# LINE X TESTER ANALYSIS IN PIGEONPEA



**THESIS**

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Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola
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By

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# DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the thesis entitled **"LINE X TESTER ANALYSIS IN PIGEONPEA"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or Scientific Organization. The sources of material used and all assistance received during the course of investigation have been duly acknowledged.

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# CERTIFICATE

This is to certify that the thesis entitled **"LINE X TESTER ANALYSIS IN PIGEONPEA"** submitted in partial fulfillment of the requirement for the degree of "**Master of Science In Agriculture (Agricultural Botany)"** of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **Dhiraj Suresh Hivrale** under my guidance and supervision.

The subject of thesis has been approved by the Student's Advisory Committee.

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## (D) Abbreviations

| | | |
|---|---|---|
| % | - | Per cent |
| / | - | Per |
| C.D. | - | Critical differences |
| CGMS | - | Cytoplasmic Genetic Male Sterility |
| cm | - | Centimeter |
| d.f. | - | Degree of freedom |
| Deptt. | - | Department |
| Dr. PDKV | - | Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola |
| e.g. | - | Exampli gratia (For example) |
| EMS | - | Ethyl Methyl Sulphonate |
| et al. | - | Et alia (and others) |
| etc. | - | Et cetra |
| Fig. | - | Figure |
| FS | - | Full Sibs |
| g | - | gram |
| GAU | - | Gujrat Agriculture University |
| gca / GCA | - | General Combining Ability |
| GMS | - | Genetic Male Sterility |
| ha | - | hectare |
| HS | - | Half Sibs |
| i.e. | - | That is |
| ICAR | - | Indian Council of Agriculture Research |
| ICRISAT | - | International Crop Research Institute for Semi-Arid Tropics |
| J. | - | Journal |
| kg | - | Kilogram |
| m | - | Million |
| M / ha | - | Million per hectare |
| M.Sc. | - | Master of Science |

| | | |
|---|---|---|
| $m^2$ | - | Square meter |
| MS | - | Mean square |
| MSe | - | Error mean squares |
| MT | - | Metric Tonnes |
| No. | - | Number (s) |
| q/ha | - | Quintals per hectare |
| sca / SCA | - | Specific Combining Ability |
| Sci. | - | Science |
| SE | - | Standard Error |
| SE(d) | - | Standard error of difference |
| SE(m) ± | - | Stnadard error of mean |
| Sr. No. | - | Serial number |
| Unpub. | - | Unpublished |
| *Viz.,* | - | Videlicet (namely) |
| vs | - | versus |
| $\sigma$ | - | Standard deviation |
| $\Sigma$ | - | Summation |
| $\sigma^2$ | - | Variance |

(E) **THESIS ABSTRACT**

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## ABSTRACT

The present investigation entitled "Line X Tester Analysis in Pigeonpea" was undertaken to estimate the extent heterosis and to estimate the combining ability effects in pigeonpea genotypes to find out the high yielding hybrid combinations. Line x Tester analysis (Kempthorne, 1957) was used for the evaluation of 4 cms lines (females) and 9 testers (male). The

critisisum and suggestioins of Arunachalam (1974) was ketp in view.

The set of 13 parents four females viz., AKV-2A, AKV4A, AKV-8A, AKV-9A. nine males viz., AKPR-324, AKPR-23, AKPR-312, AKPR-386, AKPR-227, AKPR-210, AKPR-345, AKPR-205, AKPR-250 and their 36 hybrids along with two check 'Asha' and 'Maruti' were evaluated in RBD with three replications at the field of Pulses Research Unit, Dr. PDKV, Akola during Kharif 2009-2010.

The data were recorded on the characters viz., plant height per plant (cm), number of branches per plant, Number of clusters per plant, number of pods per plant, , 100 seed weight (g), number of seeds per pod, grain weight per plant (g) on five randomly selected plants, days to 50 percent flowering and days to maturity are recorded on plot basis.

The highest significant useful heterosis for grain weight per plant was recorded by AKV-9A X AKPR-23 (5.691%, 8.333%) over both the check Asha and Maruthi respectively.

AKV-9A and AKV8A among the female parents were found to possess significant gca effect for yield and most of the yield contributing characters. AKPR-205 and AKPR-23 among the male parents exhibited highly significnat gca effect and was the best general combiner among the males for yield and yield contributing characters.

AKV-9A X AKPR-23 (59.006) recorded the highest and highly significant positive sca effect followed by AKV-4A X AKPR-386 (49.199), AKV-2A X AKPR-210 (32.479) for yield and most of the yield contributing characters.

Considering the per se performance for useful heterosis, gca effects of parents, sca effects of croses, the five crosses viz. AKV-9A X AKPR-23, AKV-4A X AKPR-386, AKV-9A X AKPR-324, were identified as best crosses for further crop improvement programme.

# CHAPTER I

# INTRODUCTION

## 1.1 Background information

Pulses constitute an important ingredient in predominantly vegetarian diet and are important as source of protein that nutritionally balances the proteins from cereal grains. They supply minerals and vitamins and provide an abundance of food energy. Pulses provide a cheaper source of protein, as they generally contain nearly twice as much protein as that of cereals and hence correctly called poor man's meat. Pulses are also important for sustainable agriculture, enriching the soil through biological nitrogen fixation. They enrich the soil with nitrogen upto 20-40 kg N/ha and organic matter through leaf fall and profuse underground root growth (Hariprassanna and Bhatt, 2002).

Pigeon pea [*Cajanus cajan* (L.) Millspaugh] is a short-lived perennial shrub that is traditionally cultivated as an annual crop in developing countries. It is an important legume crop mostly produced in Asia, Africa, Latin America, and the Caribbean region. Based on the vast natural genetic variability in local germplasm and the presence of numerous wild relatives, van der Maesen concluded that India is probably its primary center of origin. Pigeon pea is a hardy, widely adapted and drought tolerant crop with a large temporal variation (90–300 days) for maturity. These traits allow its cultivation in a range of environments and cropping systems.

Pigeonpea (*Cajanus cajan* (L.) Millsp.) is the most versatile food legume with diversified uses as food, feed, fodder and fuel. pigeonpea is one of the important pulse crops of India and ranks second to chickpea in area and production. It is commonly known as Tur, red gram or arhar. It belongs to family leguminoseae, sub family papilionaceae having chromosome number 2n = 2x = 22 (Dundas, 1990).

Based on the occurrence of wild forms in Africa, particularly in the regions of the upper Nile and coastal districts of Angola, Decandolle (1904) and Krauss (1932) suggested Africa as the possible center of origin for pigeonpea. Keeping in view the wide range of diversity in India, pigeonpea was considered to be of the Indian origin (Vavilov, 1951). Abundance of *cajanus cajan* and its wild relatives in the every green forest area of western Ghats and Malabar coast of India indicates this regeon (De, 1974). Presence of wild relatives, large diversity of gene pool, ample linguistic evidences, a few archaeological remains and wide home consumption usage shows that pigeonpea is originated in India. pigeonpea is supposed to be evolved from tall bushy plants like *Cajanus cajanifolius* (Van der Maesen, 1990).

Pigeonpea is the fourth most important pulse crop in the world with almost all production confining to developing countries. In World total area under pigeonpea cultivation is about 4.58 million ha. With production 3.27 M.tones (Anonymous 2008). India is largest pulses producer and account for 27-28 percent of global production. In Asia, India (3.58 Mha), Myanmar (560,000 ha), China (150,000 ha), and Nepal (20,703 ha) are major pigeon pea growing countries. On the African continent, Kenya (196,261 ha), Malawi (123,000 ha), Uganda (86,000 ha), Mozambique (85,000 ha), and Tanzania (68,000 ha) grow considerable pigeon pea (Anonymous 2008). The Caribbean islands and some South American countries also have considerable area devoted to growing pigeon pea. The traditional pigeon pea cultivars and landraces are long duration types grown as an intercrop with other more early maturing cereals and legumes. In addition to its main use as de-hulled split peas, its immature green seeds and pods are also consumed fresh as a green vegetable. The crushed dry seeds are fed to animals while the green leaves form a quality fodder. In rural areas, dry stems of pigeon pea are used for fuel. In a cropping season, pigeon pea plants fix 40 kg $ha^{-1}$ atmospheric nitrogen (Rao *et al.* 1983) and add valuable organic matter to the soil through fallen leaves. Its roots help in releasing soil-bound phosphorus to make it available for plant growth (Ae *et al.* 1990). With so many benefits at low cost, pigeon pea has become an ideal crop for sustainable agriculture systems in rain-dependent areas.

In India, Pigeonpea is grown on 3.53 million ha. mainly in Uttar Pradesh, Maharashtra, Gujarat and Rajasthan with the production of 2.61 million tones (Anonymous, 2008)

In Maharashtra, the area under pigeonpea is approximately 11.81 lakh ha. with the production of 11.06 lakhs tones and average yield is 937 kg/ha. In Vidharbha region the area under pigeonpea lies around 5.419 lakh ha with the production of 5.37 lakh tones and the average productivity is 1024.6 kg/ha. (Anonymous, 2008)

Pigeonpea is a rich source of proteins, carbohydrates and certain minerals (Gopalan *et al.,* 1971). Protein content of commonly grown pigeonpea cultivars ranges between 17.9 and 24.3 g per 100 g for whole grain samples and split grains (Salumkhe *et al.,* 1986). Pigeonpea seeds also contain about 57.3 to 58.7 per cent carbohydrate, 1.2 to 8.1 per cent crude fibre and 0.6 to 3.8 per cent lipids (Sinha, 1977). Seed of pigeonpea is a good source of iron and iodine and rich in essential amino acids like lycine, tyrocine, cystime and arginine. It is study crop and can be grown on wide range of soil and under diverse agroecological environment. Being legume it has symbiotic association with *rhizobium* which play an important role in fixing atmospheric nitrogen for which pigeonpea is inevitable part of various cropping system. The outer covering of its seed together with part of kernels provides a valuable feed for milch cattle (Singh, 2003).

### 1.2 Importance and need of study

Green revolution made our nation self sufficient in case of cereals but we are still deficient in pulse production. India still imports red gram from countries like Myanmar, Australia and Africa to satisfy the pulse requirement. This impose great burden on our economy. To get rid off this bulky expenditure, we have to think about pigeonpea improvement, as a remedial measure (Singhal, 2003).

In order to initiate hybrid production programme on commercial scale, there are some basic requirement that has to be fulfilled by the crop *viz.,* abundant natural out pollination, efficient system of emasculation, restoration system etc. to get good hybrid seed yield.

Efficient pollen transfer system and sufficient amount of natural out pollination is much essential for hybrid seed production. In pigeonpea pollination is mediated by none bee (Bhatia *et al.,* 1981). Howard *et al.* (1919) observed the natural cross pollination upto 14 per cent. Whereas Saxena *et al.* (1990) recorded the ample amount of natural out pollination upto 70 per cent, which is favorable factor in production of hybrid seed.

To achieve a breakthrough in yield, pigeon pea breeders unsucessfully tried various breeding methods such as pureline breeding, population breeding, mutation breeding, and inter-specific crosses. ICRISAT scientists also developed a hybrid breeding system using partial natural out crossing of the crop coupled with genetic male-sterility (Reddy *et* al. 1978). Combining these two components, Saxena et al. developed the world's first pigeon pea hybrid ICPH 8, which was released for cultivation in 1991. Performance of ICPH 8 in 100 multilocation trials, under diverse agro-ecological conditions, conducted over a period of 6 years recorded an average30.5% yield gain over the best available pure line variety UPAS 120. Such yield gains of the hybrid were confirmed in a series of on farm trials (Saxena *et al.*,1992). These results revealed substantial levels of hybrid vigor that could be exploited commercially. This hybrid, in spite of high yields, failed to be adopted due to the high cost of seed production and this necessitated breeding for a more efficient cytoplasmic nuclear male-sterility (CMS) system.

For commercial hybrid seed production, there is need for ease in hybridization. Traditionally it is achieved by hand emasculation followed by pollination. But in crop like pigeonpea which is cleistogamous in nature, hand emasculation and hand pollination are not feasible for hybrid seed production because these are tedious and costly operations. This difficulty can be overcome by genetical method of emasculation i.e. through male sterility system (Chaudhary, 1986).

First report of male sterility in pigeonpea was published by Deshmukh (1959). However it was associated with female sterility, so it was of little use. In 1978, Reddy *et al.* has given first stable genetic male sterility system in pigeonpea. After these Wanjari *et al.* (1995) discovered another male sterility source derived from cross *Cajanus volubilis* x *Cajanus cajan*. On the basis of GMS system reported by Reddy *et al.* (1978), there are six GMS based hybrids *viz.*, ICPH-8 (ICRISAT, Hyderabad), PPH-4 (PAU, Ludhiana), COH-1 and COH-2 (TNAU, Coimbatore), AKPH-4101and AKPH-2022 (Dr. PDKV, Akola).

Genetic male sterility has it's own limitations i.e In case of hybrids seed production 50 percent fertile plants from female row has to be rougued out. This account to near about 50 per cent loss of plant population from female plots at flowering stage. Male fertile plants, which need to be rogue out, if they are not identified properly at flowering, can leads to contamination and it interferes the purity of hybrid seed. To avoid such problems, efforts are necessary to identify seedling markers associated with male sterility (Patil *et al.*, 1998).

The other alternative is to go for cytoplasmic genetic male sterility. Reddy and Faris (1981) reported the possibility of maternal inheritance of male sterility in progenies derived from "*Cajanus scarabaciodes* x *Cajanus cajan*". Zaveri (1992) reported the progenies from a cross "*Cajanus sericeus* x *Cajanus cajan*" showing cytoplasmic male sterility. Tikka *et al.* (1997) reported first stable cytoplasmic male sterility in derivatives of inter specific cross involving the cytoplasm of *Cajanus scarabaeoides*. Wanjari *et al.* (1999) identified new source from *Cajanus volubilis* cytoplasm. So far five primary CMS sources derived from various inter specific crosses have been reported in pigeonpea. These are designated as i) $A_1$ cytoplasm, derived from *Cajanus sericeus* ii) $A_2$ cytoplsm, derived from *Cajanus scarabaeoides* iii) $A_3$ cytoplasm, derived from *Cajanus volubilis* iv) $A_4$ cytoplasm, derived from *Cajanus cajanifolius* v) $A_5$ cytoplsm, derived from cultivated pigeonpea from these CMS sources $A_2$ and $A_4$ cytoplasm have been found to be stable and are being used in the hybrid breeding programmes in India.

