Research Article

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Heterobeltiosis and interrelationship of some of important quantitative traits in oilseed rape genotypes

Abstract: Half diallel crosses of eight spring genotypes of oilseed rape (*Brassica napus* L.) were considered to evaluate heterobeltiosis effects of plant height, yield component characters, seed yield and harvest index. Significant mean squares of general and specific combining abilities (GCA and SCA) were determined for all the traits except 1000-seed weight demonstrating prominence of additive and non additive genetic effects for the mentioned traits. Narrow-sense heritability estimates were high for siliquae on main raceme and 1000-seed weight representing the major importance of additive genetic effects for the characters. Most of the crosses with significant positive high parent heterosis for seed yield had also significant heterotic effects for siliquae per plant; therefore, this trait can be considered as indirect selection criterion for enhancing seed yield. Seed yield was significantly correlated with the traits including plant height, siliquae on main raceme and siliquae per plant based on mean performances of the traits and this result was confirmed with correlations based on heterobeltiosis. The crosses including L41×LF2 and L31×L401 with highly significant heterobeltiosis estimates of grain yield were superior combinations for breeding this trait. which proved good specific combiners for most of the traits.

Keywords: Additive; diallel; heterobeltiosis; selection criterion

1 Introduction

Oilseed rape (*Brassica napus* L.) is an important oilseed crop in the world, as a result of its high quality oil and meal and its potential as a renewable resource for *bioproducts* and biofuel (Downey and Rimer **19**93; Oghan et al. 2016). The successes of hybrid breeding are the reason for its expansion in all major fields of agriculture (Mather and Jinks 1982; Rameeh 2014b). For developing a hybrid, as a first step information about genetic control of important characters is necessary. For this purpose, genetic information on heterosis is useful for developing breeding strategies to meet the demands of increased varieties (Mather and Jinks 1982). Heterosis and heterobeltiosis have comprehensively been explored and utilized for improving various quality traits in different crops. Therefore, information about the nature of GCA of parents and heterosis of their cross combinations have important role in the hybridization program in different environmental conditions (Marjanovic-Jeromela et al. 2007; Hashemi Ameneh et al. 2010: Khan et al. 2008).

Assessment of genetic component parameters for yield associated traits can also be important for indirect selection for seed yield (Downey and Rimer 1993; Nassimi et al. 2006b; Teklewold and Becker 2005) and the correlation of the traits is important to determining selection criteria (Shen et al. 2002; Rameeh et al. 2004; Qian et al. 2007; Huang et al. 2010; Rameeh 2010; Sabaghnia et al. 2010; Singh et al. 2010). Heterosis refers to the phenomenon that progeny of diverse genotypes of a species or crosses between species exhibit greater biomass, yield component characters and seed yield than both parents (Mather and Jinks 1982). Despite the successful establishment of heterosis in many agronomic crops, there is still challenge between the use of agricultural heterosis and our understanding of the genetic basis of heterosis, which inhibits the effective use of this biological occurrence (Brandle and McVetty 1990; Katiyar et al. 2000). Breeding for heterosis is one of the most successful technology options that involves improving the variety of prod-

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ucts. Heterosis can be visualized in terms of increase in strength, size, productivity, and resistance to diseases and pests of insects or climatic forces. One of the basic requirements for creating hybrid varieties in Brassica, has been proved to be heterosis. It is often observed that heterosis can be better expressed, although the crosses include the native or adapted and strange germplasm parents (Riaz et al. 2001; Rameeh 2014a). Improvement of hybrid varieties has been popular in many *Brassica* species. Mid-parents and heterobeltiosis have expansively been explored and utilized for enhancing various quantity and quality traits in oilseed rape (Teklwold and Becker 2005; Zhang and Zhu 2006). Heterosis is commercially exploited in oilseed rape and its potential use has been demonstrated in Indian mustard (*B. juncea* L.) and turnip rape (*B. rapa* L.) and for grain yield and most of the agronomic characteristics For seed yield in spring oilseed rape hybrids, an average heterobeltiosis of 30% with a range of 20 to 50% was detected, while for winter oilseed rape hybrids an average high parent heterosis of 50% was reported, ranging from 20 to 80% as reviewed by McVetty (1995).

Keeping in view the importance of edible oil and its inappropriate condition in the country, the present study was aimed to evaluate eight oilseed rape genotypes for heterotic effects and identify their potential hybrids for developing new genotypes.

