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COMBINING ABILITY FOR MATURITY AND PLANT HEIGHT IN *BRASSICA RAPA* (L.) SSP. *DICHOTOMA* (ROXB.) HANELT

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Abstract

A 5 × 5 F_1 diallel cross hybrids of *Brassica rapa* (L.) ssp. *dichotoma* (Roxb.) Hanelt along with parents were evaluated through combining ability for days to flowering (initiation and completion), days to maturity and plant height. Highly significant differences were recorded for all the traits. Mean squares due to general, specific and reciprocal combining ability were significant for all the traits except plant height for which the latter two components were non-significant. Prevalence of additive (plant height), non-additive (days to flowering completion; days to maturity) and reciprocal effects (days to flowering initiation) were detected. Parental line G-403 was best general combiner for all the traits. The F_1 hybrids G-902 × G-265 (days to flowering initiation), G-902 × G-403 (days to flowering completion), G-265 × G-1500 (days to maturity) and G-909 × G-265 (plant height) were superior and may be exploited for future breeding programs.

Key words: *Brassica rapa*, Diallel, Combining ability, Maturity, Plant height.

Introduction

Brassica occupies a prominent place in world's agrarian economy as vegetables, oilseed, feed, fodder, green manure and condiment (Malode *et al.,* 2010). In Pakistan rapeseed and mustard is a major oil seed crop along with others. *Brassica napus* (canola) is generally has lower levels of glucosinolates and erucic acid, better in oil content and quality than rapeseed cultivars, but late maturing and susceptible to insects, particularly aphids (Ahmad *et al*., 2012).The domestic production cannot meet the national requirements and a considerable proportion is imported (Fayyaz *et al*., 2014). There is a huge production consumption gape which can be reduced by breeding improved cultivars (Azam *et al*., 2013) .The success in breeding programs of a crop species largely relies on the presence of genetic diversity in the germplasm and knowledge about the inheritance of various characteristics of the genotypes (Moghaddam *et al.,* 2009). Early maturity and short stature variables are desirable from breeding perspective. Early harvest of *Brassica* is desirable to escape the crop from disease and aphid attack that normally coincides with the flowering stage (Kaur *et al.,* 2009). Plant height is critical with respect to yield and agronomic parameters. Generally the dwarf varieties being resistant to lodging and more responsive to fertilizer were found high yielder than the tall ones (Rahman *et al.,* 2009).

Combining ability is a principal scheme to test the knack of the different inbred lines for substantiating their inclusion in future breeding programs on the basis of their GCA, SCA and RCA. Combining ability is the relative ability of an inbred to transmit desirable characteristics to its hybrids. GCA is "the average performance of a line in a series of hybrid combinations" whereas in SCA "certain combinations do relatively better or worse than would be expected on the basis of the average performance of the lines involved" (Sprague & Tatum, 1942). Breeding strategies may not result in appreciable improvement in the dearth of genetic variability and the knowledge of gene action operating in trait expression (Cheema & Sadaqat, 2004). In addition to identification of promising cross combinations, the combining ability is used to get information on inheritance of various traits of interest (Suchindra & Singh, 2006; Parmar *et al.,* 2011). GCA component is largely a function of additive x additive genetic variance and that of SCA is prevalently due to non-additive genetic variance (dominance variance) but either would include various type(s) of epistatic interactions if it exists. The present study was therefore aimed to identify the superior general and specific combiners and to determine the mode of gene actions operative in expression of various traits.

Materials and Methods

The experiment was conducted during crop season 2011-12 at The University of Agriculture, Peshawar, Pakistan. Twenty five *Brassica rapa* (L.) ssp. *dichotoma* (Roxb.) Hanelt (syn. *B. campestris* var. brown sarson) genotypes (20 F_1 hybrids + 5 parental lines) were planted in a randomized complete block design with two replications. Each genotype was planted in two rows with row length of 4 meters each. Rows and plants spacing were kept 50 and 30 cm, respectively. Recommended cultural practices were followed from sowing till harvesting. Data were recorded and analyzed through Steel and Torrie (1980) and combining ability analysis was carried out according to Griffing (1956) Method-I, based on Eisenhart's Model-II.

