Determining Heterotic Response, General Combining and specific Combining Ability for Yield and Yield Contributing Traits in Cowpea (*Vigna unguiculata* (L). Walp.)

Dr. Anand Singh[1]; Dr. Amit Visen[2]; Dr. S.K.S.Chandel[3]; Dr. Abhishek Pratap Singh[4]; Aditya Singh[5*]

[1]Dept. of Horticulture, Janta College Bakewar, Etawah.
[2]Dept.of Horticulture, B.N.P.G.College. Rath, Hamirpur
[3]Dept.of soil Science & Ag. Chemistry, Janta College Bakewar, Etawah.
[4]Dept.of Extension, Janta College, Bakewar, Etawah.
[*5]Ph.D Scholar. C.S.A.Univ.Kanpur
*Corresponding Author

Received:- 03 September 2025/ Revised:- 11 September 2025/ Accepted:- 16 September 2025/ Published: 30-09-2025

***Abstract*—** *Gene action, General Combining and specific Combining Ability, Cowpea. Cowpea belongs to the genus Vigna and species unguiculata under the subfamily Faboideae (Papilionoideae) of the family fabaceae (Leguminosae) with a chromosome number of 2n=22. The present investigation was carried out during 2012-2013 at G.B. Pant University of agriculture and Technology, Pantnagar. First experiment was undertaken to estimate the relative importance of combining ability and heterosis for 11 quantitative characters including seed yield in cowpea (Vigina unguculata (L). Walp). Second experiment was conducted to understand the nature of gene effects involved in the inheritance of various quantitative characters. Pant Lobia-1, Pant Lobia-2, Pant Lobia-3, PGCP-12, PGCP-14, Bucksora Local and Pant Vegetable-3 along with their 21* F_1*'s were evaluated for genetic analysis. Six generations viz; - P1, P2, F1, F2, BC1 and BC2 of each three families, PGCP-12 x PGCP-14 (Family 1), Pant Lobia-1x PGCP-14 (Family 2), Pant Lobia-1x Pant Lobia-3 (Family 3), were evaluated. Analysis of variance revealed significant mean squares of general and specific combining abilities (GCA and SCA) for all the traits studied. Pant lobia-2 and Pant Lobia-3 had good GCA for seed yield per hectare. Pant Lobia-1 was best general combiner for 100-seed weight and number of pods per plant whereas, Pant Lobia-2 was found to be good general combining ability for number of pods per plant, seed yield per hectare and seed weight per plant. The hybrids PGCP-12 x PGCP-14 and PGCP-14 x PVCP-3 revealed highest SCA effects for seed yield per hectare. The magnitude of relative heterosis, heterobelteosis and economic heterosis for seed yield per hectare ranged from -18.24 to 63.34%, -18 .40 to 47.69% and -4.66 to 93.40% respectively. Pant Lobia-2 x Pant Lobia-3 was best cross combination for days to 1st flowering, Pant Lobia-2 x PVCP-3 for days to pod maturity. Cross PGCP-14 x PVCP-3 showed highest value for pod length. Cross PGCP-12 x PGCP-14 gave highest positive SCA effect for green pod weight per plant. For number of seeds per pod Pant Lobia-3 x PGCP-12 was the best cross combination, Cross PGCP-14 x PVCP-3 for seed weight per plant. Significant estimates of additive [d] and dominance [h] effects as well as all three epistasis were observed for most of the quantitative characters in all the three families. The opposite signs of [h] and [l] indicated that duplicate epistasis was important in inheritance for some of the traits in all the three families. The presence of additive gene action suggested that a part of the heterosis can be fixed in subsequent generations to take advantage in further selection. The preponderance of non-additive gene action, however brought out that heterosis component could be explained in hybrid development in cowpea.*

Keywords*— *Cowpea, Heterosis, General Combining Ability, Specific Combining Ability, Gene Action, Yield Traits, Hybrid Performance, Plant Breeding.

I. INTRODUCTION

Cowpea's high protein content, its adaptability to different types of soil and intercropping systems, its resistance to drought, and its ability to improve soil fertility and prevent erosion makes it an important economic crop in many developing regions. Cowpea belongs to the genus *Vigna* and species *unguiculata* under the subfamily *Faboideae* (*Papilionoideae*) of the family fabaceae (*Leguminosae*) with a chromosome number of 2n=22. *Vigna* is a pantropical genus with 22 species in India and Shoutheast Asia, 120 species in Africa and few in America and Australia. The speices *Vigna unguiculata* has one subspeices *unguiculata* which has three cultigroup, namely cv.gr. *Unguiculata,* cv.gr. *Biflora* and cv.gr. *Sesquipedalis.* Legumes represent the second largest family of higher plants, second only to grasses in agricultural importance **(Doyle and Luckow, 2003)**. Cowpea, (*Vigna unguiculata* (L.) Walp.), is an important food legume cultivated extensively in the tropics and sub-tropics of Africa, Asia, Brazil and some southern states of the United States of America **(Smart, 1976)**. An estimate of 14.5 million hectares of land is planted to cowpea each year worldwide. Global production of dried cowpeas in 2010 was 5.5 million metric tons; Africa was responsible for 94% of the total production **(CGIAR, 2010).** The experimental yields of the improved genotypes have been reported around 15 quintals per hectare. In India, cowpea is grown in almost all the states but the major cowpea growing states are Gujarat, West Bengal, Tamil Nadu, Andhra Pradesh, Kerala and Orissa.