In order to make use of these cytoplasmic male sterility in commercial hybrid seed production, availability of good fertility in $F_1$ hybrids. Some indications regarding fertility restoration were observed with germplasm line ICP-10875, at Pulses Research Unit, Dr. PDKV, Akola (Patel, 2000).

Though India ranks first in area and production of pigeonpea, the average productivity of pigeonpea, the average productivity of the crop is low at around 712 kg/ha. To break the yield barriers in Pigeonpea in India, one of the ways is to exploit the phenomenon of heterosis is important.

## 1.3 Objectives of the study

The present study is undertaken with the following objectives.

1. To asses *per se* performance of newly developed male sterile and restorer lines.
2. To estimate general combining ability of parents and specific combining ability of hybrids.
3. To study heterosis and heterobeltosis for grain yield and its components

## 1.4 Hypothesis

Heterosis results in increase in size, yield, general vegetative growth, etc. in $F_1$ hybrids compared to parents.

Combining ability analysis provides the information for selection for the desirable parents and cross combinations for exploitation. In this analysis, total genetic variation is partitioned into GCA and SCA effects to verify the parents in terms of combining ability to combine in hybrid combination. Combining ability is the ability to transmit the superior performance to its progeny i.e resulting hybrids.

### 1.5 Scope and limitations of the study

The present investigation entitled as "Line×Tester analysis in pigeonpea" was conducted at the field of Pulses Research Unit, Dr.P.D.K.V., Akola. During *kharif* 2009-10.

Data were subjected to statistical analysis using line×tester analysis

Application of biometrical techniques like line×tester analysis has, appeared to be the most useful tool for screening lines with rapidity and reasonable degree of confidence. This approach has practical utility in breeding programme aimed at genetic improvement for yield.

In case of line×tester design each parent does not have opportunity to mate recombine with every parent.

# CHAPTER II

# REVIEW OF LITERATURE

Hybrid pigeonpea breeding has a very short history starting from the discovery of genetic male sterility in 1978. Further, emphasis has been shifted to cytoplasmic genetic male sterility. The object of the present review is to highlight the salient related research on "Line x Tester analysis in pigeonpea" a brief review of literature related to project entitled above has been illustrated in this chapter, under following headings,

2.1 Pollination in Pigeonpea

2.2 Pod and seed setting on Pigeonpea male sterile lines

2.3 Male sterility in Pigeonpea

2.4 Heterosis

2.5 Combining ability

## 2.1 Pollination in pigeonpea

Pollination behaviour of crops plants play an important role in deciding the breeding strategies for its improvement. In pigeonpea, early part of flower bud's life cycle is cleistogamous. This condition is knows as preanthesis cleistogamy. This leads to maximum self pollination. However, certain reports shows that considerably high level of cross pollination occurs in pigeonpea.

Datta and Deb(1970) observed that out crossing in pigeonpea due to slow growth of pollen tube.

Prasad *et al.* (1972) observed the extent of natural out crossing in pigeonpea i.e. 3.79 per cent to 26.66 per cent. He also observed that different varieties differ in extent of natural out crossing.

Faegri and Vander Pijl (1979) used special terminology i.e. Melittophily for out crossing by honey bees in pigeonpea.

Bhatia *et al.* (1981) reported that out crossing in pigeonpea is mediated by honeybees especially megachile and Apis species.

Onim (1981) observed a reason that out crossing in pigeonpea is due to delay in pollen germination after anther dehiscence.

Saxena *et al.* (1990) observed ample amount of out pollination up to 70 per cent and stated that this is sufficient level of out crossing for hybrid seed production on commercial scale.

Wanjari *et al.* (1993) reported that establishment of honey bee colonies in pigeonpea plants promotes hybrid seed setting and stated that sufficient amount of natural out pollination is very much essential for production of hybrid seed.

Kumar and Saxena (2001) reported wind pollination in GMS and CMS lines of pigeonpea.

Shiying *et al.* (2002) observed the natural out pollination in China in the range of 15 to 30 per cent and also found that in some progenies it extends up to 60 per cent.

Sindhu *et al.* (2003) reported cross pollination in GMS line i.e. female of pigeonpea hybrid PPH-4 in the range of 73.2 to 81.8 per cent.

**2.2. Pod and seed setting on pigeonpea male sterile lines:**

Pigeonpea generally flowers profusely but most of the flowers are shed without setting pods. Pod set is reduced by more pod shading and about 10-20% set pods (Sexena *et al.*, 1990). It may depend on the presence of already developing pod bearing on the plant. The balance of source-sink, probably depends on availability of assimilates and other nutrients (Sheldrake and Narayanan, 1979). The number of flowers produced by a plant is probably too high to be supported physiologically by the plants. Pandey and Singh (1981) reported flower abortion as high as 86 per cent.

In breeding, program is concern lies with it as a factor to obtain desired setting of pod / seed, selfed or crossed as per the objective of the programme. Successful hybridization depends upon time of emasculation and pollination (Veerswamy *et al.*, 1973), size of bud, environmental conditions besides the technical skill and competence of the workers. Pod set in pigeonpea under natural (Hammerton., 1975; Pandey and Singh., 1981) as well as artificial hybridization (Singh *et al.*, 1978) is usually very low due to abundant flower drop. However, wide range of successes in hybrid seed set has been reported in the literature. For the experimental testing to identify heterotic crosses; the hybrid seeds are produced by hand pollinating female (male sterile) flowers. One trained person can pollinate about 400 flowers in a day and around 20-40 per cent pod set is achieved (Sexena *et al.*, 1986). Despite proper conditions and careful handling of buds, the pod setting in mechanical hybridization of pigeonpea as a whole is rather poor.

Rangaswamy *et. al.* (1975), studied flowering and pod setting pattern in red gram and reported that at Coimbatore, flower production and pod set were maximum during $1^{st}$ three weeks of flowering in summer, seed weight and pod seed ratio were highest for pod formed in the $1^{st}$ week of flowering.

Pandey and Singh (1981) observed 86 per cent flower abortion in pigeonpea. The varieties of late maturity had generally less proportional pod set, where as it was comparatively high with the early maturing varieties. It may be affected adversely due to moisture stress at flowering of late types. Pod set percentage varied from 16 to 38 per cent.

Wanjari *et al.* (1993) and Patel (2000) reported that pod setting on male sterile plants depends upon extend of out-crossing, pollen source, insect pollination, agronomical practices etc. vary degree of pod setting in pigeonpea is reported by many research workers. An average pod setting of 38 per cent with range of 2 to 10 per cent is a set of 28 crosses involving eight parents of 11 was recorded in by Singh *et al.* (1980).

Kharb *et al.* (1995) reported that, crosses performed between 8.00 AM to 12.00 PM gave the best results with respect to pod setting .They observed that, rains after pollination and high wind velocity during crossing had adverse effect on pod setting.

Rao *et al.* (1996) studied pod and seed set in CMS lines and they observed 62.5% pod set and average 2.6 seed / pod on pollination with ICPL-85010.Under open pollination there was good pod set with an average 45 hybrid pods/ plants and 1.8 seeds/ pod.

Patel (2000), reported that in respect of seasonal variation 1999-2000 was comparatively better to pod set while 1998-99 was found better in respect of seeds per pod excepct in case of AKcms-1. There were genotypic differences among the male sterile lines. CMS GT-288 was observed to be the best in respect of all three parameter viz. pod set per hundred flower buds, seed set per pod and seed set per hundred flower buds. AKcms-1 appeared to be in all three parameters except during 1999-2000, where it was second highest for seeds per pod. Further periodical observations revealed that $48^{th}$ to $4^{th}$ metrological week i.e. $26^{th}$ November to $2^{nd}$ December to 22-$28^{th}$ January was found to be better for hybrid pod and seed set under both situations i.e. in open pollination and with hand pollination. There were very limited differeeces in respect of interaction of male sterile line and period of tagging per pollination. AKms-2 set more number of seeds per pod under wide range of period. Number of pod set under open pollination depends upon availability of pollination. it was 50.69 pods per hundred flower buds. Although pod and seed setting are the characters influenced by female. Observations were revealed that pollinators viz. ICPL-87119, BSMR-853 and BWR-376 influenced the seeds per pod on male sterile lines. Study of seed set under net-cage revealed that both genetic male sterile and cytoplasmic male steriles were stable over environment. While under pollination, besides environmental factors, other factor which affects the pod setting may be genotypic differences, presence of already developed pods and technical skill of workers.

Chavan (2001) reported that pod setting was observed at weekly interval from 14th November, 2000 to 14th December, 2000. Mean pod setting percentage on the male sterile plants in each week from 14th November to 14th December, 2000 showed significant difference for the pod setting behavior due to the time of pod setting recorded in these four weeks. Earlier period i.e. 1st week (14-21 Nov., 2000) and 2nd week (22-29 Nov., 2000) had better pod set (28.62 to 29.50%) than latter period i.e. 3rd week (30th Nov.- 6th Dec. 2000) and 4th week (7-14th Dec. 2000) where pod set was 25.00 to 25.25 per cent.

Yadav *et al.* (2001) conducted the experiment during October-November (wet season) and March-April (dry season) 1996-97 and October-November 1997-98 to study pod set in pigeonpea with hybridization using GMS line ms UPAS 120. Average pod set of 20.1% with a range of 5.00-66.7 % was observed in case of pollination made during March–April 1996-97.The lower pod set of 13.2% with a range of 5.7-24.2% was observed in October-November 1997-98 pollination. Thus, dry season favors the seed setting on male sterile lines

Siddanagouda (2004) reported that studies on pod setting / 100 flowers buds on male sterile lines under open pollination revealed that, highest pod setting recorded on AKV-4A (23.53%) which is based on *C. scarabaeoides* cytoplasm followed by AKms Vol 4 (23.33%), CMS lanceolatus-231186 (22%) and other s. Lowest average pod set per 100 flower buds was recorded an AKms Vol.3 (7.3%), followed by AKV-8 (13.4%) which is on *C. scarabaeoides* cytoplasm and others. Also reported that seed set / pod set was highest on AKms Vol. 3 (2.72) followed by AKms 4 (2.71), AKms 2 (2.68) and others. Lowest seed set / pod set recorded on CMS *lanceolatus*-2321183 (2.29) and seed set / 100 flower buds was highest as CMS AKV-a (59) followed by AKms Vol-4. (58.35) AKms 22 (57.26) and others. Lowest seed set / 100 flower buds were recorded on CMS AKV-2 (32.6). In all these three cases i.e. pod set / 100 flower buds, seed set / pod and seed set / 100 flower buds there was no much difference in mean pod or seed set in these three meteorological weeks studied under open pollination.

Saxena *et al.* (2006) Insect-aided natural out-crossing in pigeonpea [*Cajanus cajan* (L.) Millsp.] is a common event. It is considered to be a prime constraint in maintaining genetic purity of cultivars and genetic stocks. On the contrary, the out-crossing has also been exploited to select high-yielding varieties from landraces. This paper, for the first time, reports natural out-crossing in four wild relatives of pigeonpea. The highest (17.1%) natural out-crossing was recorded in C. lineatus and it was comparable to the control cultivar Asha (22.2%). C. albicans and C. scarabaeoides exhibited 10.0 and 8.3% outcrossing, respectively. C. sericeus was found to have lowest (2.3%) natural out-crossing.

### 2.3 Male sterility in pigeonpea

In hybridization programme for any field crop emasculation is primary and essential operation. Emasculation involved removal of male organ from bisexual flower before dehiscence of anther. Emasculation carried out manually, physically, chemically or genetically. Generally hand emasculation in hard and tough job, when flower are small and cleistogamous in nature as that of pigeonpea. With hand emasculation followed by hand pollination very small number of seeds is obtained.

Physical and chemical means of inducing male sterility are not much impressive die to indeterminate flowering habit of pigeonpea, which continues up to time of harvest. All these things create the need to search genetic mechanism of emasculation i.e. male sterility system, which can be effectively used in hybridization programme.

#### 2.3.1 Male sterility

Male sterility refers to a condition in which pollen are either absent or if present, they are non-functional. Koelreuter in 1763 first reported male sterility in flowering plants. Later on numerous cases of male sterility in angiosperm were reported. Allard (1960) and Duvick (1965) presented good amount of male sterility in flowering plants. More recently, work on male sterility has been reviewed by Frankel (1977) and Kaul (1988). Evidence for genetic control of male sterility comes from the work of Bateson *et al.* (1908)

on sweet peas. A recessive gene governing sterility was found in several plant species. However Soloman (1910) demonstrated that dominant genes determine male sterility in potato. Correns (1908) reported for first time that cytoplasmic factor could influence the occurrence of male sterility in which the trait would be inherited maternally. Following these initial findings, spontaneously occurring as well as induced male sterility variants have been identified in large number of plant genera, species and crosses within and between them (Kaul, 1998). The male sterility may be heritable or non-heritable and may be produced by chemicals, ionizing radiations, environmental manipulations, genetic engineering etc., Kaul (1988) gave the general pattern of classification of male sterility.

Male sterility type

- Genetic (Spontaneous or induced)
  - 1. Phenotypic
    - i) Sporogenous
    - ii) Structural
    - iii) Functional
  - 2. Genotypic
    - i) Genic
    - ii) Cytoplasmic
    - iii) Genic-cytoplasmic
- Non-genetic (Induced)
  - 1. Chemicals — Male gametocides and other chemicals
  - 2. Physiological
    - Imfluenced by temperature
    - Photoperiod
    - Enzyme balance
    - Other biochemicals
  - 3. Ecological
    - Climatic
    - Edaphic
    - Biotic
    - Physiographic

Some male sterile plants exhibit more than one phenotypic manifestation. Therefore, classification of male sterility on genotypic basis is vital. Accordingly depending upon nuclear and cytoplasmic genome constitution as evidenced by the inheritance pattern, male sterility has been primarily classified into genetic, cytoplasmic and genetic cytoplasmic type.

### 2.3.1.1 Genetic male sterility (GMS)

Genetic male sterility is controlled by nuclear genes whose action in not influenced by cytoplasm. So, inheritance pattern and expression of sterility is entirely Mendelian. It exhibits minimum reciprocal difference and it is controlled by recessive nuclear genes in majority of cases.