Results

According to analysis of variance, highly significant differences were recorded for all the traits (Table 1), and then the data were subjected to combining ability analysis. The GCA, SCA and RCA mean squares were significant for all the traits except plant height for which the latter two components were non-significant (Table 2). The various effects, operative and prevalent mode of gene action are detailed below:

Days to flowering initiation: Negative combining ability effects for days to flowering initiation are desirable. The three parental lines exhibited negative GCA effects viz., G-403 (-1.79), G -265 (-1.64) and G -902 (-0.74). The maximum positive GCA effect of 3.61 was recorded for genotype G-1500 followed by G-909 (0.56) (Table 3). The two F_1 hybrids exhibited negative SCA effects. The highest negative SCA effects -2.26 were noted for F_1 hybrid G -403 × G-1500 followed by -1.36 (G-909 × G-1500) whereas F_1 cross combination G-902 × G-1500 acquired maximum positive SCA effect (8.94) (Table 4). The RCA effects for two F_1 crosses were negative, the highest being -10.50 (G-902 × G-265) followed by G-1500 × G-403 (-0.50). The maximum positive RCA value of 17.50 was noted for G-909 × G-265 (Table 5). Additive, non-additive and cytoplasmic effects were operative as revealed by significant mean squares (Table 2). Relative variances due to GCA (σ^2_{GCA}), SCA (σ^2_{SCA}), RCA (σ^2_{RCA}) and ratio $\sigma^2_{GCA}/\sigma^2_{SCA}$ were of magnitude -7.95, 77.2, 135.1 and -0.103, respectively indicated prevalence of maternal effects in said trait expression (Table 6).

Table 1. Mean squares various traits in *B. rapa* (L.) ssp. *dichotoma* (Roxb.) Hanelt.

Plant traits	Mean squares		
	Treatment	Error	CV (%)
Days to flowering initiation	358.7**	10.8	4.9
Days to flowering completion	376.2**	7.66	2.4
Days to maturity	41.2**	4.3	1.2
Plant height	408.2**	142.5	6.96

Table 2. Mean squares of combining ability for various traits in *B. rapa* (L.) ssp. *dichotoma* (Roxb.) Hanelt.

Variables	Mean squares			
	GCA (df=4)	SCA (df=10)	RCA (df=10)	Error (df=24)
Days to flowering initiation	49.47**	135.2**	275.5**	5.39
Days to flowering completion	257.4**	210.1**	138.4**	3.83
Days to maturity	17.37**	28.28**	14.25**	2.165
Plant height	727.0**	85.43ns	113.6ns	71.25

Table 3. General combining ability effects for various traits in *B. rapa* (L.) ssp. *dichotoma* (Roxb.) Hanelt.

Genotypes	Days to flowering initiation	Days to flowering completion	Days to maturity	Plant height
G-265	-1.64	0.37	-1.06	4.88
G-403	-1.79	-8.43	-1.01	-5.32
G-902	-0.74	1.17	-0.81	1.31
G-909	0.56	1.62	1.44	10.44
G-1500	3.61	5.27	1.44	-11.31
S.E(gi) ±	0.66	0.55	0.42	2.39
S.E(gi-gj) ±	1.04	0.88	0.66	3.77

Table 4. Specific combining ability effects for various traits in *B. rapa* (L.) ssp. *dichotoma* (Roxb.) Hanelt.

F_1 hybrids	Days to flowering initiation	Days to flowering completion	Days to maturity	Plant height
G-265 × G-403	6.24	5.93	0.71	6.10
G-265 × G-902	2.94	7.83	4.01	0.05
G-265 × G-909	4.64	3.88	4.01	-1.21
G-265 × G-1500	2.84	-5.52	-2.49	-8.14
G-403 × G-902	3.09	7.88	2.96	-6.32
G-403 × G-909	3.79	1.43	1.46	-5.61
G-403 × G-1500	-2.26	10.28	1.21	-7.23
G-902 × G-909	3.99	5.08	-1.49	-2.74
G-902 × G-1500	8.94	-2.07	2.26	1.76
G-909 × G-1500	-1.36	3.73	0.76	6.13
S.E (Sii) ±	1.35	1.14	0.86	4.92
S.E (Sik-Skl) ±	1.80	1.52	1.14	6.54

Table 5. Reciprocal combining ability effects for various traits in *B. rapa* (L.) ssp. *dichotoma* (Roxb.) Hanelt.

