 4. Seed sets, crossability, 25-kernel weight and the number of seeds germinated of the F₁ seeds and the percentage of the F₁ plants grown till maturity in the reciprocal crosses among the different levels of R-D substitution lines in hexaploid triticale

Female parent	Male parent	No. of florets pollinated	No. of seeds obtained	Cross-ability	X_c^2	25-kernel weight (gr)	No. of seeds germinated	No. of plants grown till maturity	% of plants grown till maturity	X_c^2
C/P ¹	WEL ¹⁾	99	50	50.5		0.721	35	31	62.0	
WEL	C/P	153	53	34.6	5.63*	0.821	50	49	92.5	12.04**
C/P	BGL	64	33	51.6		0.391	18	14	42.4	
BGL	C/P	264	67	25.4	15.46**	0.799	65	62	92.5	27.76**
C/P	CNY	147	69	46.9		0.685	58	55	79.7	
CNY	C/P	86	31	36.1	2.20	0.702	24	20	64.5	1.90
BCO	BGL	99	44	44.4		0.411	26	22	50.0	
BGL	BCO	269	12	4.5	86.54**	2)	11	10	83.3	3.02
BVR	BGL	62	26	41.9		0.598	23	21	80.8	
BGL	BVR	118	40	33.9	0.82	0.776	39	39	97.5	3.52
CML	BGL	34	21	61.8		0.557 ³⁾	19	18	85.7	
BGL	CML	37	1	2.7	26.18**	2)	1	1	100.0	1.13
WEL	BGL	74	34	45.9		0.598	24	20	58.8	
BGL	WEL	90	42	46.7	0.06	0.821	37	36	85.7	5.68*
WEL	CNY	140	41	29.3		0.603	36	34	82.9	
CNY	WEL	94	42	44.7	5.17*	0.811	34	32	76.2	0.22
BGL	CNY	82	39	47.6		0.928	37	36	93.3	
CNY	BGL	204	60	29.7	7.74**	0.867	20	13	21.7	44.40**

¹⁾ Abbreviations are followed by Table 1.

²⁾ Due to few seeds obtained, 25-kernel weight was not recorded.

³⁾ Converted from the weight of 21 kernels.

*, ** Significant at 5% and 1% levels respectively.

of both complete and substitution type hexaploid triticales compared to the reciprocal crosses, except the case with the substitution type hexaploid triticales Camel/Pato, Camel and Beaver. In case of the cross with the pollen of Camel, significantly lower crossability was obtained than the reciprocal cross (Table 2).

The specific effect of the rye genotype on cytological characteristics of triticales was firstly shown by LELLY (1975). SOWA (1986) stated that a gene or genes controlling fertility were located on chromosome 5R. In rye trisomics, additional 5R improved the seed setting (METTIN *et al.* 1972). GUPTA and FEDAK (1986) reported that an autopolysyndesis in the hybrid between triticales and the alien species was influenced by R-genome(s) of triticales. In the present study much differences in the morphological character of the seeds were observed between the 5R missing parent Camel/Pato and other triticales lines with different cytological background (Fig. 1).

DE SOSA (1974) stated that the number of seeds per spikelet and the number of spikelets per spike in the F_1 hybrid of octoploid $\times$ hexaploid triticales were less than those of the parents. It was found in the present experiment that although the seed characters of the F_1 hybrid were, in general, poorer than those of the parents in the cross between octoploid triticales and hexaploid triticales, the seeds obtained from octoploid triticales used as female were heavier and the percentage of the plants grown till maturity was distinctly higher than those obtained by the reverse cross. This suggests that the ploidy level has a strong effect on seed characters not only in the interspecific crosses in wheat species, but also in the crosses among different triticales lines, though in the case of wheat the female gametes crossed with the male gametes having lower ploidy level than the former were inferior in crossability but superior in germination rate of F_1 seeds and vice versa (WAKAKUWA, 1934).