The dominant world view is that the cowpea originated in West Africa, probably in the sub humid savanna grasslands of Nigeria, the area of its greatest diversity **(Faris, 1965, Rawal, 1975, Lush and Evans, 1981 Ng and Marechal, 1985).** It is, however agreed that the cowpea was domesticated about 4000 years ago from the wild progenitors *Vigna unguiculata* ssp. *Dekindtiana* var, *dekintiana* (in sub Sahelian West Africa) and *mensensis* (in the humid and sub humid zones) and distributed thereafter throughout sub Saharan Africa, reaching Middle East by 2000 B.C. and India by 1500 B.C. **(Lush and Evans, 1981 and Steele, 1976)**. The Indian cultigroups of *V. unguiculata* ssp. u*nguiculata* namely, Biflora (the catjang bean) and Sesquipedalis (the yard long or asparagus bean) arose probably by selection from the early cowpea domesticates **(Faris, 1965).**

According to **Bressani (1985**), the mature legume contains 23-25% protein and 50-67% carbohydrate, 1.9% fats, 6.35% fibre and small percentage of the B-vitamins such as folic acid, thiamine, riboflavin and niacin as well as some micronutrients such as iron and zinc. The richness in protein makes cowpea a source of cheap plant protein **(Anderson, 1985)** to people who hardly can afford animal protein derived from meat, fish, milk and eggs. According to **Yadav and Yadav (1986),** cowpea fix 563 kg of atmospheric nitrogen ha^{-1}.

Cowpea is a very diverse, usually glabrous, annual herb which is twinning to sub-erect and rarely erect. The first pair of leaves is simple and opposite. According to **Fery (1985)**, the inflorescence is axillary and formed of a peduncle 10 to 30 cm long, at the end of which there is a rachis with each node bearing a pair of flowers. The pod is green at early stage and when maturing it becomes usually yellow, light brown, pink or purple. The pod length may vary from less than 11 cm to more than 100 cm **(Rachie, 1976).**

Cowpea can withstand considerable drought and a moderate amount of shade. Cowpeas are short-day, warm-weather plants, sensitive to cold and damaged by frost **(Duke and James, 1990)**. According to **Duke and James (1990),** cowpeas can thrive on highly acid to neutral soils but they are less well adapted to alkaline soils. The crop is more tolerant of low fertility, due to its high rates of nitrogen fixation **(Elawad and Hall, 1987)** and effective symbiosis with mycorrhizae **(Kwapata and Hall, 1985). Singh (1987)** reported that the best cowpea yields are obtained in well-drained sandy loam to clay loam soils between pH 6 to 7.

The success of artificial pollination has been reported to be low ranging from 0.5 to 50% **(Rachie *et al.*, 1975)** and varies with genetic and physiological factors as well as the care taken in handling floral parts during the process of emasculation. In autogamous crop like cowpea, the objective of recombination breeding is to develop high yielding pure line varieties. Recombination breeding involves hybridization, the long process of selection and critical evaluation. Early generation testing and selection have gained momentum in self-pollinated crops, as additive genetic variance is more important. Genetic analysis in early generation helps the selection of desirable transgressive segregants and thereby reducing the population size in letter generations.

The basic objective of any breeding method is to increase yield per unit area, to meet the demand food for increasing populations. A distinct knowledge about type of gene effect, its magnitude and composition of genetic variance *i.e*., additive, dominance and epistatic help in formulating an effective and sound breeding programme.

The precise knowledge of nature and magnitude of gene action for characters related to productivity is helpful in the choice of effective breeding methods to accelerate the pace of genetic improvement of seed yield and other economically important characters. However, epistasis is important in the inheritance of quantitative traits besides additive and non-additive effects. Therefore, the present study was to study the nature and magnitude of heterosis and gene action for yield and yield components.

II. MATERIALS AND METHODS

The present investigation was carried out at the Breeder Seed Production Center of G. B. Pant University of Agriculture & Technology, Pantnagar (Uttarakhand). Geographically, Pantnagar is situated at 29^0N latitude and 79.30^0E longitude and at an altitude of 243.84 m above the mean sea level and falls in the humid subtropical zone. It is situated in the *Tarai* region of Shivalik range of the great Himalayas.