F_1 hybrids	Days to flowering initiation	Days to flowering completion	Days to maturity	Plant height
G-403 × G-265	12.25	-7.25	-2.50	-8.49
G-902 × G-265	-10.50	-6.25	-1.00	-5.68
G-902 × G-403	1.00	-9.00	1.00	-1.80
G-909 × G-265	17.50	5.75	3.75	-15.00
G-909 × G-403	12.00	12.00	1.75	-14.45
G-909 × G-902	15.75	8.75	1.50	-0.55
G-1500 × G-265	9.25	14.50	5.25	0.63
G-1500 × G-403	-0.50	-5.50	1.00	3.63
G-1500 × G-902	8.25	2.25	3.75	-2.20
G-1500 × G-909	16.25	4.50	-1.00	2.80
S.E (rij) ±	1.64	1.38	1.04	5.97
S.E (rij-rkl) ±	2.32	1.96	1.47	8.44

Table 6. Estimates of variances due to GCA, SCA and RCAfor various traits in *B. rapa* (L.) ssp. *dichotoma* (Roxb.) Hanelt.

Variables	σ^2_{GCA}	σ^2_{SCA}	σ^2_{RCA}	σ^2_e	$\sigma^2_{GCA}/\sigma^2_{SCA}$
Days to flowering initiation	-7.95	77.2	135.1	5.39	-0.103
Days to flowering completion	5.72	122.8	67.3	3.83	0.047
Days to maturity	-0.967	15.54	6.04	2.165	-0.062
Plant height (cm)	64.22	8.438	21.16	71.25	7.611

Days to flowering completion: The parental line G-403 exhibited desirable negative GCA effect (-8.43), while four other genotypes revealed positive GCA effects ranged 0.37 (G-265) to 5.27 (G-1500) (Table 3). The two F_1 hybrids exhibited negative SCA effects. However, the maximum negative SCA effects were achieved by F_1 hybrid G-265 × G-1500 (-5.52) followed by G-902 × G-1500 (-2.07). The highest positive SCA effect of 10.28 was obtained by F_1 hybrid G-403 × G-1500 followed by G-403 × G-902 (7.88) (Table 4). RCA effects for four F_1 crosses were negative. However, the highest negative RCA effect of -9.00 was noted for G-902 × G-403 followed by G-403 × G-265 (-7.25). The F_1 hybrid G-1500 × G-265 attained maximum positive RCA effect (14.50) (Table 5). All the tree type of genetic effects viz., additive, non-additive and reciprocal were involved (Table 2). The ratios of σ^2_{GCA} (5.72), σ^2_{SCA} (122.8), σ^2_{RCA} (67.3) and $\sigma^2_{GCA}/\sigma^2_{SCA}$ (0.047) revealed predominance of non-additive effects for the trait under consideration (Table 6).

Days to maturity: For early maturity the negative combining ability effects are desirable. The three parents viz., G-265, G-403 and G-902 exhibited negative GCA effects of -1.06, -1.01 and -0.81, respectively (Table 3). The two F_1 hybrids exhibited negative SCA effects. However, the F_1 hybrid G-265 × G-1500 achieved the maximum negative SCA effects (-2.49) followed by G-902 × G-909 (-1.49). The maximum positive SCA effects (4.01) were noted for F_1 hybrids G-265 × G-902 and G-265 × G-909 (Table 4). The RCA effects for three F_1 crosses were negative, the highest being -2.50 for hybrid G-403 × G-265 followed by G-902 × G-265 and G-1500 × G-909. The maximum positive RCA effect was noted in cross combination G-1500 × G-265 (5.25) (Table 5). Significant mean squares indicated that all the three types of genetic effects were operative (Table 2). Relative magnitudes of σ^2_{GCA} (-0.967), σ^2_{SCA} (15.54), σ^2_{RCA} (6.04) and $\sigma^2_{GCA}/\sigma^2_{SCA}$ (-0.062) revealed preponderance of non-additive genetic control (Table 6).

