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Short Communication

Inheritance studies of self-incompatibility in low chill requiring genotypes of cabbage (*Brassica oleracea* L var. *capitata*) for boltized flowering

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The commercial cultivars of cabbage being grown in our country are of temperate type requiring chilling treatment after head formation for a period ranging from 6-8 weeks for bolting, flowering and seed setting. It is possible in high hills only, where the cabbage seed crop takes two seasons being biennial. To tide over this problem, tropical genotypes have been developed during the last over two decades so that seed crop may be raised in lower hills also. In CSKHPKV also, mild chill requiring genotypes of cabbage have been developed during the last over one decade through hybridization of tropical genotypes, capable of producing compact heads under relatively higher temperature, with the most popular temperate cultivar 'Golden Acre' and good seed crop is possible in about 8-9 months period. As in other cole crops, cabbage favours cross-fertilization by means of self-incompatibility system. This genetic phenomenon be used to facilitate the cross fertilization required for hybrid seed production in *Brassica* was first suggested by Pearson [2]. Subsequently, studies on the practicability of F_1 hybrid seed production by making use of self-incompatibility have been made in cabbage [3], Brussel sprouts [4] and Kale [5]. The production of F_1 hybrids using incompatibility system, depends on crossing inbred lines, each homozygous for a different incompatibility allele. Four types of S-alleles interaction have been reported in *Brassica* [1, 6]. Inheritance pattern were studied in the progenies of eight self-incompatible plants belonging to five genotypes of cabbage. The progenies of the self-incompatible plants *viz*., KGAT-I-29, KGAT-I-10, KGAT-II-12, KGAT-III-5 and Golden Acre-2 segregated as per the single S-locus inheritance. The results revealed type III S-allele interaction in progeny 1 (KGAT-I-29), type II S-allele interaction in progeny 2 (KGAT-I-10) and progeny 3 (KGAT-II-12), type IV S-allele interaction in progeny 4 (KGAT-III-5) and type IS-allele interaction in progeny 7 (Golden Acre-2). However, the self-incompatible progenies of KGAT-III-20 and KGAT-III-22 could not be categorized as per S-locus inheritance, most probably due to the presence of weak S-alleles in these progenies.

The investigation was undertaken at the Department of Vegetable Science and Floriculture, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya with five low chill requiring genotypes of cabbage *viz*., KGAT-I, KGAT-II, KGAT-III, Golden Acre and population of the cross Glory x Golden Acre. On the basis of results obtained during 2002-2003 season, progenies of 8 self-incompatible plants were raised from their respective selfed seeds (bud pollination) to S-alleles inheritance studies. The inter-allelic relationship (interactions) in the pollen and stigma were worked out using the seed set data from reciprocal crosses between each heterozygote (SxSy) and its corresponding S-alleles homozygote (SxSx SySy). Atleast seven progeny plants of each self-incompatible plant except where plant population was low were crossed in full diallel at freshly opened flower stage as suggested by Mackay [1]. Anthers were removed with the help of a forcep before carrying out intra-progeny/inter-sib pollinations. Each progeny plant was also self-pollinated at bud stage (BP)

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and freshly opened flower stage (OP-I and OP-II). The cross-compability of an individual plant with another plant of the same progeny was determined by the fertility index worked out as under:

$$\text{Fertility index} = \frac{\text{Average no. of seeds/siliqua from selfing in bud stage in a given plant}}{\text{Average no. of seeds/siliqua from an intra-progeny pollination in open flower stage on that plant}}$$

The fertility indices $\geq$ 2.0 and < 2.0 were categorized as incompatible and compatible, respectively. For working out fertility indices (FI) in intra–progeny pollinations, seeds/siliqua obtained from selfing in bud stage were used rather than seeds/siliqua from natural cross-pollination because majority of the intra-progeny pollination work had been carried out inside the insect proof structure only.

Inheritance studies were carried out in the progenies of 8 self-incompatible plants. Though, the numbers of plants raised were more in each progeny, intra-progeny pollinations were carried out in 7-10 plants having synchronized flowering in each progeny.

