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Study on combining ability and heterobeltiosis of agronomic traits in spring type of rapeseed varieties using line × tester analysis

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Abstract

To estimate the general and specific combining ability (GCA and SCA) and high parent heterosis (heterobeltiosis) effects of phenological traits, plant height and seed yield, two testers and six lines of spring type of rapeseed varieties were crossed using line×tester fashion. Significant mean squares of parents and crosses for all the traits indicated significant genetic variation among the parents and their F1 crosses. Significant mean squares of parent's *vs* crosses revealed significant average heterosis for all the traits. High narrow sense heritability estimates for all the traits except days to flowering, indicating the importance of additive genetic effects for these traits except days to flowering. Due to more importance of additive genetic effects for most of the traits, significant specific combining ability and heterobeltiosis effects of the studied traits were observed for only a few of the crosses except days to flowering. Significant SCA effects of the traits were observed for the crosses which had at least one parent with significant GCA effects. Significant correlation between heterobeltiosis effects of seed yield and their respective mean performances of the crosses, indicating selection of the crosses based on heterobeltiosis can be indirect selection for high seed yield of the cross combinations.

Key words: genetic effects, phenological traits, line × tester, seed yield

Introduction

The oilseed *Brassica* species especially rapeseed (*B. napus* L.) have important role in oilseed production because of their wide adaptation to different diverse climatic conditions (Downey and Rimer, 1993). Seed yield of canola is a quantitative trait, which is largely influenced by the different environmental effects and hence in most of the cases it has low heritability (Habekotte, 1997; Diepenbrock, 2000; Rameeh, 2010). Exploitation of genetic variability in any crop species is considered to be critical for making further genetic improvement in seed yield as well as other economically important traits (Mahmood *et al*., 2003). Inter and intra *brassica* species crosses are suitable way to make genetic variations and develop the new varieties (Brandle and McVetty, 1990; Enqvist and Becker, 1991; Qian et al., 2007; Amiri-Oghana *et al*., 2009; Rameeh 2011). In rapeseed breeding program for hybrid and open pollinated varieties, general and specific combining ability effects (GCA and SCA) are important indicators of the potential of inbred lines in hybrid combinations. The line×tester analysis is one of the efficient methods of evaluating large number of inbred as well as providing information on the relative importance of GCA and SCA effects for interpreting the genetic basis of important plant traits (Singh and Chaudhury, 1977). By using this scheme, and other genetic designs like diallel analysis significant GCA and SCA effects of phenological traits, seed yield and other yield associated traits were reported in rapeseed (Shen *et al.,* 2002; Nassimi, *et al.,* 2006b; Wang *et al.,* 2007). In earlier studies on spring cultivars of rapeseed (Huang *et al.,* 2010; Rameeh, 2011) were stressed the important role of GCA and SCA effects for days to flowering but due to high heritability estimates for this trait in these reports, the prime importance of GCA effects were emphasized. Likewise, studies with winter cultivars of this species (Amiri-Oghana *et al*., 2009; Sabaghnia *et al.,* 2010) showed both additive and dominance gene effects to have a significant role in the inheritance of flowering time. Significant negative GCA and SCA effects were reported for days to flowering and plant height. Significant GCA and SCA effects were reported for seed yield in repeseed (Rameeh, 2010) and other brassica species (Teklwold and Becker, 2005; Singh *et al.*, 2010).

