Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(6): 798-802
Received: 19-09-2019
Accepted: 21-10-2019

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Heterosis and inbreeding depression in greengram (*Vigna radiata* (L.) Wilczek.)

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Abstract
A set of nine inbred lines were crossed in diallel design and developed 36 single cross hybrids. These 36 hybrids along with 9 parents and three checks were evaluated in randomized block design with three replications. The heterosis over mid parent (MP), better parent (BP) and standard check was observed for quantitative and quality traits. The highest positive significant heterosis at all the three levels for seed yield per plant was exhibited by MGG 347 x KM 11-564. This cross combination also revealed highest per se performance for this trait (36.61%). Another hybrid WGG 42 x RM 12-13 exhibited maximum positive significant heterosis at all the three levels with highest per se performance (31.41%) for seed yield per plant. LGG 543 x KM 11-564 exhibited maximum economic heterosis with highest per se performance for seed yield per plant (g).

Keywords: Heterobeltiosis, heterosis, inbreeding depression, greengram

Introduction

Pulses are rich in protein content (18-25%), which plays an important role in human and animal nutrition. Among pulses, greengram [*Vigna radiata* (L.) Wilczek] is an important pulse crop grown extensively in Madhya Pradesh, Maharashtra, Uttar Pradesh, Punjab, Andhra Pradesh, Karnataka and Tamil Nadu. It is the third important pulse crop after bengalgram and redgram. The present yield potential of improved varieties is not enough to attract the farmers or consumers because of relatively smaller seed size, low yield potential and susceptibility to diseases. Study of heterosis in greengram is important for the plant breeder to find out the superior crosses in first generation itself. In addition to this, the magnitude of heterosis provides basis for determining genetic diversity and also serves as guide to the choice of desirable parents. Though a lot of information is available on heterosis and other aspects in greengram, yet it holds future promise for further utilization. The effort could enhance its quality and productivity without sacrificing the consumers' choice. Therefore, the present study was undertaken to identify suitable cross combinations from adapted parents for commercial exploitation of heterosis on yield as well as yield related component traits and their utilization in future crop improvement programmes (Gwande *et al*., 2001) [3].

Materials and Methods

Nine parents MGG 371, MGG 347, MGG 351, WGG 42, LGG 543, K 851, RM 12-11, RM 12-13 and KM 11-564 were crossed in a diallel fashion (excluding reciprocals). An experiment, comprising 9 parents 36F_1's and 3 checks was conducted in a randomized block design with three replications at College farm, Rajendranagar during *kharif* 2016. All the 47 treatments were grown in two rows of 4m length with spacing of 30 cm between row and 15 cm. between plants. The recommended agronomic practices and plant protection measures were adopted for raising a good crop. Five competitive plants were randomly selected from the middle of each row in each entry of replication to record the observations. Data were recorded on 12 characters *viz*., plant height (cm), number of primary branches, number of cluster per plant, number of pods per plant, pod length (cm), 100 seed weight (g) and seed yield per plant (g) while, data relating to days to 50 per cent flowering, days to maturity, protein content (%) and harvest index (%) was recorded on whole plot basis. The data was statistically analyzed using average of five plants. The data were subjected to analysis of variance for mean performance (Panse and Sukhatme, 1995) [10] and heterosis over better parent (BP) and standard variety (SV) were calculated and tested as specified by Hays (1955) [4].

Results and Discussion

Presence of adequate variability among the genotypes was revealed through highly significant differences among themselves for all the traits studied (Table 1).

The parent and hybrid also manifested highly significant differences for most of the traits except for primary branches per plant. The parent vs crosses also showed significant differences for all the characters except plant height and protein content in seeds implied the presence of heterosis in the cross combinations. Many crosses exceeded their performance beyond the lower and upper limit of parents for various characters in desirable direction. Based on the mean performance, the best crosses identified for each character were WGG 42 x RM12-13 (Plant height), LGG 543 x KM 11-564 (number of primary branches per plant), MGG 347 x KM 11-564 (number of pods per plant and seed yield per plant) Table 2.