Deshmukh (1959) has given first report of male sterility in pigeonpea but it was associated with the female fertility, so it was of little use.

Reddy *et al.* (1977) made deliberate search for male sterility in more than 7000 germiplasm collections and derivatives of *Cajanus cajan* x *Atylosia* species at ICRISAT. Which resulted into identification of 72 sterile plants, which were classified into five aberrant floral types. Among this only one type having translucent white anther was found stable and useful.

Reddy *et al.* (1978) observed that the sterility was found to be caused by non-separation of tetrads during micro sporangenesis and thus, they disintegrated completely and it is found to be controlled by a single recessive gene $MS_1$.

Wallis *et al.* (1981) reported another source of GMS pigeonpea. It is characterized by shriveled arrow head shaped non dehiscent brown coloured anthers.

Dundas *et al.* (1981) found that the abnormality in anther development was due to degeneration of the pollen mother cells at the young tetrad stages which is a cause of this male sterility.

Dandas *et al.* (1982) found a male sterile source from an elite photoperiod insensitive breeding line Q PL-2.

Saxena *et al.* (1983) studied the allelic relationship between the translucent anther and arrow head brown coloured male sterile characters and reported that these are governed by different independent genes $MS_1$ and $MS_2$, respectively recessive form.

Charry and Bhalla (1988) fond male sterile mutant with shrunken pollen grains which was isolated from line ICP 7295 in $M_2$ generation after treatment with 0.2 per cent ethyl methane sulphanate (EMS) which was governed by a single recessive gene.

Mehatre *et al.* (1992) reported a male sterile mutant from gamma irradiated pigeonpea variety C-11. However this was associated with chimeral tissues. The sterility was found to be controlled by two duplicate recessive genes designated as $Stfl_1$ and $Stfl_2$. If could not be maintained for further use.

Wanjari *et al.* (1995) found another male sterility source, derived from cross *cajanus volubilis* x *cajanus cajan*. From these two male sterile lines i.e. AKMS-Vol-3 and AKMS-Vol-4 were isolated. These lines are characterized by reduced anther sterility and dirty anther sterility respectively.

Rajni Raina (1996) derived new male sterile pigeonpea line *viz.,* MSHUA-7 from high yielding, long duration variety MA-97 crossed with MS-ICP-3783, the donor of male sterility gene $MS_{-1}$.

Verulkar and Singh (1997) isolated a male sterile mutant from cultivar (0-5 at Coimbatore having transluscent anther with complete absence of pollen grains similar to that reported by Reedy *et al.* (1978). This was submitted with fertile counterpart and the $F_2$ segregation of 3:1 fertile to sterile revealed that the character is governed by single recessive gene.

Wanjari *et al.* (1999) reported two new sources of male sterility derived from the inter specific cross *cajanus sericeus* x *Cajanus cajan*. These were governed by two separate genes, one monogenic recessive and other with dominant gene respectively.

Pandey and Singh (1998) have screened 550 genotypes and natural population of six cultivars. Out of these three male sterile plants were identified one from Bahar (DAMS-1) and second from BMT-46 (DAMS-2 andDAMS-3). Segregation analysis indicated that a single recessive gene governs male sterility in DAMS-1.

Saxena and Kumar (2001) reported male sterility characterized by light yellow reduced anthers which is similar to AKMS vol. 3 in the population of a short duration pigeonpea (*Cajanus cajan*) cv. ICPL 95010. The test cross studies showed that male sterility is genetically governed by single recessive gene. Segregation in three way cross revealed that the male sterile gene was non-allelic to $MS_1$, and $MS_2$ loci and it is designated as $MS_3$.

Siddanagouda (2004) reviewed that crosses of AKMS $Sr_1$ with AKMS vol-3, AKMS vol-4 and AKMS vol-1, segregated in $F_1$ for sterility (i.e. 1F:1S $csr_1$)) indicating single dominant gene governs the sterility of AKMS Sr1 which was earlier proved by Wanjari *et al.* (2000) and confirmed that AKMS Sr1 male sterility is governed by different systems of male sterility gene i.e. single dominant MS gene.

#### 2.3.1.2 Cytoplasmic male sterility (CMS)

Another form of male sterility which is not under the influence of nuclear gene but under control of cytoplasmic heredity factors (organelle genes), is termed as cytoplasmic male sterility. This type of sterility is maternally inherited and generally leads to complete sterility under normal environmental conditions. It adversely affects the development of one or more types of cells in the anther during some stages of microsporog-enesis (Duvick, 1965). Sterile cytoplasm is indicated as (S) in contrast to (F) or (N) notations for the normal fertile cytoplasm. Crossing between CMS plants and male fertile plant result in a complete male sterile progeny since the plasmagenes responsible for sterility are transferred from the mother to offspring through the egg cells.

In crops that are grown for their vegetative, parts e.g. onions, beets, grasses etc. this type of male sterility is advantageous. In ornamental species the offspring of all male sterile plants are also male sterile and will tend to bloom longer than their seeded counterparts (Allard, 1960).

### 2.3.1.3 Cytoplasmic genetic male sterility (CGMS)

Some plants have CMS system that contains nuclear restorer genes that override the CMS condition (Kaul, 1988). These systems are designated as having cytoplasmic genic male sterility. Wild germplasm can be a source of sterile cytoplasm. Mutagenesis has also been used to develop CGMS in pigeonpea.

This type of male sterility was first discovered by Jones and Devis in (1944) in onion. CGMS is highly stable and it is not affected by environmental factors. In search of sterile cytoplasm tremendous efforts were made by various workers in many crops plants and vegetables. As al result of which number of cytoplasmic sterility sources were reported and few of them found to be efficient and stable in pigeonpea crops.

Reddy and Faris (1981) reported the possibility of maternal inheritance of male sterility in the progenies derived from "*Cajanus scrabaeiodes* x *Cajanus cajan*". But the material was associated with female sterility and other defects.

Ariyanayagam *et al.* (1993) used several accessions of four wild *Cajanus* species *viz., C. scarabaeoides, C. sericeus, C. acutifolius* and *C. albicans* as female and *C. cajan* as male. Occurrences of sterile progenies were more in cross involving *C. scarabaeioides, C. sericeus* and *C. acutifolias* crosses. He also found that these responded well in triple as well as back cross yielding 21.4 to 100 per cent sterile progenies.

Rajani Raina *et al.* (1973) searched for cytoplasmic male sterile lines using five species of Atylosia, two of Rhynocosia and two of flrmingia and crossed with nine varieties of *Cajanus cajan*. Out of the seven crosses obtained, only one plant from a cross *C. canjan* cv. T-21 x A. Mollis was male sterile. Failure in separation of tetrad was reason for sterility.

Ariyanagam *et al.* (1995) suggested a system "multiple cross genome transfer" to establish cytoplasmic male sterility in inter specific derivatives. They reported the reversion of male sterility to fertility and the morphological deformities noticed in conventional *C. sericeus* x *C. cajan* back crossing could be minimized if more than one genome are contributed to the expected interaction with the *C. sericeus* cytoplasm. The ongoing stages were named as "Genome Transfer Stage" (GTS). The $F_1$ arising from $GTS_1$ mating was used as the cytoplasm donor in mating with ICPL-87, ICP-9880 and ICPL 90035 ($GTS_2$). In the successive back crosses they obtained increase in sterility at successive GT stages. A success to get male sterility upto 97-100 per cent was observed upto $GTS_4$.

Tikka *et al.* (1997) reported stable cytoplasmic male sterility in pigeonpea utilizing *Cajanus scarabaeiodes* as female parent. The sterility was characterized by white translucent anthers. The sterility was maintained by fertile sister plants GMS line MS-288 a fertile plants from QMS-2, GT-100 and ICPL-87.

Rathnaswamy *et al.* (1999) used two wild species *C. cajanifolia* and *C. acutifolius* to develop cytoplsmic male sterile line using MS (0-5 (*C. cajan*) as a male pollinator, high degree of pollen sterility ranging from 42.2 to 85.7 per cent in the cross was observed.

Wanjari *et al.* (1999) identified new cytoplasmic male sterility sources from *Cajanus valubilis*, a wild genotypes in derivatives of cross *cajanus volubilis* x *C. cajan* var. ICPL-83024. The CMS was characterized by yellow non-dehiscent or poorly dehiscent anthers bearing completely sterile pollen grains. The cytoplasmic nature of male sterility was observed in the back cross generations where ICPL-85030, AKMS-21 and AKT-8811 were used as recurrent parents. However, few crosses of AKT-8811 and AKMS-21 were partially fertile and suspected to carry restorer genes.

Wanjari and Patel (2003) reported the new source of cytoplasmic male sterility derived from *C. lanceolatus*. In the inter specific crosses of *C. lanceolatus* as female and cultivated *C. cajan* variety ICP-87119 and ICPL-8863 as males, $F_1$ hybrid showed partial pollen fertility. However, in $F_2$ a few plants with complete pollen sterility were identified. These sterile plants were crossed with 28 varieties of cultivated species. The evaluation of MS x variety hybrids indicated that BSMR-840, AKT-9827, ICP-10741, ICP-10875 and MDRL-11 varieties acted as sterility maintainer as their $F_1$ hybrids were complete sterile. On the other hand a cross of MS x AL-313 was found to be complete fertile indicating us restoration ability.

Saxena *et al.* (2003) reviewed the work on diversification of established cytoplasmic genic male sterility in pigeonpea under national hybrid pigeonpea programme selected twelve agronomically superior and good combiner lines *viz.*, Pusa 33, ICPL-87, GT-100, SKNP-289, BDN-2, SKNP-88-3, SKNP-9523, T-15-15, T-21, UPAS-120 and ICPL-34023 have been converted into CMS lines through simple backcross breeding method.

Nalini Mallikarjuna and Kalpana (2004) obtained cytoplasmic nuclear male sterile plants by crossing *C. acutifolius* as female with *C. cajan* as male. Two types of CMS plants distinguished by anther morphology were identified. Both types of CMS plants showed complete anther sterility. Type-I CMS had partially or totally brown and shriveled anther and the process of microsporogenesis were inhibited at the premeotic stage. Type-II CMS plants had pale and Shrivelled anthers and the breakdown of micro sporogenesis observed at post meiotic stage after the formation of tetrad caused sterility in plants.

### 2.4 Heterosis

Presence of heterosis is important aspect in any crop, for development of hybrid varieties. Extent of heterosis decides the fate of the hybrid variety. Hybrid with high level of heterosis is always welcomed.

The term heterosis was first used by Shull (1914) heterosis refers to the increased or decreased vigour exhibited by hybrids in $F_1$ generation over the mean of both parents or over better parent. The heterosis is the genetic expression of the beneficial effects of hybridization. In common usage, the terms heterosis and hybrid vigour are synonymous and it has been more precisely suggested by Whaley (1952) as the developed superiority of the hybrids as hybrid viogur and the mechanism by which the superiority is developed as heterosis.

Another definition of heterosis was given by Stebbins (1957) as "greater adaptedness to human needs, which has obtained in particular environments through artificial selection followed by hybridization. In a particular cross, heterosis is measured in terms of two parameters i.e. heterosis over mid parental value (Relative heterosis) and heterosis over better parent of value (heterobeltiosis). However, in plant breeding programme, heterosis is also estimated in terms of heterosis over check or standard variety/hybrid (useful or standard heterosis). In terms of combining ability for quantitative characters heterosis is highly associated with specific combining ability effects of the cross.

Although the basic meaning of heterosis was clear, yet there was disagreement regarding the situation to which the term should be applied. Shull (1948) strictly reserved heterosis to describe an increase in a characteristic arising from hybridity. On the other hand Mackey (1976) considered heterosis heterosis as a 'two-way phenomenon. Similarly, Mayo (1987) considered 'negative heterosis' in addition to positive heterosis in the sense that it may be of value for certain characteristics such as maturity period.

### 2.4.1 Heterosis in pigeonpea

In pigeonpea there are many reports to present the possibility of good amount of heterosis for grain yield and its component in experimental hybrids. This information may be useful for exploitation of heterosis on commercial scale.

Jones (1917) postulated that heterosis is due to large number of linked favourable dominant genes.

East (1936) formulated the theory of allelic interaction and suggested that hybrid vigour is due to cumulative action of many loci.

Dobzhansky (1952) enlarged the scope of heterosis to include adaptive, selective and reproductive advantages of heteroszygosity.

Soloman *et al.* (1957) gave first report on heterosis in pigeonpea by studying the extent of heterosis in ten hybrids in respect of fourteen morphological characters. Considerable heterosis was observed in several growth parameters and yield components. Fairly conspicuous (24.5 %) vigour was noticed in few best hybrid combinations though it did not out yield the highest yielding variety.

Veeraswamy *et al.* (1973) recorded that the intervarietal hybrids in red gram between (0-1 a short duration high yielding strain) and 19 diverse varieties expressed heterosis for plant height, plant spread, number of branches, number of clusters, number of pods and days to 50 per cent flowering. The maximum heterosis were recorded for number of clusters (179.6 %) and number of pods (188.5 %) over superior parent.

Sharma *et al.* (1973) in a diallel study comprising none parents found that hybrids in general had higher mean values than mid-parent particularly for plant height and yield per plant where hybrid estimates were 80.5 and 72.2 per cent respectively. Heterosis over mid-parent was also recorded for plant spread, days to flowering and maturity.

Shrivastava *et al.* (1975) studied the extent of heterosis in 17 $F_1$ hybrid combinations involving 14 genotypes for yield, 96 per cent for secondary branches and 80 per cent for number of pods per plant. In most of the crosses low x medium and low x low parental combinations had maximum heterosis for individual characters. In case of secondary branches, heterosis was maximum I high x high as well as low x low crosses indicating the role of genetic diversity for obtaining high hybrid vigour.

Reddy *et al.* (1979) observed high heterotic effects involving diverse parents of different maturity groups. Specifically midlate x late and early x late cross combinations were of economic worth and negative heterosis was exhibited for traits *viz.*, plant height and protein content while positive heterosis was observed in respect of pod number and yield.

Venkateswarlu *et al.* (1981) observed the mean heterosis of 39 per cent for yield and about 16 per cent for days to flowering as well as pods per plant. In general early x late and midlate x late combinations resulted in high heterosis for yield.