Mid parents and high parent heterosis (heterobeltiosis) have extensively been explored and utilized for boosting various quantity and quality traits in rapeseed (Nassimi, *et al.*, 2006a; Chapi *et al.*, 2008). With sufficient level of heterosis, commercial production of hybrid varieties would be justified (Nassimi *et al.*, 2006a). For seed yield in spring rapeseed hybrids, an average high parent heterosis of 30% with a range of 20–50% was observed, while for winter rapeseed hybrids an average high parent heterosis of 50% was reported, ranging from 20 to 80% as reviewed by McVetty (1995). Flowering is the most critical stage influencing the yield of oilseed rape (Faraj *et al.*, 2008). The unset of flower initiation can have strong influence on flower, pod and seed number (Diepenbrock, 2000; Downey and Rimer, 1993; Yasari and Patwardhan, 2006). Habekotte, (1997) used a sensitivity analysis within a crop growth model to study options for increasing seed yield in winter oilseed rape. The most promising crop type for high seed yield combined late maturity with early flowering (Downey and Rimer, 1993). Heterosis is commercially exploited in rapeseed (*Brassica napus* L.) and its potential use has been demonstrated in turnip rape (*B. rapa* L.) and Indian mustard (*B. juncea* L) for most agronomic traits (Teklwold and Becker, 2005; Zhang and Zhu, 2006). Early flowering in brassica can provide adequate time for seed formation process and can certainly cause early maturity and higher yield, therefore negative heterosis is desirable for days to flowering. Significant negative mid-parent and better-parent heterosis were reported for days to 50% flowering and physiological maturity (Nassimi, *et al.*, 2006a). In this study mid parent heterosis for days to 50% flowering and physiological maturity ranged from -0.04 to -2.78 and -0.01 to -3.06, respectively and also its high parent heterosis for these traits ranged from -0.92 to -2.78 and -0.01 to -4.08, respectively. Significant correlation was reported between post-anthesis duration with some of important agronomic traits including number of pods per plant, 1000 seed weight and oil yield (Jeromela *et al.*, 2007).

Due to different genetic materials display different genetic parameters, the objectives of the present study were therefore (i) to identify general and specific combining abilities and narrow-sense heritability for phonological traits, plant height and seed yield in adapted rapeseed spring cultivars and (ii) comparison of heterosis and SCA effects of the crosses for predicting of their seed yield.

Materials and Methods

Six spring rapeseed (*B. napus* L.) cultivars including Sarigol, RGS3006, RGS003, 19H, RW and Option500 as lines were crossed with two spring testers including R1 and R2 based on line x tester crossing scheme during 2005-06. Twelve F_1s along with their parents were grown in a randomized complete block design with three replications at Biekol Agriculture Research Station, located in Neka, Iran (53Ú, 13^{2} E longitude and $36^{Ú}$ 43^{2} N latitude, 15 m above sea level) during winter 2006-07. Each plot was consisted of four rows 5 m long and 40 cm apart. The distance between plants on each row was 5 cm resulting in approximately 300 plants per plot, which were sufficient for F_1 genetic analysis. The soil was classified as a deep loam soil (Typic Xerofluents, USDA classification) contained an average of 280 g clay kg^{-1}, 560 g silt kg^{-1}, 160 g sand kg^{-1}, and 22.4 g organic matter kg^{-1} with a pH of 7.3. Soil samples were found to have 45 kg ha^{-1} (mineral N in the upper 30-cm profile. Fertilizers were applied at the rates of 100 : 50 : 90 kg/ha of N: P: K, respectively. All the plant protection measures were adopted to make the crop free from insects. Seed yield (adjusted to kg/ha) was recorded based on three middle rows of each plot. The data were recorded on ten randomly selected plants of each entry of each replication for days to flowering, days to end of flowering, duration of flowering and days to maturity and plant height. Seed yield (adjusted to kg/ha) was recorded based on two middle rows of each plot.

Table 1: Analysis of variance for phenological traits, plant height and seed yield of rapeseed (*B. napus* L.) based on line x tester fashion

S.O.V	df	M.S					
		Days to flowering	Days to Complete Flowering	Duration of flowering	Days to maturity	Plant height	Seed yield
Replication	2	16.85	19.35	1.25	0.05	196.12**	33875.07
Treatment	19	253.41**	68.70**	131.98**	82.38**	341.34**	647497.15**
parents	7	245.79**	47.79*	96.00**	136.23**	728.99**	508977.20**
parents vs crosses	1	883.48**	90.00*	409.58**	50.61**	491.31**	3458359.26**
crosses	11	200.98**	80.07**	129.64**	51.00**	81.02*	480113.29*
testers	1	342.25**	17.36	205.44**	144.00**	50.01	617052.12*
Lines	5	173.05**	103.85**	133.8**	46.80**	120.74**	611367.34**
Line x tester	5	200.65**	68.83**	110.31**	36.60**	47.51	321471.48*
Error	38	31.38	19.63	12.62	4.68	30.36	119388.37
Narrow-sense heritability		0.01	0.53	0.57	0.75	0.80	0.76

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

Data for the genotypes were subjected to line x tester analysis (Singh and Chaudhury, 1977) to estimate general combining ability (GCA) and specific combining ability (SCA). A *t*-test was used to test whether the GCA and SCA effects were different from 0. For each hybrid and each studied trait, the difference between hybrid and the mean of high parent was computed separately. A least significant difference (LSD) was used to test whether these differences were different from 0.