2 Material and methods

2.1 Plant material, study site and experimental design

Eight genotypes of oilseed rape including L41, Zafar, L56, L31, L22, LF2, L420 and L401, which were prepared by Mazandaran Agricultural and Natural Resources Research and Education Center, were crossed in half diallel mating design at Bayekola Agriculture Research Station, located in Neka, Iran (13º53′ E longitude and 43º36′ N latitude, 15 m above sea level) during winter during 2011–12.

Twenty-eight F_1 offspring along with eight parents were planted in a randomized complete block design with three replications during 2012–13. The plots consisted of four rows of 5 meters and a distance of 40 cm and a spacing of plants in each row of 5 cm. The soil was classified as a deep loam soil (Typic Xerofluents, USDA classification) enclosed 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 of mineral nitrogen (N) in the profile above 30 cm. The farm experiment received 50 kg ha⁻¹ P, 75 kg ha⁻¹ K and 100 kg ha⁻¹ N. All the plant protection measures were adopted to make the crop free from insects.

2.2 Variables studied

Grain yield (kg ha⁻¹) was recorded based on two middle rows of each plot. Plant height and yield components including siliquae in the main raceme, siliquae per plant, seed per siliqua and 1000-grain weight were measured based on 10 randomly selected plants per plot

Harvest index was determined by using the following formula:

Harvest index = [(economical or seed yield/ biological yield)] × 100

2.3 Statistical analysis

The combining ability analysis was conducted as outlined by Griffing (1956) method-II with mixed-B model. The least significant difference (LSD) was used to test the significance of the heterosis from high parent values (heterobeltiosis). All the analyses were performed by using MS-Excel and SAS software version 9.2.

Ethical approval: The conducted research is not related to either human or animal use.

3 Results and discussion

3.1 Diallel analysis of variance

Significant mean squares of GCA for the parents were found for the characters including plant height, siliquae per main raceme, siliquae per plant, seeds per siliquae, 1000-seed weight, seed yield and harvest index indicating the importance of additive genetic effects for these traits (Table 1). Significant mean squares of SCA of the crosses were found for all the traits except 1000-seed weight, demonstrating non-additive genetic effects also had important role for controlling the traits except 1000-seed weight.

High value of narrow-sense heritability estimates for 1000-seed weight, signifying that additive effect was controlling the inheritance of the trait. Similarly, significant GCA and SCA effects were reported for some important agronomic traits in *Brassica napus* (Downey and Rimer

1993; Amiri-Oghana et al. 2009; Rameeh 2010) and other brassica species (Nassimi et al. 2006b).

3.2 Means of the parents and their cross combinations

Means of parents and their F_1 combinations are shown in Table 2 and Table 3, respectively. The means of parents for plant height ranged from 139 to 180 cm in L401 and L420, respectively. The genotypes with low mean value of plant height will be more resistance to lodging, therefore, the parent including L401, L31 and LF2 with 139, 147 and 156 cm and also the crosses such as LF2×L401, L41×L31 and L22×L401 with 134, 141 and 144 cm of plant height, respectively, will be preferred. Siliquae on main raceme was significantly correlated with seed yield (Table 4), therefore high mean value of siliquae on main raceme will be leading up high mean

value of seed yield. The genotypes such as L56, L22 and Zafar with 64, 63 and 57 siliquae on main raceme are suitable for improving siliquae on main raceme. The cross combinations maintain Zafar×L40, L41×L22, L41×L56, L41×LF2, Zafar×L56, Zafar×L22 and L56×L22 with 65, 63, 62,62, 62, 62 and 61 siliquae on main raceme considered as merit combinations for this trait (Table 3). Most of crosses with high mean performance of siliquae on main raceme had at least one parent with high mean value of the trait. Siliquae per plant was significantly correlated with seed yield, therefore this trait can be good criterion for improving seed yield (Table 4). The parents comprising L22, L41 and Zafar with 158, 140 and 137 siliquae per plant were good candidate for improving seed yield. The crosses Zafar×L401, Zafar×L420, L41×LF2 and L31×LF2 with 177, 173, 172 and 172 siliquae per plant were superior combinations for improving this trait. Seeds number per siliqua is one of three components (including siliqua number and

Table 1: Analysis of variance of plant height and yield components for oilseed rape genotypes based on Griffing's method two with mixed-B

Source of variance	df	Plant height	Siliquae on main raceme	Siliquae per plant	Seeds per siliqua	1000-seed weight	Seed yield	Harvest index
Rep	2	275.3	79.8	78.7	115.4**	0.14	1571000**	6.7
Crosses	35	593.7**	359.4**	1417.3**	18.9**	0.22**	387481**	58.2**
GCA	7	1524.9**	1181.6**	1610.2**	37.3**	0.75**	975122**	76.2**
SCA	28	360.4**	153.8**	1369.1**	14.3*	0.08ns	240570**	53.8**
Error	70	151.1	27.5	103.8	8.4	0.08	64580	3.9
MS(GCA)/MS(SCA)		4.23*	7.28**	1.18	2.61*	9.38**	4.05*	1.42
.h²N		0.39	0.57	0.03	0.24	0.63	0.38	0.08

* and **: significant at 5% and 1% levels of probability, respectively.