Marekar (1981) observed overall heterosis of 17.85 and 6.75 per cent for yield over mid parent and better parent respectively for other traits *viz.*, plant height, days to flower, number of primary branches, pod weight and hundred seed weight overall heterosis over mid-parent was 17.7, 0.4, 12.0, 6.6 and 5.6 per cent respectively. Negative heterobeltiosis over better parent was obtained for plant height days to flower, number of primary branches hundred pod weight and hundred seed weight.

Singh *et al.* (1983) observed the maximum heterotic response upto 221 per cent for grain yield in line x tester studies of pigeonpea. The best heterotic cross, Mukta x Upas-120 was identified as potential of early maturing hybrids.

Jadhav and Nerkar (1983) studied the magnitude of heterosis for seed yield in a seven parent dialles of pigeonpea under three cropping systems *viz.*, a rainy season sole crop, rainy season intercrop with sorghum hybrid and winter season sole crop and found substantial heterosis over mid parent and better parent in all the three environments.

Omanga (1985) studied heterosis in seven fertile lines crossed in line x tester design and reported high heterosis percentage over mid parent for yield and other three related characters. High magnitude of heterosis was seen with MS-Prabhat that with MS3A.

Saxena *et al.* (1986) observed the heterosis for yield and six yield contributing traits which ranged between 24 and 26 per cent.

Tuteja *et al.* (1989) reported high heterosis in a best cross $A_2$ x EE 76 for yield, number of clusters and pods among thirty hybrids.

Patel *et al.* (1991) using line x tester design including three male sterile lines, 10 medium and 10 early maturity pollinators, recorded heterosis for seed yield per plant. Out of these 60 combinations, heterosis for seed yield over better parent was highest for crosses MS3A x DL78-1 and MS-Prabhat x TCPL-684 i.e. 80 and 78 per cent respectively.

Tuteja *et al.* (1992) showed a single cross Ageti x EE76 and a three way cross (ICPL-87 x EE76) x UPAS-120 was significantly better for days to maturity in negative direction.

Dhameliya and Poshiya (1995) studied $F_2$ population for seed yield and primary yield components and observed heterosis for yield mainly from increased number of pods ether than number of branches per plant.

Paul *et al.* (1996) studied heterosis for yield and yield components in hybrid pigeonpea in twenty eight late maturing pigeonpea experimental hybrids by crossing 28 lines with single male sterile lines MS-3783 and found that hybrids gave better heterotic response against T-7 as compared to Bahar varied from – 27.7 to 91.2 per cent and also conclude that pods per plant in association with number of secondary branches and dry matter at maturity were found to be the chief contributing characters.

Khapre *et al.* (1996) studied 24 hybrids along with 11 parents and ICPH-8 and BDN 2 as standard hybrid and standard variety as a check and found that crosses with line MSHY-9. Showed marked heterosis for height at first effective branches, number of primary branches, pods per plant and grain yield per plant followed by line MS Prabhat. Male parents BDN-2, Daithna local, ICPL087 and BDN-7 gave marked heterosis for yield and its components.

Khapre *et al.* (1996) studied a set of 24 crosses involving 4 lines and 6 testers of pigeonpea for high degree of heterosis for seed yield per plant and other yield components over standard checks (ICPH-8 and ICPL-87119) and found that the crosses MSHY-9 x ICPL-87, MSHY-9 x BDN-2 and M Prabhat DT x BDN-7 exhibited high heterosis for yield and other yield contributing characters. Male parent BDN-2, Daithana local, ICPL-87 and BDN-7 gave marked heterosis for yield and its components.

Verulkar and Singh (1997) studied heterosis in pigeonpea and found that the standard heterosis for yield per plant ranged from 16.5 per cent in cross ICPL-151 x ICPL-84023 to 54.6 per cent in cross UPAS-120 x ICPL-84023 also exhibited significant desirable heterosis for days to flower days to maturity, number of pods and 100 seed mass.

Kumar and Srivastava (1998) observed heterosis over better parent for seed yield range from – 77.91 to 110.97 per cent at IIPR, Kanpur using line x tester design, involving three male sterile lines and twelve male fertile parents of longer duration.

Wanjari *et al.* (1998) studied selection of male sterile populations for development of parental lines for exploitation of heterosis in pigeonpea and found that MST-21 was better female line. Among the populations MS $P_2$ having positive gca has been identified for deriving MS Sibs. Among males, AK-22 and AK-30 had been good general combiners. The MS $P_3$ x AK-22 have been found to have high sea.

Wankhede and Wanjari. (1998) studied heterosis for yield and yield components in pigeonpea involving male sterile lines i.e. three genetic male sterile lines (Females), eight testers (males) and their 24 possible crosses and revealed that the phenomenon of heterosis was of general occurrence for most of the traits, except plant height. The cross AKMA-11 x AKT-9221 showed highest seed yield per plant and exhibited high heterosis (63.19 %) and Useful heterosis over BDN-2 (83.84 %). He concluded that the mean squares due to parents and crosses were highly significant for all the characters. AKMS-11 x AKT-9221 and AKML-11 x C-11 were the best crossed followed by AKMS-21 x C-11 for seed yield, number of clusters number of pods and protein content and AKMS-21 x BDN-2 for number of clusters and pods per plant.

Hooda *et al.* (1999) reported heterosis in 40 crosses using line x tester design. Maximum heterosis for pods per plant over standard check manak was obtained for crosses QMS 1 x TAT-10 (38.1 %), QMS-1 x H-88-43

(28 %) heterosis for seed yield per plant within range of 21.2 to 28.9 per cent was found.

Manivel *et al.* (1999) suggested the use of MS Prabhat NDT as female parent for high yielding and early maturity hybrid in pigeonpea.

Singh *et al.* (1999) studied the 16 inter specific hybrids involving four lines of *cajanus sericeus* and four testers of *Cajanus cajan* and he observed average heterosis for branches per plant (85-96 %), pods per primary branch (45.43 %) and pods per plant (25.54 %).

Srinivas *et al.* (2000) studied twenty two experimental hybrids, derived from two male sterile lines *viz.*, ICP MS-288 and MS-3783 as female and 11 medium to late genotypes as male in line x tester mating design out of these crosses involving the ICP MS-3783 line, showed market heterosis for seed yield and must of component characters. The cross ICP MS-3783 x LRG-30 was best hybrid combination.

Chandirakala *et al.* (2002) studied 30 pigeonpea hybrids derived from three GMS line i.e. MS Prabhat MS Prabhat NDT, MS-0-50 and ten tester lines (ICPL-87104, ICPL-85010, ICPL-88009, ICPL-89008, ICPL-889020, ICPL-84023, ICPL-88039, ICPL-90032, ICPL-90012 and ICPL-87). Cross with MS Prabhat DT showed market heterosis for pods per plant, cluster per plant, 100 seed weight and grain yield per plant. Highest positive heterosis over mid, better and standard parents was observed in MS-C-0-5 x ICPL-88009 for number of branches per plant and in MS Prabhat NDT x ICPL-88009 and MS Prabhat DT x ICPL-84023 for grin yield per plant.

Pandey and Singh (2002) reported highly significant positive heterosis for seed yield per plant and number of primary and secondary branches per plant.

Kalaimagal and Ravikesavan (2003) Heterosis for seed yield and its components were estimated in 63 crosses obtained by crossing three genetic male sterile lines with twenty one testers in L×T fashion. ICPH 8 was used at check. The heterosis value ranged from 9.13 to 404.57, 10.11 to

57.92 and 10.42 to 106.17 over mid parent, better parent and standard check, respectively.

Aher *et al.* (2006) studied the performance of three crosses *viz.*, BDN-2 x BDN-2010, BDN-2 x Nirmal 2 and BSMR-736 x Mirmal-2 and they observed maximum positive heterosis over mid parent for number of pods per plant (45.5 %) and grain yield per plant (26.0 %) similar trend of heterosis over better parent was recorded for these traits and maximum positive inbreeding depression was observed for number of pods per plant (37.2 %) and grain yield per plant (21.0 %).

Saxena *et al.* (2006) studied a yield of new CMS-based pigeonpea hybrids and found hybrids involving $A_1$ cytoplasm, $A_2$ cytoplasm, $A_4$ cytoplasm and they found hybrids on $A_1$ cytoplasm i.e. ICPH-2319 (3017 kg/ha) was the best with standard heterosis of 61.3 per cent over the best check ICPL-360. On $A_2$ cytoplasm based hybrids ICPH-3172 (2725 kg/ha) was found to be best with 33-36 per cent superiority over controls and on $A_4$ cytoplasm based hybrids, ICPH-2438 (3414 kg/ha) was the best performing hybrids with 61 per cent superiority.

Wanjari *et al.* (2007) studied heterosis in CMS based hybrids in pigeonpea in 136 hybrids out of which 11 expressed high pollen fertility (>80 %) in all the hybrids. They found maximum heterosis in hybrid No.-230407 (GT-288 A x 220751-5) with 212.26 per cent heterosis over check, followed by hybrid No.-230466 (AKV-2 A x 22076-29) and hybrid No. 230405 (GT-288 A x 220682-55) with heterosis 140.94 per cent and 131.92 per cent over check respectively.

Anantha Raju *et al.* (2007) A high degree of heterosis for seed yield per plant and other yield components over standard check (CO 5) was observed. The hybrid combination CO 5 x ICPL 87119 was considered as the best for higher seed weight and CO 6 x ICPL 87119 and CO 6 x ICPL 332 exhibited high heterosis for yield and other yield contributing characters.

## 2.6 Combining ability

Combining ability can be defined as the relative ability of an genotype to transmits superiority to its crosses. the term general combining ability (gca) is defined as the average performance of a line in a series of crosses and a specific combining ability (Sca) of a cross is the performance of a cross combination to do relative better or worse than would be expected on the basis of average performance of the parents involved.

The concept of general and specific combining ability was first given by Sprague and Tatum (1942). They suggested that general combining ability ise x pected to be the result of genes, which are largely additive in their effects and specific combining ability largely depends on genes with dominance or epistatic effects. On the other hand, Gritting (1956) suggested that general combining ability is due to both additive as well as additive x additive gene interactions. The following methods are generally used to estimate the combining ability.

1. Top cross method (Davis, 1927)
2. Poly cross technique (Tysdal *et al.,* 1942)
3. Diallel analysis (Grifting, 1956)
4. Line x raster analysis (Kempthorne, 1957)

Lime x tester analysis is a precise approach to estimate the general and specific combining ability effects of parents and crosses respectively. It is also useful in estimating various types of gene effects. Kempthornc (1957) proposed line x tester analysis technique which is analogous to north Carolina mating design II of comstock and Robinson (1952). In this analysis a random sample of 'S' sires were taken and all of them were mated to each of 'd' dams. They also precisely expressed the variance due to general combining ability ($\sigma^2$gca) and variance due to specific combining ability ($\sigma^2$ Sca) in terms of the of the covariance of half-sibs (Cov (HS) and covariance of full-sibs (Cov (FS) respectively.

$$\sigma^2 \text{ gca} = \text{Cov (HS)}$$

$$\sigma^2 \text{ Sca} = \text{Cov (FS)-2 Cov (HS)}$$

Plant breeders in India have recently been using a modified line x tester design by indicating the parental lines also in a bid to obtain a single degree of freedom for contrast 'Parents vs hybrids' (Arumachalam, 1974).

The available literature pertaining to combining ability in pigeonpea has been reviewed here.

Sharma, *et al.* (1973) reported a diallel cross analysis. They found that general combining ability variances were higher than s.c.a. variances for the characters *viz.,* plant height, days to flowering and maturity, 100 seed weight and yield per plant. They also reported that estimates of Gca effects of the individual parental lines indicated a good agreement between ranking of lines for such effects and the ranking based on parental performance.

Dahiya and Barar (1977) reported low gca for flowering time and high gen ca for pod number, hundred seed wt. and yield per plant.

Krishna Rao and Nagur (1979) observed a variety namely Jawahar-45 as consistently exhibiting good geca for grain yield.

Reddy *et al.* (1979) reported the predominance of specific com. a. effects. The gca effect for most of the characters were generally negative for early and medium parents and positive per late parents. They also interred that specific midlate x late and early x late combination are likely to give recombinations of economic worth.

Reddy *et al.* (1980) evaluated 10 x 10, 20 x 20 and 7 x 7 variety diallels. In 7 x 7 diallels, four late maturing parents showed significant positive that Prabhat and UPAS-120 possessed significant gca effects for earliness but poor combiner for yield. The cross Prabhat x 6982-6 showed Sca for yield per plant.

Saxena *et al.* (1980) in a diallel cross analysis consisting seven early maturing lines in $F_1$ and $F_2$ generation observed a close association between gca for parents and actual parental performance in $F_1$. However, such positive association between the two was found over for days to flowering in $F_2$. Significant negative sca effect were noticed for day to flowering in both $F_1$ and $F_2$ and for plant height to $F_1$ generation in the cross UPAS 120 x 3-D-8103.

Chaudhari and Makne (1980) in a x a diallel found high magnitude of Gca for all characters. The Bs1 was found to be the best combiner for earlier and C-11 for most of the quantitative characters. C-11 x No. 148 showed significant Sca effects for yield and for number of secondary branches.

Venkateshwarlu and Singh (1982) in C. A. studies for earliness, on ten diverse cultivars representing extra early to late groups reported HPA-2, Pant-42 and T-21 as best parents for earliness. They further reported that the crosses involving diverse parents like pant $A_2$ x IC P-6997 and T-21 x ICP-7035. Which had high sca for earliness may give early maturing and high Sca for segregates.

Singh *et al.* (1983) reported that UPAS-120, Mukta and S-103 are promising for use in breeding early maturing hybrids. Since, they are best combiners for earliness and yield components.

Omanga (1985) found C-11 to be the best general combiner for seed yield. While ICP-7035 and ICP-9150 showed the highest gca effect for hundred seed wt.

Patel *et al.* (1987) analysed 30 hybrids involving 3 genetic M. S. lines and reported significant positive Sca mainly in number of pods and pod length.

Mehetre *et al.* (1988) in their studies on diallel crosses reported No. 134, 28-17-1-9 and 4834-3 as best combiners for grain yield per plant.