2.1 Development of breeding material:

Seven variety of cowpea viz. (Pant Lobia-1, Pant Lobia-2, Pant Lobia-3, PGCP-12, PGCP-14, Bucksoura Local and PVCP-3) were shown in crossing block and polyhouse during kharif 2012/summer 2013. Twenty-one (21) cross combinations were made among the parental lines in diallel mating design excluding reciprocals and three F_1s were selected and shown in polyhouse for making BC1P1, BC1P2 and F_2. In the early morning, emasculation was carried out.

During the kharif season 2013, the 21 F_1s' along with their seven parental lines were planted and evaluated for yield and yield attributing traits using RBD (Randomized Block Design) with three replications. In this study the available commercial variety Pant Lobi-1 was used as a parent as well as a check.

The experiment comprising six generations of each of three families viz. P_1, P_2, F_1, F_2, BC_1 and BC_2 were shown in family block design with three replications. The plot size consisted of variable number of rows of 4m length each for different generation P_1, P_2 (One row for each parent), whereas F_1 was raised in three row, BC_1 and BC_2 generations in two row each and F_2 was raised in seven rows. The rows were spaced 45cm apart between plants was maintained at 10 cm by thinning. Depending on the variability different numbers of plants in (P_1, P_2, F_1, BC_1 and BC_2 ten plant and in F_2 are 50 plant) were randomly selected from each plot in each replication.

Days to 1st flowering, Days to pod maturity, Number of pods per plant, Pod length (cm), Plant height (cm), Number of seeds per pods, Green pod weight per plant (g), Seed weight per plant (g) , 100-seed weight (g), Seed yield per hectare, Incidence of cowpea mosaic virus and other important Qualitative characters like Leaf type, Seed colour, Plant pigment, Flower pigment and Seed size

2.2 Photographs of Parents:

Pant Lobia-1

Pant Lobia-2

Pant Lobia-3

PGCP-12

PGCP-14

Buksoura Local

Pant Vegetable-3

2.3 Statistical Procedure:

For an in depth analysis of data recorded on various quantitative characters and estimation of certain genetic parameters, the following statistical procedure was followed.

2.4 Analysis of Variance:

Analysis of variance for all the parameters was carried out as procedure given

$$Y_{ij} = \mu + t_i + b_j + e_{ij} \quad (1)$$

where,

i = 1, 2, 3, 4,...…….t, number of genotypes i.e., treatments (t)

j = 1, 2, 3, 4,...…….r, number of replications (r)

Y_{ij}= performance of i^{th} genotype in j^{th} replication

μ = general mean of the population

t_i = effect of i^{th}genotype

b_j = effect of j^{th} replication

Heterosis expressed as the per cent increase or decrease in value of F_1s over mid-parent (heterosis), over better parent (heterobeltiosis) and over the check variety (standard heterosis) will be calculated as-

a. $\text{Heterosis } \% = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$

b. $\text{Heterobeltiosis } \% = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$

c. $\text{Standardheterosis } \% = \frac{\overline{F_1} - \overline{CP}}{\overline{CP}} \times 100$

2.5 Combining ability analysis:

Combining ability analysis was carried out following the Model II, method II (Parents and one set of crosses) of **Griffing (1956).** The mathematical model for the combining ability analysis is assumed to be:

$$X_{ijkl} = \mu + g_i + g_j + S_{ij} + \frac{1}{bc}\sum_k \sum_l e_{ijkl} \quad (2)$$

a) Estimation of gca effect

$$g_i = \frac{1}{n+2}\left[(Y_{i.} + Y_{ii}) - \frac{2}{n}y..\right] \quad (3)$$

b) Estimation of sca effect

$$S_{ij} = Y_{ij} - \frac{1}{n+2}\left(Y_{i.} + Y_{ii} + Y_{.j} + Y_{jj}\right) + \frac{2}{(n+1)(n+1)}Y.. \quad (4)$$

Calculated gi and sij effects were tested comparing with tabular t values of 5% and 1% multiplied by standard errors in which they were associated [$t_{5\%}$ X SE (gi) and $t_{1\%}$ X SE (sij)] at 5% and 1% probability levels, respectively. The estimated values of gi and sij greater then $t_{5\%}$ X SE (gi) and $t_{1\%}$ X SE (sij) the values of GCA and SCA effects regards as significant at 5% and 1% probability level.

2.6 Genetic Analysis:

The genetic analysis was done by using first degree statistics i.e. means of different generations. Adequacy of different models was tested using simple scaling test. A Gene effect was estimated following generation mean analysis.