Exploitation of heterosis is a quick and convenient way of combining desirable genes present in different parents into a single genotype. It is an indicative of producing desirable transgressive segregants for many quantitative characters in advanced generations. High heterosis coupled with low inbreeding depression indicates additive and/or additive × additive genetic variance which can be fixed in the segregating generations. The results of magnitude of heterobeltiosis and deviation of F_2 mean from F_1 mean in terms of inbreeding depression in four selected crosses of Greengram for 12 quantitative traits are tabulated in Table 3 and presented character wise.

Days to 50% flowering: Heterobeltiosis for days to 50 per cent flowering ranged from 1.90 (MGG 347 × RM 12-13) to 8.41 per cent (LGG 543 × KM 11-564). Inbreeding depression ranged from -3.66 (WGG 42 × RM 12-13) to 1.76 (LGG 543 × KM 11-564). Significant negative heterosis and inbreeding depression is considered as desirable one for days to 50 per cent flowering. All the four crosses studied, except cross LGG 543 × KM 11-564 manifested inbreeding depression in negative direction indicating the enhancement of days to flower in F2's and It also showed the preponderance of non-additive gene effects in the expression of the character. However, the cross LGG 543 × KM 11-564 exhibited positive heterosis effects with low inbreeding depression (1.76%) suggesting the operation of additive gene effects governing the inheritance of the character. On the whole, low heterosis in negative direction was associated with high negative inbreeding depression suggests the possibility of isolating early flowering genotypes in the succeeding generations. Heterosis for earliness was also reported by Singh and Chauhan (2011) [14] and Jog *et al*. (2016) [5] in Greengram.

Days to maturity: The low relative heterobeltiosis and inbreeding depression for days to maturity was observed in all the four crosses MGG 347 × KM 11-564, WGG 42 × RM 12-13, LGG540 × KM 11-564 and MGG 347 × RM 12-13. Development of high yielding early maturing varieties is desired in Greengram breeding programs. Manifested heterotic effects with low inbreeding depression in all the four crosses (0.96, 0.49, 0.48 and 2.80%) for days to maturity suggests the role of non-additive gene actions. Hence, selecting superior lines and intermating them through biparental crossing followed by recurrent selection may improve the character in these crosses. These results are supported by Singh and Chauhan (2011) [14] and Narsimhulu *et al*. (2016) [9] for heterosis in desirable direction.

Number of primary branches per plant: Heterobeltiosis for the trait ranged from 6.64 (MGG 347 × RM 12-13) to 28.06 per cent (LGG 543 × KM 11-564). Inbreeding depression ranged from 26.78 (MGG 347 × KM 11-564) to 68.95% (MGG 347 × RM 12-13). In the present study, three crosses *viz*., MGG 347 × KM 11-564, WGG 42 × RM 12-13 and LGG 543 × KM 11-564 exhibited significant heterosis for branches per plant and inbreeding depression was high (26.78, 57.96 and 55.69%) indicating the role of non additive type of variance in the inheritance of this character. However, the cross MGG 347 × RM 12-13 expressed high inbreeding depression of 68.95 per cent with non-significant heterotic indicating that the operation of epistatic gene effects which may not likely to give desirable segregants in the later generations. Similar results of higher magnitude of heterobeltiosis for branches per plant were reported by Sunil and Prakash (2011) [16] and Yashpal *et al*. (2015).

Plant height (cm): Heterobeltiosis for plant height ranged between -10.33 (WGG 42 × RM 12-13) and 6.92 per cent (MGG 347 × KM 11-564). Inbreeding depression ranged from 7.75 (MGG 347 × KM 11-564) to 12.13 (MGG 347 × RM 12-13). All the four crosses *viz*., MGG 347 × KM 11-564, WGG 42 × RM 12-13, LGG 543 × KM 11-564 and MGG 347 × RM 12-13 had low inbreeding depression (7.75,8.63,8.39 and 12.13%) along with positive heterotic effects for plant height indicating the operation of additive and/or additive × additive type of variance which is fixable in segregating generations. This kind of situation can arise due to incomplete dominance or repulsion phase linkage between different genes involved in the inheritance of plant height which may throw superior segregants in the later generations of these crosses. These results were in line with the findings of Joseph and Kumar (2000) [6] while significant and positive heterobeltiosis was reported by Singh and Chauhan (2011) [14] and Sathya and Jayamani (2011) [13].

