N.Z. Agronomy Society
Special Publication No. 5

Paper 12

POSSIBLE APPLICATIONS OF SELF-INCOMPATIBILITY IN THE PRODUCTION OF BRASSICA NAPUS CULTIVARS

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ABSTRACT

Brassica napus is usually self-compatible, but several S-genes controlling the dominance of pollen and style reactions are now available. The ways in which self-incompatibility could be used to produce hybrid or outbreeding cultivars are discussed.

KEYWORDS

Swedes, oilseed rape, hybrid production, outbreeding.

INTRODUCTION

Brassica napus is an allotetraploid derived from *B. campestris* and *B. oleracea*. Although both parental species have a sporophytic self-incompatibility system, *B. napus* is usually self-compatible. Olsson (1960), however, found self-incompatibility occured naturally in some plants of oilseed rape (ssp. *oleifera*), and he also showed that artificially produced *B. napus* could exhibit self-incompatibility. A self-incompatible line of swedes (ssp. *rapifera*) was obtained by Davey (Gowers, 1974), and several lines have since been obtained at the Scottish Crop Research Institute.

In brassicas, ovules are receptive at an early stage of bud development, before onset of the self-incompatibility reaction. This allows the production and maintenance of self-incompatible inbred lines by bud pollination. There are several ways in which self-incompatibility can be used for cultivar production in *B. napus*. A knowledge of the dominance relationship of the S-genes is essential. Four types of dominance relationship were recognised by Haruta (1962) and these are shown below. However, dominance is not always complete, there may be mutual weakening of the S-genes (Thomson, 1972), and even reversal of dominance in pollen and style (Wallace, 1979).

	Reaction in pollen	Reaction in style
Type I	Dominant	Dominant
Type II	Dominant	Co-dominant
Type III	Co-dominant	Dominant
Type IV	Co-dominant	Co-dominant

The interactions of S-genes in *B. napus* have been examined by Gowers (unpub. data). Seven different S-genes were involved in the crosses whilst three lines of different origin had the same S-gene. The results obtained with the seven different genes are shown in Table 1, which gives the scores on self-pollination and the results of test crosses made to examine the reaction of heterozygotes in both the pollen and style. In general, the reaction obtained on selfing was that expected from the combined reactions of the test crosses with the homozygotes. All types of dominance relationship were found; mutual weakening was present in some cases, and reversal of dominance was shown by several crosses involving Line R.

The reactions of the three lines with the same S-gene are given in Table 2. The test crosses involving Line N show that the reaction in the pollen is fully active, and the weakening in activity on selfing must be due to the reaction in the style. There is slight weakening in crosses involving Line T, and this appears to be due to weakening of the pollen reaction. When the interactions of these three lines with the other lines are examined (Table 3), several cases of different reactions between the lines are noted, and reciprocal differences are also observed. Background genotype can therefore influence the expression of the S-genes.

One of the major factors expected to be involved in the background effects is the presence of other alleles at the S-gene loci. Because *B. napus* is an allo-tetraploid it possesses an S locus from each parental genome. Background and environment effects can cause variation at the diploid level, so at the tetraploid level it must be expected that the S-gene reactions may differ significantly in different genotypes.

DISCUSSION

In vegetable brassicas, the monetary value of the crops and the need for uniformity means that Fl hybrids are produced on a commercial basis. The need for uniformity in agricultural brassicas is not as great, however, and seed prices are too low to justify the production of single crosses. At least two multiplications are needed to lower the cost of seed production, and this requires three-way or double-cross hybrids. Using near isogenic lines, the yields

Table 1. S-gene interactions in *Brassica napus*.

