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CURRENT STATUS AND FUTURE PROSPECTS OF RAPESEED BREEDING IN INDIA

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ABSTRACT

Basic results of applied value were obtained from studies on crosses between self-compatible and incompatible varieties of brown sarson, inter-varietal crosses among brown sarson, yellow sarson and toria, well defined single and three-way crosses and 'multiple cross-multiple pollen' hybrids. Some of the complex hybrids have been advanced to F_2 and studies were conducted to test the efficiency of intra-population selective hybridisation emphasising choice of female parents in improving the yield of the populations. It was reported that these basic results are not utilized in the breeding programmes currently in vogue in India. It was pointed out that one of the short term strategies to tone up the yield level of rapeseed in India is to advocate breeding of composite populations using the methods suggested by basic research. The future of rapeseed can be safeguarded by propagating composite populations, advocating the concept of replacement in lieu of regeneration of composites when their yield levels deteriorate and strengthening the breeder-seed-producer-farmer link, Well-defined policies allotting the right priority to rapeseed breeding and advocating mono-and mixed cropping in appropriate areas are the need of the hour to ameliorate the low yield levels of rapeseed.

INTRODUCTION

Brassica campestris L. is known to be a potential oleiferous crop possessing three distinct varietal forms, namely, Brown sarson (BS), Yellow sarson (YS) and Toria (TR). Further, BS contains self-incompatible (SI), self-compatible (SC) and intermediate-compatible (Int) forms and as a consequence, is endowed with a wide range of exploitable genetic diversity. On the other hand, YS has a compact plant type with few secondary branches, contains bi-to multi-locular siliquae with yellow seeds and its oil possesses a high clarity and consumer preference. TR, however has a relatively dwarf plant frame, smallseeded siliquae and is early to mature. All the varietal forms are susceptible to aphids, the most important pest of this crop, to diseases like alternaria blight and to frost.

Till now, this crop is raised in a large part of its area as a mixed crop, with wheat in most cases. However distinct pockets can be located in U. P., Delhi, Haryana, West Bengal and some other parts of Northern India where the crop has the potential of being raised as a monocrop with attractive yields. In those areas, frost will not be a serious factor to be reckoned with.

But it is well known that the average yield and oil quality of this crop in India is far lower than in advanced countries like Sweden and Canada. During the past decade, more emphasis is laid on improving the lot of this crop but the success is not commensurate with the efforts. Recently, cooperative programmes with Sweden and Canada have been started with a view to strengthening application-oriented research in this crop.

It is true, however, that basic results of applied value remains to be utilised in time-bound, mission-oriented breeding strategies in India. The purpose of this paper is to place some of the results obtained by the biometrical genetics unit at the Indian Agricultural Research Institute, New Delhi for over a decade in proper perspective and to underline possible new approaches for enhancing the productivity of this crop in India.

BASIC RESULTS RELEVANT TO RAPESEED BREEDING

An analysis of genetic divergence in self-compatible and self-incompatible varieties of brown sarson clearly showed that there was substantial divergence within each of the SI and SC types. While plant height and seeds per siliqua were important in SC types, height and number of branches contributed to the differentiation in SI types (Murty *et al*, 1965). The inter-relationship among important component characters like primary branches, secondary branches and height in SC types was parallel, though not identical, to that in SI types. Further studies revealed that a change in the breeding structure of the populations might be responsible for the differences between SC and SI types. Natural selection and differences in the initial composition of the population from which SC types could have arisen could explain to a great extent the differences in the character associations. More than geographic diversity, differences in the evolutionary mechanisms and natural selection were important factors for the existing differences between SC and SI types (Murty and Arunachalam, 1966a, b; Qadri *et al.*, 1966).

It was then of interest to examine whether heterosis could be generated by making crosses within and between SI and SC types. It was found that heterosis occurred highest in crosses between SI and SC types followed by SC × SC crosses (Table 1). Heterosis was observed to be the least in SI x SI crosses for individual component characters.

Table 1 : Relation between heterosis and parental self-incompatibility in single cross hybrids

Character	Number of heterotic crosses				Total
	SI × SI	SI × SC	SC × SI	SC × SC	
PB	1	7	5	5	18
SB	0	5	4	3	12
SMA	2	0	5	0	7
SS	3	10	4	11	28
OC	7	12	5	6	30
Overall+	0	4	2	2	8
Crosses made	8	16	12	24	60
Percent of heterotic crosses+	0	25	16	8	

+ Heterosis for 3 or more characters ; PB = number of primary branches ; SB = number of secondary branches ; SMA = number of siliquae on main axis ; SS = number of seeds per siliqua ; OC = oil content ; SI = self-incompatible ; SC = self-compatible.