Results and Discussions

Analysis of variance

Significant mean squares of parents and their crosses for phenological traits, plant height and seed yield revealed significant genetic variability among the parents and also their crosses for these traits (Table 1). Significant mean squares of parents *vs* crosses which are indicating significant average heterosis were also significant for all the traits. Significant mean squares of line x tester for all the traits, except plant height, indicating non-additive genetic effects, have important role for controlling these traits except plant height. High narrow-sense heritability estimates for all the traits except days to flowering exhibited the prime importance of additive genetic effects for these traits except days to flowering. Similarly, earlier researchers (Rameeh, 2011) and winter (Amiri-Oghana *et al*., 2009; Huang *et al*., 2010; Sabaghnia *et al*., 2010; Rameeh, 2011) reported the important role of additive genetic effects for phenological traits. Although in the most of the studies (Rameeh, 2010) were noted the importance of non additive genetic effects for seed yield but it can be different based on genotypes under study and in this study additive genetic effect was most important for seed yield.

General combining ability of the parents

Significant GCA effect of days to flowering for R2 and RGS003, indicating these parents are suitable for decreasing this trait and also these parents had negative and significant positive GCA effects for days to complete flowering and duration of flowering, respectively (Table 2). Significant negative GCA effects were also detected for R1, Sarigol and Option500. The mean performances of duration of flowering for R2 and RGS003 were 44

Table 2: Estimates of GCA effects for phenological traits, plant height and seed yield of rapeseed (*B. napus* L.).

Parents	Days to flowering	Days to Complete Flowering	Duration of flowering	Days to maturity	Plant height	Seed yield
1-R1	3.08**	0.69	-2.39**	2.00**	-1.17	-130.92
2-R2	-3.08**	-0.69	2.39**	-2.00**	1.19	130.92
3-Sarigol	1.58	-2.25	-3.83*	2.50**	4.12	-26.84
4-RGS3006	0.58	-0.58	-1.17	-1.50	-4.65*	375.38*
5-RGS003	-10.42**	-2.25	8.17**	-4.50**	0.35	293.16*
6-19H	2.58	0.75	-1.83	1.00	1.07	375.73*
7-RW	5.08*	7.92**	2.83	3.00**	-5.93*	362.50*
8-Option500	0.58	-3.58	-4.17**	-0.50	5.05*	96.53
S.E(gca(tester)	1.32	1.04	0.84	0.51	1.30	81.44
S.E(gca(line)	2.29	1.81	1.45	0.88	2.25	141.06

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

and 47 days, respectively. In the earlier studies (Huang *et al*., 2010; Sabaghnia *et al*., 2010; Rameeh, 2011) were reported significant negative GCA effects for phenological traits. The parents with significant negative GCA effects for days to maturity had significant negative GCA effects of days to flowering, therefore, selection based on early flowering will be indirection selection of early maturity genotypes. The parents including RGS3006 and RW with significant negative GCA effects for plant height were suitable for decreasing this trait and their mean performances for this trait were 142.17 and 151.67 cm, respectively. RGS3006 and RGS003 with significant positive GCA effect of seed yield were suitable combiners for this trait.In previous study (Teklwold and Becker, 2005) was reported significant negative GCA effect for plant height in *B. juncea*. Among the parents only two lines had significant GCA effect for seed yield and most of parents with positive GCA effects of duration of flowering had positive GCA effect of this trait. This finding is in agreement with the results of Rameeh, (2010) and Amiri-Oghana *et al*., (2009) reports for significant positive GCA effects of parents for seed yield in rapeseed.