All the progeny plants (progeny 1) of the self-incompatible plant 29 of KGAT-I (I-29) were self-incompatible and the presence of incompatible and compatible reactions in the inter-sib pollinations indicated the heterozygous nature of this progeny (Fig. 1). Out of the 9 progeny plants, 4 of the plants were in heterozygous group (B), 3 plants in one of the homozygous groups (A) and one plant in the other homozygous group (C). Plants belonging to the phenotypic groups A and B were reciprocally cross-incompatible with each other. The plants of the group A were reciprocally cross compatible with group C. The plants of group B (as female) were cross-compatible with the plants of group C (as male) but they were incompatible as reverse cross *viz*., C (as female) x A (as male). In all, three discrepancies in the intra-and inter-group pollinations could be noted. Based on inter-group compatibility reaction, type III S-allele interaction viz., the dominance of one of the alleles over the other (x>y) in stigma but independent /co-dominance (x=y) in the pollen was noticed. Similar allelic interaction was observed by Adamson [3].

All the progeny plants (progeny 2) of the self-incompatible plant 10 of KGAT-I (I-10) were self-incompatible. Plants within the respective phenotypic groups were reciprocally cross-incompatible with each other with one exception (8×5). Plants of phenotypic groups B and C were reciprocally cross-incompatible with each other with one exception (9×3) (Fig. 1). There were reciprocal differences in cross-compatibility between the plants belonging to the groups A and B with four discrepancies (8×6, 5×6, 1×8 and 7×8). There was dominance of one of the alleles over the other (y>x) in the pollen but co-dominant in the stigma (type II S-allele interaction). Similar results were also observed by Adamson [3] in cabbage, Hoser-Krauze [6] in cauliflower and Yadav [7] in sprouting broccoli. Relatively more number of discrepancies observed in the progeny 2 can be explained by considering the effect of genetic (weak S-allele) and environmental factors on the phenotypic expression of the incompatible/compatible reactions under open field conditions. The breakdown of incompatibility might occur as a result of competitive interaction between S-alleles in a heterozygote resulting in both alleles having reduced activity [8]. Environmental factors *viz*., temperature [9], humidity [10], stage of flowering [11] and flower age have been reported to influence the level of self-incompatibility in *Brassica oleracea*.

All the progeny plants (progeny 3) of the self-incompatible plant KGAT-II plant 12 (II-12) were self-incompatible and the presence of incompatible and compatible reactions in the inter-sib pollinations suggested the heterozygous nature of this progeny (Fig. 2). Plants within the respective phenotypic groups were reciprocally cross-incompatible with each other with two exceptions (3×6 and 6×9). Plants of the phenotypic group A were reciprocally cross-incompatible with group B. There were reciprocal differences in cross-compatibility between the plants belonging to the groups B and C with two exceptions (2×4 and 5×9). The inter-group pollination results suggested type II (dominance of one of the alleles over the other in the pollen and co-dominance of both in the stigma) S-allele interaction.

All the progeny plants (progeny 4) of the self-incompatible plant 5 of KGAT-III (III-5) were self-incompatible and the presence of incompatible and compatible reactions in the inter-sib pollinations suggested the heterozygous nature of this progeny. Plants within a phenotypic group were reciprocally cross-incompatible with each other with one exception (3×7). Plants belonging to the group A were cross-compatible with plants of group C, when used both as male and female parents. The plants of group A were reciprocally cross-incompatible with group B. The plants of group B were also reciprocally cross-incompatible with group C with one exception (7×6). The inter-group pollinations

I-29

Male →		A			B				C
Female		xx			x=y				yy
↓	1	1	4	5	3	7	8	9	6
	1	-	-	-	-	-	-	-	+
A xx	4	-	-	-	-	-	-	-	+
	5	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	+
B x>y	7	-	-	-	-	-	-	-	+
	8	-	-	-	+	-	-	-	+
	9	-	-	-	-	-	-	-	+
C yy	6	+	+	+	-	-	-	-	-

