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COMBINING ABILITY AND FACTOR ANALYSIS IN F_2 DIALLEL CROSSES OF RAPESEED VARIETIES

ABSTRACT

Fifteen F_2 progenies derived from a 6×6 half diallel crosses along with their parents of rapeseed (*Brassica napus* L.) varieties were evaluated for pods per main axis, pods per plant, length of pod, seeds per pod, 1000-seed weight , grain yield and oil content. The Analysis of variance based on Griffing's method two, with mixed–B model on F_2 progenies and their parents revealed significant mean squares for general combining ability (GCA), specific combining ability (SCA) indicating that both additive and non-additive genetic effects were involved in controlling these traits. High narrow-sense heritability estimates and degree of dominance less than one were observed for length of pod and 1000-seed weight indicated the prime importance of additive genetic effects for controlling these two traits. Narrow-sense heritability estimates for pods per main axis, pods per plant, seeds per pod, grain yield and oil content were estimated 0.22, 0.14, 0.30, 0.15 and 0.08, respectively concluded that the importance role of non-additive genetic effects for controlling these traits. Among yield components, pods per main axis and pods per plant had significant positive correlation with grain yield (0.54* and 0.60**), so any changing of these traits would have significant effects on grain yield. Based on the results of factor analysis on GCA effects revealed that pods per main axis, pods per plant and grain yield had high coefficients of factor loading in the factor one, but on SCA effects pods per main axis, pods per plant and 1000-seed weight had high coefficients of factor loading and the same direction of variation.

Key words: additive, degree of dominance, factor loading, SCA.

INTRODUCTION

Although F_1 data is mostly used to estimate the genetic parameters in Griffing's method (1956), but it is usually difficult to obtain sufficient F_1 seeds especially for multilocation testing or have enough replications in self-pollinated crops where hand emasculation must be done. Due to easiness of production of large quantity of F_2 seeds, many researchers use F_2 generation for diallel analysis to estimate combining ability and other genetic parameters (Cho and Scott, 2000; Kao and Mc Vetty, 1987). These researcher all reported that F_2 analysis provide reliable and better information than F_1 generation. Grain yield

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and its quality related characters have important role for increasing the expansion of rapeseed cultivation. Yield per area is the product of population density, the pods per plant, the number of seeds per pod and the individual seed weight. Hence, seed yield is a complex trait that includes various components and finally results in a highly plastic yield structure (Diepenbrock, 2000). Habekotte (1997) used a sensitivity analysis within a crop growth model to study options for increasing seed yield in winter oilseed rape. Advancement in the yield of brassica requires certain information regarding the nature of combining ability of parents available for use in the hybridization program. In addition, information about the nature of gene action involved in expression of quantitative and qualitative traits of economic importance is required to develop desirable lines. Information on general and specific combining ability effects is very important in conducting a successful breeding program (Amiri-Oghan *et al.*, 2009). Estimation of genetic parameters for yield components can be important for indirect selection for seed yield. Rapeseed (*B. napus*) is usually classified as a largely self-pollinated species, significant levels of heterosis have been obtained in F_1 hybrids of both the spring and winter forms (Downeyand Rimer,1993; Nassimi *et al.*, 2006; Teklewold and Becker, 2005). Although combining ability studies in oilseed *Brassica* spp. are scanty, most of these studies emphasized the preponderance effect of GCA on yield and most of the yield components indicating the importance of additive gene action (Brandle and McVetty, 1989; McGee and Brown, 1995; Wos *et al.*, 1999). On the other hand, Pandey *et al.* (1999) reviewed evidences for the presence of significant SCA effects for yield and yield components. Ramsay *et al.* (1994) reported that variation for both GCA and SCA were responsible for dry matter yield and other quantitative traits in *B. napus*. Significant GCA and SCA effects were reported for pods per main axis, pods per plant, length of pod, number of seeds per pods, 1000-seed weight and seed yield in *B. napus* (Leon, J. 1991; Singh and Murty, 1980; Thakur and Sagwal,1997), but in other study (Singh *et al.*, 1995) the importance of additive genetic effects for pods per plant and 1000-seed weight was emphasized. Singh and Yadev (1980) and Thakur and Sagwal (1997) while examining the genetic control of grain yield in oilseed rape found both additive and non additive gene effects to be involved.

