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Identification of Transgressive Segregants for Yield and Its Components in Basil (*Ocimum basilicum* L.)

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The objective of this study was to estimate gene effects and identification of transgressive segregants for five quantitative traits of seven crosses of *Ocimum basilicum* L. *viz*. EC388788 × IC333322, EC387893 × IC326711, EC388896 × IC369247, EC388887 × IC386833, EC387837 × EC338785, IC369247 × IC370846 and IC344681 × IC326735 by generation mean analysis. In cases both type of epistasis (complementary and duplicate) model was sufficient to explain variation in generation means. Generation mean analysis with three parameter model with $\chi 2$ test indicated that additive-dominance model was inadequate for all the traits like number of inflorescence, length of inflorescence, fresh herb yield, dry herb yield and oil content in all the crosses used of six parameter models to estimate the gene effects. The observed frequencies of transgressive segregants for trait oil content (4.942), fresh herb yield (11.824), dry herb yield (13.97) and length of inflorescence (5.820). A comparison of generation mean analysis for observed and predicted frequencies of transgressive segregants indicated that the potential crosses for transgressive segregants were those that had additive and dominance gene effects. The adequacies of certain models of inheritance as well as the importance and significance of gene effects and identifications of transgressive segregants for analyzed traits were dependent upon the particular crossing combination and experimental site. The present study indicated that early generation selection is effective and should be practiced for future breeding programme.

Key Words: Gene effects, Generation mean analysis, Joint scaling test, *Ocimum basilicum*, Quantitative traits, Transgressive segregation

Introduction

The genus *Ocimum* of the family *Lamiaceae* is characterized by a great variability of morpho- and chemotypes (Balyan and Pushpangadan, 1988; Lawrence, 1988). The ease of cross-pollination leads to a large number of subspecies, varieties and forms (Guenther, 1949). The aromatic leaves of many *Ocimum* species are used fresh or dried as a flavouring agent for foods and as a remedy for many diseases, confectionery products and beverages. Traditionally, the basil plant has been used as medicine for its carminative, stimulant and antispasmodic properties. Based on chemical composition, several chemotypes of basil, like methyl cinematic, methyl chavicol, eugenol and linalool rich have been identified (Pareek *et al.,* 1982). Basil essential oil finds diverse uses in perfumery, pharmaceutical, cosmetics, food and flavour industries (Duglas, 1969). *Ocimum tenuiflorum* L. (the *tulsi)* leaf, when eaten, can control thirst, and so was invaluable to weary travellers (Lal *et al*., 2008; Lal, 2014). Generation mean analysis is a simple but useful technique for estimating gene effects for polygenic traits, its greatest merit lying in the ability to estimate epistatic gene effects such as additive x additive (aa), dominance x dominance (dd) and additive x dominance (ad) effects (Singh and Singh, 1997). Besides gene effects, breeders need information on the variation in a crop genepool and to what extent this variation is heritable, because efficiency of selection mainly depends on additive genetics variance, influence of the environment and genotype and environmental interaction (Lal *et al*., 2013). The estimates of genetic parameters can be used to predict the frequencies of transgressive segregants that would appear in a F_2 generation. In the present study, attempts were made to predict the frequencies of transgressive segregants for yield and its components using generation mean analysis (GMA) and to test the validity of predictions by isolating the transgressive segregants for traits in F_2 population and carried out to provide information about gene effects for the most important quantitative traits of basil.

Materials and Methods

The present study was conducted at the Research Farm, Department of Genetics and Plant Breeding (formerly,

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Agricultural Botany), Ch. Charan Singh University, Meerut during 2007-08 and 2008-09. Experimental material of this study comprised 13 accessions of basil (*Ocimum basilicum* L.) obtained from National Bureau Plant Genetic Resources (NBPGR), New Delhi. The selection of parents was made on the basis of contrasting traits like number of inflorescence, length of inflorescence, fresh herb yield, dry herb yield and oil content. Thirteen accessions used in the study were, EC388788, EC387893, EC388896, EC388887, EC338785, EC387837, IC369247, IC344881, EC333322, IC326711, IC386833, IC370846 and IC326735. The six basic generation of P_1, P_2, F_1, F_2, B_1 (F_1 x P_1) and B_2 (F_1x P_2) of seven crosses *viz*. (i) EC388788 × IC333322, (ii) EC387893 × IC326711, (iii) EC388896 × IC369247, (iv) EC388887 × IC386833, (v) EC387837 × EC338785, (vi) IC369247 × IC370846 and (vii) IC344681 × IC326735 selected on the basis of GMA were used to determine gene effects and to predict the frequencies of transgressive segregants.