Specific combining ability effects of crosses

Out of 12 crosses, 5 crosses had significant SCA effects of days to flowering (Table3). The crosses including Option500 x R1, RGS003 x R2 and RW with the significant negative SCA effects of days to flowering were good combinations for these traits. Significant positive SCA effect of days to complete flowering was displayed for RW x R1, therefore this combination was considered as good combination for increasing this trait. Significant positive SCA effect of days to complete flowering was displayed for RW x R1, therefore this combination was considered as good combination for increasing this trait. The crosses including Option500 x R1 and RGS003 x R2 with the significant positive SCA effects of duration of flowering were merit combinations for increasing this trait. Significant negative SCA effect of days to maturity was only detected for RGS3006 x R2, therefore this combination was suitable for decreasing this trait.

Significant positive correlation was exhibited between SCA effect and mean performance for all the phenological traits (Table 4), therefore any selection based on SCA effects of these traits will be effective on mean performance of these traits. The cross combinations were more variated for days to flowering than the other phenological traits. The crosses with significant negative SCA effects for days to flowering are suitable for decreasing this trait. Due to significant correlation between days to flowering and days to maturity (0.56*), selection based low amount of days to flowering will be indirect selection of early maturity genotypes. Similarly, significant negative SCA effects were

Table 3: Estimates of SCA effects for phenological traits, plant height and seed yield in crosses of two testers and six lines of rapeseed

Crosses	Days to flowering	Days to Complete Flowering	Duration of flowering	Days to maturity	Plant height	Seed yield
1-Sarigol x R1	-2.58	-0.69	1.89	-2.00	-2.26	-316.86
2-RGS3006 x R1	-2.58	0.97	3.56	4.00**	2.85	29.81
3-RGS003 x R1	6.42*	-0.69	-7.11**	2.00	1.96	69.81
4-19H x R1	-2.58	-3.69	-1.11	-0.50	2.68	-192.41
5-RW x R1	7.92*	6.14*	-1.78	-1.50	-3.54	347.66
6- Option x R1	-6.58*	-2.03	4.56*	-2.00	-1.67	61.99
7-Sarigol x R2	2.58	0.69	-1.89	2.00	2.26	316.86
8-RGS3006 x R2	2.58	-0.97	-3.56	-4.00**	-2.85	-29.81
9-RGS003 x R2	-6.42*	0.69	7.11**	-2.00	-1.96	-69.81
10-19H x R2	2.58	3.69	1.11	0.50	-2.68	192.41
11-RW x R2	-7.92*	-6.14*	1.78	1.50	3.54	-347.66
12-Option x R2	6.58	2.03	-4.56*	2.00	1.67	-61.99

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

Table 4: Correlation between mean performance and SCA effect and also between mean performance and heterobeltiosis for each studied trait.

Traits	Correlation between mean performance and SCA	Correlation between mean Performance and heterobeltiosis
1-Days to flowering	0.67*	0.57*
2-Days to Complete Flowering	0.62*	0.91**
3-Duration of flowering	0.62*	0.89**
4-Days to maturity	0.57*	-0.36
5-Plant height	0.51	-0.19
6-Seed yield	0.55	0.72**

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

reported for phenological traits in *B. napus* L. (Rameeh, 2011) and *B. juncea* (Singh *et al*., 2010). Significant positive SCA effects were observed for the crosses which had significant SCA effects for days to flowering. Among the cross combination only RGS3006 x R2 had significant negative SCA effect and one of its parents had significant negative GCA effect for this trait.

None of crosses had significant SCA effect for plant height and the crosses including RW x R1, RGS3006 x R2 and 19H x R2 with high negative SCA effects for this trait were considered as suitable combinations. The crosses such as RW x R1, Sarigol x R2 and 19H x R2 with high positive SCA effects for seed yields was considered as good combinations. Although some of parents had significant GCA effects for plant height but non of cross combinations had significant SCA effects for this trait, therefore additive genetic effects have more important role for genetic controlling of this trait. None of the crosses had significant SCA effects for seed yield and the crosses including RW x R1 and Sarigol x R2 with high positive SCA effects for seed yield were favored. Similarly, in earlier studies were reported the important SCA effect of crosses for seed yield in on rapeseed cultivars (Amiri-Oghana *et al*., 2009; Huang *et al*., 2010; Sabaghnia *et al*., 2010; Rameeh, 2011).