Number of clusters per plant: Low heterobeltiosis for this trait were observed in WGG 42 × RM 12-13 (8.00 per cent) and high in MGG 347 × KM 11-564 (24.00). Inbreeding depression ranged from 7.02 (LGG 543 × KM 11-564) to 17.93 (MGG 347 × RM 12-13). All the cross combinations *viz*., WGG 42 × RM 12-13, LGG 543 × KM 11- 564, MGG 347 × KM 11-564 and MGG 347 × RM 12-13, and exhibited significant and positive heterotic effects for clusters per plant with low to moderate inbreeding depression (7.02,7.52,13.21 and 17.93%) suggesting the predominance of non-additive gene action. This is in conformation with Patil *et al*. (1999) and better parent heterosis recorded earlier by Sathya and Jayamani (2011) [13] and Yashpal *et al*. (2015).

Number of pods per plant: Heterobeltiosis was low in LGG 543 × KM 11-564 (17.70 per cent) and high in MGG 347 × RM 12-13 (32.16 per cent), respectively and inbreeding depression ranged from -0.27 (LGG 543 × KM 11-564) to 32.16 (MGG 347 × RM 12-13). Number of pods per plant had showed considerable influence on seed yield/plant. All the four crosses exhibited significant and positive heterotic effects with low to moderate inbreeding depression indicating the operation of nonadditive gene action in the expression of the character which cannot be fixed in segregating generations. Therefore selecting superior lines and intermating them through bi-parental crosses followed by recurrent selection may improve the character. Similar results were also reported by Joseph and Kumar (2000) [6] and Khattaka *et al*. (2002). Significant positive better parent heterosis were reported by Singh and Chauhan (2011) [14] and Sunil and Prakash (2011) [16] in Greengram.

Table 1: Analysis of variance (mean squares) for twelve characters in Greengram

Source of variation	df	Days to flowering	Days to maturity	Primary branches	Plant height (cm)	No. of clusters/ plant	No. of pods/plant	Pod length (cm)	No. of seeds/pod	100 seed wt (g)	Seed yield /plant (g)	Protein content (%)	Harvest index (%)
Replications	2	3.89	0.63	0.309	11.247	3.355	4.765	0.407	0.454	0.038	3.288	0.799	6.399
Treatments	44	2.67**	2.77**	0.610 **	28.431 **	3.662 **	101.399 **	0.486 **	1.352 **	0.276 **	23.026 **	1.205 *	28.481 **
Parents	8	3.46**	2.75**	0.435 **	14.853 *	2.982**	97.130 **	0.293 **	1.119	0.076 **	19.725 **	1.211	14.230 **
Crosses	35	2.03**	2.86**	0.606 **	31.687 **	3.026 **	105.171 **	0.531 **	1.605 **	0.279 **	38.954 **	1.804*	25.427 **
Parents Vs Crosses	1	3.218**	3.615**	2.141 **	23.105**	49.142 **	23.536**	0.445 *	1.728	1.791 **	11.123 **	1.909	249.397 **
Error	88	1.02	1.14	0.127	6.465	1.182	6.42	0.09	0.591	0.025	1.465	0.791	3.629

*, ** Significant at 5% and 1% levels, respectively

Table 2: List of best promising hybrids showing heterosis for seed yield per plant in Greengram