S-gene line	A	D	L	M	N	R	Z
A	0	MS 0 >1 MS	0 0 >1 0=0	0 0=0 0 >3	0 0 >3 0 >3	0 0=0 1=1	- - -
D	1 1< 0 1< 0	0	1 0=0 0=0	0 0=0 1 >4	0 0 >4 0 >3	1 1 >2 3< 0	0 0=0 1<
L	1 2< 0 1=1	1 1< 0 0 ?	0	4 0=0 1 >3	4 0 >1 0 >3	2 0 >5 1=1	2 3< 0 3 >4
M	0 0=0 4< 2	1 0=0 3< 0	- - -	0	0 0 >4 0 >5	4 1 >5 4< 3	1 0 ? 5=5
N	0 2< 0 5< 2	0 4< 0 5 ?	4 4< 1 3< 2	0 3< 0 5< 0	2	5 5=5 5< 2	0 3< 0 5< 4
R	0 1< 0 0 >1	0 1< 0 ? 0	0 3< 0 0=0	5 5< 0 4 >5	5 5< 3 0 >3	1	0 5< 0 0 >1
Z	1 0 >5 0=0	MS 0=0 MS	4 1 >3 3 >5	1 0=0 2 ?	0 0 >2 ? 5	0 0 >5 3=3	0

Example: Z x A hybrid

Self pollinated	1	
Z pollen onto hybrid	0 >5	A pollen onto hybrid
Hybrid pollen onto Z	0=0	hybrid pollen onto A

Dominant >recessive; = co-dominant (both genes equally active); MS - male sterile.

Incompatibility scores:

0	less than 1 seed set per pollination
1	1 to 3 seeds/pollination
2	3 to 6 seeds/pollination
3	6 to 10 seeds/pollination
4	10 to 15 seeds/pollination
5	>15 seeds/pollination (considered fully compatible).

Table 2. Interactions of three lines with the same S-gene.

S-gene line	N	T	Q
N	2	1 0=0 3< 1	0 0=0 2< 1
T	1 0=0 1 >2	0	1 1< 0 1< 0
Q	0 0=0 0 >3	0 0=0 0 ?	0

Table 3. Interactions of N/T/Q lines with other S-gene lines.

S-gene line	A	D	L	M	R	Z
N x	0 2< 0 5< 2	0 4< 0 5 ?	4 4< 1 3< 2	0 3< 0 5< 0	5 5=5 5< 2	0 3< 0 5< 4
T x	2 4< 0 5 ?	0 3< 0 5< 0	3 4< 0 4< 0	1 5< 0 5< 0	-	-
Q x	0 0=0 5< 1	3 3< 0 4< 0	4 3< 1 4< 1	0 1< 0 5< 0	5 1 >4 5< 3	0 3< 0 5< 3
Reciprocal crosses						
x N	0 3< 0 3< 0	0 4< 0 3< 0	4 1< 0 3< 0	0 4< 0 5< 0	5 3 >5 3< 0	0 2< 0 5 ?
x T	0 3< 0 2< 1	0 0=0 2< 0	4 3< 2 4< 2	1 2< 1 ? 0	2 0=0 4< 1	3 4< 0 5< 0
x Q	-	0 0=0 3< 0	3 1< 0 0 >1	-	5 0 >4 5< 1	0 0=0 ? 4

of such hybrids should approach those of true F1 hybrids, whilst seed costs would be considerably cheaper.

The reactions of the S-genes must be known before these more complex hybrids can be produced. However, the reaction in the new background created by single crosses cannot be definitely known until the inbred lines have been produced and crossed. It is hoped to avoid this problem and simplify the breeding procedure using a modified double-cross method (Fig. 1). This method needs only two self-incompatible lines, and uses self-compatible lines as pollen donors in the single crosses. The S-genes used must, therefore, be dominant to self-compatibility and be capable of enforcing outcrossing in the final multiplication. Apart from halving the number of self-incompatible lines which have to be produced, the reactions of the heterozygotes are known from the first backcross and tested at each subsequent generation in the breeding of the self-incompatible lines.

The method has the disadvantage that compatible lines have to be discarded from the single-cross multiplications.

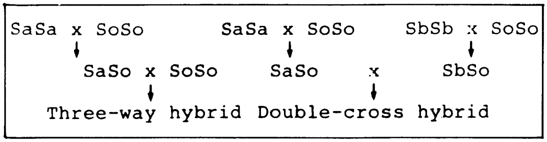

Figure 1. Three-way and double-cross hybrid production using self-compatible pollinator lines (SoSo) and dominant S-gene lines (SaSa, SbSb).