Six basic generations were grown in a randomized block design with three replications. The data on quantitative traits of number of inflorescence, length of inflorescence, fresh herb yield, dry herb yield and oil content were recorded on five randomly selected plants in each of P_1, P_2 and F_1 generations, 15 randomly selected plants each of B_1 and B_2 and 30 randomly selected plants of F_2 generation. The essential oil was extracted from the air dried herb by hydro-distillation using Clevenger's apparatus for 2.5 h. The estimates of GMA following a three parameter model of Jinks and Jones (1958) with joint scaling test of Cavalli (1952) were carried out to estimate the presence or absence of nonallelic interaction. A six parameter model suggested by Hayman (1958) to estimate variance components to fit models of increasing complexity until an adequate description of the means were found as shown by non-significance in the $\chi 2$ test. The type of epistasis was determined only when dominance (d) and dominance x dominance (dd) effects were significant; when these effects had the same sign the effects were complementary while different sign indicated duplicate epistasis (Kearsey and Pooni, 1996). The significance of genetic parameters was tested by t-test. In order to identify transgressive segregants in F_2 population, a total of 30 plants in each F_2 population from each replication were taken randomly. The predicted and observed frequencies of transgressive segregants for different traits in F_2 population of seven crosses were compared and the validity of prediction was tested using χ^2 test (Jinks and Pooni, 1976 and 1980). The frequencies of transgressive segregants were predicted as described by Yadav *et al*. (1998), on the basis of GMA and F_2 families. The estimates of d and D, D and H and d, h, i, j, and l calculated from generation mean analysis and were used to determine the frequency of transgressive segregation in above populations (F_2 population). The significance of transgressive segregation was tested using $\chi 2$ test.

Results and Discussion

Analysis of Variance (ANOVA)

The ANOVA for five quantitative traits recorded for 13 parents (P_1, P_2, F_1,s, $F_{2's}$, $B_{1's}$ and $B_{2's}$) in the study are presented in Table 1. The mean squares due to treatment of all the five traits were highly significant, thereby, suggesting the presence of sufficient genetic variability in the materials under study.

Gene Effects

The GMA was performed for the additive – dominance model on six generation for all the traits (Table 2). The χ^2 (3d.f.) values were found to be significant in the six crosses except one cross (EC388788 × IC333322) for all the traits except for oil content in the three crosses EC388788 × IC333322, IC369247 × IC370846 and IC344681 × IC326735. In presence or absence of non-allelic interaction, rest of the traits were used in six parameters model to estimates of gene effects (Table 2). The additive component [d] was significant and pronounced for all

Table 1. Analysis of variance for five quantitative traits of 13 parents, F_1s F_2s, B_1s, and B_2s of seven crosses in basil

Source of variation	d.f.	Number of inflorescence	Length of inflorescence (cm)	Fresh herb yield (g)	Dry herb yield (g)	Oil content (%)
Replication	2	0.75	0.50	18848.00	3966.00	.020
Treatment	40	391.30**	48.82*	390958.40**	103503.00**	2.63**
Error	80	0.94	0.36	9650.60	9887.36	0.04

*, ** significant at 5% and 1% level of significance, respectively

Table 2. Estimates of genes obtained from three and six parameter model and observed and predicted frequencies of transgressive segregants in F_2 population for five traits of seven crosses in basil (*Ocimum basilicum* L.)

