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Genetic analysis of agronomic traits in *Gobhi Sarson* (*Brassica napus* L) breeding lines

Ravindra Kumar, Meenakshi Sharma, Vijay Singh and Saurabh Gupta

Mata Gujri College (Punjabi University, Patiala), Fatehgarh Sahib 140406, Punjab, India
**Corresponding author: godwalravindra@gmail.com*
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Abstract

Understanding the knowledge of gene action and the nature of genes/ traits is important for an effective breeding program. The objective of this study was to determine the general combining ability (GCA) and specific combining ability (SCA), variances and their effects on seed yield and components of *Gobhi Sarson* (*Brassica napus* L.) breeding materials. Five diverse *B. napus* genotypes selected for their seed yield were crossed using a half-dialle mating design. The analysis of the variance of parents and their cross effects was significant for all parameters measured. Among five parents, two parents namely EC-338978 and RBS bold showed positive GCA effect may be considered as good general combiners for seed yield and components. The best four selected crosses with significant SCA effects for seed yield were EC 338978 × RBS Bold, EC 338978 × HMS4, EC 338978 × BMS4 and RBS Bold × BMS4, respectively. The selected crosses are valuable genetic resources for *B. napus* breeding for seed yield and yield components in the Punjab region or similar environments.

Keywords: *Additive, dominance, gene action, genotypes, Gobhi Sarson, SCA*

Introduction

Gobhi Sarson (*Brassica napus* L.) is the major edible oilseed crop of the world and belongs to the family Brassicaceae. This species appears to have originated relatively recently, with the South-Western and Mediterranean regions showing the highest levels of diversity. *B. napus* is amphidiploids (2n= 38; AACC) that resulted from the interspecific cross between *B. rapa* (2n= 20; AA) and *B. oleracea* (2n= 18; CC) followed by chromosome doubling (Downey and Rimmer, 1993 and Nagaharu, 1935). The natural evolution of this cytogenetic relationship is widely accepted (Gulden *et al.,* 2008; Kays and Dias, 1995; Vaughan, 1977). Cultivation of *B. napus* in India spans diverse agro-climatic conditions, ranging from the northeastern and northwestern hills to the southern regions, encompassing both irrigated and rainfed fields, as well as varying sowing times, saline soils and mixed cropping systems. Historically, it was not a traditional crop in India. However, despite its disease resistance and high seed yield nature in 1968, several accessions from Europe and Canada were introduced and evaluated for their suitability for cultivation in Indian conditions and successfully adapted in this region and are being grown by farmers. Rapeseed oil is the most used edible oil however excessive levels of glucosinolate and erucic acid reduce the nutritional value of oil.

Mating designs are essential in genetic studies because they provide a structured framework for controlling and manipulating the genetic makeup of populations, which in turn allows for a better understanding of the nature of genes, exploitation of genetic variability and understanding of gene action (Gowen, 1952). In essence, the selection of a mating design is a strategic decision that should align with the specific breeding requirements. The half-diallel mating design provides a comprehensive understanding of variance components, the degree of dominance, as well as specific and general combining abilities across inbred and derived crosses (Pant *et al*., 2018; Yadav *et al.,* 2022). To begin with, Sprague and Tatum (1942) defined general and specific combining abilities. A study on combining ability found that both general and specific combining abilities had an impact on yield and its components. Earlier breeders concluded of their studies that the modifications in surrounding gene results in special developments contributing to yield and yield changes in rapeseed. Therefore, for the different environmental condition, one has to recommend diverse selection criteria for the development or increase in the yield (Hussain *et al*., 2008; Choudhary *et al.,* 2020). Identifying suitable parental material combinations with powerful heterosis for yield and procuring genetic parameters are the major steps in the evaluation of new cultivars. By exploiting heterosis in F_1 hybrids production cost could be reduced with an increase in yield level and enhancing input use efficiency. Therefore, the present study was undertaken with the objective to determine the general combining ability (GCA) and specific combining ability (SCA), variances and their effects on seed yield and components of *Gobhi Sarson* (*Brassica napus* L.) breeding materials.

Materials and Methods

The present investigation was carried out during the winter season of 2021-22 at experimental farm of Mata Gujri College, Fatehgarh Sahib, Punjab. The experimental material consists of five genotypes received from the National Bureau of Plant Genetic Resources, New Delhi. The experiment was laid out in a randomized block design with three replications. Standard agronomic practices were followed to ensure a good crop stand. Observations on days to first flowering and 50% fruiting were taken on a plot basis. Five plants were randomly selected for recording of data on various yield traits such as plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, siliqua length (cm), number of seeds per siliqua, days to maturity, biological yield per plant (g), seed yield per plant (g), harvest index (%) and test weight (g). Data recorded on these aforesaid parameters were used for the statistical analysis. Analysis for combining ability was performed by using Windostat® v9.2 software.

