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METHODS TO IMPROVE THE GENE FLOW FROM RYE AND WHEAT TO TRITICALE

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SUMMARY

Triticum turgidum ssp. carthlicum v. stramineum and T. aestivum ssp. sphaerococcum cross readily with rye to give a set of over 20% viable kernels. They can thus serve as effective bridges for transferring rye genes to Triticale breeding lines. Gamma-irradiation of Triticale and rye pollen enhances their crossability with common wheat; the most effective gamma-ray dose for Triticale pollen is 0.5-1.5kR and for rye pollen 0.05-0.8kR (15kR/hr). From a practical point of view the Triticale pollen should not receive more than 0.75kR gamma-irradiation or else most of the resulting F_1 *hybrids will be sterile.*

INTRODUCTION

The superior potential of the *Triticale* introductions from the Canadian-Mexican improvement program and from Salinas, Cal., was immediately apparent in the Eastern Orange Free State (JORDAAN *et al.*, 1970) and also at Stellenbosch. They, however, lacked general adaptation and failed under adverse conditions. In 1970 it was therefore decided to start a *Triticale* improvement program at Stellenbosch.

Crossability with Rye

Eighty-two of the better durum introductions and other tetraploid wheats were screened for crossability with the seven best local and introduced rye cultivars. The results summarized in Table 1 were similar to those of KROLOW (1970). Only 0.6% of the cross-pollinated durum florets yielded viable kernels, but by means of ROMMEL's (1958) embryo-culture technique the yield of seedlings was improved to 1.2% (Table 2).

KNOBLOCH (1968) cited various successful crosses between *Triticum turgidum* ssp. *carthlicum* and rye. Seventeen different crosses between this subspecies and rye were therefore made. Two introductions of ssp. *carthlicum* v. *stramineum* hybridized readily with the rye cultivars and yielded more than 23 viable kernels per 100 cross-pollinated florets (Table 1). It can, therefore, serve as a very effective bridge for transferring rye genes to the secondary *Triticales*. The other varieties of *carthlicum*, notably *rubiginosum*, were incompatible with rye. A *carthlicum* hexaploid strain from Sweden hybridized readily with rye to yield very fertile octaploids after colchicine treatment.

Table 1. Seed set and viability from crosses of tetraploid and hexaploid wheats x rye without using the embryo-culture technique

♀ parent and no. strains or cultivars	No. rye cvs.	No. of pollinations: Spikes	No. of pollinations: Florets (basal)	No. kernels set: Filled	No. kernels set: Shrivelled	Kernels set (% pollin. flor.)	Germination %	Viable kernels (% poll. florets)
4x wheats								
carthlicum (5)*	4	22	658	86	144	34.9	30.9	10.8
dicoccoides (3)	2	6	180	0	80	44.4	3.8	1.7
dicoccon (2)	2	3	90	0	22	24.4	0.0	0.0
durum (82)	7	211	7570	0	2577	34.0	1.7	0.6
polonicum (1)	2	3	100	0	40	40.0	0.0	0.0
pyramidale (1)	1	1	38	0	6	15.8	0.0	0.0
turgidum (3)	4	5	150	0	17	11.3	0.0	0.0
dur.-carth. F_1	4	5	214	0	66	30.8	0.0	0.0
6x wheats								
vulgare (10)	7	59	1933	57	18	3.9	64.0	2.4
sphaerococcum (4)	6	28	860	277	19	34.4	60.1	20.7
vulg.-sphaer. F_1	5	11	376	63	18	21.5	53.1	11.4
sphaer.-vulg. F_1	4	7	226	60	6	29.2	75.8	22.1
sphaer.-dur. F_1	4	13	490	0	0	0.0	0.0	0.0
carth. - type	3	3	110	14	1	13.6	73.3	10.0

*Three compatible and two incompatible strains. The three compatible *stramineum* strains were subsequently found to be hexaploid.