Most of the crosses exhibiting high Sca effect involved one of the parent from good combiners.

Hazarika *et al.* (1988) observed significant gca and Sca effects for yield components in pigeonpea. They reported 477-219, ICPL-96 and ICPL-87 as good combiner for majority of characters. Determinate plants were generally good combiners for seeds per pod and seed size. In terminate plants were generally good for pods and yield per plant.

Patel *et al.* (1992) analysed 10 hybrids involving three GMS lines and reported that hybrids showing significant positive Sca effect mainly involved on good and other poor combining parent. This was especially noted in respect of pod and branches per plant.

Satpute *et al.* (1992) from diallel crosses reported that No. 148 and T-21 are good combiners for seed yield, pods and seeds per plant. The two crosses *viz.*, ICPL-86007 x No. 148 and ICPL-86012 x NO. 148 had positive and significant Sca effects for seed yield, No. of pods and seeds per plant.

Sindhu *et al.* (1992) in 8 x 8 diallel cross evaluated the crosses for days to 50 per cent flowering, days to maturity, plants height, number of pods per plant, 100 seed wt. and seed yield plant significant. sca, gca and reciprocal differences were observed for all the characters except seed wt. in case of seed wt. only sca effects were significant. Equal magnitude of Sca and reciprocal estimates points to considerable change in the performance of the cross depending upon order of the female/male parent in the same cross. This is important since only one way hybridization is feasible when sterile lines are used in production of hybrids.

Khapre *et al.* (1993) combining ability analysis for grain yield and it's components in diallele crosses involving seven divers pigeonpea cultivars over three cropping systems viz. sole crop, intercrop with sorghum and intercrop with pearlmillet revealed the predominance of additive gene effects for the characters. Parents BDN 2, ICP 6997, PBNA 54 and daintha local were the best general combiners for all characters except days to maturity.

Prabhat showed consistence desirable gca effects for days to maturity. The hybrids ICP 6997×PBNA 54 and ICP 6997× BDN 2 showed significant sca effects for grain yield.

Ghodke *et al.* (1993) reported that the gca effect were highly significant for all characters whereas sca was highly significant for days to maturity and 100 seed weight. They further reported 9 hybrids exhibiting good Sca effects for yield and other characters. Two hybrids showing high Sca effects involved both parents with low gca effects.

Khapre *et al.* (1996) studied heterosis and combining ability analysis for grain yield and its components in pigeonpea and reveled a significant role of non-additive gone action for all the characters. The parent MS Hy 9, MS small leaf, Igithana local, BDN-2 and ICPL-87 were the best general combines. Seven hybrids showed significant positive Sca effects and high per se performance for grain yield and other yield attributes.

Narladkar and Khapre (1997) studied combining ability in pigeonpea and found that out of 24 hybrids 10 hybrid showed significant positive Sca effects and high per se performance for grain yield and also showed significant Sca effects for other related morpho-physiological traits.

Kumar and Srivastava (1998) among lines K PMS 1050 and MSNP (WR) 15 and among testers PR-5149, PDA-92-1, KPP-1034-1, KPP-1034-5 and KPP-1034-7 were found to be good general combiners for seed yield. He also concluded that gene action was predominantly non-additive for the characters studied.

Wanjari *et al.* (1998) found that among males, AK-22 and AK-30 had been good general combines. The MS $P_3$ x AK-22 has been found to have high sca. He also concluded that a hybrid MS $P_9$ x AK-31 is expected to be with complementary epistasis.

Singh and Srivastava (2001) studied combining ability variances and effect were estimated using four lines of the wild species *Cajanus sericeus* and four testers of cultivated species. *Cajanus cajan* in a line x tester fashion and found that among the lines *C. sericeus* (ICPW-160) proved to be a good general combiners for days to flowering, plant height, number of primary branches per plant, pod length, number of seed per pod, 100-seed weight and seed yield per plant. Among the tester *Cajanus cajan* la. Bahar proved to be good general combiners.

Pandey and Singh (2002) utilizing three genetic male sterile lines (DAMS-1, ICPMS 3783 and KPMS 1050) and 12 diverse genotypes of the long duration group of pigeonpea [Cajanus cajan (L.) Millsp] were evaluated for general and specific combining ability, variance components and standard heterosis. Among the lines DA 32, DA 34, DA 37, DA 46, DA 93-4, DA 93-2, DA 94-6 and Bahar mutant and testers DAMS-1 and ICPMS 3783 were found to be good general combiners for seed yield/plant-1 and other yield contributing traits such as secondary branches/plant-1, clusters/plant-1 and number of pods/plant-1. The tester DAMS-1 was also a good general combiner for primary branches/plant-1 and per cent pod setting.

Jahagirdar (2002). The combining ability analysis of 24 F1's of pigeonpea obtained from crosses between 3 lines and 8 testers along with their parents revealed significant non-additive gene action for almost all morpho-physiological traits, as variances due to sca were higher than gca variances. The parents BDN 2, ICPL 87, BSMR 736 and ICPL 87119 were the best general combiners for grain yield/plant, number of pods/plant, total biomass/plant and grain productivity/day. Ten out of 24 F1's showed significant positive sca effects and high per se performance for grain yield.

Pawar and Tikka (2003) studied 64 hybrids and revealed higher magnitude of sca variance over gca variance for all the traits which indicated pre ponderance of non-additive gene action. The parents MS-228, MS Pusa-33, SKNP-9256 and AL-15 were good general combiners for seed yield and its two or more component traits. They found out of 64 hybrid having significant positive Sca effect for seed yield and its two or more component traits.

Banu *et al.* (2006) study the general (GCA) and specific combining abilities (SCA) in 45 pigeon pea hybrids along with their parents based on days to 50% flowering, days to maturity, plant height, primary branches per plant, clusters per plant, pods per plant, seeds per pod, pod length, 100-seed weight and single plant yield. The components of variance due to GCA and SCA revealed pre-dominance of non-additive gene action for most of the characters studied. The parents ICP 13201 and ICP 13207 were found to be the best general combiners for the yield attributing traits. The hybrid ICP 11967 x CO 5 was identified as the best combination and could be exploited for improving seed yield in pigeon pea.

Anantha and Muthian (2007) study the combining ability and heterosis for seed yield and its components using line x tester mating design involving 12 crosses. A high degree of heterosis for seed yield per plant and other yield components over standard check (CO5) was observed.

Phad *et al.* (2007) the experimental materials comprised of five lines (females) and twelve testers and sixty crosses were evaluated. The parents ICPL-87119, BDN-20M, ART-8811, BSMR-736 and BSMR-853 had good general combining ability, whereas among the crosses BDN-2 x BDN-2010, BDN-2 x BSMR-853 and BSMR-736 x ART8811 were the best specific cross combinations for grain yield/plant and plant spread, number of primary branches/plant, number of secondary branches/plant and number of pods/plant.

Baskaran Muthiah (2009) combining ability analysis was carried out in pigeonpea through line×tester analysis revealed the predominance of nonadditive gene action over additive for all the characters studied. The parents, CO 5, VBN 1, and ICPL 83027 were found to be some male sterile plants exhibit more than one phenotypic manifestation. Therefore, classification of male sterility on genotypic basis is vital. Accordingly depending upon nuclear and cytoplasmic genome constitution as evidenced by the inheritance pattern, male sterility has been primarily classified into genetic, cytoplasmic and genetic cytoplasmic type.

# CHAPTER III

# MATERIALS AND METHODS

The present investigation was carried out during 2009-10 at pulses research unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. Geographically Akola is situated at 23°43' N latitude and 77°64' E longitude with an altitude of 281 m above mean sea level. It has typical semi arid climate with moderate rainfall (mm) during June to October.

The methodology and materials used for present investigation are presented below.

## 3.1 Experimental material

### 3.1.1 Parental material

The parental material for the present study comprises of following four CMS (cytoplasmic male sterile) lines (female parents) and nine pollinators/testers (male parents).

| Females (lines) | Males (testers) |
|---|---|
| 1. AKV – 2A | 1. AKPR-324 |
| 2. AKV – 4A | 2. AKPR-23 |
| 3. AKV – 8A | 3. AKPR-312 |
| 4. AKV – 9A | 4. AKPR-386 |
| | 5. AKPR-227 |
| | 6. AKPR-210 |
| | 7. AKPR-345 |
| | 8. AKPR-205 |
| | 9. AKPR-250 |

### 3.1.2 Crossing programme

The crosses were made during *Kharif* 2008-09. The $F_1$ seed of the possible 36 crosses was obtained by crossing on each of the females with each of the males. The parental seed was multiplied by self-fertilization.

The experimental material thus comprised of 13 parents [four CMS lines(female parents), nine pollinator testers (male parents)] and their possible 36 $F_1$ along with the two varieties Asha and Maruti as standard check.

### 3.2 Methods

#### 3.2.1 Experimental details

The details of the experiment are as under.

| | | |
|---|---|---|
| 1. | Experimental design | : Randomized Block Design (RBD) |
| 2. | Replications | : Three |
| 3. | Genotypes | : 51 (36 Hybrids + 13 parents + 2 check) |
| 4. | Number of row per plot | : Two |
| 5. | Number of plants per row | : Ten |
| 6. | Spacing | : |
| | i) Row to row | : 60 cm |
| | ii) Plant to plant | : 30 cm |
| 7. | Date of sowing | : 30$^{th}$ June 2009 |
| 8. | Method of sowing | : Hand dibbling |
| 9. | Cultural practices | : All the cultural practices as per the recommendations for pigeonpea cultivation were followed. |

The parents and $F_1$S were randomized separately and sown in single block (replication).

### 3.2.2 Observations recorded on plant basis

**1. Plant height per plant (cm)**

The plant height was recorded in centimeters from the ground levels to the tip of the main branch at the time of harvest.

**2. Number of branches per plant**

The number of primary branches per plant were recorded at the time of harvest.

**3. No. of clusters per plant**

The number of clusters per plant were recorded before harvesting by counting total number of clusters on each observational plant.

**4. Number of pods per plant**

The number of pods per plant were recorded before harvesting by counting total number of pods on each observational plant.

**5. Number of seeds per pod**

Five fully matured pods were randomly selected from each observational plant and the total number of seeds were counted. The average number of seeds per pod was recorded.

**6. 100 seed weight (g)**

The weight of 100 seeds from each of the observational plants was measured in grams separately and the average was calculated.

**7. Grain yield per plant (g)**

The total seed obtained from the each observational plants were weighed and averaged.

### 3.2.3 Observations recorded on plot basis

**1. Days to 50 per cent flowering**

The number of days required from sowing to flowering of 50 per cent plants in each genotypes and replication wise days was recorded as days to 50 per cent flowering.

**2. Days to maturity**

The number of days required from sowing to the full maturity in each genotype and replication wise days were recorded as days to maturity.

### 3.2.4 Statistical methodology

The data were subjected to the following statistical and biometrical analysis for various characters.

1. Analysis of variance
2. To asses *per se* performance of newly developed male sterile and restorer lines
3. Estimation of average heterosis, heterobeltosis and standard heterosis.
4. Analysis of variance for combining ability (Line x Tester)
5. Estimation of general and specific combining ability effects using line x tester analysis

**1. Analysis of variance**

The analysis of variance will be performed to test the significance of differences among genotypes/crosses for all the characters. The statistical model for ANOVA is as under. Analysis of variance will be carried out as per standard method (Panse and Sukhatme, 1967) for all characters under study.

$$Y_{ijk} = \mu + g_{ij} + b_k + e_{ijk}$$

Where,

$Y_{ijk}$ = Phenotypic performance of $ij^{th}$ genotype in $k^{th\ block}$

$\mu$ = General mean

$g_{ij}$ = The effect of $ij^{th}$ genotype

$b_k$ = The effect of $k^{th}$ block

$e_{ijk}$ = The environmental effect

**Table : ANOVA**

| Source of variation | Degree of freedom | Sum of square | Mean sum of square(observed) | Mean square(expected) |
|---|---|---|---|---|
| Replication | r-1 | SSr | MSr | $\sigma^2{}_e + g\,\sigma^2 r$ |
| Genotype | g-1 | SSg | MSg | $\sigma^2{}_e + r\,\sigma^2{}_g$ |
| Parents | p-1 | SSp | MSp | $\sigma^2{}_e + rc\,\sigma^2 p$ |
| Crosses | c-1 | SSc | MSc | $\sigma^2{}_e + rp\,\sigma^2 c$ |
| Parents Vs crosses | 1 | SSp/c | MSp/c | $\sigma^2{}_e + rp\,\sigma^2 pc$ |
| error | (r-1)(g-1) | SSe | Mse | $\sigma^2{}_e$ |

Where, r = number of replication

t = number of treatments

p = number of parents

h = number of hybrids

df - degrees of freedom

MSe – Error mean sum of square

**2. Estimation of average heterosis, heterobeltosis and standard heterosis**

**Average heterosis**

$$\text{Average heterosis } (H_1)\ (\%) = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

Where,

$\overline{F_1}$ - Mean performance of $F_1$

$\overline{MP}$ – Mid parental value

$$\overline{MP} = \frac{\overline{P}_1 + \overline{P}_2}{2}$$

$P_1$ and $P_2$ – Mean performance of parent 1 and 2 respectively.

**Heterobeltosis**

$$\text{Heterobeltiosis } (H_2) \ (\%) = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Where,

$\overline{F_1}$ - Mean performance of $F_1$

$\overline{BP}$ – Mean of better parent of a cross

**Standard heterosis**

$$\text{Standard heterosis } (H_3) \ (\%) = \frac{\overline{F_1} - \overline{CHECK}}{\overline{CHECK}} \times 100$$

Where,

$\overline{CHECK}$ – Mean performance of check

The standard error of differences and critical differences were computed as

$$SE(d) \text{for } H_1 = \sqrt{\frac{3\ Mse}{2\ r}}$$

$$CD \text{ for } H_1 = SE(d)H_1 \times t$$

$$SE(d) \text{ for } H_2 = \sqrt{\frac{2\ MSe}{r}}$$

$$CD \text{ for } H_2 = SE(d)H_2 \times t$$

$$SE(d) \text{ for } H_3 = \sqrt{\frac{2\ MSe}{r}}$$

CD for $H_3$ $= SE(d)H_3 \times t$

Where,

t = table value at 5% and 1% level for error degrees of freedom. The 't' test will be used to determine whether the $F_1$ mean values differed significantly from mean values of mid parent, better parent or check.