III. RESULTS AND DISCUSSION

The experimental results obtained from present investigation have been presented under the following points like Analysis of variance, General and specific combining ability for yield and yield attributes, Heterosis and Gene action.

3.1 Analysis of Variance:

Analysis of variance for various characters is presented in table 1. There were significant differences among genotypes for all the characters studied.

3.1.1 Analysis of Variance for Combining Ability Effects:

The concept of combining ability is used in connection with testing procedures, in which it is desired to study and compare the performances of lines in hybrid combinations. The best lines identified could be used for variety development to accumulate desirable genes, or for hybridization to exploit heterosis. **Sprague and Tatum (1942)** developed original theory of combining ability and it has two components *i.e.,* general and specific combining abilities. The term general combining ability (GCA) is used to designate the average performance of a line in hybrid combinations. The term specific combining ability (SCA) is used to designate those cases in which certain combinations do relatively better or worse than would be expected on the basis of the average performance of the lines involved in that specific cross.

The mean squares due to general and specific combining ability variances for all the characters studied are presented in table 1. The variances due to general combining ability were found to be significant for all the characters. Variances due to specific combining ability were also significant for all the characters.

3.2 Estimates of General Combining Ability Effects:

The estimates of general combining ability effects of parents for all eleven characters are presented in table.2.

All the parents showed highly significant GCA effects. Pant Lobia-1, Pant Lobia-2 and PGCP-14 expressed GCA effect in positive direction, whereas, Pant Lobia-3, PGCP-12, Buksoura Local and PVCP-3 showed negative gca effects for Number of pods per plant. For Pod length (cm) all the parents exhibited highly significant GCA effects. Buksoura Local and PVCP-3 expressed GCA effect in positive direction, whereas, Pant Lobia-1, Pant Lobia-2, Pant Lobia-3, PGCP-12 and PGCP-14 showed negative GCA effects. Thus Buksoura Local and PVCP-3 were best combiners for improving pod length.

In grain cowpea dwarf bush type plant is desirable. The genotypes PGCP-12 and PVCP-3 were found best combiners for dwarfism.

TABLE 1
ANALYSIS OF VARIANCE FOR DIFFERENT CHARACTERS (RBD)

Source of variation	Mean square											
	d.f.	Days to 1st flowering	Days to pod maturity	Number of pods per plant	Pod length (cm)	Plant height (cm)	Green pod weight per plant (g)	Number of seeds per pod	Seed weight per plant (g)	100-Seed weight (g)	Seed yield per hectare	Incidence of cowpea mosaic virus
Replication	2	0.34	0.87	0.537	0.398	0.258	0.892	0.231	0.175	0.845	4.686	0.249
Treatment	27	30.382**	35.341**	88.281**	75.317**	73.196**	115.621**	14.644**	41.441**	40.202**	90.186**	1.474**
Error	54	1.441	1.248	0.604	0.734	0.491	0.423	0.931	0.122	0.218	2.948	0.895
CD at 1%		2.617	2.436	0.536	0.59	1.528	1.418	0.665	0.763	1.018	3.743	0.652
CD at 5%		1.965	1.829	0.402	0.443	1.147	1.065	0.499	0.573	0.764	2.81	0.489
CV (%)		2.953	1.707	1.91	1.329	1.688	1.603	1.988	2.095	2.651	6.899	23.269
SEM±		0.693	0.645	0.141	0.156	0.404	0.375	0.176	0.202	0.269	0.991	0.172

***** Significant at 1% probability level***
**** Significant at 5% probability level***

TABLE 2
GENERAL COMBINING ABILITY EFFECTS OF PARENTS

Name of parents	Mean square										
	Days to 1st flowering	Days to pod maturity	Number of pods per plant	Pod length (cm)	Plant height (cm)	Green pod weight per Plant (g)	Number of seeds per pod	Seed weight per plant (g)	100-Seed weight (g)	Seed yield per hectare	Incidence of cowpea mosaic virus
Pant Lobia-1	-0.448*	-0.382	0.954**	-2.720**	1.791**	-4.033**	-1.775**	-0.769**	2.175**	-1.302**	-0.106*
Pant Lobia-2	2.467**	1.796**	3.510**	-1.249**	1.269**	-1.115**	0.677**	0.990**	-0.084	1.328**	0.672**
Pant Lobia-3	-0.674**	-1.893**	-3.024**	-1.453**	0.387**	-1.678**	0.840**	1.516**	-0.858**	2.632**	-0.254**
PGCP-12	-0.837**	-1.701**	-0.676**	-0.868**	-3.428**	-1.233**	1.177**	1.994**	2.016**	2.802**	0.228**
PGCP-14	-2.577**	0.177**	0.680**	-2.320**	0.861**	-1.581**	-0.660**	-1.032**	0.812**	-1.687**	-0.069
Buksoura Local	1.749**	0.725**	-0.809**	2.343**	0.480**	4.037**	-0.253**	-2.006**	-2.732**	-3.131**	-0.217**
PVCP-3	0.319	1.277**	-0.635**	6.266**	-1.361**	5.604**	-0.005	-0.695**	-1.329**	-0.642*	-0.254**
SEM± (gi)	**0.214**	**0.199**	**0.044**	**0.048**	**0.125**	**0.116**	**0.054**	**0.062**	**0.083**	**0.306**	**0.053**