Results and Discussion

The success of any breeding programme largely depends on the choice of parents and the breeding procedure adopted. Combining ability is an efficient tool to discriminate good as well as poor combiners and for choosing desirable parental lines in a hybridization programme. It also provides information on specific promising combinations to exploit heterosis.

Analysis of variance for combining ability

The analysis of variance of combining ability partitioned the genetic variance into variance due to general combining ability (GCA) representing additive gene action and variance due to specific combining ability (SCA) representing non-additive gene action (Table 1). Variance due to GCA and SCA were highly significant ($p<0.05$) for all the studied agronomic traits. However, the magnitude of the GCA variance component was higher than SCA for all the characters (Table 1) indicating additive gene action and selection is effective. Variances due to GCA and SCA were significant indicating that both additive and dominance gene action were important in the expression of such characters. Further, the ratio GCA/SCA was above unity for most of the characters which indicates that there is the preponderance of additive gene action in comparison to dominance gene action. This finding has important implications because additive gene actions are of a fixable nature therefore one can expect larger genetic gain due to selection. A similar finding was reported by Sabaghnia *et al*. (2010) in rapeseed-mustard breeding materials. Choudhary *et al.* (2020) evaluated 51 Indian mustard breeding lines and hybrids for the estimation of combining abilities. Results revealed that the contribution of GCA was higher than that of SCA for all the important traits. Similar finding accordance with Kaur *et al*., 2019).

Combining abilities effects

The main aim of combining ability is to identify parents who are likely to transfer the required traits to their offspring and to identify the particular mating pattern that is suitable for seed yield and the traits of its constituents**.** The estimates of GCA effects on parents and SCA effects of the crosses for all the traits have been presented in Tables 2 and 3. For days to first flowering, parent like HMS4 exhibited a significant positive GCA effect while one parent namely EC 338978 showed a significant negative GCA effect. For days to 50% flowering, two parents namely HMS4 and BMS4 exhibited a significant positive GCA effect, while two parents namely EC 338975 and EC 338978 exhibited significant negative GCA effects. For days to maturity, two parents namely EC 338975 and EC 338978 showed a significant positive GCA effect, while two parents i.e., HMS4 and BMS4 showed a significant negative GCA effect. A perusal of data on the SCA effect led to the inference that for days to 50% flowering and days to maturity the scenario was similar to that observed for the GCA effect. For the number of primary branches, RBS Bold showed a significant positive GCA effect. On the other hand, two parents i.e., EC-338978 and EC-338975 exhibited a significant negative GCA effect. For positive SCA effect, all ten crosses showed significant positive SCA effects for this character. A similar finding reported by Kumar *et al.* (2021). For a number of secondary branches, all ten crosses have recorded significant positive SCA effects. The estimates of combining ability effects for plant height revealed that EC-338978 expressed a positive significant GCA effect. For positive significant SCA effects, ten crosses showed significant positive SCA effects for this character. For a number of siliquae per plant, two parents namely RBS Bold and EC-338978 expressed positive significant GCA effects while three parents (HMS4, EC 338975, BMS4) exhibited significant negative GCA effect. For positive significant SCA effects, five crosses namely RBS Bold × BMS 4, EC 338978 × HMS 4, EC 338978 × BMS 4, EC 338975 × HMS 4 and EC 338978 × EC 338975 recorded significant positive SCA effect, while EC 338975 × BMS4 exhibited significant negative SCA effect (Table 3). The estimation of combining ability effects for the number of seeds per siliqua revealed that EC-338978 exhibited a significant positive GCA effect and RBS Bold showed a significant negative GCA effects. In addition, ten crosses recorded a significant positive SCA effect (Table 2). The estimates of combining ability

Table 1: Estimation of ANOVA for combining ability half diallel analysis in *B. napus*

Source of variation	Degree of freedom	Days to first flowering	Days to 50% flowering	Days to maturity	No. of primary branches	No. of Secondary branches	Plant height (cm)	No. of siliqua/plant
GCA	4	11.3*	130.4*	5.5*	0.5*	0.31	5.2*	3267.2*
SCA	10	0.6	0.8	0.5	1.4*	35.0*	324.7*	250.6*
Error	28	0.5	5.8	0.5	0.1	0.8	7.5	150.0
Variation due to GCA		1.6	17.8	0.7	0.1	-0.1	1.1	445.3
Variation due to GCA		0.1	-5.0	0.0	1.3	34.2	317.2	100.6
GCA/SCA ratio		13.9	-3.5	69.3	0.1	0.0	0.0	4.4

Conti.