Because grain yield is probably the most difficult and costly trait to measure accurately, numerous attempts have been made to identify the most important yield components (Downey and Rimer, 1993; Gupta *et al.*, 1991; Gupta *et al.*, 1997).The main applications of factor analytic techniques are to reduce the number of variables, and to detect structure in the relationship between variables, that is to classify variable (Dillon and Goldstein, 1984; Johnson and 1982). In plant breeding factor analysis is mainly applied as structure detection method and sometimes it can be used as index selection for improving more than one trait (Murty *et al.*, 1970). Factor analysis was used to determine structural factors related to growth trait and yield components (Bramel *et al.*, 1984;Denis and Adams, 1978; Lewis and Lisle, 1999; Rao and Parada, 1982) and also it was used for detecting factors relating to environmental stress including drought resistance in *Brassica napus (*Librikbt and Udovenko, 1991; Rameeh, *et al.*, 2004).

In Iran, oilseed rape is edible oil crop and has recently been exploited to boost its production. Iran has diverse agro-ecological region in order to increase area and production of oilseed rape (Ali *et al.*, 2003). Due to applied genetic material (parents and their crosses), genetic parameters which estimated by genetic design are different. The objective of the present study was to determine the importance of genetic parameters for yield components, seed yield and oil content in order to select suitable breeding program for rapeseed breeding lines and cultivars and also to detect structural relationship among GCA and SCA effects of parents and crosses, respectively by using factor analysis.

MATERIALS AND METHODS

The material under study consisted of six cultivars which were selected based on their different agronomic characters. These were crossed in half diallel crosses during 2004-05. In order to produce F_2 seeds, fifteen F_1 populations from a 6 × 6 diallel cross were selfed by light transparent white mesh cloth at Biekol Agriculture Research Station, located in Neka, Iran (13°, 53′ E longitude and 43° 36′ N latitude, 15 m above sea level) during winter 2005-06. F_2 progenies along with 6 parents including RGS-003, Option-500, RW-008911, RAS-3/99, 19-H and PF7045/91 were grown in a randomized complete block design with four replications during 2006-07. The plots consisted of four rows 5 m long and 40 cm apart. The distance between plants on each row was 5 cm resulting in approximately 400 plants per plot, which were sufficient for F_2 genetic analysis. Crop management factors like land preparation, crop rotation, fertilizer, and weed control were followed as recommended for local area. All the plant protection measures were adopted to make the crop free from insects. The pods per main axis and pods per plant were recorded based on 20 randomly plants of each plot. The length of pod and number of seeds per pod were recorded based on five randomly pods on the main axis of 10 plants in each plot. Grain yield (adjusted to kg/ha) was recorded based on two middle rows of each plot. Oil content was estimated with the help of nuclear magnetic resonance spectrometry (Madson, 1976).

The combining ability analysis was performed using mean values their F_2 generation along with parents by using Griffing's method 2 with mixed – B model. The statistical t-student test was applied to examine the effects of general combining ability (GCA) and specific combining ability (SCA).

Factor analysis was applied for detecting the relationship among GCA and

SCA effects of grain yield and yield associated traits in parents and their half diallel crosses, respectively.

All the analyses were performed using MS-Excel and SAS soft wares.

RESULTS

The analysis of variance for pods per main axis, pods per plant, length of pod, number of seeds per pods, 1000-seed weight, grain yield and oil content revealed highly significant differences among genotypes (Table 1). The mean squares including GCA and SCA were highly significant (*P*<0.01) for all the traits under study indicating the importance of additive and dominance genetic effects for these traits. GCA/SCA ratios were 1.48, 0.93,1.37,0.87,5.57,1.11 and 0.48 for pods per main axis, pods per plant, length of pod, number of seeds per pod, 1000-seed weight , grain yield and oil content, respectively. GCA/SCA ratios more than unity and high narrow-sense heritability estimates for length of pod and 1000-seed weight confirmed the predominance of additive genetic effects over non-additive effects .

Table 1

Analysis of variance for yield components, grain yield andoil content based on Griffing's method two with mixed-B model

S.O.V	DF	M. S Pods on main axis	Pods per Plant	Length of pod	Seeds per Pod	1000-Seed Weight	Grain yield	Oil [%]
Replication	3	81.92**	1057.04**	0.760**	52.42**	0.23	276606.58	5.19
Cross	20	323.56**	1478.50**	0.420**	22.66**	0.64**	456133.05**	17.31**
GCA	5	427.11**	1404.01**	0.520**	20.55**	1.67**	493071.66*	9.62**
SCA	15	289.04**	1503.32**	0.380**	23.37**	0.30**	443820.18**	19.88**
Error	60	11.46	234.57	0.068	5.00	0.08	146217.31	1.88
MS(GCA)/ MS(SCA)		1.48	0.93	1.370	0.87	5.75	1.11	0.48
Degree of dominance		2.67	3.48	0.860	2.03	0.73	3.02	4.72
Narrow-sense heritability		0.22	0.14	0.710	0.30	0.53	0.15	0.08