***** Significant at 1 % probability level***
**** Significant at 5 % probability level***

TABLE 3
SPECIFIC COMBINING ABILITY EFFECT FOR SEED YIELD PER HECTARE

Parents	Pant Lobia-1	Pant Lobia-2	Pant Lobia-3	PGCP-12	PGCP-14	Buksoura Local	PVCP-3
Pant Lobia-1		6.418**	4.447**	6.410**	-4.468**	-3.690**	1.121
Pant Lobia-2			3.751**	-2.353**	-0.531	0.647	4.758**
Pant Lobia-3				2.310*	2.599**	0.81	-0.479
PGCP-12					7.195**	2.106*	-1.016
PGCP-14						-3.705**	6.806**
Buksoura Local							0.818
PVCP-3							

	Sem±	CD at (1%)	CD at (5%)
Var (sij)	0.89	2.364	1.78

***** Significant at 1% probability level***
**** Significant at 5% probability level***

All the parents exhibited highly significant GCA effects except PVCP-3 for number of seeds per pod. Pant Lobia-2, Pant Lobia-3, and PGCP-12 expressed GCA effects in positive direction, whereas, Pant Lobia-1, PGCP-14 and Buksoura Local showed negative GCA effects. The results revealed that Pant Lobia-2, Pant Lobia-3 and PGCP-12 were good combiners for number of seeds per pod.

All the parents exhibited highly significant GCA effects. Pant Lobia-2, Pant Lobia-3 and PGCP-12 expressed GCA effects in positive direction, whereas, Pant Lobia-1, PGCP-14, Buksoura Local and PVCP-3 exhibited significant negative gca effects. The results indicated that Pant Lobia-2, Pant Lobia-3 and PGCP-12 were good combiners for seed weight per plant.

Pant Lobia-1, PGCP-12 and PGCP-14 expressed significant positive GCA effects, whereas, Pant Lobia-2, PVCP-3, Buksoura Local and Pant Lobia-3 exhibited significant negative GCA effects. Therefore, Pant Lobia-1, PGCP-12 and PGCP-14 were good combiners for 100-seed weight (g).

For Seed yield per hectare All the parents exhibited highly significant GCA effects. Significant positive effect was noticed for Pant Lobia-2, Pant Lobia-3 and PGCP-12, whereas, Pant Lobia-1, PGCP-14, Buksoura Local and PVCP-3 exhibited highly significant negative GCA effects. The results indicated that Pant Lobia-2, Pant Lobia-3, PGCP-12 were good combiner for seed yield per hectare and Pant Lobia-1, PGCP-14, Buksoura Local and PVCP-3 were poor combiners.

Genetically, GCA is a consequence of additive gene action while SCA is a consequence of non-additive (Dominance and Epitasis) gene action **(Henderson, 1952, and Falconer, 1989)**. A ratio of the two variances (GCA/SCA) could indicate which type of gene action is more important. When the ratio of GCA to SCA variances is more than unity, it indicates that additive gene action is more important than non additive gene actions in controlling the expression of the character and less than unity indicates the importance of non-additive gene action (Dominance and Epitasis) **(Gardner, 1963)**. If additive gene action is predominant in self-pollinated species, then the breeder can effectively select at various levels of inbreeding, because additive effects are readily transmissible from one generation to another. On the other hand, sufficient non-additive gene action may warrant the production of hybrids **(Gravois and Mcnew, 1993)**.

In the present study variances due to general combining ability were observed to be significant for all the characters studied. Variances due to specific combining ability were also significant for all the characters expect virus indicating the importance of additive as well as non-additive effects for these traits. Importance of both additive and non-additive effects for various characters was reported earlier by **Jatasara *et al.* (1980), Hazra *et al.* (1994), Bhushana *et al.* (1998), and Chaudhari *et al.* (2013).**

General combining ability study helps in making the choice of the parents and also helps in the isolation of suitable germplasm for further improvement. General combining ability is primarily a function of additive and additive x additive gene action. In present study significant and negative GCA effects were considered desirable for days to 1st flowering, days to pod maturity, plant height and cowpea mosaic virus, whereas, for other characters significant and positive GCA effects were considered desirable.