I-10

Male →		A			B					C
Female		xx			x<y					yy
↓	8	5	1	2	3	6	7	9		
	8	-	+	+	+	+	-	+	-	
A xx	5	-	-	+	+	+	-	+	-	
	1	+	-	-	-	-	-	-	-	
	2	-	-	-	-	-	-	-	-	
B x=y	3	-	-	-	-	-	-	-	-	
	6	-	-	-	-	-	-	-	-	
	7	+	-	-	-	-	-	-	-	
C yy	9	+	-	-	-	+	-	-	-	

Fig. 1. Grouping of progeny plants of the progeny-1 (I-29) and progeny 2 (I-10) in different phenotypic groups and sib-compatibility relationships

Male →		A		B						C	
Female		xx		x>y						yy	
↓	7	10	1	3	4	6	8	9		2	5
	7	-	-	-	-	-	-	-	-	+	+
A xx	10	-	-	-	-	-	-	-	-	+	+
	1	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-
B x=y	4	-	-	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	+	-	-
	8	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	-	-	-	-	-
	2	+	+	+	+	-	+	+	+	-	-
C yy	5	+	+	+	+	+	+	+	-	-	-

Fig. 2. Grouping of progeny plants of the progeny 3 (II-12) in different phenotypic b groups and sib-compatibility relationships

Male →		A			B					C	
Female		xx			x=y					yy	
↓	1	4	8	2	5	6		3	7		
	1	-	-	-	-	-	-		+	+	
A xx	4	-	-	-	-	-	-		+	+	
	8	-	-	-	-	-	-		+	+	
	2	-	-	-	-	-	-		-	-	
B x=y	5	-	-	-	-	-	-		-	-	
6	-	-	-	-	-	-	-		-		
C yy	3	+	+	+	-	-	-		-	+	
	7	+	+	+	-	-	+		-	-	

Fig. 3. Grouping of progeny plants of the progeny 4 (III-5) in different phenotypic groups and sib-compatibility relationships

Male →		A	B
Female		xx	yy or xy (y>x)
↓	1	2	3
	1	-	-	+
A xx	2	-	-	+
B yy or xy (y>x)	3	+	+	-

Fig. 4. Grouping of progeny plants of the progeny 7 (GA-2) in different phenotypic group and sib-compatibility relationships

suggested type IV S-allele (both the allele active in pollen as well as stigma) interaction. Type IV S-allele interaction has also been reported earlier in cabbage [12]

All the progeny plants (progeny 5) of the self-incompatible plant 20 of KGAT-III (III-20) were self-incompatible and the presence of incompatible and compatible reactions in the inter-sib pollinations indicated the heterozygous nature of this progeny. This progeny was not considered appropriate in view of relatively more seed-set upon selfing in freshly opened flowers during fag end of flowering (OP-II) which may be attributed to the possible presence of weak S-alleles in it.

All the progeny plants (progeny 6) of the self-incompatible plant 22 of KGAT-III (III-22) were self-incompatible and the presence of incompatible and compatible reactions in the inter-sib pollinations indicated the heterozygous nature of this progeny. There was either no seed set or negligible seed-set

in all the progeny plants upon selfing in bud stage (BP) suggesting the presence of male sterility in the progeny plants.

Seven progeny plants (progeny 7) of the self-incompatible plant 2 of Golden Acre (GA-2) were studied. Surprisingly, the seed-set in BP and some of the intra-progeny pollinations could be noticed only in three of the progeny plants (plants 1, 2 and 3). Possibly the remaining 4 plants behaved as male sterile although there was satisfactory anther dehiscence and pollen availability at the time of pollination. Hence, only 3 of the progeny plants were grouped and only two phenotypic groups (A and B) could be identified (Fig. 4). Plants belonging to group A were reciprocally cross-compatible with the plants of group B. The inter-group pollinations suggested type-I S-allele interaction in this progeny.

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