Model	Parameter	Traits				
		Number of inflorescence/ plant	Length of inflorescence (cm)	Fresh herb yield/plant (g)	Dry herb yield/plant (g)	Oil yield (%)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
		EC388788 x IC333322				
3-Parameter	m	91.37**±0.64	18.55**±0.64	2269.09**±0.64	1158.73**±0.60	3.45**±0.64
	[d]	19.83**±0.63	1.87**±0.63	68.09±0.63	-84.50**±1.18	0.10±0.63
	[h]	1.38±1.18	0.19±1.18	286.89**±1.18	-100.43**±1.18	0.07±1.18
χ2 (3 d.f.)	Epistasis	25.71**	12.10**	38522**	26556.91**	1.20
Observed frequencies	TS	0.115	0.260	11.824**	1.176	0.029
χ2 (5 d.f.) Expected frequencies	3.841					
6-parameter	m	82.34**±0.56	14.25**±0.17	1580.00**±18.55	790.00**±5.77	–
	[d]	24.53**±1.21	4.98**±0.47	21.66**±119.28	-277.00**±28.14	–
	[h]	66.74**±3.20	19.22**±1.22	2435.83**±902.62	1531.45**±66.60	–
	[i]	29.57**±3.10	7.48**±1.17	2070.00**±901.62	1059.33**±62.00	–
	[j]	31.30**±1.20	4.31**±0.51	-1591**±443.94	-265.71**±31.40	–
	[1]	38.40**±5.38	18.51**±0.21	18.51**±0.21	-2831±1800.00	1062.90**±127.06
Epistasis effects		C	C	………….	C	–
		EC387893 × IC326711				
3-Parameter	m	103.37**±0.64	21.39**±0.64	1960.04**±0.64	744.73**±0.64	2.72**±0.64
	[d]	-178**±0.63	-187**±0.63	-154.66**±0.63	27.66**±0.63	0.66±0.963
	[h]	-178**±0.63	1.14±1.18	-398.28**±1.18	52.03**±1.18	1.64±1.18
χ2 (3 d.f)	Epistasis	56.97**±1.18	9.26**	54617.95**	4994.75	8.22**
Observed frequencies	TS	0.315	0.137	7.034**	13.031*	0.048
χ2 (5 d.f). Expected frequencies	3.841					
6-parameter	m	82.40**±0.83	23.50**±0.26	2603.00**±26.03	1066.66**±44.09	1.69**±0.33
	[d]	15.00**±0.81	10.90**±0.79	127.33**±27.77	40.00±26.14	-3.60**±0.02
	[h]	27.76**±3.76	-11.53**±1.85	-968.33118.02	1361.00**±351.73	14.05**±0.02
	[i]	8.39**±3.76	-19.31**±1.84	985.33±118.02	1046.00**±183.96	-3.50**±0.01
	[j]	18.50**±0.92	19.13**±1.80	280.00**±32.39	271.66±296.27	1.37**±0.10
	[1]	30.86**±4.83	14.39**±0.74	3600.00**±161.30	1243.33**±933.66	0.44±0.46
Epistasis effects		C	D	C	C	–
		EC388796 x IC369247				
3-Parameter	m	96.05**±0.964	20.78**±0.64	24.82.06**±0.64	1156.60**±0.64	2.75**±0.64
	[d]	10.29**±0.63	-1.87**±0.63	-111.00**±0.63	45.73**±0.63	0.43±0.63
	[h]	18.38**±1.18	1.14±1.18	-254.60**±1.18	4.07**±1.18	1.64±1.18
χ2 (3 d.f)	Epistasis	67.19**	22.45**	1648**	9733.26**	8.23**
Observed frequencies	TS	0.005	0.086	2.216	13.976**	4.942**
χ2 (5 d.f. Expected frequencies	3.841					