[Source : Arunachalam and Katiyar, 1978]

Table 2 : Distribution of heterotic inter-varietal crosses

Combination	n	h	p
BS—YS	50	13	26
BS—TR	50	12	24
YS—TR	50	9	18
Total	150	34	23

n = number of crosses made ; h = number of crosses heterotic at least for one of the four characters studied ; p = percent of heterotic crosses ; BS = Brown sarson ; YS = Yellow sarson ; TR = Toria.

[Source : Devarathinam *et al.*, 1976]

Yet another breeding approach was to incorporate the desirable traits of BS, YS and TR into a productive line. A pioneer study of 150 inter-varietal crosses (Devarathinam *et al.*, 1976) showed that BS, YS and TR were cross-compatible. While TR × BS, BS × YS and TR × YS were 70 — 80 per cent compatible, the other combinations were completely compatible (Arunachalam and Amirthadevarathinam, 1978). Thirty eight per cent of the observed heterotic crosses was found in BS — YS, 35 in BS — TR and 27 in YS — TR, though only 23 per cent of the total 150 crosses was heterotic (Table 2). The depression in the means of component characters was more pronounced in BS — YS than in others when the inter-varietal crosses were selfed (Table 3) but there was substantial improvement uniformly when biparental matings were made. The results pointed to the possibility of utilising inter-varietal hybridisation for achieving yield improvement.

Table 3 : Change in the magnitude of important yield components in F_1, F_2 and BIP of inter-varietal crosses

Cross		PB	SB	SM	SS
	a	10.3	20.3	56.1	17.3
BS — YS	b	8.5	8.8	54.3	16.1
	c	12.7	30.6	65.9	17.0
	a	8.8	17.9	48.7	16.9
BS — TR	b	7.2	9.4	46.9	14.7
	c	9.2	26.1	47.7	15.5
	a	7.9	16.6	46.4	15.1
YS — TR	b	8.4	10.9	47.2	15.3
	c	9.4	28.3	52.1	15.8

PB = number of primary branches ; SB = number of secondary branches ; SM = number of siliquae on main axis ; SS = number of seeds per siliqua ; a = F_1 mean ; b = F_2 mean ; c = BIP mean ; BS = Brown sarson ; YS = Yellow sarson ; TR = Toria.

[Source : Arunachalam and Amirthadevarathinam, 1978]

Though the existence of distinct SI and SC classes was recognised, they were not given their due importance in maintenance over time. They were allowed random open-pollination for a long time so that SI and SC types did not have any phenotypically distinguishable attributes. Regardless of the possible inter-mixing of specific variability of SI and SC types, a particularly interesting productive variant (P) which was usually later to flower than the original (O) with profuse siliquae, few primary branches and thick but hollow stem was isolated in many SI and SC varieties. They were mated to give P × O crosses in each variety. Their F_1 was again mated to some existing productive varieties to generate a number of three-way crosses (TC). In a parallel programme, some of the SC and SI varieties were subjected to about 5 cycles of disruptive (DS) and stabilising (SS) selection for the character, flowering time. The DS derivatives in their advanced generation were mated to some SS derivatives to produce single crosses (SC). Some of these SC and TC and some inter-varietal crosses were evaluated for their performance and single plant selections made in their F_2. In addition, a few promising varieties (VR) were also selected. These selections and VR were used as seed parents and pollen from single (SP), two (DP) or three varieties were used to obtain a system of "multiple cross—multiple pollen hybrids" to be denoted as "mucromphs" (See for details, Arunachalam and Katiyar, 1978 ; Arunachalam and Bandyopadhyay, 1979). Thus by different mating systems, inter-varietal crosses, SC, TC and "mucromphs" were generated and they provided a wealth of material to obtain basic results of applied value.

New methods were applied to all these systems of complex crosses to assign a High (H) or Low (L) general combining ability (gca) status to each parent and specific combining ability (sca) status likewise to each cross based on a score over the gca or sca effects of several component characters. A cross was defined to be heterotic if it showed significant heterosis over better parent for at least n/4 characters where n = total number of characters (Arunachalam and Bandyopadhyay, 1979).

These methods helped us to understand clearly the relationship between heterosis and components of combining ability. It was found in SC, TC and 'mucromphs' alike, that, out of the observed heterotic crosses, a large proportion was found in HL cross category followed by HH (Table 4). This gave a major clue that a breeder should allot a high priority to crosses between parents of which one is high and the other low in overall gca status. Further, most of the crosses showed heterosis on the strength of high sca only.