Source of variation	Degree of freedom	No. of seeds/siliqua	Siliqua length (cm)	Test weight (g)	Biological yield (g)	Harvest index (%)	Yield/plant (g)
Replication	4	1.2*	0.4*	0.1	1589*	54.7*	71.8*
Treatment	10	12.3*	3.0*	2.1*	3462*	7.0*	273.8*
Parents	28	0.2	0.1	0.1	19	1.2	2.6
Hybrids		0.1	0.1	-0.0	224	7.6	9.9
Parents Vs crosses		12.1	2.9	2.09	3442	5.8	271.1
Error		0.0	0.0	-0.01	0.1	1.3	0.1

*Where; *: significant at 1% level of significance*

Table 2: Estimation of general combining ability (GCA) for yield and its components in *B. napus*

Parents	Days to First Flowering	Days to 50% Flowering	Days to maturity	No. of primary branches	No. of secondary branches	Plant height (cm)	No. of siliqua/ plant	No. of seeds/ siliqua	siliqua length (cm)	Test weight (g)	Biological yield (g)	Harvest index (%)	Yield/ plant (g)
EC 338978	-1.8**	-4.6**	1.2**	-0.2*	-0.3	2.3*	25.6**	0.6**	0.00	0.11	-8.7**	3.5**	4.5**
RBS Bold	-0.3	0.4	-0.3	0.4**	-0.1	-1.8	21.2**	-0.5**	-0.41**	-0.02	3.8*	0.2	1.7**
EC 338975	0.2	-4.2**	0.6*	-0.2*	-0.1	-0.2	-17.2**	-0.0	0.03	0.08	24.9**	-4.3**	-3.1**
HMS 4	1.7**	4.2**	-0.7**	-0.1	0.1	-0.1	-18.1**	-0.0	0.09	-0.15	-10.1**	-0.0-	2.9**
BMS 4	0.2	4.2**	-0.8**	0.1	0.3	-0.3	-11.6**	-0.1	0.29*	-0.02	-9.8**	0.7	-0.3
SE (gi)	0.2	0.8	0.2	0.1	0.3	0.9	4.1	0.1	0.12	0.13	1.5	0.4	0.5

*Where; *: Significant at 5% level of significance, **: significant at 1% level of significance*

Table 3: Estimates of specific combining ability (SCA) effects of hybrids for yield and its components in *B. napus*

Parents	Days to First Flowering	Days to 50% Flowering	Days to maturity	No. of primary branches	No. of secondary branches	Plant height (cm)	No. of siliqua/ plant	No. of seeds/ siliqua	siliqua length (cm)	Test weight (g)	Biological yield (g)	Harvest index (%)	Yield/ plant (g)
EC 338978 × RBS Bold	-0.4	-0.5	-0.4	0.8**	1.8**	8.6**	-5.1	1.5**	0.9**	1.1**	32.0**	.4**	13.2**
EC 338978 × EC 338975	-0.5	-1.0	-0.6	0.9**	3.2**	15.4**	13.4*	1.4**	0.9**	0.9**	31.9**	-0.4	6.7**
EC 338978 × HMS 4	-0.5	0.5	-0.5	0.3*	3.7**	11.8**	16.9**	.0**	0.9**	0.8**	28.6**	1.4**	10.5**
EC 338978 × BMS 4	-0.2	-0.9	-0.4	0.7**	4.6**	11.4**	16.7**	2.7**	0.9**	0.9**	35.8**	4.8**	18.4**
RBS Bold × EC 338975	-0.5	-0.7	-0.5	0.6**	3.8**	7.5**	-2.5	2.4**	1.4**	1.0**	29.9**	1.3*	7.9**
RBS Bold × HMS 4	-0.3	-0.6	-0.2	0.9**	4.4**	8.5**	-6.7	2.2**	1.1**	0.8**	45.7**	-1.6**	7.2**
RBS Bold × BMS 4	-0.4	-0.2	-0.4	0.6**	4.0**	5.7**	23.2**	1.7**	0.9**	0.6**	34.0**	1.7**	10.9**
EC 338975 × HMS 4	-0.5	-0.1	-0.4	0.7**	2.8**	12.0**	14.2*	1.2**	0.9**	0.5**	45.5**	-1.1*	5.8**
EC 338975 × BMS 4	-0.6	1.1	-0.3	0.4**	2.8**	12.3**	-12.7*	2.6**	1.2**	0.8**	23.1**	-0.3	3.2**
HMS 4 × BMS 4	-0.4	-1.1	-0.3	0.7**	2.7**	8.7**	-2.4	2.1**	0.9**	0.8**	30.3**	0.1	7.8**
SCA (i)	0.6	2.1	0.6	0.2	0.8	2.4	10.7	0.4	0.3	0.3	3.8	1.0	1.4
SCA (ij)	0.3	1.0	0.3	0.1	0.4	1.2	5.3	0.2	0.1	0.2	1.9	0.5	0.7

*Where; *: Significant at 5% level of significance, **: significant at 1% level of significance* effects for siliqua length revealed that BMS4 exhibited a significant positive GCA effect and RBS Bold showed a significant negative GCA effect, while ten crosses revealed a significant positive SCA effect. For test weight, ten crosses showed a significant positive SCA effect.