Ten high-quality *T. aestivum* ssp. *vulgare* cultivars were crossed with 7 rye cultivars in order to transfer genes for better adaptation and quality via new primary *Triticales* to the introduced secondary *Triticales*. An average of 2.4% of the cross-pollinated florets yielded viable kernels (Table 1). Embryo culture did not significantly improve the yield of seedlings (Table 2).

According to RILEY and CHAPMAN (1967) the wheat cultivars from the East tend to hybridize more readily with rye. Since KNOBLOCH

Table 2. Seed set and viability from crosses with rye, making use of the embryo-culture technique

♀ parent and no. cultivars	No. rye cvs.	No. of pollinations: Spikes	No. of pollinations: Florets	Kernels set (16-18 days): No.	Kernels set (16-18 days): % poll. florets	No. kernels dissected	No. embryos transplanted	Seedlings obtained: % dissected kernels	Seedlings obtained: % poll. florets
4x wheats									
durum (21)	6	42	1616	600	37.1	325	282	5.8	1.2
6x wheats									
vulgare (1)	4	5	186	9	4.8	9	9	55.6	2.7
sphaerococcum	1	1	24	13	54.1	10	10	70.0	29.1

(1968) also cited various successful *T. aestivum* ssp. *sphaerococcum* x *S. cereale* crosses, it was decided to cross 4 *sphaerococcum* introductions with 6 rye cultivars. All *sphaerococcum* varieties, including *echinatum*, *rotundatum* and *rubiginosum*, hybridized readily with rye - on the average 20.7% of the florets yielded viable kernels (Table 1). The *sphaerococcum* x *vulgare* F1 hybrids when crossed with rye likewise gave a good set of viable kernels (Table 1). *T. aestivum* ssp. *sphaerococcum* must, therefore, be considered an efficient bridge for transferring rye genes via new primary octaploid *Triticales* to the secondary *Triticales*.

SISODIA and McGINNIS (1970b) recommended that pentaploid wheat hybrids, resulting from Dinkel X Emmer crosses, be hybridized with rye. Our *sphaerococcum* x *durum* F_1 hybrids, when crossed with 4 rye cultivars, did not set any kernels (Table 1).

Triticale Crossability

According to SISODIA and McGINNIS (1970a, b) the germplasm of 6*x* wheat, both at the nuclear and cytoplasmic level, is important in the improvement of hexaploid *Triticale*. Eight *Triticale* introductions from Salinas, Cal., were therefore crossed as pollen parents with 6 *vulgare* cultivars and 3 *sphaerococcum* strains. Many crosses did not yield any viable kernels and an average set of only 1 viable kernel per 100 cross-pollinated florets was obtained (Table 3). Dissection of the F_1 kernels at 16 days after pollination revealed that the endosperm was a fluid, degenerate mass and that the embryos were underdeveloped - only 1 out of 21 embryo cultures gave rise to a seedling. The methods employed by KRUSE (1967, 1969) to overcome incompatibility reactions did not improve the set of viable kernels. In the reciprocal crosses (*Triticale* x common wheat) 23% of the cross-pollinated florets yielded viable kernels.

All the durum x *Triticale* crosses made to date yielded only inviable kernels.

Irradiation of Triticale Pollen and Eggs

BREWBAKER and EMERY (1962) stated that irradiation of mature pollen had been tested with only a minor measure of success in overcoming interspecific incompatibilities. They reported that NISHIYAMA and IIZUKA obtained a few viable kernels from two interspecific *Avena* crosses in 1952 when X-irradiated pollen was used. With this result in mind, and also attempting to induce haploidy in common wheat, gamma-irradiated pollen of various species was used to pollinate emasculated wheat spikes. It was found that irradiated *Triticale* pollen resulted in a much improved set of viable F_1 kernels in the common wheat x 6*x* *Triticale* crosses (Table 3, Fig. 1). When pollination was effected immediately after pollen irradiation by a ^{60}Co source, the best set of viable F_1 kernels was obtained at a gamma-ray dose of 1 kR (15 kR/hr) - at this dose nearly 36% of the cross-pollinated florets yielded viable kernels. Pollination 1 and 3 days after pollen irradiation resulted in peak sets of viable F_1 kernels at gamma-ray doses of 1.5 kR and 2kR, respectively (Table 3, Fig. 1). Pollination immediately after the pollen received a gamma-ray dose of 3kR yielded no viable kernels; when the pollination was effected 3 days afterwards, 14.5 per cent of the florets yielded viable kernels.