Table 2: Mean performance of yield and yield-components of eight oilseed rape genotypes

Parents	Plant height (cm)	Siliquae on main raceme	Siliquae per plant	Seeds per siliqua	1000-seed weight(g)	Seed yield (kg ha⁻¹)	Harvest index
L41	165	54	140	28	3.81	2929	21.62
Zafar	172	57	137	27	4.08	2925	19.88
L56	175	64	130	21	4.31	2867	21.95
L31	147	52	119	22	3.96	2188	19.71
L22	161	63	158	25	3.73	3121	30.81
LF2	156	28	112	29	4.29	2738	23.27
L420	180	40	130	26	3.94	2613	22.22
L401	139	24	94	20	3.84	2083	24.44
LSD(P=0.05)	19.87	8.48	16.47	4.69	0.46	410.84	3.19
LSD(P=0.01)	26.20	11.18	21.71	6.18	0.60	541.65	4.21

Table 3: Comparison of mean for yield components and seed yield in half diallel crosses of eight oilseed rape genotypes

Crosses	Plant height (cm)	Siliquae on main raceme	Siliquae per plant	Seeds per siliqua	1000-seed weight(g)	Seed yield (kg ha⁻¹)	Harvest index
L41×Zafar	167	55	145	28	4.22	2839	22.84
L41×L56	174	62	136	25	4.30	3181	26.63
L41×L31	141	48	138	26	3.58	2316	20.21
L41×L22	164	63	156	29	3.64	3413	28.25
L41×LF2	169	62	172	25	4.44	3400	31.57
L41×L420	188	57	162	24	3.95	3000	27.15
L41×L401	174	47	154	28	3.71	2908	21.35
Zafar×L56	184	62	139	27	4.35	3031	25.68
Zafar×L31	156	49	129	24	3.75	2674	21.27
Zafar×L22	162	62	145	29	3.81	3348	30.73
Zafar×LF2	166	54	146	22	4.22	2513	19.10
Zafar×L420	164	45	173	23	3.91	3311	33.68
Zafar×L401	193	65	177	24	3.72	2975	18.48
L56×L31	156	56	139	24	4.24	2302	19.52
L56×L22	171	61	148	20	3.86	3287	28.12
L56×LF2	154	48	124	28	4.43	2915	21.89
L56×L420	152	46	105	25	3.74	2696	26.88
L56×L401	148	36	96	22	3.85	2197	18.34
L31×L22	151	52	145	25	3.53	2627	21.85
L31×LF2	150	44	172	22	3.94	2512	23.79
L31×L420	148	34	112	25	3.67	2538	26.13
L31×L401	145	47	166	23	3.45	2813	24.07
L22×LF2	147	37	112	26	4.13	2728	25.40
L22×L420	166	55	106	28	3.80	2414	19.38
L22×L401	144	47	143	23	3.75	2883	33.51
LF2×L420	152	39	131	27	4.25	3080	27.98
LF2×L401	134	38	125	24	4.10	2546	19.64
L420×L401	161	34	125	25	3.75	2365	18.93
LSD(P=0.05)	19.87	8.48	16.47	4.69	0.46	410.84	3.19
LSD(P=0.01)	26.20	11.18	21.71	6.18	0.60	541.65	4.21

grain weight) of yield and an important target characteristic of breeding in oilseed rape. As with other crops, seeds number per siliqua is usually negatively correlated with the other two yield components. These trade-offs are usually clarified as competition among sinks. Genetically, the correlation between traits is generally considered to be either genetic linkage or pleiotropy (Mather and Jinks 1982). LF2, L41 and Zafar with 29, 28 and 27 seeds per siliquae were superior parents and also the crosses including L41×L22, Zafar×L22,