(1)	(2)	(3)	(4)	(5)	(6)	(7)
6-parameter	m	89.60**±0.83	17.17**±0.50	1655.00**±47.69	802.00**±27.15	4.59**±0.33
	[d]	21.50**±0.77	6.21**±0.35	320.00±658.33	-63.33±76.73	-1.02**±0.34
	[h]	49.96**±0.37	13.85**±2.48	1900.00**±655.54	1896.50**±189.10	6.07**±1.33
	[i]	44.60**±3.60	15.04**±2.46	675.00**±314.06	1412.20**±188.02	7.12**±1.33
	[j]	-98.33**±4.79	-13.70**±2.84	3288.00**±658.33	-2532.34**±328.23	9.31**±1.38
	[1]	-98.33**±4.79	-13.70**±2.84	3288.00**±658.33	-2532.34**±328.23	9.31**±1.38
Epistasis effects		D	D	C	D	C
			EC388887 x IC386833			
3- Parameter	m	90.49**±0.64	19.85*±0.64	2373.20**±0.64	997.24**±0.64	3.48**±0.64
	[d]	-2.81**±0.63	-3.43**±0.63	144.40**±0.63	-0.23±0.63	-0.23±0.63
	[h]	1.58±1.18	-3.01**±1.18	-357.40**±1.18	220.24**±1.18	0.51±1.18
χ2 (3 d.f)	Epistasis	30.71**	28.64**	73666.62**	24476.6**	1.33
Observed frequencies	TS	4.791**	0.568	12.52**	8.255**	0.278
χ2 (5 d.f). Expected frequencies	3.841					
6-parameter	m	93.86**±0.83	18.14**±0.50	2327.27**±14.05	1052.89**±37.78	–
	[d]	14.43**±0.61	-7.81**±0.46	-632.00**26.55	-418.80**±32.77	–
	[h]	31.38**±2.11	9.35*±2.43	-1285.00**±79.09	-197.12±183.36	–
	[i]	21.48**±1.78	10.30**±2.39	1445.00**±77.35	-309.00±164.00	–
	[j]	11.04**±0.80	-1.48**±0.50	-976.31**±124.67	-472.64**±44.01	
	[1]	88.01**±3058	-24.43±30.02	1581.10**±124.67	-37.30±25.60	
Epistasis effects						
			EC387837 x EC358785			
3-Parameter	m	88.80**±0.64	18.18**±0.64	1004.53**±0.64	1004.53**±0.64	4.90**±0.64
	[d]	6.40**±0.63	1.58**±0.63	8.33**±0.63	113.33**±0.63	-139±0.63
	[h]	-14.62**±1.18	-118±1.18	-357.40**±1.18	-19.09**±1.18	-1.73±0.63
χ2 (3 d.f)	Epistasis	44.83**	114.99**	73666.62**	61350.90**	9.66**
Observed frequencies	TS	0.015	5.820**	8.157**	1.231	0.107
χ2 (5 d.f) observed frequencies	3.841					
6-parameter	m	90.26**±0.58	16.82**±0.19	1816.31**±230.02	860.88**±12.07	3.27**±0.13
	[d]	-25.66**±2.90	0.50±0.62	934.00**±81.25	196.00±11.16	0.48*±0.20
	[h]	24.27**±2.90	-3.53*±1.48	545.00**±115.57	-216.10**±60.30	-1.07**±0.10
	[i]	28.59**±2.83	-1.48±1.43	857.41**±111.29	-109.54**±53.19	-5.80**±0.07
	[j]	-14.55**±0.83	-4.01**±0.68	1098.00**±32.62	248.64**±27.29	-0.20±0.75
	[1]	50.40**±4.17	14.31**±2.69	1368.00**±167.30	471.40**±60.90	3.50*±0.17
Epistasis effects		D	D	C	D	D
			IC369247 x IC370846			
3-Parameter	m	94.12**±0.64	23.20**±0.64	1140.41**±0.64	665.03**±0.64	3.56**±0.64
	[d]	5.14**±0.63	-3.50**±0.63	296.95**±0.63	121.66**±0.63	0.55±0.63
	[h]	-1.60±1.18	-1.60±1.18	705.64**±1.18	231.03**±1.18	0.12±1.18
χ2 (3 d.f)	Epistasis	139.95**	577.90**	554533.80**	10189.15**	0.49
Observed frequencies	TS	0.187	17.63**	43.14**	10.299**	0.074

(1)	(2)	(3)	(4)	(5)	(6)	(7)
χ2 (5 d.f) observed frequencies	3.841					
6-parameter	m	101.10**±0.57	14.30**±0.14	2308.00**±22.04	900.00**±28.86	–
	[d]	9.66**±0.55	-2.69**±0.43	-247.50**±55.43	45.33±69.19	–
	[h]	55.15**±2.60	7.34**±129	36.33±152.40	1118.00**±186.68	–
	[i]	44.30**±0.26	6.87**±1.11	-2583.00**±141.00	1117.33**±180.68	–
	[j]	18.48**±0.58	-5.58**±0.45	444.16**±60.99	-60.66±75.63	–
	[1]	74.70**±3.40	-2.62±2.18	593.33**±263.94	-1596.00**±315.00	–
Epistasis effects		C	D		D	–
			IC344681 x IC326735			
3-Parameter	m	91.03**±0.64	18.67**±0.64	1833.93**±0.64	815.57**±0.64	3.86**±0.64
	[d]	3.37**±0.63	-173**±0.63	179.53**±0.63	93.00**±0.63	-0.44±0.93
	[h]	-196±1.18	-196±1.18	160.27**±81.18	159.23**±1.18	-0.75±1.18
χ2 (3 d.f)	Epistasis	69.89**	56.61**	56991.24**	6964.56**	0.26
Observed frequencies	TS	0.056	0.063	11.118**	5.420**	0.290
χ2 (5 d.f) observed frequencies	3.841					
6-parameter	m	97.03**±0.54	21.16**±0.38	2197.00**±53.50	105.00**±28.86	–
	[d]	3.36**±0.69	-3.40**±0.80	-163.33**±67.16	-180.99**±48.69	–
	[h]	31.27**±2.62	-2.59±0.80	259.00±254.01	75.83±156.02	–
	[i]	31.27**±2.62	-6.98**±2.18	-880.00**±53.50	268.33±151.06	–
	[j]	19.16**±2.58	-2.80**±0.80	-577.00**±71.86	-1433.00**±52.53	–
	[1]	18.01**±3.65	-6.50±3.54	-3.94.00**±356.41	-338.33**±239.53	–
Epistasis effects		C	D	–	–	–