Pant Lobia-1 exhibited desirable GCA effect for days to 1st flowering, days to pod maturity, number of pods per plant, 100-seed weight. Pant Lobia-2 showed desirable GCA effect for number of pods per plant, number of seeds per pod, seed weight per plant, and seed yield per hectare. Pant Lobia-3 exhibited desirable GCA effect for days to 1st flowering, days to pod maturity, number of seeds per pod, seed weight per plant, seed yield per hectare. The variety PGCP-12 showed desirable GCA for days to 1st flowering, days to pod maturity, number of seeds per pod, seed weight per plant, 100-seed weight, seed yield per hectare. PGCP-14 and PVCP-3 exhibited desirable GCA effect for three characters *viz;* days to 1st flowering, number of pods per plant, 100-seed weight and pod length, plant height, green pod weight per plant. Buksoura Local showed exhibited desirable GCA effect for three characters *viz;* pod length, green pod weight per plant.

These results indicated that the parent deferred genetically in the manifestation of their GCA effects for different characters. These genotypes can successfully be utilized for improving seed yield of cowpea. Similar findings were also reported by **Patil and Bhapkar (1986), Mishra *et al.* (1987)**, **Hazra *et al.* (1994), Umaharan (1997), Manivannan and Kesar (2005), Pal *et al.* (2007), and Ayo-Vaughan *et al.* (2013)**.

3.3 Estimates of Specific Combining Ability Effects:

The SCA effects of all 21 crosses derived from 7 parents are presented for various characters. Results on character wise SCA effects are described here under:

Twelve crosses exhibited significant SCA effects. The estimate of SCA effect revealed highly significant negative values for Pant Lobia-2 x Pant Lobia-3 (-3.47) followed by Pant Lobia-2 x PGCP-14 (-2.569), PGCP-14 x Buksoura Local (-1.817), Pant Lobia-1 x PVCP-3 (-1.517) and Pant Lobia-3 x PVCP-3(-1.291). The cross Pant Lobia-2 x PVCP-3 (6.602) showed highly significant positive effect followed by Pant Lobia-1 x Buksoura Local (3.054), Pant Lobia-1 x Pant Lobia-3 (2.576), Pant Lobia -3 x PGCP-14 (1.606), PGCP-12 x Buksoura Local (1.409) and Pant Lobia-2 x Buksoura Local (1.139) showed significant positive SCA effect for days to 1st flowering.

Out of twenty-one crosses, nineteen crosses were found to have significant SCA effects. The cross Pant Lobia-1 x Pant Lobia-2 (11.997) had highest positive value. The number of pods per plant is one important yield component trait thus the likely to give better recombination in advanced generation.Out of twenty-one crosses, twenty crosses were found to have significant SCA effects. The cross PGCP-14 x PVCP-3 (2.228) had highest positive value and Pant Lobia-2 x PVCP-3 (-0.443). The crosses showing positive SCA effects for this trait are likely give long podded recombinants during the cause of selfing.

In case of 100-Seed weight (g) eighteen crosses exhibited significant SCA effects. The estimated SCA effect revealed significant positive value for Pant Lobia-1 x Pant Lobia-3 (6.301) followed by Buksoura Local x PVCP-3 (5.579), PGCP-14 x PVCP-3 (3.901) and PGCP-12 x PGCP-14 (0.590), whereas, highest negative value were found cross Pant Lobia-3 x PVCP-3 (-6.429) followed by Pant Lobia-1 x Buksoura Local (-2.092), Pant Lobia-1 x Pant Lobia-2 (-0.873), Pant Lobia-1 x PGCP-14 (-0.836) and Pant Lobia-1 x PVCP-3 (-0.062). The cross combinations showing positive SCA effects are likely to give bold seeded recombination upon selfing.

Best result for Seed yield per hectare out of twenty-one crosses, fourteen crosses were found to have highly significant SCA effects (Table 3). The cross PGCP-12 x PGCP-14 (7.195) had highest positive value followed by PGCP-14 x PVCP-3 (6.806), and PGCP-12 x Buksoura Local (2.106). Thus the crosses positive SCA effects emerged as better combinations which are likely to high yielding recombinants in advanced generation.

Summary of estimate of SCA effects of hybrid for yield and yield contributing traits are presented. Out of 21 F_1's evaluated, many crosses displayed significant SCA effects in the desired direction like 6 for days to 1st flowering, 6 for days to pod maturity, 11 for number of pods per plant, 13 for pod length, 11 for plant height, 16 for green pod weight per plant, 13 for number of seeds per pod, 13 for seed weight per plant, 13 for 100-seed weight, 10 for seed yield per hectare.