The most fertile F_1 hybrids resulted from *Triticale* pollen which received a gamma-ray dose of 0.1-0.5kR; they yielded as many kernels (±4) per F_1 spike as the F_1 resulting from the control

Table 3. The effect of pollen irradiation on the enhancement of viable kernel sets in common wheat x *Triticale* and common wheat x rye crosses

Dose in kR	When polli-nated[1]	No. cultivars ♀ (wheat)	No. cultivars ♂	No. of pollinations Spikes	No. of pollinations Florets	No. kernels set Filled	No. kernels set Shriv-elled	Kernels set (% of pollinated florets)	Germi-nation %	Viable kernels (% poll. florets)
Wheat x Triticale (6x) and controls										
0.0	-	2	(selfed)	18	570	522	0	91.6	98.6	90.4
0.0	-	6	8	35	1046	15	806	78.5	1.3	1.0
0.1	0-8 hr	2	3	3	88	6	48	61.4	5.6	3.4
0.25	do.	3	4	7	216	8	137	67.1	7.6	5.1
0.5	do.	3	4	9	272	34	141	64.3	24.0	15.4
0.75	do.	2	1	4	108	19	66	78.7	17.6	13.9
1.0	do.	3	4	10	304	95	106	66.1	54.2	35.9
1.25	do.	2	1	4	120	37	47	70.0	33.3	23.3
1.5	do.	2	1	5	150	36	73	72.7	23.9	17.3
2.0	do.	3	4	10	308	48	168	70.1	10.2	7.1
2.5	do.	2	1	6	178	5	112	65.7	0.9	0.6
3.0	do.	2	1	4	110	4	76	72.7	0.0	0.0
4.0	do.	1	1	2	52	0	41	78.8	0.0	0.0
0.1	1 day	1	1	1	30	0	28	93.3	0.0	0.0
0.25	do.	2	2	3	88	1	69	79.5	1.4	1.1
0.5	do.	3	2	4	120	12	91	85.8	10.7	9.2
0.75	do.	2	1	2	60	10	35	75.0	15.6	11.7
1.0	do.	3	2	4	130	29	84	86.9	25.7	22.3
1.25	do.	2	1	2	58	21	27	82.8	16.7	13.8
1.5	do.	3	1	4	112	41	52	83.0	37.6	31.3
2.0	do.	3	2	5	150	30	97	84.7	15.7	13.3
2.5	do.	3	1	3	92	14	40	58.7	9.3	5.4
3.0	do.	1	1	1	28	5	21	92.9	3.8	3.6
4.0	do.	1	1	1	28	0	18	64.3	0.0	0.0
0.25	3 days	2	2	3	86	0	69	80.2	1.5	1.2
0.5	do.	2	2	3	80	4	55	73.8	5.1	3.7
0.75	do.	2	1	2	50	5	41	92.0	4.3	4.0
1.0	do.	2	2	4	114	11	56	58.8	23.9	14.0
1.25	do.	2	1	2	56	13	32	80.4	17.8	14.3
1.5	do.	2	2	4	114	36	58	82.5	30.9	25.4
2.0	do.	2	2	4	108	45	36	75.0	38.3	28.7
2.5	do.	2	1	3	84	25	37	73.8	25.8	19.0
3.0	do.	2	2	3	76	14	35	64.5	22.4	14.5
4.0	do.	1	1	1	26	2	19	80.8	0.0	0.0
Wheat x rye and controls										
0.0	-	2	(selfed)	4	164	154	0	93.9	99.4	93.3
0.0	-	2	2	12	401	26	3	7.2	68.9	4.9
0.05	6-10 hr	2	2	3	103	18	1	18.4	73.7	13.6
0.1	do.	2	2	3	120	15	1	13.3	81.3	10.8
0.2	do.	2	2	3	109	27	1	25.7	75.0	19.3
0.4	do.	2	2	3	96	28	1	30.2	62.1	18.8
0.6	do.	2	2	3	111	24	3	24.3	55.6	13.5
0.8	do.	2	2	3	79	22	0	27.8	63.6	17.7
1.0	do.	2	2	3	105	18	3	20.0	52.4	10.5
1.5	do.	2	2	3	104	8	2	9.6	50.0	4.8
2.0	do.	1	1	2	70	0	9	12.9	11.1	1.4
3.0	do.	1	1	1	38	0	0	0.0	0.0	0.0