Table 4 : Heterosis in relation to gca and sca status

gca/sca		H		L		N		Total	
		n	h	n	h	n	h	n	h
	a	4	2	8	0	2	0	14	2
HH	b	23	4	15	0	4	0	42	4
	c	11	7	8	0	9	2	28	9
	a	12	3	16	1	6	0	34	4
HL	b	25	6	24	1	3	0	52	7
	c	35	17	25	0	24	1	84	18
	a	5	1	4	0	3	0	12	1
LL	b	11	1	4	0	1	0	16	1
	c	23	8	16	0	16	0	55	8
	a	21	6	28	1	11	0	60	7
Total	b	59	11	43	1	8	0	110	12
	c	69	32	49	0	49	3	167	25

n = number of crosses made ; h = number of heterotic crosses ; a = single crosses ; b = 3-way crosses ; c = multiple cross-multiple pollen hybrids ; N = non-significant sca for all characters.

[Source : Katiyar and Arunachalam, 1981 ; Bandyopadhyay and Arunachalam, 1980]

As it would be obvious, the types of crosses, SC, TC and 'mucromphs', studied involved diverse and complex parental genotypes. The parents were not inbred to avoid consequent ill-effects. As a consequence, even their F_1 and more so their F_2 generation showed a high degree of genetic segregation. In fact, the types of crosses generated provided ideal base gene pools which could be ordered into productive composite populations.

Taking 'mucromphs' first, a system of selective hybridisation was used to study the improvement in yield. Six 'mucromphs' were selected and in their F_1, a set of Early (EY) and Late (LT) plants were selected in addition to the general bulk (BK). EY and LT were carried forward by sibbing to obtain EE and LL populations. The open-pollinated bulks of EY and LT provided EGB and LGB populations. In the progeny of EY and LT, some plants which were phenotypically good with respect to early vigour, primary branches and general growth were selected and termed as Early High and Late High plants. In a similar manner, Early low and Late low plants whose phenotypes were below average were identified. Some early and late high plants were fixed as female and called mother plants. They were pollinated by mixed pollen from high or low plants to produce the following cross combinations.

EL 1 = Early hjgh × Late high

EL 0 = Early high × Late low

LE 1 = Late high × Early high

LE 0 = Late high × Early low

This process was termed 'selective hybridisation' in which the female plants were selected to be high phenotypes and pollinated by mixed pollen from 'high' or 'low' phenotypes. This 'selective hybridisation' and sibbing (to provide EE and LL mentioned earlier) were carried out at intra-population level in the 6 representative 'mucromphs'. The performance of the progeny populations of these systems of mating were measured using a number of parameters (Das, 1979). In addition, some inflorescences in the selected female plants were selfed and the performance of selective hybrids compared with that of the selfed progeny of those female parents also.

A comparison of the advance in yield of various types of progenies over the best of EGB and LGB (measured as the per cent improvement of the progeny over the best of EGB and LGB) grown in the same year showed that EL 1 and LE 1 ranked superior in that order. EL 0 produced negative and LE 0 insignificant advance (Table 5). Pooling over pollen types, Late × Early hybrid progeny registered high advance. Pooling over female parents, High pollen showed the potential to produce high advance. A study of the percentage of crosses which showed yield advance in each category, confirmed the above results. It was thus possible to infer that a choice of Late high plants as female and pollen from Early high plants could produce a progeny population with a high degree of yield improvement.

When a comparison of the yield performance of the population of selective hybrids was made with that of the original population (in the previous generation), it was found that "Late female × Early male" hybrid performance was superior to that of "Early female × Late male" in some populations and pooled over all of them

(Table 6). However, the salient result was that substantial yield improvement could definitely be obtained by intra-population selective hybridisation.

Table 5 : Percent yield advance due to intra-population selective hybridisation

Type of cross/pollen	P	G
EL 1	35	12.0
EL 0	21	— 7.4
LE 1	43	9.3
LE 0	37	2.0+
EL	30	4.8
LE	41	6.6
High pollen	39	10.6
Low pollen	29	— 2.6+

+ = not significant from the value zero ; A = advance over the best bulk measured in the same year ; P = percentage of crosses showing advance ; G = percentage yield advance.

[Source : Das, 1979]

Table 6 : Percentage yield response in one generation due to intra-population selective hybridisation in 6 'mucromph' populations.

Population	Selective hybridisation		
	EL	LE	Mean
P_1	−29	−19	−24
P_2	67	77	72
P_3	50	58	54
P_4	147	141	144
P_5	38	52	45
P_6	14	2+	8
lsd	7	5	
overall	48	52	
lsd	3		

lsd = least significant difference at 5% level ; + = not significant from the value zero ; P_1 = SC × DP ; P_2 = SC × TP ; P_3 = BP × DP ; P_4 = BP × TP ; P_5 = TC × DP ; P_6 = TC × TP

[Source : Das, 1979]

The above results were checked for individual component characters also (Table 7). It would be seen that EL 1 scored over EL 0, LE 1 over LE 0 and High pollen over Low pollen for many component characters in producing favourable response.