The estimates of combining ability effects for biological yield per plant revealed that RBS Bold 4 and EC 338975 expressed significant positive GCA effect and three lines like EC 338978, BMS4 and HMS4 showed a significant negative GCA effect, while ten crosses revealed a significant positive SCA effect. For harvest index, EC-338978 revealed a significant positive GCA effect and EC-338975 revealed a significant negative GCA effect. Five crosses namely EC 338978 × BMS4, EC 338978 × RBS Bold, RBS Bold × BMS4, EC 338978 × HMS4 and RBS Bold × EC 338975 had a significant positive SCA effect, while two crosses like EC 338975 × HMS4 and RBS Bold × HMS4 revealed a significant negative SCA effect. For seed yield per plant, RBS Bold and EC-338978 had a positive significant GCA effect whereas, HMS4 and EC 338975 exhibited significant negative GCA effect. For positive significant SCA effects, ten crosses recorded significant positive SCA effect. The estimates of specific combining ability effects revealed that all crosses exhibited significant and positive SCA effects for seed yield per plant. Similar results reported by Kaur *et al.* (2020).

The maximum significant positive SCA effects was exhibited by hybrid EC 338978 × RBS Bold, EC 338978 × HMS4, EC 338978 × BMS4 and RBS Bold × BMS4, thus they were good hybrid combination, contributing towards higher seed yield. Similar findings reported by Aghao *et al*. (2010). The potentiality of a parent in hybridization may be assessed by it per se performance and GCA effects. The result revealed that most of the genotypes had relatively high degree of correspondence between per se performance and GCA effects for the observed characters. This can be ascribed to the predominant role of additive and additive × additive type of gene action for the inheritance of these traits. A cross combination exhibiting high SCA effects as well as high per se performance involving at least one parent as good general combiner for a particular trait, is expected to throw desirable segregates in the segregating generations. Significant SCA effects of those combinations involving good × good combiners showed the major role of additive type of gene effects, which is fixable. However, two good general combiners may not necessarily yield desirable segregates. Similarly, from the superior crosses involving both the poor × poor general combiners, very little gain is expected in their segregating generation because high SCA effects may dissipate with increased homozygosity. Similar result was reported by Kumar *et al*. (2019) and Singh *et al.* (2019).

Better performance of hybrids involving average × poor general combiners indicated dominance × dominance (epistasis) type of gene action. Such crosses could be utilized in the production of high yielding homozygous lines (Darrah and Hallauer, 1972). In the present study, two of the top four crosses which exhibited high SCA effects for yield per plant, the crosses EC 338978 × RBS Bold and EC 338978 × BMS4 involved one good general combiner (EC 338978) indicating additive × dominance type of gene interaction which is expected to produce desirable transgressive segregates in subsequent generations. Falk *et al*. (2014) was reported the involvement of additive × additive, additive × dominance and epistatic type of gene action in expression of yield and other traits in rapeseed-mustard. The crosses, where poor × good and poor × poor general combiners produced high SCA effects may be attributed due to presence of genetic diversity in the form of heterozygous loci for specific traits. Thus, the ideal crosses would be the one, which have good per se performance, high heterosis or Heterobeltiosis, at least one good general combiner parent and high SCA effects. On the basis of combining ability, the parent EC-338978 was good general combiner. Considering mean performance, heterosis and combining ability, none of the hybrids was found promising for commercial exploitation. Similar research finding was reported by Kumar *et al*. (2019).

Conclusion

The major objective of half diallel analysis is to find out genetic architecture of the parents, so that the right type of parents may be selected along with the suitable breeding plant. Among tested breeding materials, EC-338978 and RBS bold showed positive GCA effect may be considered as good general combiners for seed yield and other component traits. Four crosses (EC 338978 × RBS Bold, EC 338978 × HMS4, EC 338978 × BMS4 and RBS Bold × BMS4) were also found promising for other desirable traits, hence could be further evaluated in heterosis breeding programme. A perusal of data on GCA effects summarized that the breeding materials lacked good general combiners for plant height and test weight. This is important consideration from the agro climatic conditions of Punjab region where short duration and dwarf varieties would be given preference on account of its cultivation under limited moisture condition therefore in further attempts must be done to broaden the genetic base for these two traits.

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