Plant height: The negative combining ability effects for plant height are desirable, as dwarf plants are less likely to lodge and that's why more responsive to fertilizers. The two parents exhibited negative GCA effects, while maximum negative GCA effect (-11.31) was recorded for parental line G-1500 followed by -5.32 (G-403). The highest positive GCA effect of 10.44 was recorded for genotype G-909 (Table 3). The six F_1 hybrids exhibited negative SCA effects ranged -8.14 to -1.21. The desirable highest negative SCA effect was achieved by F_1 hybrid G-265 × G-1500 (-8.14) followed by G-403 × G-1500 (-7.23) whereas positive SCA effects was highest in F_1 hybrid G-909 × G-1500 (6.13) (Table 4). The reciprocal effects for seven F_1 hybrids were negative, ranged -15.00 to -1.80. The desirable highest SCA value was being -15.00 (G-909 × G-265) followed by G-909 × G-403 (-14.45). The maximum positive RCA effects of 3.63 were noted for F_1 hybrid G-1500 × G-403 (Table 5). Mean squares indicated that additive effects were operative in trait control (Table 2). Higher σ^2_{GCA} (64.22) compared to σ^2_{SCA} (8.438), σ^2_{RCA} (21.16) and $\sigma^2_{GCA}/\sigma^2_{SCA}$ (7.611) also depicted importance of additive genetic control (Table 6).

Discussion

Success of any crop improvement in response to selection and bioengineering programs mainly depends upon the magnitude of genetic variability (Iqbal *et al*., 2014; Akhtar *et al.,* 2007). Amiri-Oghan *et al.,* (2009) reported highly significant differences for days to 50% flowering and days to maturity. Vaghela *et al.,* (2011) reported significant differences for days to 50% flowering. Akbar *et al.,* (2008), Sincik *et al.,* (2011), Vaghela *et al.,* (2011) and Rameeh (2012) reported significant differences for plant height.

Significant GCA, SCA and RCA components indicated that additive, non-additive and maternal genetic effects were operative in traits expression, respectively. Predominance of one or more of these components determined by the relative magnitude of variance due to GCA (σ^2_{GCA}), SCA (σ^2_{SCA}) and RCA (σ^2_{RCA}). A trait exhibiting higher magnitude of σ^2_{GCA} compared to σ^2_{SCA} ($\sigma^2_{GCA}/\sigma^2_{SCA} \geq 1$) reveals prevalence of additive type of gene action. Whereas, the non-additive type of genetic control in trait expression is pre-dominant when variance of SCA is greater than that of GCA ($\sigma^2_{GCA}/\sigma^2_{SCA}<1$). Maternal effects are prevalent when the variance due to reciprocal effects is higher than GCA and SCA.

Highly significant GCA, SCA and RCA mean squares for days to flowering and completion are in conformity with earlier reports in Indian mustard (Aghao *et al.,* 2010; Singh *et al.,* 2010; Gupta *et al.,* 2011;Vaghela *et al.,*2011, rapeseed (Amiri-Oghan *et al.,* 2009) and Ethiopian mustard (Teklewold & Becker 2005). They reported highly significant GCA and SCA effects for days to 50% flowering. Huang *et al.,* (2010) documented highly significant GCA and SCA effects for days to 50% flowering. Non-significant GCA and SCA mean squares for days to flowering in yellow *sarson* reported by Singh *et al.,* (2001) are in partial conformity. Highly significant GCA, SCA and RCA mean squares were reported for days to 50% flowering (Suchindra & Singh, 2006). The findings of Nasrin *et al.,* (2011) for SCA were in partial contradiction to the present results as they reported significant GCA and non-significant SCA for days to 50% flowering.