*, ** Significant at p=0.05 and 0.01, respectively

On the basis of GCA estimation effects it be concluded that for each yield component different parents were considered as good general combiners. RW008911, RGS003 and PF7045/91 with significant positive GCA effects were good combiners for pods per main axis (Table 2). Among the parents this trait was varied from 24.73 to 46.73 related to Option500 and

RW008911, respectively (Table 3). The variety PF7045/91 was the best combiner for pods per plant due to its highest significant positive GCA effect and also it had the highest mean of this trait. The positive correlation between pods per plant and grain yield (0.60**) revealed the importance effect of this yield component on grain yield. Length of pod was varied from 5.47 to 6.42cm related to RW008911 and RGS003, respectively and also PF7045/91, RGS003 and 19H were good combiners for this trait. The high amount of seeds per pod was related to PF7045/91 and RW008911 (24.33 and 22.06, respectively) and PF7045/91 was the best combiner for this trait. 1000-seed was varied from 3.30 to 4.25gr related to PF7045/91 and 19H, respectively and 19H was the best combiner for this trait. This trait had high narrow-sense heritability estimate, therefore selection efficiency for this trait will be high. PF7045/91 had high performance of grain yield (3131.92 kg × ha^{-1}) followed by RGS003 and RAS3/99 with 2971.84 and 2635.52 kg × ha^{-1} had high amount of grain yield and also PF7045/91 was the best combiner for this trait. RGS003 and Option 500 due to significant positive GCA effects were good combiners for oil content.

Table 2

Estimates of GCA effects for yield components, grain yield and oil content in 6 parents of *B. napus*

Parents	Pods on main axis	Pods per Plant	Length of pod	Seeds per pod	1000-Seed Weight	Grain Yield	Oil [%]
1-RAS-3/99	1.36	-6.91*	-0.09	-0.79	0.09	43.22	-0.55
2-RW008911	2.70**	1.97	-0.09	0.04	0.12	-31.50	-0.48
3-19H	-4.12**	-3.45	0.12*	0.64	0.29**	-80.48	0.13
4-RGS 003	1.42*	1.06	0.12*	-1.11*	0.02	55.50	0.64*
5-Option 500	-5.02**	-4.33	-0.16*	0.27	-0.17*	-173.01**	0.63*
6-PF7045/91	3.66**	11.66**	0.11*	0.94*	-0.35**	186.26**	-0.37

*, ** Significant at p<0.05 and 0.01, respectively

Table 3

The means ofyield components, grain yield and oil content of 6 parents of *B. napus*

Parents	Pods on main axis	Pods per plant	Length of pod	Seeds per pod	1000-Seed Weight	Grain Yield	Oil [%]
1-RAS-3/99	43.94	130.50	5.81	21.41	4.00	2635.52	42.20
2-RW008911	46.73	123.00	5.47	22.06	3.95	2505.83	43.50
3-19H	33.10	114.67	6.24	21.13	4.25	2447.92	45.25
4-RGS 003	46.20	149.55	6.42	17.97	3.75	2971.84	46.20
5-Option 500	24.73	121.67	5.62	20.03	3.43	2218.58	47.13
6-PF7045/91	38.65	160.08	6.01	24.33	3.30	3131.92	41.43
LSD (α=0.01)	6.3	28.8	0.5	4.2	0.5	719.2	2.6

Table 4

Estimates of SCA effects on yields components, grain yield and oil content in the half diallel crosses of 6 parents of *B. napus* L.

Crosses	Pods on main axis	Pods per plant	Length of pod	Seeds per pod	1000-Seed Weight	Grain Yield	Oil [%]
1- RAS-3/99 x RW008911	-4.08*	32.41**	0.64**	-3.83**	0.03	411.34*	-1.55*
2- RAS-3/99 x 19H	5.54**	8.38	0.08	-0.88	0.37*	95.33	2.49**
3- RAS-3/99 x RGS 003	-5.91**	-3.68	-0.36**	-0.11	-0.06	351.84	-0.30
4- RAS-3/99 x Option 500	3.39*	-25.81**	-0.28*	-1.93	-0.37*	-178.90	-1.29*
5- RAS-3/99 x PF7045/91	11.48**	-6.48	0.04	-0.30	-0.31*	71.08	1.96*
6-RW008911 x 19H	9.14**	28.97**	0.25*	-0.58	0.28*	75.04	1.48*
7-RW008911 x RGS 003	1.49	-13.01	-0.19	0.69	-0.31*	249.47	-1.24
8- RW008911 x Option 500	0.53	13.35	-0.15	1.60	0.06	-44.93	-3.35**
9- RW008911 x PF7045/91	3.12	-7.36	0.24*	-2.45*	-0.21	20.30	3.65**
10-19H x RGS 003	-3.04	-11.34	-0.13	1.57	-0.08	-115.55	-1.73*
11- 19H x Option 500	-4.06*	10.88	0.24*	2.72*	-0.37*	285.71	-2.71**
12- 19Hx PF7045/91	2.59	9.80	-0.33**	-3.43**	-0.26	290.61	-1.61*
13- RGS 003 x Option 500	12.04**	19.94*	0.13	-3.19	0.35*	164.32	2.67**
14- RGS 003x PF7045/91	1.57	5.71	0.27*	-0.16	-0.04	-522.87**	-1.30
15- Option 500 x PF7045/91	11.42**	13.44	0.30*	0.34	0.08	493.47**	0.88