Significant positive SCA effects for seed yield per hectare in PGCP-12 x PGCP-14 was associated with significant and desirable SCA effects for number of pods per plant, green pod weight per plant, seed weight per plant and 100-seed weight. The desirable SCA effects for seed yield per hectare in Pant Lobia-1 x Pant Lobia-2, Pant Lobia-1 x PGCP-12 and Pant Lobia-2 x PVCP-3 accompanied by significant SCA effects in desired direction for four, three and five components' characters, respectively. Thus, these crosses could be judged as outstanding crosses for simultaneous improvement of seed yield and one or more component characters.

The ranking of high SCA crosses for seed yield showed the parents having high estimates of GCA did not necessarily record high estimates of SCA. Out of ten crosses only one cross namely PGCP-12 x PGCP-14 had both the good general combiner parents. This cross is therefore amenable for improvement through selection. Remaining nine crosses exhibiting significant positive SCA effects for seed yield per hectare combined either both or at least one poor/average general combiners. The results therefore, indicate the operation of dominant x dominant and or additive x dominant gene interactions for the genetic control of expression of yield in these crosses. Based on this heterosis breeding appears to be the best approached for the exploitation of available genetic variability. Similar results were reported by **Patil and Bhapkar (1986), Mishra *et al.* (1987), Manivannan and Kesar (2005) and Ushakumari (2010).**

Based on SCA effects the crosses Pant Lobia-2 x Pant Lobia-3 and Pant Lobia-2 x PGCP-14 appeared promising crosses for earliness of flowering. These observations suggest that maintenance of heterozygosity in the population could be necessary for desired expression of these characters. Similar results were reported by **Patil and Bhapkar (1986), Mishra *et al.* (1987), Pal *et al.*, (2007) and Mote *et al.* (2007)**.

3.4 Estimates of Heterosis:

Heterosis was explained as per cent increase (positive) or decrease (negative) in the average performance of hybrid over the mid parent (relative heterosis), better parent (heterobeltiosis) and check variety (economic and standard heterosis).

The Days to 1st flowering estimate of relative heterosis, heterobeltiosis and economic heterosis is presented. Out of the twenty-one crosses, fifteen crosses showed significant relative heterosis, which ranged from -10.00 to 22.15%. The cross Pant Lobia-

2 X Pant Lobia-3 (-10.00) followed by Pant Lobia-1 x PGCP-14 (-6.94), Pant Lobia-2 x PGCP-12 (-6.90), Pant Lobia-2 x PGCP-14 (-5.36), Pant Lobia-1 x PGCP-12 (-4.31) and PGCP-14 x Buksoura Local (-3.80) showed heterosis in negative value that is heterosis for flowering. The estimate of heterobeltiosis ranged from -2.50 to 28.20 %. The one cross showed significant heterobeltiosis in desired direction (negative heterobeltiosis) Pant Lobia-2 x Pant Lobia-3 (-2.50).

Number of pods per plant the estimate of relative heterosis, heterobeltiosis and economic heterosis is presented. Relative heterosis was found to be significant for all cross combination that ranged from 15.52 to 238.58 %. The combination PGCP-14 x Buksoura Local (238.58) showed highest relative heterosis by Pant Lobia-1 x Pant Lobia-2 (210.70) and Pant Lobia-3 x PVCP-3 (15.52). The range of economic heterosis was -11.95 to 223.70 %. nineteen crosses showed significant economic heterosis Pant Lobia-1 x Pant Lobia-2 (223.47) and Pant Lobia-3 x PGCP-14 (6.96).

The significant heterobeltiosis was showed by the entire cross which ranged from -46.15 to 24.66%, out of the eleven cross combinations showed heterosis in positive direction. The heterobeltiosis was noticed for Pant Lobia-2 x Pant Lobia-3 (24.66) by Pant Lobia-3 x PGCP-12 (21.25) and Pant Lobia-2 x PGCP-14 (1.28). The estimate of relative heterosis, heterobeltiosis and economic heterosis for seed weight per plant presented. Significant relative heterosis was showed by crosses which constitute a range of -18.09 to 63.07 %. Out of twenty-one, the eighteen-cross relative heterosis in positive direction. The highest value was notice of for Pant Lobia-1 x Pant Lobia-2 (63.07) followed by PGCP-12 x PGCP-14 (63.00), Pant Lobia-1 x PGCP-12 (59.24), and Pant Lobia-3 x PVCP-3 (5.21). All crosses exhibited significant heterobeltiosis. The range was -18.38 to 67.22%. Out of twenty-one, eighteen cross showed heterobeltiosis in desired direction.