*Significant at <0.05, **significant at P<0.01, C = complimentary epitasis, D = Duplicate epistasis, TS = Transgressive segregants

the traits in all the crosses except to fresh herb yield for cross EC388788 × IC333322, dry herb yield in cross EC388796 × IC326711, length of inflorescence in cross EC387837 × EC358785. The dominance components [h] were found to be significant for all the traits in all crosses except length of inflorescence, fresh herb yield and dry herb yield in cross IC344681 × IC–326735. The additive x additive [i] components of epistasis were found to be significant for all the traits in all the crosses except to EC38887 × IC386833 for dry herb yield, EC387837 × EC358785 for length of inflorescence and IC344681 × IC326735 for dry herb yield. The additive x dominance [j] components of epistasis were found to be significant for all the crosses except to EC369247 × IC370846 for dry herb yield. The dominance x dominance [l] components of epistasis were found to be significant to all the traits in all the crosses except to EC388788 × IC333322 for fresh herb yield, EC38887 × IC386833 for length for inflorescence in crosses to EC369247 × IC370846 and IC344681 × IC326735, indicated that epitasis also played an important role in determining the inheritance of different traits in one or other crosses. Generation mean analysis showed that dominance, additive x additive and dominance x dominance gene action play important role in the inheritance of oil content. Similar results were found by Dani and Kohl (1989) and Kumar *et al.* (2012). The negative additive, dominance x additive and dominance x dominance estimate shows the gene pairs responsible for oil content are in dispersive form (Mather and Jinks, 1977).

Having considered the relative importance of different gene effects for the above traits in present study, a strategy could be developed for efficient breeding programmes aimed at improvement of that trait. As presented above, a trait has exhibited the preponderance of either additive gene effects or non-additive gene effects or both. Those traits showed that complimentary and duplicate types of gene interaction were present confirming the importance of dominance effects as suggested by Grewall (1988). Thus, considerable non-additive genetic effects observed in this study suggests that selection in advanced generations may be more appropriate because effective selection in early generation of segregating material can be achieved only when additive gene effects are substantial and environment effects are small.

All the crosses exhibited complimentary type of epitasis for the number of inflorescence except cross EC388896 × IC369247 which showed duplicate type of epistasis. For this trait, dominance and dominance x dominance type of gene effect were predominant. The non fixable gene effects were higher than fixable gene effects indicating a greater role of non-additive gene effects, which suggested that this trait can be improved through recurrent selection. These results confirm the findings of Pathak *et al*. (2000); Kumar *et al*. (1994) and Noshin *et al*. (2003) who also reported the involvement of additive type of gene action for this trait. The non-additive type gene effect was found significant in cross EC388788 × IC333322 for the traits number of inflorescence per plant, length of inflorescence, fresh herb yield and cross in EC387893 × IC326711 for the traits number of inflorescence per plant, length of inflorescence, in cross EC388796 × IC369247 for all the traits, cross EC388887 × IC386833 only two traits like number of inflorescence per plant and fresh herb yield and in the cross of EC387837 × EC358785 for all the traits and cross IC369247 × IC370846 for two traits number of inflorescence per plant and dry herb yield per plant and cross IC344681 × IC326735 only for one trait like number of inflorescence per plats. The crosses EC387893 × IC326711, EC388896 × IC369247 and EC387837 × EC338785 showed duplicate type of interaction and the cross EC388788 × IC333322 showed complimentary type of epistasis for the trait length of inflorescence. The non-additive gene effects were predominant for the trait fresh herb yield. All the three type of non-allelic gene interaction were significant in all the crosses except EC388788 × IC333322. Duplicate type of interaction showed in cross EC387893 × IC326711. EC388896 × IC369247 and EC388887 × IC386833 showed complimentary type of epistasis. For dry herb yield, I-type was significant in crosses: EC388788 × IC333322, EC387893 × IC326711, EC388896 × IC369247, EC388887 × IC386833 and EC387837 × EC338785. J type of interaction was significant in EC388788 × IC333322, EC388896 × IC369247, EC388887 × IC386833, IC344681 × IC326735 and (l) type of gene interaction were found in EC388788 × IC333322, EC387893 × IC326711, EC388896 × IC369247, IC369247 × IC370846 and IC344681 × IC326735. In all the significant cases the magnitudes of (h), (i), (j) and (l) were higher than that of additive gene effects. In crosses (i) EC388788 × IC333322, (ii) EC387893 × IC326711 and (iii) IC344681 × IC326735 showed complimentary type of epistasis and duplicate type of epistasis showed in (ii) EC387893 × IC326711,(v) EC387837 × EC338785, (vi) IC369247 × IC370846. The crosses (iii) EC388896 × IC369247 showed complimentary and cross (v) EC387837 × EC338785 showed duplicate type of epistasis. This suggested that duplicate type of gene interaction were present, as also observed Grewall (1988). In crosses having considerable additive genetic affects with less environmental effects selections would be made in early generation of segregating materials.