Character	Range of heterosis (%)	Best hybrids On the basis of highest heterosis over better parent (BP)	Per se of the hybrids
Days to 50% flowering	-0.14 to 10.37	MGG-347 x WGG-42 WGG-42 x RM 12-13 WGG-42 x LGG-543	-2.53 -1.92 -1.35
Days to maturity	-1.69 to 23.60	MGG-347 x WGG-42 WGG-42 x LGG-543 MGG-347 x KM11-564	-1.93 -1.29 -0.99
No. of primary branches per plant	-23.53 to 28.06	LGG-543 x KM11-564 MGG-347x KM11-564 WGG-42 x RM 12-13	1.09 1.08 1.02
Plant height (cm)	-10.33 to 27.28	WGG-42 x RM12-13 MGG-347 x KM 11-564 LGG-543x KM 11-564	-5.04 3.95 3.85
No. of clusters per plant	-14.14 to 26.12	MGG-347 x KM11-564 WGG-42 x RM12-13 LGG-543 x KM 11-564	2.02 1.67 1.38
No. of pods per plant	5.27 to 32.16	MGG-347 x KM11-564 LGG-543 x KM 11-564	9.24 7.55
Pod length (cm)	0.80 to 8.35	MGG-347 x KM 11-564 WGG-42x KM 11-564 LGG-543 x KM 11-564	0.69 0.67 0.58
No. of seeds per pod	0.01 to 12.10	MGG-347 x RM 12-13 MGG-347 x KM 11-564 MGG-371 x KM11-564	1.16 0.97 0.95
100 seed weight (g)	-0.34 to 16.99	MGG-347 x RM12-13 LGG-543 x KM 11-564 MGG-347 x KM 11-564	0.29 0.41 0.21
Protein content (%)	3.31 to 10.23	WGG-42 x KM 11-564 MGG-371 x RM12-13 K-851 x RM12-13	1.28 1.01 0.98
Harvest index (%)	9.14 to 32.00	MGG-351 x RM12-13 RM 12-11 x KM11-564 MGG-371 x KM11-564	11.17 9.08 6.77
Seed yield per plant (g)	-4.35 to 34.54	MGG-347 x KM 11-564 LGG-543 x KM11-564 WGG-42 x RM12-13	3.36 3.22 3.14

Table 3: Heterobeltiosis (BP) and inbreeding depression (ID) for twelve characters of four crosses in Greengram

Characters	MGG 347 x KM 11-564		WGG 42 x RM 12-13		LGG 543 x KM 11-564		MGG 347 x RM 12-13	
	BP(%)	ID(%)	BP(%)	ID(%)	BP(%)	ID(%)	BP(%)	ID(%)
Days to 50% flowering	4.73*	-3.47	2.94	-3.66	8.41**	1.76	1.90	-1.83
Days to maturity	1.44	0.96	3.99	0.49	0.01	0.48	-0.49	-2.80
No. of primary branches per plant	20.26**	26.78	19.80**	57.96	28.06**	55.69	6.64	68.95
Plant height (cm)	6.92*	7.75	-10.33*	8.63	0.61	8.39	5.40*	12.13
No. of clusters per plant	24.00**	13.21	8.00	7.02	9.43*	7.52	21.03**	17.93
No. of pods per plant	22.74**	14.60	20.10**	12.03	17.70**	-0.27	32.16**	21.73
Pod length (cm)	0.67	0.27	0.82	0.41	4.83**	4.13	1.50*	0.13
No. of seeds per pod	11.11**	6.48	3.77*	8.70	4.26*	3.40	9.43**	13.28
100 seed weight (g)	8.68*	8.40	-3.60	0.87	-3.68	6.09	6.37*	4.92
Protein content (%)	4.40*	4.58	5.39*	7.42	7.39*	6.74	4.52*	5.30
Harvest index (%)	14.78*	17.40	4.78	12.23	17.90**	37.62	11.30*	17.18
Seed yield per plant (g)	34.54**	26.02	25.00**	54.39	22.50**	28.07	23.75**	35.05

*, ** Significant at 5% and 1% levels, respectively

Number of seeds per pod: The heterobeltiosis and inbreeding depression for number of seeds per pod observed were low in LGG 543 × KM 11-564 (4.26 and 3.40 per cent) and high in MGG 347 × KM 11-564 (11.11 and 6.48 per cent). A seed per pod is one of the most important components of seed yield and will be helpful in breaking the yield ceiling. Thus, the crosses with positive heterosis are desirable for this important trait. Two crosses *viz*., WGG 42 × RM 12-13 and LGG 543 × KM 11-564 manifested significant and positive heterotic effects with low inbreeding depression (3.40 and 8.77) suggesting the role of additive gene action which is likely to give desirable segregants in subsequent generations. The cross MGG 347 × RM 12-13 expressed inbreeding depression in negative direction (-3.77) with positive heterobeltiosis suggesting the importance of additive and additive × additive type of inter-allelic interactions pertaining to the cross. Higher heterosis was also reported earlier by Sekhar *et al*. (1994) over better parent for number of seeds per pod.