### 3. Analysis of variance for combining ability (Line x Tester analysis)

ANOVA for combining ability will be based on the methodology given by Kempthorne (1957).

**The Analysis of Variance for combining ability**

| Sr. No. | Source of variation | Degree of freedom | Sum of square | Mean sum of squares | |
|---|---|---|---|---|---|
| | | | | Observed | Expected |
| 1 | Replications | r-1 | SSr | | |
| 2 | Females (lines) | f-1 | SSf | M1 | $\sigma^2$+ lr cov (H.S) |
| 3 | Males (tester) | m-1 | SSm | Mt | $\sigma^2$ e + tr (cov. H.S) |
| 4 | Females x Males | (f-1) (m-1) | SSfm | Ml×t | $\sigma^2$+ r cov(F.S) - 2 cov. (H.S) |
| 5 | Error | (r-1) (fm-1) | SSe | Me | $\sigma^2$ e |

Where, f - Number of females (Lines)

m - Number of males (Tester)

r - Number of replications

### 4. Estimates of general and specific combining ability effects

i. Population mean $\mu = \frac{X...}{rmf}$ ...... where, $X... = \sum_{i=1}^{f} \sum_{j=1}^{m} \sum_{k=1}^{r} X_{ijk}$

ii. General combining ability effects of female parents

$$gi = \frac{X_i}{rm} - \frac{X\ldots}{rmf} \quad \ldots\ldots \text{ where, } Xi\ldots = \sum_{j=1}^{m} \sum_{k=1}^{r} X_{ijk}$$

iii. General combining ability effects of male parents

$$gi = \frac{X_j}{rf} - \frac{X\ldots}{rmf} \quad \ldots\ldots \text{ where, } Xi\ldots = \sum_{j=1}^{f} \sum_{k=1}^{r} X_{ijk}$$

iv. Specific combining ability effect of crosses

$$S_{ij} = \frac{X_{ij}}{r} - \frac{Xi.}{rm} - \frac{X_{i \times j}}{rf} + \frac{X\ldots}{rmf}$$

Where, $X_{ij} = \sum_{k=1}^{r} x\ X_{ijk}$

Where,

- $X\ldots$ - Total of all hybrid
- $X_{i.}$ - Total of $i^{th}$ female parent over all males
- $X.j$ - Total of $j^{th}$ male parent over all females
- $Xij$ - Total of $ij^{th}$ combinations over replications.

Standard error of effect will be calculated as square root of the variance of effects.

The variance of various effects will be calculated as:

**1. gca effects for lines**

$$\text{Var. } gi = \frac{(f-1)\ \sigma^2 e}{rmf} = \frac{(f-1)\ M_4}{rmf}$$

$$\text{SE of } gi = \sqrt{\text{var. (gi)}}$$

**2. gca effects for testers**

$$\text{Var. } gj = \frac{(m-1)\ \sigma^2 e}{rmf} = \frac{(m-1)\ M_4}{rmf}$$

$$\text{SE of } gj = \sqrt{\text{var. (gj)}}$$

**3. sca effects for hybrids**

$$\text{Var. } \sigma_{ij} = \frac{(f-1)\ (m-1)\ \sigma^2 e}{rmf} = \frac{(f-1)\ (m-1)\ M_4}{rmf}$$

$$\text{SE of } (s_{ij}) = \sqrt{\text{var. } (S_{ij})}$$

Where,

f = Number of female parents

m = Number of male parents

r = Number of replications

$M_4$ = Error mean sum of square

The critical differences will be calculated by multiplying the standard error of difference with respective `t' table value at 5% and 1% level at error degrees of freedom.

# CHAPTER IV

# RESULTS AND DISCUSSION

The experimental results of the present investigation "LINE X TESTER ANALYSIS IN PIGEONPEA" for various characters obtained from the statistical analysis are presented under following subheads:

## 4.1 Results

4.1.1 Analysis of variance

4.1.2 *Per se* performance of parents and hybrids over check Asha

4.1.3 *Per se* performance of parents and hybrid over check Maruti

4.1.4 Useful heterosis estimated over check Asha and Maruti

4.1.5 Aveage heterosis estimated over mean value of parents

4.1.6 Heterobeltosis estimated over better parents

4.1.7 Analysis of variance for combining ability

4.1.8 General combining ability effects of parents

4.1.9 Specific combining ability effects of crosses

### 4.1.1 Analysis of variance

The analysis of variance for various characters has been presented in Table 4.1.

It is revealed from Table 4.1 that mean squares due to genotypes were highly significant for all the traits studied. This indicated the presence of substantial genetic variability for these characters.

Further partitioning of genotypic variance into components viz., parents, hybrids and parents vs hybrids revealed that the parent differed among themselves significantly for all the characters. Similarly hybrids also showed highly significant differences for all the traits. The mean square due to parents vs hybrids were significant for all the characters indicating the significant differences between parents and hybrids.

**Table 4.1: Analysis of variance**

| Source of variation | d.f. | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters per plant | 100 seed weight (gm) | Number of seeds per pod | seed yield per plant (gm) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Replications | 2 | 1.285 | 0.362 | 51.758 | 7.510 | 6.412** | 0.005 | 24.725 | 11.925** | 2.632 |
| Treatments | 48 | 1138.461** | 2.411** | 36569.634** | 157.937** | 2.064** | 0.293** | 4257.409** | 137.79** | 221.527** |
| Parents | 12 | 2406.899** | 1.823** | 16244.372** | 69.794** | 2.556** | 0.205** | 1179.61** | 223.867** | 381.247** |
| Hybrids | 35 | 319.865** | 2.36** | 27075.872** | 147.831** | 1.845** | 0.296** | 4525.983** | 52.211** | 149.34** |
| Parents Vs Hybrids | 1 | 14568.034** | 11.236** | 612754.439** | 1569.343** | 3.845** | 1.214** | 31790.94** | 2100.127** | 831.428** |
| Error | 96 | 0.971 | 0.126 | 167.32 | 2.772 | 0.161 | 0.065 | 10.082 | 0.682 | 1.75 |

Note

* - **Significant at 5 % level of significance**

** - **Significant at 1 % level of significance**

**Others - Non-significant**

## 4.2 *Per se* performance of parents, hybrids and check

*Per se* performance of parents, hybrids and standard check viz., Asha and Maruti for various characters are presented in Table 4.2 ana 4.3. Higher values are desirable for all the traits under study except, days to 50 % flowering and days to maturity for which lower values are preferred.

### 1) Plant height per plant (cm)

The average plant height per plant ranged from 125.10 cm to 220.34 cm and 158.37 cm to 201.926 cm among the parents and hybrids, respectively.

Among the parents, AKPR-210 (220.34 cm) recorded the highest plant height. Whereas, lowest plant height was recorded by the parent AKV-4A (125.10 cm). Out of 13 parents only two parent exhibited significance for plant height. AKPR-210 (220.34 cm) was found to be significantly superior over both checks Asha (170.350 cm) and Maruti (180.45 cm).

Among the crosses, AKV-9A X AKPR-23 (201.926cm) was recorded maximum plant height per plant followed by AKV-2A X AKPR-345 (196.846 cm), AKV-2A X AKPR-250 (196.34 cm), AKV-8A X AKPR-205 (192.786 cm), AKV-8A X AKPR-324 (187.406 cm). Whereas the cross AKV-4A X AKPR-345 (158.37cm) showed least plant height among all the hybrids. Out of 36 hybrids only 26 and 11 hybrids showed significantly higher plant height over checks Asha (170.350) and Maruti (180.45) respectively.

### 2) Number of branches per plant

Number of branches per plant ranged from 4.27 to 7.2 and 4.73 to 7.93 among the parents and hybrids respectively.

Among the parents, AKPR-210 (7.2) recorded the maximum number of branches per plant, followed by AKPR-345 (6.466), AKV-2A (6.333), AKPR-227 (6.07). The parent AKPR-386 and AKPR-312 (5.20) recorded the least number of branches per plant. Two and one of the parents showed

Table 4.2: *Per se* performance of parents, hybrids with standard check Asha.

| Genotypes | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters per plant | 100 seed weight (gm) | Number of seeds per pod | Grain Weight per plant (gm) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| **Females** | | | | | | | | | |
| AKV-2A | 143.95 | 6.333* | 338.13 | 34.93 | 11.13 | 3.67 | 42.41 | 127 | 174.66** |
| AKV-4A | 125.10 | 5.33 | 381.53 | 35.00 | 9.10 | 3.47 | 82.90 | 122.67** | 170.66** |
| AKV8A | 131.48 | 5.67 | 332.87 | 31.47 | 9.61 | 3.93 | 34.61 | 124.666* | 173.33** |
| AKV-9A | 131.90 | 4.27 | 337.13 | 31.40 | 10.33 | 3.13 | 82.04 | 123.00** | 173.33** |
| **Males** | | | | | | | | | |
| AKPR-324 | 155.38 | 5.40 | 270.20 | 33.00 | 11.27 | 3.47 | 82.94 | 104.00** | 156** |
| AKPR-23 | 161.64 | 5.40 | 369.00 | 35.67 | 9.98 | 3.73 | 80.94 | 113.33** | 161.66** |
| AKPR-312 | 127.90 | 5.20 | 191.87 | 25.27 | 9.93 | 3.13 | 68.08 | 110.00** | 150.66** |
| AKPR-386 | 197.83 | 5.20 | 332.73 | 33.07 | 10.16 | 3.67 | 50.36 | 110.67** | 150** |
| AKPR-227 | 155.31 | 6.07 | 254.27 | 33.20 | 10.76 | 3.73 | 53.45 | 106.00** | 146.66** |
| AKPR-210 | 220.34** | 7.2** | 374.20 | 36.00 | 12.148* | 3.27 | 93.87 | 131.00 | 181.67 |
| AKPR-345 | 171.72* | 6.466* | 483.27 | 45.47 | 11.02 | 3.67 | 60.59 | 115.00** | 152.66** |
| AKPR-205 | 163.13 | 4.67 | 258.67 | 28.80 | 12.207* | 3.20 | 87.87 | 111.00** | 158.33** |
| AKPR-250 | 137.63 | 5.93 | 282.20 | 28.73 | 10.74 | 3.33 | 91.57 | 110.67** | 160.33** |
| **Hybrids** | | | | | | | | | |
| AKV-2A X AKPR-324 | 181.533** | 6.866** | 418.40 | 40.93 | 11.67 | 4.27* | 56.81 | 133.333 | 176.66* |
| AKV-2A X AKPR-23 | 168.69 | 7.933** | 501.20 | 41.60 | 11.30 | 4.5** | 100.79 | 129.333 | 171.33** |
| AKV-2A X AKPR-312 | 173.6** | 5.53 | 412.47 | 29.47 | 11.08 | 4.666** | 84.68 | 123.33** | 166** |
| AKV-2A X AKPR-386 | 161.25 | 5.20 | 470.67 | 31.33 | 12.02 | 3.67 | 27.15 | 128.333 | 179.33 |
| AKV-2A X AKPR-227 | 162.13 | 4.93 | 289.27 | 27.73 | 10.06 | 3.47 | 99.58 | 126.666 | 173.66** |
| AKV-2A X AKPR-210 | 170.87 | 7.866** | 326.93 | 35.07 | 11.73 | 3.93 | 111.83 | 125.666 | 174** |
| AKV-2A X AKPR-345 | 196.846** | 7.533** | 544.60 | 40.20 | 10.75 | 3.20 | 83.99 | 123.00** | 169** |
| AKV-2A X AKPR-205 | 178.82** | 6.00 | 365.07 | 37.40 | 10.59 | 3.53 | 113.26 | 121.33** | 167** |
| AKV-2A X AKPR-250 | 196.34** | 6.4* | 510.20 | 45.33 | 11.35 | 3.73 | 94.05 | 123.33** | 174** |

contd....

| Genotypes | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters per plant | 100 seed weight (gm) | Number of seeds per pod | Grain Weight per plant (gm) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| AKV-4A X AKPR-324 | 172.17 | 7.133** | 501.67 | 43.27 | 10.66 | 3.93 | 102.71 | 127.67 | 172** |
| AKV-4A X AKPR-23 | 179.08** | 5.93 | 460.27 | 38.20 | 9.24 | 3.27 | 79.02 | 127.00 | 167.33** |
| AKV-4A X AKPR-312 | 182.966** | 6.07 | 650.60 | 51.20 | 10.85 | 3.73 | 44.44 | 125.67 | 163.33** |
| AKV-4A X AKPR-386 | 175.52** | 5.00 | 507.00 | 40.53 | 10.83 | 3.73 | 101.11 | 123.666** | 180.00 |
| AKV-4A X AKPR-227 | 181.8** | 5.20 | 364.47 | 34.20 | 11.65 | 3.60 | 39.47 | 121.666** | 172.66** |
| AKV-4A X AKPR-210 | 175.206** | 5.00 | 507.33 | 40.60 | 10.60 | 3.87 | 106.17 | 124** | 177.33 |
| AKV-4A X AKPR-345 | 158.37 | 6.6** | 316.60 | 34.67 | 9.79 | 3.60 | 62.87 | 124.33** | 161** |
| AKV-4A X AKPR-205 | 158.90 | 6.333* | 351.87 | 35.40 | 11.09 | 3.87 | 121.87 | 122.666** | 169.66** |
| AKV-4A X AKPR-250 | 182.486** | 6.27 | 553.20 | 48.00 | 10.99 | 3.87 | 112.30 | 124** | 163.66** |
| AKV-8A X AKPR-324 | 187.406** | 7** | 375.27 | 41.20 | 11.95 | 3.33 | 99.43 | 131.67 | 183.67 |
| AKV-8A X AKPR-23 | 177.3** | 4.73 | 473.67 | 50.00 | 10.04 | 3.53 | 86.59 | 131.00 | 177.00 |
| AKV-8A X AKPR-312 | 173.62** | 5.33 | 588.50 | 50.07 | 11.19 | 3.80 | 108.39 | 126.00 | 166** |
| AKV-8A X AKPR-386 | 174.54** | 7.266** | 433.40 | 39.73 | 10.66 | 3.33 | 45.78 | 126.00 | 160** |
| AKV-8A X AKPR-227 | 167.45 | 5.07 | 510.53 | 38.73 | 10.80 | 3.13 | 117.44 | 124.12** | 160.33** |
| AKV-8A X AKPR-210 | 184.4** | 5.13 | 509.73 | 45.47 | 10.88 | 3.93 | 128.52 | 124.33** | 167** |
| AKV-8A X AKPR-345 | 183.033** | 7.666** | 634.60 | 53.73 | 12.287** | 4.27 | 136.97 | 125.00 | 162.33** |
| AKV-8A X AKPR-205 | 192.786** | 7.2** | 614.60 | 47.27 | 11.70 | 3.67 | 164.98 | 126.67 | 159.66** |
| AKV-8A X AKPR-250 | 172.986** | 5.93 | 418.40 | 34.47 | 10.85 | 3.27 | 115.52 | 124.23** | 157** |