Transgressive Segregants

Transgressive segregants were also observed during the present study (Table 2). The results indicated significant transgressive segregants for only few traits. The frequencies of transgressive segregants were predicted from GMA and F_2 family. For instance significant transgressive segregants were observed for fresh herb yield in IC369247 × IC370846 (43.14), EC388887 × IC386833 (12.52), EC388788 × IC333322 (11.824), IC344681 × IC326735 (11.18), EC387837 × EC358785 (8.15) and EC387893 × IC326711 (7.037), dry herb yield in EC388896 ×IC369247 (13.976), EC387893 × IC326711 (13.031), IC369247 × IC370846 (10.299), EC388887 ×IC386833 (8.255), IC344681 × IC326735 (5.420), oil content EC388896 × IC369247 (4.942), number of inflorescence in EC388887 × IC386833 (4.791) and length of inflorescence, EC388887 × IC386833 (17.63) and EC387837 × EC338785 (5.820). Of the traits in F_2 population in the present study, early generation selection is effective and should be practiced for future breeding programmers. The results of present investigation demonstrated that the genetic studies can provide information that could be used for predicating the frequencies of transgressive segregants for different traits in basil (Pooni and Kinks, 1978,1979). However, the limitation of GMA is the large amount of practical work required to produce the experimental generation. Therefore, attempts were made to compare the prediction of GMA with F_2 families. The results are in agreement with the results of some earlier workers such as McGinnins and Shebeski (1968), De Pauw and Shebeski (1973), Sneep (1981),, Singh and Singh (1997). Significant differences between predicted and observed transgressive segregants for most of the traits in F_2 population in basil in the present study has indicated that early generation selection is effective and should be practiced for future breeding programmes. This approach will provide an opportunity for basil breeders to concentrate on a few potential crosses for getting transgressive segregants.

References

Balyan SS and Pushpangadan P (1988) A study of the taxonomic status and geographical distribution of genus *Ocimum*. *Pafai J.* **10:** 13-19.

Cavalli LL (1952). An analysis of linkage in quantitative inheritance. In: ECR Rieve and CH Waddington (eds) *Quantitative Inheritance*, HMSO, London, pp. 135-144.

Dani RG and RJ Kohl (1989) Maternal effects and generation mean analysis of seed oil content in cotton (*Gossypium hirsutum* L.). *Theor. App. Genet.* **77**: 569-575.

De Pauw RM and LH Shebeski (1973) An evaluation of an early generation yield testing procedure in (*Triticum aestivum* L.) *Canadian J. Plant Sci.* **53**: 465-470.

Duglas JS (1969) Introducing essential oil crops. *World Crops* **21**: 122-124.

Guenther E (1949) Oil of *Boronia megastigma* (boronia flower oil). In: the *Essential Oil,* Van Nostrand, New York, pp 367-368.

Grewal RPS (1988) Genetic basis of resistance to zonate leaf spot disease in forage sorghum. *Theor. App. Genet*. **76:** 505-554.