*, ** Significant at p<0.05 and 0.01, respectively

The crosses Option 500 × PF7045/91, RGS 003 × Option 500, RAS-3/99 × PF7045/91 and RW008911x 19H due to their significant positive SCA effects for pods per main axis were considered as good combinations for this trait (Table 4). The crosses RAS-3/99 × RW008911, RW008911 × 19H and RGS 003 × Option 500 had significant positive SCA effects for pods per plant and were selected as good combinations for this trait and the means of crosses were 173.95, 174.89 and 162.9 respectively. The crosses RAS-3/99 × RW008911, RW008911 × 19H, RW008911 × PF7045/91, 19H × Option 500, RGS 003 × PF7045/91 and Option 500 × PF7045/91 with significant positive SCA effects for length of pod (0.64, 0.25, 0.24, 0.24, 0.27 and 0.30, respectively) were detected as good combinations for this trait. Most of the crosses with significant positive SCA effect had at least one parent with significant positive GCA effect for length of pod, so GCA effects can be considered as good criterion for prediction of SCA effects for this trait. 19H × Option 500 had significant positive SCA effects for number seeds per pod and both of its parent had positive GCA effect for this trait. Due to significant positive SCA effects of 1000-seed weight for the crosses RAS-3/99 × 19H, RW008911 × 19H and RGS 003 × Option 500 (0.37, 0.28 and 0.35, respectively) they were determined as good combinations for this trait. The crosses RAS-3/99 × RW008911 and Option 500 × PF7045/91 with significant positive SCA effects (411.34 and 493.47 respectively) for grain yield were considered as good combinations for this trait and the mean of for grain yield for these two crosses were 3347.50 and 3431.17, respectively. The crosses RAS-3/99 × 19H, RAS-3/99 × PF7045/91, RW008911x19H, RW008911 × PF7045/91 and RGS 003 × Option 500 with significant positive SCA effects for oil content were good combinations for this trait.

The results of factor analysis based on minimum eigenvalue revealed three factors for 7 studied traits related to GCA effects of parents (Table 5). The eigenvalues for factor 1 to factor 3 were 3.22, 1.49 and1.67 respectively. The cumulative variation for these factors was 0.84 and also it's portions for factor one to four were 0.23, 0.21 and 0.17, respectively. Factor one was detected as yield components in which, pods per main axis, pods per plant and grain had high coefficients for factor loading. In factor 3 length of pod and oil content and had high coefficients for factor loading.

Table 5

Factor analysis of grain yield and their associated traits for GCA effects of parents and SCA effects of crosses

Traits	Factor loadings for GCA effects of six parents			Factor loadings for SCA effects crosses	
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2
Pods on main axis	0.85	-0.48	-0.06	0.62	-0.58
Pods per plant	0.89	0.36	0.03	0.72	0.62
Length of pod	0.49	0.19	0.77	0.65	0.38
Seeds per pod	0.23	0.74	-0.38	-0.51	0.24
1000-Seed Weight	-0.54	-0.50	0.29	0.76	0.10
Grain Yield	0.93	-0.22	0.18	0.28	0.41
Oil [%]	-0.50	0.49	0.56	0.68	-0.61
Eigenvalue	3.22	1.46	1.67	2.71	1.47
Proportion	0.46	0.21	0.17	0.39	0.21
Cumulative	0.46	0.67	0.84	0.39	0.60

The results of factor analysis for SCA effects of crosses revealed two factors for 7 studied traits. The eigenvalues for factor 1 and factor 2 were 2.71 and 1.41 respectively. The cumulative variation for these two factors was 0.60 and it's portions for factor 1 and factor 2 were 0.39 and 0.21 respectively. In factor 1 the traits including pods per main axis, pods per plant, 1000-seed weight and oil content had high coefficients for factor loading.