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| Genotypes | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters per plant | 100 seed weight (gm) | Number of seeds per pod | Grain Weight per plant (gm) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| AKV-9A X AKPR-324 | 178.42** | 6.13 | 388.07 | 38.47 | 11.98 | 3.60 | 101.39 | 126.67 | 169.33** |
| AKV-9A X AKPR-23 | 201.92** | 6.66** | 705.9** | 59.13* | 9.71 | 3.87 | 204.15** | 130.00 | 169.33** |
| AKV-9A X AKPR-312 | 170.81 | 6.13 | 461.73 | 47.87 | 10.87 | 3.67 | 120.07 | 121** | 159.33** |
| AKV-9A X AKPR-386 | 170.89 | 6.00 | 460.27 | 37.13 | 10.12 | 3.27 | 105.39 | 115** | 164.33** |
| AKV-9A X AKPR-227 | 181.38** | 6.53* | 469.80 | 41.87 | 10.23 | 3.80 | 152.87 | 113** | 158.66** |
| AKV-9A X AKPR-210 | 179.86** | 6.6** | 407.40 | 33.00 | 12.96** | 3.47 | 41.45 | 118.33** | 160.66** |
| AKV-9A X AKPR-345 | 187.146** | 6.66** | 493.63 | 39.93 | 11.08 | 4.666** | 168.17 | 121** | 164.33** |
| AKV-9A X AKPR-205 | 187.27** | 6.8** | 460.27 | 34.53 | 10.92 | 3.93 | 149.03 | 120.66** | 158** |
| AKV-9A X AKPR-250 | 186.92** | 6.4* | 454.53 | 35.00 | 11.91 | 3.67 | 136.03 | 123.33** | 162** |
| Standard Check : Asha | 170.35 | 5.73 | 642.27 | 57.67 | 11.39 | 3.70 | 186.97 | 123.00 | 173.67 |
| Mean | 172.33 | 6.09 | 438.33 | 39.25 | 10.96 | 3.67 | 97.38 | 122.26 | 166.41 |
| SE (m) ± | 0.569 | 0.205 | 7.468 | 0.961 | 0.231 | 0.147 | 1.833 | 0.476 | 0.763 |
| CD at 5% | 1.598 | 0.575 | 20.966 | 2.699 | 0.652 | 0.415 | 5.147 | 1.339 | 2.14 |
| CD at 1% | 2.156 | 0.762 | 27.758 | 3.573 | 0.863 | 0.549 | 6.814 | 1.772 | 2.84 |

**Note:**

* Significant over check Asha at 5 % level of significance

** Significant over check Asha at 1 % level of significance

Table 4.3: *Per se* performance of parents, hybrids with standard check Maruti.

| Genotypes | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters per plant | 100 seed weight (gm) | Number of seeds per pod | Grain Weight per plant (gm) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| **Females** | | | | | | | | | |
| AKV-2A | 143.95 | 6.33 | 338.13 | 34.93 | 11.13 | 3.67 | 42.41 | 127.00 | 174.67 |
| AKV-4A | 125.10 | 5.33 | 381.53 | 35.00 | 9.10 | 3.47 | 82.9 | 122.67 | 170.67 |
| AKV8A | 131.48 | 5.67 | 332.87 | 31.47 | 9.61 | 3.93 | 34.61 | 124.67 | 173.33 |
| AKV-9A | 131.90 | 4.27 | 337.13 | 31.40 | 10.33 | 3.13 | 82.04 | 123.00 | 173.33 |
| **Males** | | | | | | | | | |
| AKPR-324 | 155.38 | 5.40 | 270.20 | 33.00 | 11.27 | 3.47 | 82.94 | 104** | 156** |
| AKPR-23 | 161.64 | 5.40 | 369.00 | 35.67 | 9.98 | 3.73 | 80.94 | 113.33** | 161.66** |
| AKPR-312 | 127.90 | 5.20 | 191.87 | 25.27 | 9.93 | 3.13 | 68.08 | 110** | 150.66** |
| AKPR-386 | 197.83 | 5.20 | 332.73 | 33.07 | 10.16 | 3.67 | 50.36 | 110.66** | 150** |
| AKPR-227 | 155.31 | 6.07 | 254.27 | 33.20 | 10.76 | 3.73 | 53.45 | 106** | 146.66** |
| AKPR-210 | 220.33** | 7.2** | 374.20 | 36.00 | 12.148** | 3.27 | 93.87 | 131** | 181.67 |
| AKPR-345 | 171.72 | 6.47 | 483.27 | 45.47 | 11.02 | 3.67 | 60.59 | 115** | 152.66** |
| AKPR-205 | 163.13 | 4.67 | 258.67 | 28.80 | 12.20** | 3.20 | 87.87 | 111** | 158.33** |
| AKPR-250 | 137.63 | 5.93 | 282.20 | 28.73 | 10.74 | 3.33 | 91.57 | 110.66** | 160.33** |
| **Hybrids** | | | | | | | | | |
| AKV-2A X AKPR-324 | 181.53 | 6.66* | 418.40 | 40.93 | 11.67 | 4.27* | 56.81 | 133.33 | 176.67 |
| AKV-2A X AKPR-23 | 168.69 | 7.933** | 501.20 | 41.60 | 11.30 | 4.40** | 100.79 | 129.33 | 171.33 |
| AKV-2A X AKPR-312 | 173.60 | 5.53 | 412.47 | 29.47 | 11.08 | 4.07 | 84.68 | 123.33 | 166** |
| AKV-2A X AKPR-386 | 161.25 | 5.20 | 470.67 | 31.33 | 12.01** | 3.67 | 27.15 | 128.33 | 179.33 |
| AKV-2A X AKPR-227 | 162.13 | 4.93 | 289.27 | 27.73 | 10.06 | 3.47 | 99.58 | 126.67 | 173.67 |
| AKV-2A X AKPR-210 | 170.87 | 7.866** | 326.93 | 35.07 | 11.72* | 3.93 | 111.83 | 125.67 | 174.00 |
| AKV-2A X AKPR-345 | 196.846** | 7.53** | 544.60 | 40.20 | 10.75 | 3.20 | 83.99 | 123.00 | 169.00 |
| AKV-2A X AKPR-205 | 178.82 | 6.00 | 365.07 | 37.40 | 10.59 | 3.53 | 113.26 | 121.33** | 167** |
| AKV-2A X AKPR-250 | 196.34** | 6.40 | 510.20 | 45.33 | 11.35 | 3.73 | 94.05 | 123.33 | 174.00 |

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| Genotypes | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters per plant | 100 seed weight (gm) | Number of seeds per pod | Grain Weight per plant (gm) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| AKV-4A X AKPR-324 | 172.17 | 7.13** | 501.67 | 43.27 | 10.66 | 3.93 | 102.71 | 127.67 | 172.00 |
| AKV-4A X AKPR-23 | 179.08 | 5.93 | 460.27 | 38.20 | 9.24 | 3.27 | 79.02 | 127.00 | 167.33** |
| AKV-4A X AKPR-312 | 182.966** | 6.07 | 650.6** | 51.2** | 10.85 | 3.73 | 44.44 | 125.67 | 163.33** |
| AKV-4A X AKPR-386 | 175.52 | 5.00 | 507.00 | 40.53 | 10.83 | 3.73 | 101.11 | 123.67 | 180.00 |
| AKV-4A X AKPR-227 | 181.80 | 5.20 | 364.47 | 34.20 | 11.65 | 3.60 | 39.47 | 121.66* | 172.67 |
| AKV-4A X AKPR-210 | 175.21 | 5.00 | 507.33 | 40.60 | 10.60 | 3.87 | 106.17 | 124.00 | 177.33 |
| AKV-4A X AKPR-345 | 158.37 | 6.6* | 316.60 | 34.67 | 9.79 | 3.60 | 62.87 | 124.33 | 161** |
| AKV-4A X AKPR-205 | 158.90 | 6.33 | 351.87 | 35.40 | 11.09 | 3.87 | 121.87 | 122.67 | 169.67 |
| AKV-4A X AKPR-250 | 182.486** | 6.27 | 553.20 | 48.00 | 10.99 | 3.87 | 112.3 | 124.00 | 163.66** |
| AKV-8A X AKPR-324 | 187.406** | 7** | 375.27 | 41.20 | 11.95** | 3.33 | 99.43 | 131.67 | 183.67 |
| AKV-8A X AKPR-23 | 177.30 | 4.73 | 473.67 | 50.00 | 10.04 | 3.53 | 86.59 | 131.00 | 177.00 |
| AKV-8A X AKPR-312 | 173.62 | 5.33 | 588.50 | 50.07 | 11.19 | 3.80 | 108.39 | 126.00 | 166** |
| AKV-8A X AKPR-386 | 174.54 | 7.26** | 433.40 | 39.73 | 10.66 | 3.33 | 45.78 | 126.00 | 160** |
| AKV-8A X AKPR-227 | 167.45 | 5.07 | 510.53 | 38.73 | 10.80 | 3.13 | 117.44 | 124.33 | 160.33** |
| AKV-8A X AKPR-210 | 184.4** | 5.13 | 509.73 | 45.47 | 10.88 | 3.93 | 128.52 | 124.33 | 167** |
| AKV-8A X AKPR-345 | 183.033** | 7.66** | 634.6** | 53.73** | 12.28** | 4.27* | 136.97 | 125.00 | 162.33** |
| AKV-8A X AKPR-205 | 192.786** | 7.2** | 614.6** | 47.27 | 11.7* | 3.67 | 164.98** | 126.67 | 159.66** |
| AKV-8A X AKPR-250 | 172.99 | 5.93 | 418.40 | 34.47 | 10.85 | 3.27 | 115.52 | 124.33 | 157** |

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| Genotypes | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters per plant | 100 seed weight (gm) | Number of seeds per pod | Grain Weight per plant (gm) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| AKV-9A X AKPR-324 | 178.43 | 6.13 | 388.07 | 38.47 | 11.97** | 3.60 | 101.39 | 126.67 | 169.33 |
| AKV-9A X AKPR-23 | 201.926** | 6.66* | 705.9** | 59.13** | 9.71 | 3.87 | 204.15** | 130.00 | 169.33 |
| AKV-9A X AKPR-312 | 170.81 | 6.13 | 461.73 | 47.87 | 10.87 | 3.67 | 120.07 | 121** | 159.33** |
| AKV-9A X AKPR-386 | 170.89 | 6.00 | 460.27 | 37.13 | 10.11 | 3.27 | 105.39 | 115** | 164.33** |
| AKV-9A X AKPR-227 | 181.38 | 6.53* | 469.80 | 41.87 | 10.23 | 3.80 | 152.87** | 113** | 158.66** |
| AKV-9A X AKPR-210 | 179.87 | 6.6* | 407.40 | 33.00 | 12.96** | 3.47 | 41.45 | 118.33** | 160.66** |
| AKV-9A X AKPR-345 | 187.14** | 6.66* | 493.63 | 39.93 | 11.08 | 4.07 | 168.17** | 121** | 164.33** |
| AKV-9A X AKPR-205 | 18.73 | 6.8* | 460.27 | 34.53 | 10.92 | 3.93 | 149.03* | 120.66** | 158** |
| AKV-9A X AKPR-250 | 186.96** | 6.40 | 454.53 | 35.00 | 11.90** | 3.67 | 136.03 | 123.33 | 162** |
| Standard Check : Maruti | 180.45 | 5.93 | 594.53 | 49.60 | 11.03 | 3.80 | 143.8 | 120.00 | 166.00 |
| Mean | 172.33 | 6.09 | 438.33 | 39.25 | 10.96 | 3.67 | 97.38 | 122.26 | 166.26 |
| SE (m) ± | 0.569 | 0.205 | 7.468 | 0.961 | 0.231 | 0.147 | 1.833 | 0.476 | 0.763 |
| CD at 5% | 1.60 | 0.575 | 20.966 | 2.699 | 0.652 | 0.415 | 5.147 | 1.339 | 2.145 |
| CD at 1% | 2.16 | 0.762 | 27.758 | 3.573 | 0.863 | 0.549 | 6.814 | 1.772 | 2.839 |

**Note:**

* **Significant over check Asha at 5 % level of significance**

** **Significant over check Asha at 1 % level of significance**

significance for number of branches per plant over both check Asha (5.60) and Maruti (6.10) respectively.

Among the hybrids, AKV-2A X AKPR-23 (7.933) and AKV-2A X AKPR-210 (7.866) followed by AKV-8A X AKPR-345 (7.666) recorded maximum number of branches per plant. Whereas, the hybrid AKV-8A X AKPR-23 (4.73) and AKV-2A X AKPR-227 (4.93) recorded lowest number of branches per plant. Out of 36 crosses only 18 and 14 hybrids exhibited superiority for this trait over checks Asha (5.730) and Maruti (5.93) respectively.

**3) Number of pods per plant**

Table 4.2 and 4.3 reveals that the average number of pods per plant ranged from 191.87 to 483.27 and 289.27 to 705.9 among the parents and hybrids, respectively.

Among the parents AKPR-345 (483.27) recorded the highest number of pods per plant followed by parents AKV-4A (381.53), AKPR-210 (374.20), AKPR-23 (369.00). While minimum number of pods recorded by the parent AKPR-312 (191.87). None of the parent Showed significance for number of pods per plant for checks Asha (642.267) and Maruti (594.53)

Among the hybrids, AKV-9A X AKPR-23 (705.9) recorded the maximum number of pods per plant and the hybrid was significantly superior over the both the checks Asha (642.267) and Maruti (594.53), and the remaining parents were at par with the check. AKV-2A X AKPR-227 (289.27) was recorded least number of pods per plant.