Hayman BI (1958) Maximum likelihood estimation of genetic components of variation. *Biometrics* **16**: 369-81.

Jinks JL and RM Jones (1958) Estimation of components of heterosis. *Genetics* **43:** 223-234.

Jinks JL and HS Pooni (1976) Predicting the property of recombinant inbred lines derived by single seed descent. *Heredity* **36**:253-266.

Jinks JL and HS Pooni (1980) Comparing prediction of mean performance and environmental sensitivity of recombinant inbred lines based upon F_3 and triple test cross families. *Heredity* **45**: 305-312.

Kearsey MJ and HS Pooni (1996) *The Genetical Analysis of QuantitativeTtraits*. Chapman and Hall, London.

Kumar VD, SR Singh, MC Punder, Kamboj and N Chandra (1994) Genetics of yield and its components in Indian mustard (*Brassica juncea* L. *Crop Res.* **7**: 243-246.

Kumar R, L Ramesh, PA Reddy and RP Patel (2012) Genetic association for oil yield and its component traits in different *Ocimum* species. *Electronic J. Plant Breed.* **3:** 794-799.

Lal RK, P Gupta, V Gupta, S Sarkar and S Singh (2013) Genetic variability and character associations in vetiver [*Vetiveria zizanioides* (L.) Nash]. *Industrial Crop Production* **49**: 273-277.

Lal RK, SPS Khanuja, H Rizavi, AK Shasany, R Ahmad, R Chandra, AA Naqvi, HO Misra, A Singh, N Singh, RS Lohia, K Bansal, MP Darokar, AK Gupta, A. Kalara, OP Dhawan, JR Bahl, AK Singh, H Shankar, Kumar and DM Alam (2008) Registration of a high yielding dark purple pigmented, variety 'CIM-Angana' of shyam tulsi (*Ocimum sanctum* L.). *J. Med. Aromatic Plants* **30**: 92-94.

Lal RK (2014) Breeding for new chemotypes with stable high essential oil yield in *Ocimum*. *Industrial Crops Products* **59**: 41-49.

Lawrence BM (1988) A further examination of the variation of (*Ocimum basilicum* L.). In: BM Lawrence, BD Mookherjee, BJ Willis (eds) *Flavors and Fragrances: A World Perspective*, Elsevier Science, Amsterdam.

Mather K and JL Jinks (1977) *Introduction to Biometrical Genetics*. Chapman and Hall, London.

McGinnis RC and LH Shebeski (1968) The reliability of single selection for yield in F_2. Proceeding 3rd International Wheat Genetic Symposium, Canberra Australia, pp 410-415.

Morris JA, A Khettry, EWM Seitz (1979) Antimicrobial activity of aroma chemicals and essential oils. *J. Amer. Oil Chem. Soc.* **56**: 595-603.

Noshin MM, ID Rahim and SJ Khan (2003) Genetical analysis of yield and its components in F_{1s} generation of brown mustard [*Brassica juncea* (L.) Coss. and Czern.]. *Asian J. Plant Sci.* **2**: 1017-1033.

Pareek SK, R Gupta, and ML Maheshwari (1982) A eugenol rich sacred basil (*Ocimum sanctum* L.), its domestication and industrial utilization. *Pafai J.* **3:** 13-17.

Pathak AD, RM Tripathi, MK Sharma and R Tripathi (2000) Evaluation of genetic components in Indian mustard (*Brassica juncea* L. Coss and Czern) through partial diallele crosses in incomplete block design. *Ann. Agric. Res.* **21**: 282-287.

Pooni H S and JL Kinks (1978) Predicting the properties of recombinant inbreed lines derived by single seed descent for two or more characters simultaneously. *Heredity* **40:** 349-361.

Pooni H S and JL Kinks (1979) Sources and biases of the predictors of the properties of recombinant inbreed produce by single seed descent. *Heredity* **42:** 41-48.

Singh KH and TB Singh (1997) Random bulk *vs* individual plant slection in F_2 generation of bread wheat. *Cereal Res. Commu.* **25**: 51-53.

Sneep J (1981) Some results of selection in early generation of small grain. In: A Callis (ed) *Quantitative Genetics and Breeding Method*. Luingnan, France.

Yadav B, SS Tyagi and D Singh (1998) Genetics of transgressive segregation for yield and yield components in wheat. *Ann. Appl. Biol*. **133**: 227-235.