100 seed Weight (g): Heterobeltiosis for 100 seed weight ranged between -3.68 (LGG543 × KM 11- 564) and 8.68 per cent (MGG 347 × KM 11-564). Inbreeding depression ranged from 0.87 (WGG 42 × RM 12-13) to 8.40 (MGG 347 × KM 11-564). Hundred seed weight is also one of the most important components of seed yield which influences the yield conspicuously. Two crosses *viz*., MGG 347 × KM 11-564 and MGG-345 × RM 12-13 exhibited positive heterosis for 100 seed weight with low inbreeding depression (8.40 and 4.92) suggesting the role of additive and/or additive × additive variance which are fixable in segregating generations. Similar results of significant negative or positive better parent heterosis were also reported by Sathya and Jayamani (2011) [13] and Sunil and Prakash (2011) [16].

Protein content (%): Heterobeltiosis observed was low in MGG 347 × KM 11-564 (4.40 per cent) and high in LGG 543 × KM 11-564 (7.39 per cent) and inbreeding depression varied from 4.58 (MGG 347 × KM 11-564) to 7.42 per cent (WGG 42 × RM 12-13). All the four crosses MGG 347 × KM 11-564, WGG 42 × RM 12-13, LGG-460 × WGG-37 and MGG 347 × RM 12-13 expressed the non significant and positive heterosis, with low inbreeding depression (4.58,7.42,6.74 and 5.30 per cent) which suggests the role of additive gene actions in the inheritance of seed protein.

Harvest Index (%): Heterobeltiosis found low in WGG 42 × RM 12-13 (4.78per cent) and high in LGG 543 × KM 11-564 (17.92per cent). Inbreeding depression ranged from 17.18 (MGG 347 × RM 12-13) to 37.62 (LGG 543 × KM 11-564). Two cross combinations MGG 347 × KM 11-564 and LGG 543 × KM 11-564 exhibited significant heterotic effects for harvest index with moderate inbreeding depression suggests the role of non-additive gene actions in the expression of the character. The significant positive heterosis for harvest index was also reported by Narsimhulu *et al*. (2016) [9] in Greengram.

Seed yield per plant (g): Heterobeltiosis ranged from 22.50 (LGG543 × KM 11-564) to 34.54 per cent (MGG 347 × KM 11-564). Inbreeding depression ranged from 26.02 (MGG 347 × KM 11-564) to 54.49 (WGG 42 × RM 12-13). Significant and positive heterotic effects with moderate inbreeding depression was recorded in all four crosses for seed yield per plant suggesting the operation of both additive and non-additive gene effects in the inheritance of seed yield per plant in Greengram. All the cross combinations recorded significant heterosis effects coupled with considerable inbreeding depression (26.02, 54.49, 28.07 and 35.05) indicating the presence epistatic gene effects which may likely to give desirable segregants in the subsequent generations. These results were in line with the findings of Bhagora *et al*. (2013), Srivastava and Singh (2013) [13] and Jog *et al*. (2016) [5] in Greengram.

Conclusion
Significant positive heterosis for seed yield was associated with heterosis for number of pods per plant, number of clusters per plant and number of primary branches per plant in majority of the crosses. Nature and magnitude of heterosis and inbreeding depression varied with crosses as well as characters. However, a close relationship between heterotic response and inbreeding depression for characters suggests the predominance of non-additive genetic variance in the present set of biological material. Therefore, few cycles of recurrent selection followed by pedigree method would be effective and useful in utilizing all types of gene effects by maintaining considerable heterozygosity through mating of selected plants in early segregating generations

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