DISCUSSION

The ratio of GCA/SCA more than unity and high narrow-sense heritability estimates for length of pod and 1000-seed weight confirmed the predominance of additive genetic effects over non-additive genetic effects and provided additional evidence that selection can be effective in the F_2 and later generations for these two traits. But for number pods per plant, number seeds per pod and oil content due to GCA/SCA ratios less than one indicating the importance of non-additive genetic effects, therefore these traits must be improved based on hybridization method mainly using cytoplasmic male sterility (CMS). Although combining ability studies in oilseed *Brassica* spp. are scanty, most of these studies emphasized the preponderance effect of GCA on yield and most of the yield components indicating the importance of additive gene action (Brandle and McVetty, 1989;McGee and Brown, 1995; Woś *et al.*, 1999). On the other hand, Pandey *et al.*, (1999) reviewed evidences for the presence of significant SCA effects for yield and yield components. Ramsay *et al.* (1994) reported that variation for both GCA and SCA were responsible for dry matter yield and other quantitative traits in *B. napus*. The importance of additive and non-additive genetic effects for yield and yield components was emphasized by Thakur and Sagwal (1997), but in another study Brandle and McVetty(1989) additive genetic effects was reported to be more important. Singh *et al.*, (1992) suggested that when SCA effects are predominant in self-pollinated crops then the major portion of the variability is due to additive × additive effects and selection should be delayed to later generations. Bhullar *et al.*, (1979) pointed out that this could also be due to divergence among progenies in the same parental array.

Significant positive correlation (0.53*) was observed between pods per main axis and grain yield, so any changing for this trait can have considerable effect on grain yield. In general, the most parents with high performance for yield and yield components had significant positive GCA effects, suggested the possibility of further selection of parents for these traits on the basis of *per se* performance.

Most of these crosses had high performance of pods per main axis but the SCA effects and mean performances of crosses have not the same rank. Among these crosses at least one of their parents had significant positive GCA effects. In a previous study (Thakur and Sagwal ,1997) the similar result was reported. Therefore GCA effects can be considered as good criterion for prediction of SCA effects for pods per main axis.

Due to significant positive correlation of grain yield with pods per main axis (0.53*) and pods per plant (0.60**), most of the crosses with significant positive SCA effects for these two yield components had high mean performance of grain yield. Therefore it be suggested that the possibility of further selection of crosses for these two yield components on the basis of *per se* performance. Most of the crosses with significant positive SCA effect had at least one parent with significant positive GCA effect for length of pod, so GCA effects can be considered as good criterion for prediction of SCA effects for this trait.

Significant GCA and SCA effects were reported for pods per main axis, pods per plant, length of pod, number of seeds per pods, 1000-seed weight and seed yield in *B. napus* (Leon, J. 1991; Singh and Murty, 1980; Thakur and Sagwal,1997), but in other study (Singh *et al.*, 1995), the importance of additive genetic effects for pods per plant and 1000-seed weight was emphasized. Singh and Yadev (1980) and Thakur and Sagwal (1997) while examining the genetic control of grain yield in oilseed rape found both additive and non additive gene effects to be involved.

Factor analysis for GCA effects revealed the positive correlation of GCA effects for two yield components including pods per main axis and pods per plant with grain yield. Therefore selecting parents based on GCA effects of pods per main axis and pods per plant make selection of parents with significant positive GCA effects for grain yield. In factor 2 seeds per pod had high coefficients for factor loading.

Although significant positive correlation were observed between grain yield and each two yield components including pods per main axis and pods per plant but on basis of factor analysis SCA effects of these two yield components were not been correlated to SCA effect of grain yield, therefore most of the crosses with significant positive SCA effects for these two yield components may have not significant positive SCA for grain yield . In previous study factor analysis was used to determine structural factors related to growth trait and yield components (Bramel *et al.*, 1984; Denis and Adams, 1978; Lewis and Lisle, 1999; Rao and Parada, 1982) but it is not used to determine the relationship among GCA or SCA effects in genetic designs such as diallel analysis.

CONCLUSION

Most of the crosses with significant positive SCA effects for yield components had at least one of parents with significant positive GCA effects, therefore GCA effects can be considered as good criterion for prediction of SCA effects for these traits. Significant positive correlation of grain yield with pods per main axis and pods per plant indicated these two yield components can be considered as suitable selection criteria for grain yield improving. The results of factor analysis revealed that the GCA effects of these two yield components of parents are more reliable than SCA effects crosses for breeding the genotypes with high grain yield.

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