L41×L401, L41×Zafar, L56×LF2 and L22×L420 with 29, 29, 28, 28, 28 and 28 seeds per siliquae were superior genotypes.1000-seed weight ranged from 3.73 to 4.31 in L22 and L56, respectively. L56, LF2 and Zafar with 4.31, 4.29 and 4.08g of 1000-seed weight were detected as good parents for breeding this trait. Most of the crosses with high mean value of 1000-seed weight had at least one parent with high mean value of this trait. Seed yield of parents varied from 2083 to 3121 kg ha⁻¹ in L401 and L22, respectively, and it ranged from 2197

Table 4: Pearson correlation coefficient estimates of seed yield and its components based on means of the crosses

Traits	Plant height	Siliquae on main raceme	Siliquae per plant	Seeds per siliqua	1000-seed weight	Seed yield	Harvest index
Plant height	1						
Siliquae on main raceme	0.65**	1					
Siliquae per plant	0.44*	0.51**	1				
Seeds per siliqua	0.11	0.17	-0.17	1			
1000-seed weight	0.21	0.18	-0.04	0.11	1		
Seed yield	0.48**	0.57**	0.53**	0.23	0.20	1	
Harvest index	0.06	0.19	0.31	0.03	0.09	0.76**	1

* and **: significant at 5% and 1% levels of probability, respectively.

to 3413 kg ha⁻¹ in L56×L401 and L41×L22, respectively. The crosses including L41×L22, L41×LF2, Zafar×L22, Zafar×L420 and L56×L22 with 3413, 3400, 3348, 3311 and 3287 kg ha⁻¹ were good combinations for improving this trait. One of the important oilseed rape breeding is to develop varieties which combine high seed yield with high harvest index. Among the yield components, siliquae per plant significantly correlated with seed yield (Table 4). Harvest index varied from 19.71 to 30.81 in L31 and L22, respectively, this trait ranged from 18.31 to 33.68 in L56×L401 and Zafar×L420, respectively. The crosses including Zafar×L420, L22×L401, L41×LF2 and Zafar×L22 with 33.68, 33.51, 31.57 and 30.75 of harvest index were good combinations for improving this trait.

3.3 Heterobeltiosis

The result of heterobeltiosis effects of crosses for the studied traits are presented in Table 6. Out of 28 crosses, 8 crosses had significant negative heterobeltiosis effects for plant height. Due to low mean value of plant height has direct effect on resistance to lodging, the crosses including L41×L31, L56×L420, L56×L401, L31×L420 and LF2×L420 with highly significant negative heterobeltiosis effects considered as superior combinations (Table 5). Significant positive correlation was detected between heterobeltiosis effects of siliquae on main raceme and seed yield (Table 6), therefore, heterobeltiosis effects of siliquae on main raceme can be suitable selection criterion for improving seed yield. Out of 28 crosses, 6 crosses had significant positive heterobeltiosis effects of siliquae per plant. The crosses viz. L41×LF2, L41×L420, Zafar×L420, Zafar×L401, L31×LF2 and L31×L401 with highly significant positive heterobeltiosis effects for siliquae per plant were considered

as preferred crosses for improving this trait. Non of the cross combinations had significant positive heterobeltiosis effects for seeds per siliqua. Due to high narrow-sense heritability estimates for 1000-seed weight, none of the cross combinations had also significant positive heterobeltiosis effects for this trait. L41×Zafar and Zafar×L56 had positive heterobeltiosis effects for seeds per siliqua and 1000-seed weight, simultaneously. Out of 28 crosses, 7 crosses had significant heterobeltiosis effects for seed yield. The crosses including L41×LF2 and L31×L401 with high significant positive heterobeltiosis effects for seed yield were superior combinations for improving this trait.

Mid parents heterosis and heterobeltiosis have been widely investigated and used to increase the qualitative and qualitative characteristics of oilseed rape (Nassimi et al. 2006a). Harvest index is a complex polygenic phenomenon that is strongly affected by both environmental and genotype factors. The implications of these results are that HI can be increased by reducing plant height or decreasing inefficient transport from siliquae to grains in oilseed rape. Harvest index is a complex polygenic phenomenon that is strongly influenced by both environmental and genotype factors. The implications of these results are that HI can be increased by decreasing plant height or reducing inefficient transport from siliquae to seeds in oilseed rape. Positive and significant correlation was determined between high parent heterosis effects of harvest index and grain yield (Table 6), therefore heterobeltiosis effects of harvest index can be suitable selection criterion for improving seed yield. The crosses including L41×L56, L41×LF2, L41×L420, Zafar×L56, Zafar×L420, L56×L420 and LF2×L420 with significant positive heterobeltiosis effects for harvest index considered as merit combinations for improving this trait.