Data perusal revealed highly significant GCA, SCA and RCA mean squares for days to maturity which are not in conformity with Aghao *et al.,* (2010). They reported non-significant GCA and SCA mean squares. However, the present findings are in partial conformity with earlier research work of Teklewold and Becker (2005) in Ethiopian mustard. They reported highly significant GCA and non-significant SCA for days to maturity. Highly significant GCA and SCA for days to maturity were reported in some earlier studies in Indian mustard (Acharya & Swain, 2004; Singh *et al.,* 2010; Gupta *et al.,* 2011; Vaghela *et al.,* 2011) and rapeseed (Amiri-Oghan *et al.,* 2009). Highly significant GCA (males), non-significant GCA (females) and SCA (males × females) effects for days to maturity were reported by Huang *et al.,* (2010). Significant GCA and SCA effects for days to maturity in yellow *sarson* were reported by Singh *et al.,* (2001). Results were in conformity with Suchindra and Singh (2006) as they reported highly significant GCA, SCA and RCA effects for days to maturity. Results are in continuity with Nasrin *et al.,* (2011) and documented significant GCA and SCA for days to maturity.

Combining ability analysis revealed highly significant GCA and non-significant SCA, RCA components for plant height (Table 2). The present results are in contrast to Aghao *et al.,* (2010), who revealed non-significant GCA and significant SCA effects for plant height. Highly significant GCA and SCA effects for plant height in Indian mustard (Acharya & Swain 2004; Singh *et al.,* 2010; Gupta *et al.,* 2011; Vaghela *et al.,* 2011), Ethiopian mustard (Teklewold & Becker, 2005) and *B. napus* (Akbar *et al.,* 2008) were reported previously which are in agreement for GCA effects of the trait under reference. Singh *et al.,* (2001) in yellow *sarson* and Nasrin *et al.,* (2011) in Indian mustard reported significant GCA and SCA for plant height which are in conformity for GCA and in contrast for SCA mean squares with current study. The GCA, SCA and RCA were highly significant for plant height as mentioned by Suchindra and Singh (2006) and Sincik *et al.,* (2011). However, Sincik *et al.,* (2011) also reported non-significant GCA and RCA mean squares in the genotype by environment interaction studies.

Akbar *et al.,* (2008) reported importance of non-additive genetic control for plant height. Gupta *et al.,* (2011) reported additive genetic effects were effective for managing days to 50% flowering, days to maturity and plant height. Parmar *et al.,* (2011) reported prevalence of additive effects for days to 50% flowering and days to maturity. Vaghela *et al.,* (2011) reported predominant role of non-additive genetic effects in inheritance of days to 50% flowering, days to maturity and plant height. Gupta *et al.,* (2006) indicated importance of additive genetic effects for days to maturity, plant height and non-additive for days to 50% flowering. Aher *et al.,* (2009) revealed prevalence of non-additive gene action in the expression of days to 50% flowering whereas additive gene action was vital for plant height. Acharya and Swain (2004) reported that additive and non-additive genetic control for days to maturity and plant height was equally important. Huang *et al.,* (2010) reported that both additive and non-additive control was operative, but additive genetic control was more prevalent for days to flowering.

Breeding methodologies based on type of gene action involved in trait expression are likely to fetch better results. Selection in early and late segregating generations was suggested for improvement of traits under additive and non-additive genetic control, respectively (Cheema & Sadaqat, 2004). Finding pre-dominance of non-additive control in trait expression, Vaghela*et al.,* (2011) recommended use of bi-parental mating pursued by reciprocal recurrent selection for likely increase in frequency of genetic recombinants and hastening the rate of improvement.

Conclusions

Non-additive genetic control, as predominant mechanism for traits i.e., days to flowering completion, days to maturity necessitates the use of schemes like diallel selective mating followed by recurrent or reciprocal recurrent selection. Plant height predominantly governed by loci with additive mechanism can be improved by simple pedigree method of post hybridization selection whereas crossing order should also be considered for days to flowering. The F_1 hybrids G-902 × G-265 (days to flowering initiation), G-902 × G-403 (days to flowering completion), G-265 × G-1500 (days to maturity) and G-909 × G-265 (plant height) were superior and may be exploited for future breeding programs.

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