Table 7 : Response scores for various component characters by various systems of selective hybridisation

Character / Systems of mating	Response scores						Total score
	AYD	PYD	PB	YDP	MFT	VFT	
EL 1 — EL 0	1	1	1	1	1	—1	4
LE 1 — LE 0	1	1	1	0	1	1	5
EL — LE	0	0	—1	0	—1	0	—2
Pollen : H — L	1	1	1	1	1	0	5

AYD = seed yield per sampled plot ; PYD = seed yield per 100-plant sample ; PB = number of primary branches per 100-plant sample ; YDP = seed yield per primary branches ; MFT = mean flowering time ; VFT = Variance flowering time expressed in log scale

[Source : Das, 1979]

Table 8 : Progressive yield status (q/ha) of composite populations

+Population	1975	1976	1977	1979
1	10.4	7.8	14.7	19.0*
2	13.4	10.3	17.9	15.3
6	13.4	8.0	19.7	—
Check (Pusa Kalyani)			15.5	17.2

* Large plot of approximately 600 sq.m. ; open pollination without isolation ; + Base gene pool (1975) ; 1, 2 = progeny of biparental matings in F_3 of single crosses ; 6 = progeny of biparental matings in F_2 of a 3-way cross

[Source : Arunachalam and Katiyar, 1981]

It was then equally important to identify a set of component characters which would be adequate not only to characterise the combining ability status of parents and crosses but also to identify heterotic crosses. Detailed studies using a number of new parameters showed that, for example, the characters-flowering time, number of primary branches per unit height, number of secondary branches per primary branch and single plant yield-which could easily be measured at population level, could adequately serve the purpose. It was also found that a number of 'mucromphs' showed stable and desirable yield levels over three years. They were essentially crosses between parents one of which was High and the other Low in their overall gca status (Bandyopadhyay and Arunachalam, 1982).

Lastly, the SC and TC base gene pools were carried forward by a few cycles of mass inter-mating in isolation. Once the components of the base gene pool which may be SC, TC, inter-varietal crosses or 'mucromphs' were identified in a proper manner on a quantitative evaluation of their performance with respect to yield and a number of component characters, the process of inter-mating was found to be very potent in generating composite populations with stable yield improvement (Table 8).

CURRENT STATUS OF RAPESEED BREEDING

A review of the recent breeding programmes in rapeseed (Proceedings of the All India Oilseed Workshop, Hyderabad, August 1981) in the major research centres revealed that the following methods are broadly in practice.

1. Repeated cycles of mass selection in the self compatible population BSH-1.
2. Single crosses made to diallel or line × tester designs and their further generations, the major aim being to identify superior derivatives.
3. Backcross method of incorporating resistance to aphid ; however, the resistant donor needs to be genetically identified and the stability of resistance is to be tested.
4. Maintenance of germplasm and screening them under field conditions for desirable attributes including resistance to alternaria blight and frost.
5. Generation of several populations by mixing seeds of a number of component varieties and testing their performance in yield trials.
6. Maintenance of inbred stocks to generate 'synthetics'.

We may note that all the above programmes are going on conventional lines without incorporating any of the basic results bearing on breeding methodology that were reported earlier. Attempts are still made to obtain variety derivatives only, not taking into account the breeding system and the compatibility status of the varieties. As genetic resistance to aphid is yet to be marked, it is high time that serious attention is paid to breed for broad-based populations that can stand risks due to environment, diseases and pests better than a homozygous derived line. The hit-and-miss processes involved in generating and testing populations should be replaced by well-defined techniques of compositing populations.

FUTURE PROSPECTS OF RAPESEED BREEDING IN INDIA

It was made clear while reviewing mission-oriented basic research results earlier that strong evidence is available that it is possible to tone up the yield levels of rapeseed crop by breeding productive composite populations alone. Methods have been devised to construct base gene pools by appropriate quantitative evaluation of the component varieties or crosses of the gene pool. A viable short term strategy to generate productive composites has been outlined in detail (Arunachalam, 1980 ; Arunachalam and Katiyar, 1982). In addition to the large scale intermating in the base gene pool in isolation as a method of generating a composite population, evidence has been provided that intra-population selective hybridisation can also be equally effective (Das, 1979). Since composite populations can easily be generated once a base gene pool is efficiently synthesised, it is fruitful to work on the concept of replacing a composite by another in the pipeline rather than regenerating the same.

However the success of this concept will depend to a large extent on the capacity to produce adequate quantities of seed of the composite populations, the essential requirements for which are large plots and isolation. The standards for seed certification should rest primarily on phenotypic uniformity of the crop and especially on uniform flowering and maturity. Since "Composite populations" contain a large number of heterozygotes also, there will be genetic heterogeneity which must be maintained in addition to phenotypic homogeneity.

In conclusion it can be observed that with a well-knit breeder-seed producer-farmer link, composite populations can answer the requirements of quantum jump in yields of rapeseed in India.

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