Heterobeltiosis

The result of high parent heterosis (heterobeltiosis) effects of crosses for all the traits is presented in Table 5. Out of 12 crosses, 10 crosses had significant negative heterobeltiosis effects of days to flowering. The crosses including Sarigol x R1, Sarigol x R2 and RGS003 x R2 with high significant negative heterobeltiosis for days to flowering were considered as good combinations. The combination RW x R1 with significant positive heterobeltiosis effect of days to complete flowering was considered as good combination. Significant positive heterobeltiosis effect of duration of flowering was detected for RGS003 and RW x R2, therefore these crosses were suitable for increasing this trait. Significant negative heterobeltiosis of days to maturity was displayed for RGS003 x R2. The variation of cross combinations for heterobeltiosis of days to flowering and days to complete effects were more than their respective SCA effects. Early flowering in brassica can provide adequate time for seed formation process and can certainly cause early maturity and higher yields, therefore negative heterosis is desirable for days to flowering. Similarly, earlier study (Nassimi, *et al.*, 2006a) was reported significant negative mid-parent and better-parent heterosis for days to 50% flowering and physiological maturity. In this study mid parent heterosis for days to 50% flowering and physiological maturity ranged from -0.04 to -2.78 and -0.01 to -3.06, respectively and also its high parent heterosis for these traits ranged from -0.92 to -2.78 and -0.01 to -4.08, respectively. Most of the crosses had significant negative heterobeltiosis for days to flowering, therefore non additive genetic effects make decreasing of this trait in F1 generation of rapeseed. Due to high narrow sense heritability estimates for all the traits except days to flowering, most of the crosses had non significant heterobeltiosis effects except days to flowering. Significant positive correlation was detected between mean performance and heterobeltiosis for all the phenological traits except days to maturity, therefore any selection based on heterobeltiosis effects of these traits will be effective on mean performance of these traits except days to maturity.

Table 5: High parent heterosis for phenological traits, plant height and seed yield in crosses of two testers and six lines of rapeseed

Crosses	Days to flowering	Days to Complete Flowering	Duration of flowering	Days to maturity	Plant height	Seed yield
1-Sarigol x R1	-19**	-11.00**	1.00	-3.00	-18.78**	-416.54
2-RGS3006 x R1	-10*	-5.00	3.00	4.00*	12.72**	892.22**
3-RGS003 x R1	-2	-8.00*	-5.00	4.00*	7.78	233.33
4-19H x R1	-15**	-8.00*	-2.00	0.00	-6.56	-81.11
5-RW x R1	9	14.00**	2.00	1.00	-4.45	472.19
6- Option x R1	-13**	-7.67*	1.00	-1.00	0.97	378.11
7-Sarigol x R2	-20**	-11.00**	-4.00	-3.00	-11.89**	479.01
8-RGS3006 x R2	-11*	-8.00**	-3.00	-3.00	9.38*	1255.56**
9-RGS003 x R2	-17**	-3.00	14.00**	-4.00*	6.22	355.56
10-19H x R2	-16**	-2.00	1.00	-3.00	-9.56*	105.22
11-RW x R2	-13**	0.00	6.00*	0.00	5.00	210.93
12-Option x R2	-6	-5.00	-7.00*	-1.00	6.67	524.97
LSD(α=0.05)	9.33	7.38	5.92	3.60	9.18	575.53
LSD(α=0.01)	12.58	9.95	7.98	4.86	12.37	775.83

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

The crosses including Sarigol x R1 and Sarigol x R2 with the significant negative heterobeltiosis of plant height were suitable for decreasing this trait. Significant positive heterobeltiosis of seed yield was determined for RGS3006 x R1 and RGS3006 x R2, therefore these crosses were suitable for increasing seed yield. Significant correlation between heterobeltiosis effects of seed yield and their respective mean performances of the crosses, indicating selection of the crosses based on heterobeltiosis can be indirect selection for high seed yield cross combinations

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