[1]Time after irradiation

crosses of common wheat x *Triticale*. *Triticale* pollen which received a gamma-ray dose of more than 1kR gave rise to sterile F_1 plants.

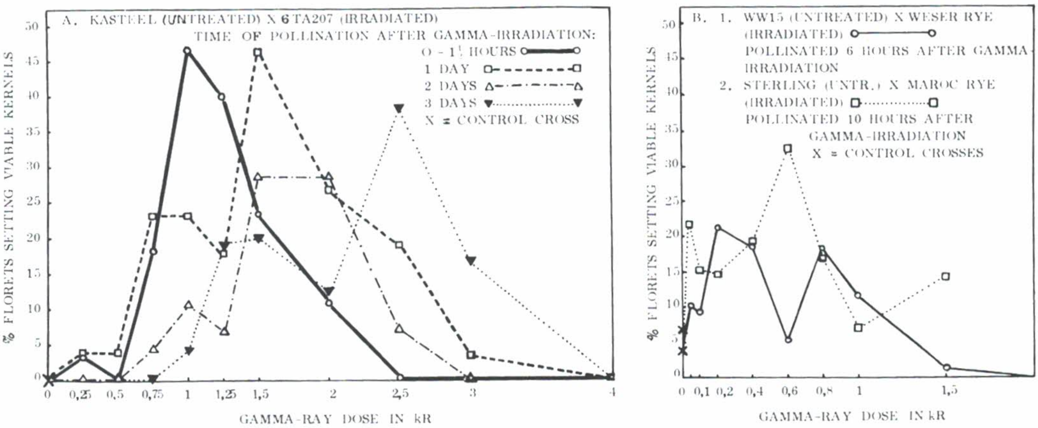

Figure 1. The effect of gamma-irradiated A) *Triticale* and B) rye pollen crosses with common wheat: Viable F_1 kernels as a percentage of the pollinated florets

In one family of 13 plants, obtained after the *Triticale* pollen received a gamma-ray dose of 0.05 kR, a single haploid common-wheat plant with 21 somatic chromosomes was found.

In the 6*x* *Triticale* x common-wheat crosses the production of viable F_1 kernels was not improved by irradiating the *Triticale* parent. The egg cells of *Triticale* can tolerate a much higher dose of irradiation than the pollen (*ca.* 7kR vs. *ca.* 3 kR).

Irradiation of Rye Pollen

When gamma-irradiated pollen of two rye cultivars was used in crosses with two common-wheat cultivars, a substantial increase of viable F_1 kernels was obtained over the control crosses (Table 3, Fig. 1). The best set of viable F_1 kernels was obtained at gamma-ray doses of 0.05kR-0.4kR. In contrast to the irradiated *Triticale* pollen, irradiated rye pollen resulted in an increased kernel set; the germination capacity of these kernels remained constant up to a dose of 0.8kR.

Conclusion

Irradiation of rye and 6*x* *Triticale* pollen effectively facilitates the production of primary octaploid and secondary hexaploid *Triticales*, respectively.

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