Table 5: Heterobeltiosis of oilseed rape crosses for yield associated traits in half diallel crosses of eight oilseed rape genotypes

Crosses	Plant height (cm)	Siliquae on main raceme	Siliquae per plant	Seeds per siliqua	1000-seed weight(g)	Seed yield (kg ha^{-1})	Harvest index
L41×Zafar	-4.9	-2.1	5.4	0.5	0.14	-90	1.2
L41×L56	-1.8	-2.0	-4.0	-2.2	-0.01	252	4.7**
L41×L31	-23.7**	-6.5	-1.3	-1.6	-0.38	-613**	-1.4
L41×L22	-0.5	-0.4	-1.6	1.5	-0.17	292	-2.6
L41×LF2	4.7	7.5	31.8**	-4.5	0.15	471*	8.3**
L41×L420	8.4	3.3	22.2**	-3.7	0.01	71	4.9**
L41×L401	8.9	-6.9	13.8	0.6	-0.12	-21	-3.1
Zafar×L56	8.2	-1.6	1.4	0.9	0.04	106	3.7*
Zafar×L31	-16.3	-7.9	-8.2	-2.9	-0.33	-251	1.4
Zafar×L22	-9.6	-1.5	-12.2	2.1	-0.27	227	-0.1
Zafar×LF2	-6.5	-2.5	8.8	-7.2	-0.07	-413*	-4.2**
Zafar×L420	-15.7	-12.1**	35.5**	-3.4	-0.16	386	11.5**
Zafar×L401	20.4*	7.9	39.4**	-2.3	-0.36	50	-6.0**
L56×L31	-19.2*	-7.3	8.9	2.1	-0.07	-564**	-2.4
L56×L22	-4.1	-3.1	-9.4	-4.3	-0.45	167	-2.7
L56×LF2	-21.9*	-15.7**	-5.9	-1.8	0.12	49	-1.4
L56×L420	-27.8**	-18.0**	-25.1**	-1.2	-0.57*	-171	4.7**
L56×L401	-27.8**	-28.2**	-34.0**	1.1	-0.46*	-670**	-6.1**
L31×L22	-10.1	-11.1	-12.5	0.7	-0.43	-494*	-9.0**
L31×LF2	-6.2	-8.3	52.8**	-7.0**	-0.35	-226	0.5
L31×L420	-32.1**	-18.5**	-18.0*	-1.6	-0.29	-75	3.9
L31×L401	-2.6	-5.6	46.8**	0.8	-0.51*	625**	-0.4
L22×LF2	-13.9	-26.9**	-45.9**	-3.8	-0.16	-393	-5.4**
L22×L420	-13.4	-8.8	-51.1**	2.0	-0.14	-707**	-11.4**
L22×L401	-16.7	-16.8**	-14.8	-1.4	-0.09	-238	2.7
LF2×L420	-27.8**	-1.4	1.7	-2.2	-0.04	342	4.7**
LF2×L401	-21.7*	10.3	13.3	-5.4*	-0.19	-191	-4.8**
L420×L401	-18.9	-6.1	-5.0	-0.9	-0.19	-247	-5.5**

Based on least significant test (LSD); * and **: significant at 5% and 1% levels of probability, respectively.

4 Conclusion

Significant mean squares of SCA of the crosses were determined for all the traits except for 1000-seed weight demonstrating that except for 1000-seed weight, non-additive genetic effects had also an important role for controlling the traits. High narrow-sense heritability estimates for 1000-seed weight indicating prime importance of additive genetic effects, therefore, none of crosses had significant heterobeltiosis effect for this trait. The same trend was determined for correlation between both traits based on mean performance and heterobeltiosis. Siliquae on main raceme and siliquae per plant were highly correlated with seed yield from aspect of correlation of mean performance and heterobeltiosis.

Table 6: Pearson correlation coefficient estimates of seed yield and its components based on heterobeltiosis of the crosses

Traits	Plant height	Siliquae on main raceme	Siliquae per plant	Seeds per siliqua	1000-seed weight	Seed yield	Harvest index
Plant height	1						
Siliquae on main raceme	0.58**	1					
Siliquae per plant	0.49**	0.57**	1				
Seeds per siliqua	-0.05	-0.19	-0.36	1			
1000-seed weight	0.24	0.31	0.08	-0.06	1		
Seed yield	0.40*	0.44*	0.54**	-0.08	0.20	1	
Harvest index	0.01	0.11	0.39*	-0.24	0.29	0.62**	1

* and **: significant at 5% and 1% levels of probability, respectively.

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