However, the single crosses need only be on a relatively small scale as, with a multiplication factor of 1000 or more, only 1 kg of single-cross seed is needed to produce 1 tonne of double-cross seed. Not having to discard a pollinator in the final crop is, however, a major advantage over methods of hybrid production which use male sterility. A single S-gene could be used as a male-sterile gene to produce a three-way hybrid, but this should only be contemplated if only one strong S-gene was available.

It should not be necessary to consider the use of a triple-cross hybrid with *B. napus*. The triple-cross is used in kale (Thompson, 1964) because of difficulty in producing seed from inbred lines which suffer severely from inbreeding depression. Because *B. napus* is usually self-compatible, seed is set predominantly by self-pollination and the species is generally tolerant of inbreeding. This means that seed production is easier, and also that a higher proportion of sibs can be tolerated in a hybrid cultivar because the inbreds themselves are relatively high yielding.

The modified double cross appears to be the most efficient method of hybrid production for swedes, which are a vegetative crop. In oilseed rape, however, there may be some problems in seed set which are only partly overcome by the modified double cross. With self-incompatible plants, cross pollination in the early stages of flowering may be insufficient for full seed set. Thompson (1978) proposed that self-incompatible genes that are recessive to self-compatibility should be used, with the compatible lines acting as pollinators in three-way crosses.

Although a double cross involving co-dominance has only 25% of pollen which is cross-compatible, in other cases higher proportions of cross-compatibility can be obtained. From the results of the interactions in Table 1, the best double-cross would involve AR x MN, which would give AM:AN:RM:RN in the progeny; the first two types would have 50% cross-compatibility, and the other two would be self-compatible. Again, this would rely on the same results being obtained in different backgrounds when the S-genes were transferred to inbred lines. The modified double-cross using self-compatibility would not have as much self and cross-compatibility, but it would be easier to produce and be more predictable in its reaction.

Two other possible uses of self-incompatibility would be to produce a pair-cross hybrid or an out-breeding cultivar. To produce a complete out-breeder, four or more S-genes would be required if the genes were co-dominant. With dominance present, however, an XY type of system could be set up using a heterozygote and a recessive homozygote. A population of SdSr:SrSr could be produced and maintained on mass multiplication. Lower yields would be expected than with a hybrid cultivar, but seed would be produced by simple mass multiplication. Complete dominance in both stigma and style would be preferred because co-dominance in the style or stigma would cause half of the plants to be self and cross-incompatible.

The pair-cross hybrid was suggested by Gowers (1981) for producing the equivalent of a double-cross hybrid from outcrossing cultivars of brassicas. The method could be used for maintaining the single crosses of double-cross hybrids if co-dominance was present. Self-pollination of the single crosses would produce homozygotes in the progeny (Fig. 2), which on mass multiplication would produce the self-incompatible heterozygotes needed for double-cross production. This would require the maintenance of only one line for each single cross, and avoid the need for a pollinator line in their production. Only half the plants in the single crosses would set seed, but the whole crop would be harvested without the need to cut out a pollinator line. However, it does require the breeding of two self-incompatible lines for the initial production of the single crosses, and requires that the S-genes are co-dominant.

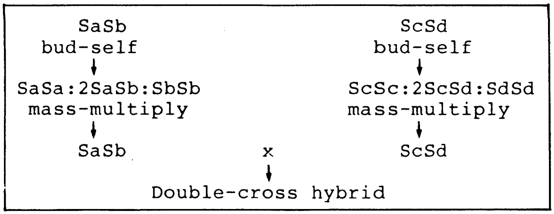

Figure 2. Pair-cross maintenance and multiplication to produce double-cross type hybrids.

CONCLUSION

Self-incompatibility can be used in several ways in *B. napus* breeding, each method has certain advantages and disadvantages. The disadvantage of the modified double-cross using self-compatibility is that pollinator lines have to be discarded in the single crosses. However, this should not involve much effort in what are relatively small multiplications. The advantages in reduced breeding effort and in predictability of response appear to make the modified double-cross the most efficient method of producing hybrid cultivars in *B. napus*.

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