Based on the results from the trigeneric hybrid of triticales $\times$ *Triticum* $\times$ *Hordeum*, FERNANDEZ-ESCOBER and MARTIN (1985) reported that the fertility of the hybrid was clearly influenced by the parents. It was found that the crossabilities were significantly different depending on the female parent used in the intervarietal crosses of triticales (HSAN, unpublished data). Together with those information, it can be concluded that the higher crossability, the heavier F_1 seed and the higher percentage of the plants grown till maturity are obtained when the octoploid triticales is used as a female parent in the crosses with hexaploid triticales than in their reciprocal crosses with the exception of the cross with substitution type Camel which gives the reversed result in respect only to the crossability but not other traits studied.

It can also be stated that the heavier F_1 seed is obtained when the complete type hexaploid triticales is crossed as female with the substitution type hexaploid triticales than in case of the reciprocal cross combinations (Table 3, 4), and in addition that the heavier the hybrid seeds, the higher the percentage of plants grown till maturity since there is a positive correlation of $r=0.785$ $F(d.f.=24, P<0.01)$ between those two characters shown in Table 2 and 4 excluding the data for two combinations of Camel/Pato $\times$ Welsh and Beagle $\times$ Currency shown on the top and bottom in Table 4 respectively.

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倍数性および染色体構成がライコムギ間交雑
における交雑率と F_1 植物の生育に及ぼす影響

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ライコムギの倍数性および染色体構成がライコムギ間の交雑率や F_1 植物の生育に及ぼす影響を調査するため, R ゲノム染色体が全部揃っている八倍性ライコムギ(完全型八倍体) 1 系統, 完全型六倍性ライコムギ 2 品種, $2D/2R$ 置換型六倍性ライコムギ 2 品種, $2D/2R \cdot 4D/4R$ 置換型六倍性ライコムギ 2 品種および $2D/2R \cdot 4D/4R \cdot 5D/5R$ 置換型六倍性ライコムギ 1 品種を用いて (Table 1) 交雑実験を行った. 八倍体 $\times$ 六倍体の相互交雑における交雑率は, $2D/2R$ 置換型の Beaver, $2D/2R \cdot 4D/4R$ 置換型の Camel, および $2D/2R \cdot 4D/4R \cdot 5D/5R$ 置換型の Camel/Pato との交雑においては八倍体を母方にした方がその逆交雑の場合よりも低い値を示したが, それ以外の 4 組合せでは八倍体を母方にした方がより高い値を示した (Table 2). また交雑によって得られた F_1 種子の重量および F_1 植物の完熟期達成率は, 八倍体を母方にした 7 交雑組合せのすべてにおいて逆交雑の場合よりも高い値を示した (Table 2, 3). 置換型六倍性ライコムギと完全型六倍性ライコムギ間の 14 交雑組合せにおける交雑率は, $2D/2R \cdot 4D/4R$ 置換型の Welsh を母方にして完全型の Beagle および Currency と交雑した 2 交雑組合せ以外はすべて置換型を母方にした場合の方がより高い交雑率を示した (Table 4). しかし F_1 種子の重量は置換型を母方とした組合せで低い値を示した (Table 3, 4). Camel/Pato または Welsh を母方とした Beagle または Currency との交雑から得られた F_1 種子, および Camel/Pato と Welsh の相互交雑によって得られた F_1 種子の形状はすべて短小で, ややコムギの種子に近似していた (Fig. 1). 本実験から, 八倍性ライコムギと完全型六倍性ライコムギの交雑においては八倍体を母方にした方がその逆交雑の場合よりも交雑率, F_1 種子の重量, F_1 植物の完熟期達成率が大になること, 八倍体と置換型六倍体との交雑においては八倍体を母体にした方がその逆交雑の場合よりも F_1 種子の重量, F_1 植物の完熟期達成率が大になる傾向が見られるが, 交雑率には一定の傾向が見られないこと, また完全型六倍体と置換型六倍体との交雑においては, 完全型を母方とした交雑組合せにおいて F_1 種子の重量が大になるが, 交雑率と F_1 植物の完熟期達成率には一定の傾向が見られないことが明らかになった (Table 3, 4).