For 100-seed weight (g) the estimate of relative heterosis, heterobeltiosis and economic heterosis is presented. The results of relative heterosis depicted that out of twenty-one, twenty crosses showed significant relative heterosis, which ranged from 38-28 to 72-70%. Heterobeltiosis ranged from-36.17 to 47.69%, twenty-one crosses should significant Heterobeltiosis, out of which twelve crosses expressed heterobeltiosis in positive Heterosis. The cross Buksoura Local x PVCP-3 (47.69) and Pant Lobia-3 x PGCP-14 (1.21), should positive heterosis. All the combinations except Pant Lobia-3 x PGCP-12 showed significant which ranged from -54.73 to 26.63%, six crosses combination should economic heterosis in desired direction.

For Seed yield per hectare **t**he estimates of all three types of heterosis are given all the crosses showed significant relative heterosis with the range of -18.24 to 63.34. The maximum value in positive direction was noticed for Pant Lobia-1 x Pant Lobia-2 (63.34) followed by PGCP-12 x PGCP-14 (63.01), PGCP-14 x PVCP-3 (-9.31) and Pant Lobia-1 x PGCP-12 (59.22). Twenty crosses exhibited significant heterobeltiosis for Seed yield per hectare the range was -18.40 to 47.69%. The best combination was Pant Lobia-1 x PGCP-12 (47.64) followed by PGCP-14 x PVCP-3 (46.26), Pant Lobia-2 x PGCP-14 (43.10), and Pant Lobia-3 x Buksoura Local (7.69) showed positive Heterosis.

Heterosis is usually described in terms of the superiority of F_1 hybrid performance over some measure of parental performance that means definition of heterosis differs depending on the basis of comparison used. Heterosis is defined as improvement of F_1 over the mean of both parents (mid parent heterosis or relative heterosis) **(Pickett, 1993 and Stuber, 1999),** over the mean of the better parent or heterobeltiosis **(Briggs and Knowles, 1967 and Jinks, 1983)**. These definitions coincide with that of **Hayes *et al.* (1955)**

In the present investigation heterosis has been measured over better parent, BP (heterobeltiosis), over mid parental value, MP (relative heterosis) and standard variety, Pant Lobia-1 (economic heterosis). For days to 1st flowering the negative heterosis is desired to develop early genotypes. The cross Pant Lobia-2 x Pant Lobia-3 (-2.50) was found to be best heterotic combination for relative heterosis (-10.00) and heterobeltiosis (-2.50). Seventeen crosses combination showed heterosis over check in the desired direction. All the crosses showed economic heterosis in positive value. Similar results were obtained by **Marangappanavar (1984), Shakarad (1989), Bhushana *et al.* (2000), Ushakumari *et al.* (2010) and Patel *et al.* (2013).**

For seed weight per plant, relative heterosis, heterobeltiosis and economic heterosis ranged from -18.09 to 63.07 %, -18.38 to 67.22 % and -4.13 to 93.46 %, respectively. Cross Pant Lobia-1 x Pant Lobia-2 emerged as best combination for relative heterosis (63.07) and PGCP-14 x PVCP-3 was best combination for heterobeltiosis (67.22). One cross PGCP-12 x PGCP-14 (93.46), combination showed highest economic heterosis in desired direction. The results of investigation matched with the findings of **Sangwan and Lodhi (1995), and Patel *et al.* (2013).**

The range of relative heterosis, heterobeltiosis and economic heterosis for seed yield per hectare was -18.24 to 63.34, -18 .40 to 47.69% and -4.66 to 93.40%, respectively. The best heterotic combination for relative heterosis was Pant Lobia-1 x Pant Lobia-2 (63.34). The cross Pant Lobia-1 x PGCP-12 (47.64) was found to be the best for heterobeltiosis and PGCP-12 x PGCP-14 (93.40) was found to be best for economic heterosis. Similar results were reported by **Marangappanavar (1984),**

Srikantaradhya (1984), Kabiraj-Neupane (1986), Sangwan and Lodhi (1995), Bennett-Lartey (1999) and Patel *et al.* (2009).

IV. CONCLUSION

Based on the finding of the present investigation Pant Lobia-1, Pant Lobia-2, Pant Lobia-3, PGCP-12 and PGCP-14 were good general combiners for number of seeds per pod, seed weight per plant, 100-seed weight and seed yield per hectare which can be used in hybridization programme to improve grain yield. Buksoura local and PVCP-3 were good general combiner for number of pods plant, pod length, green pod weight per plant thus can be exploited for developing vegetable type varieties.

Considering results of gene action, it is apparent that most of the characters in either of the family were found under the control of both fixable (additive, additive x additive) and non-fixable (dominance and epistatic) gene effects coupled with duplicate type of epistasis. Therefore, selection programme aiming to improve such traits in a population should accumulate the fixable additive genes first in early generations. Simultaneously breeding method like modified recurrent selection *i.e.,* alternating pedigree and recurrent selection cycle, diallel selective mating system may be tried for the effective and efficient exploitation non-fixable gene effects.

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