**4) Number of clusters per plant**

Table 4.2 and 4.3 reveals that the average Number of clusters per plant ranged from 25.27 to 45.47 and 27.73 to 59.133 among the parents and hybrids respectively.

Among the parents AKPR-345 (45.47) recorded the highest Number of clusters per plant followed by parents AKPR-210 (36.00), AKPR-23 (35.67), AKV-4A (35.00) while minimum Number of clusters per plant recorded by the parent AKPR-312 (25.27). None of the parents showed significance for Number of clusters per plant for both checks Asha (57.670) and Maruti (49.60).

Among the hybrids, AKV-9A X AKPR-23 (59.133) exhibited maximum Number of clusters per plant and the hybrid was significantly superior over the both check Asha (57.670) and Maruti (49.60). AKV-2A X AKPR-227 (27.73) was exhibited minimum Number of clusters per plant among the all hybrids.

**5) 100 seed weight (g)**

Table 4.2 and 4.3 reveals that mean 100 seed weight ranged between 9.10 g to 12.148 g and 9.24 g to 12.960 g among the parents and hybrids respectively.

Among the parents, AKPR-205 (12.207 gm) recorded the highest 100 seed weight followed by AKPR-210 (12.148 gm). Both these parents were significantly superior over the checks Asha (11.390 g) and Maruti (11.03 g). Parent AKV-4A (9.10 g) showed least 100 seed weights among the parents. Two of the parents showed significance for 100 seed weight over both checks Asha (11.390) and Maruti (11.03).

In case of hybrids, maximum 100 seed weight was observed in AKV-9A X AKPR-210 (12.960 g) and showed significantly superior over both check Asha (11.390 g) and Maruti (11.03 g). Whereas, AKV-4A X AKPR-23 (9.24 g) showed least seed weight. Out of 36 hybrids only two hybrids exhibited significance over check Asha (11.390 g) whereas eight hybrids exhibited significance over check Maruti (11.03 g).

**6) Number of seeds per pod**

Number of seeds per pod ranged between 3.13 to 3.93 for parents and 3.13 to 4.666 for hybrids in Table 4.2.

Among the parents, maximum number of seeds per pod was observed in AKV-8A (3.93) followed by AKPR-23 (3.73) and AKPR-227 (3.73). Least number of seeds per pod was recorded in AKV-9A (3.13) and AKPR-312 (3.13). None of the parents showed significance over both checks.

Among the hybrids, AKV-2A X AKPR-312 (4.666) and AKV-9A X AKPR-345 (4.666) recorded maximum number of seeds per pod followed by AKV-2A X AKPR-23 (4.5), AKV-2A X AKPR-324 (4.27). Minimum number of seeds per pod was recorded by AKV-8A X AKPR-227 (3.13). Out of 36 hybrids, three and none of the hybrid showed significance over both check Asha (3.7) and Maruti (3.8) respectively.

**7) Grain weight per plant (g)**

Average seed yield per plant ranged from 34.61 g to 93.87 g and 27.15 g to 204.15 g among the parents and hybrids, respectively.

None of the parents significantly out yielded the standard check Asha (186.970 g) and Maruti (143.8 g). However, AKPR-210 (93.87 g) and AKPR-250 (91.57 g) recorded the highest grain weight per plant among the parents. AKV-8A (34.61 g) recorded the lowest grain weight per plant than the checks and was significantly inferior for this character.

Among the hybrids, only AKV-9A X AKPR-23 (204.15 g) exhibited the highest and significantly superior over both the checks Asha (186.970 g) and Maruti (143.8 g). AKV-2A X AKPR-386 was found to yield lowest among the hybrids and was significantly inferior for this trait. Out of 36 hybrids, one and five of the hybrids showed significance over both check Asha (186.970 g) and Maruti (143.8 g) respectively.

**8) Days to 50% flowering**

The average number of days to 50 per cent flowering ranged from 104 to 131 and 113 to 133.33 among the parents and hybrids, respectively (Table 4.2 and 4.3).

Among the parents, all male parents exhibited significance over the checks Asha (127.33) and Maruti (120) except AKPR-210 (131). All female parents and AKPR-210 (131) exhibited maximum days to 50% flowering which is inferior for this trait. AKPR-324 (104) was earlier and significant over both checks Asha (123) and Maruti (120) followed by AKPR-227 (106), AKPR-312 (110), AKPR-386 (110.67).

Among the hybrids, AKV-9A X AKPR-227 (113) was found to be earlier and significantly superior over the check Asha (123.00) and Maruti (120.00) followed by AKV-9A X AKPR-386 (115.00), AKV-9A X AKPR-312 (121.00) and AKV-9A X AKPR-345 (121.00) for days to 50 per cent flowering.

**9) Days to maturity**

The average number of days to maturity ranged form 146.66 to 181.67 and 157.00 to 183.67 among the parents and hybrids respectively (Table 4.2 and 4.3).

Among the parent all the male parents exhibited significance over the checks Asha (173.67) and Maruti (166.00) except all females. AKV-2A (174.66) exhibited maximum days to maturity which is inferior for this trait.

AKPR-227(146.66) was earlier and significant over both checks Asha (173.67) and Maruti (166.00) followed by AKPR-386 (150.00), AKPR-312 (150.66), AKPR-345 (152.66).

Among the hybrids, AKV-8A X AKPR-250 (157.00) was found to be earlier and significantly superior over the checks Asha (173.67) and Maruti (166.00) followed by AKV-9A X AKPR-205 (158.00), AKV-9A X AKPR-312

(159.33) for days to maturity. AKV-4A X AKPR-386 (180.00) was found to be latest among all the hybrids for days to maturity.

### 4.1.4. Useful heterosis estimated over check Asha and Maruti

The percentage of useful heterosis over check Asha and Maruti for the characters studied is given in Table 4.4. In pigeonpea, positive heterosis is desirable for all the characters except days to 50 per cent flowering and days to maturity for which negative heterosis is desirable. Character wise results of useful heterosis observed in the 36 hybrids tested are presented.

#### 1) Plant height per plant

Useful heterosis ranged from -7.032 per cent to 18.538 per cent over check Asha (Table 4.4). Out of 36 hybrids, only twenty two hybrids revealed significant positive useful heterosis. Maximum heterosis was depicted by hybrids AKV-9A X AKPR-23 (18.538 %) followed by AKV-2A X AKPR-345 (15.556%) and AKV-2A X AKPR-250 (15.256%).

Over check Maruti Useful heterosis ranged from -12.236 per cent to 11.903 per cent (Table 4.4). Only ten hybrids showed significant positive heterosis. Maximum heterosis was shown by hybrid AKV-9A X AKPR-23 (11.903 %) followed by AKV-2A X AKPR-345 (9.088%) and AKV-2A X AKPR-250 (8.805%).

#### 2) Number of branches per plant

Standard heterosis for this character ranged from -17.45 per cent to 38.44 per cent (Table 4.4) over check Asha. Only five hybrids exhibited significant and positive standard heterosis for this trait. The cross AKV-2A X AKPR-23 (38.44 %) showed highest standard heterosis followed by crosses AKV-2A X AKPR-210 (37.27%), AKV-8A X AKPR-345 (33.79%), AKV-2A X AKPR-345 (32.65%).

**Table 4.4 : Percentage of useful Heterosis estimated over check Asha and Maruti (%)**

| Hybrids | | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters pr plant | 100 seed weight (gm) | Number of seeds per pod | Grain wt per plant (gm)) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| AKV-2A X AKPR-324 | A | 6.562** | 19.82** | -34.86 | -29.03 | 2.45 | 15.41** | -69.62 | 8.40 | 1.72 |
| | B | 0.60 | 12.31** | -29.63 | -17.48 | 5.80 | 12.37* | -60.49 | 11.11 | 6.43 |
| AKV-2A X AKPR-23 | A | -0.97 | 38.44** | -21.96 | -27.87 | -0.79 | 21.62** | -46.09 | 5.15 | -1.35* |
| | B | 0.60 | 33.78** | -29.63 | -17.48 | 2.45 | 15.79** | -60.49 | 11.11 | 3.21 |
| AKV-2A X AKPR-312 | A | 1.907** | -3.49 | -35.78 | -48.90 | -2.72 | 26.11** | -54.71 | 0.268** | -4.41** |
| | B | -3.80 | -6.75 | -30.62 | -40.58 | 0.45 | 7.11** | -41.11 | 2.78 | 0.00 |
| AKV-2A X AKPR-386 | A | -5.34 | -9.24 | -26.72 | -45.67 | 5.53 | -0.81 | -85.48 | 4.33 | 3.25 |
| | B | -10.64 | -12.31 | -20.83 | -36.83 | 8.88** | -3.42 | -81.12 | 6.94 | 8.03 |
| AKV-2A X AKPR-227 | A | -4.83 | -13.96 | -54.96 | -51.92 | -11.67 | -6.22 | -46.74 | 2.98 | -0.01 |
| | B | -10.15 | -16.86 | -51.34 | -44.09 | -8.79 | -8.68 | -30.75 | 5.56 | 4.62 |
| AKV-2A X AKPR-210 | A | 0.31 | 37.27** | -49.10 | -39.19 | 2.98 | 6.22 | -40.19 | 2.17 | 0.19 |
| | B | -5.31 | 32.65** | -45.01 | -29.29 | 6.26* | 3.42** | -22.23 | 4.73 | 4.82 |
| AKV-2A X AKPR-345 | A | 15.556** | 31.47** | -15.21 | -30.29 | -5.62 | -13.51 | -55.08 | 0.000** | -2.69** |
| | B | 9.088** | 26.98** | -8.40 | -18.95 | -2.54 | -15.79 | -41.59 | 2.50 | 1.81 |
| AKV-2A X AKPR-205 | A | 4.972** | 4.71 | -43.16 | -35.15 | -7.02 | -4.59 | -39.42 | -1.358** | -3.84** |
| | B | -0.90 | 1.18 | -38.60 | -24.60 | -3.99 | -7.11 | -21.24 | 1.1083** | 0.60 |
| AKV-2A X AKPR-250 | A | 15.256** | 11.69** | -20.56 | -21.40 | -0.35 | 0.81 | -49.70 | 0.268** | 0.19 |
| | B | 8.805** | 7.93** | -14.18 | -8.61 | 2.90 | -1.84 | -34.60 | 2.78 | 4.82 |
| AKV-4A X AKPR-324 | A | 1.068** | 24.49** | -21.89 | -24.97 | -6.41 | 6.22 | -45.07 | 3.80 | -0.96 |
| | B | -4.59 | 20.24** | -15.62 | -12.76 | -3.35 | 3.42 | -28.57 | 6.39 | 3.61 |
| AKV-4A X AKPR-23 | A | 5.12 | 3.49 | -28.34 | -33.76 | -18.88 | -11.62 | -57.74 | 2.98 | -3.65** |
| | B | -0.76 | 0.00 | -22.58 | -22.98 | -16.23 | -13.95 | -45.05 | 5.56 | 0.80 |
| AKV-4A X AKPR-312 | A | 7.408** | 5.93 | 1.30 | -11.22 | -4.74 | 0.81 | -76.23 | 2.17 | -5.95** |
| | B | 1.40 | 2.36 | 9.4310** | 3.225* | -1.63 | -1.84 | -69.10 | 4.73 | -1.61* |

| Hybrids | | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters pr plant | 100 seed weight (gm) | Number of seeds per pod | Grain wt per plant (gm)) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| AKV-4A X AKPR-386 | A | 3.03 | -12.74 | -21.06 | -29.72 | -4.92 | 0.81 | -45.92 | 0.545** | 3.64 |
| | B | -2.73 | -15.68 | -14.72 | -18.29 | -1.81 | -1.84 | -29.69 | 3.06 | 8.43 |
| AKV-4A X AKPR-227 | A | 6.72 | -9.25 | -43.25 | -40.70 | 2.28 | -2.70 | -78.89 | -1.894** | -0.58 |
| | B | 0.75 | -12.31 | -38.70 | -31.05 | 5.62 | -5.26 | -72.55 | 0.56 | 4.02 |
| AKV-4A X AKPR-210 | A | 2.85 | -12.74 | -21.01 | -29.60 | -6.94 | 4.59 | -43.22 | 0.813** | 2.11 |
| | B | -2.90 | -15.68 | -14.67 | -18.15 | -3.90 | 1.84 | -26.17 | 3.33 | 6.83 |
| AKV-4A X AKPR-345 | A | -7.033** | 15.18** | -50.71 | -39.88 | -14.05 | -2.70 | -66.37 | 1.081** | -7.30** |
| | B | -12.2361** | 11.30** | -46.75 | -30.10 | -11.24 | -5.26 | -56.27 | 3.61 | -3.01** |
| AKV-4A X AKPR-205 | A | -6.721** | 10.52 | -45.22 | -38.62 | -2.63 | 4.59 | -35.13 | -0.813** | -2.31** |
| | B | -11.94 | 6.75** | -40.82 | -28.63 | 0.54 | 1.84** | -15.65 | 1.67 | 2.21 |
| AKV-4A X AKPR-250 | A | 7.126** | 9.42 | -13.87 | -16.77 | -3.51 | 4.59 | -39.94 | 1.357** | -5.76** |
| | B | 1.1305** | 5.73* | -6.95 | -3.23 | -0.36 | 1.84** | -21.91 | 3.89 | -1.41* |
| AKV-8A X AKPR-324 | A | 10.014** | 22.16 | -41.57 | -28.56 | 4.92 | -10.00** | -46.82 | 6.24 | 5.76 |
| | B | 3.86 | 18.04** | -36.88 | -16.94 | 8.34** | -12.37 | -30.86 | 8.89 | 10.64 |
| AKV-8A X AKPR-23 | A | 4.08 | -17.45 | -26.25 | -13.30 | -11.85 | -4.59 | -53.69 | 6.50 | 1.92 |
| | B | -1.75 | -20.24 | -20.33 | 0.81 | -8.98 | -7.11 | -39.78 | 9.17 | 6.63 |
| AKV-8A X AKPR-312 | A | 1.919** | -6.98 | -8.37 | -13.18 | -1.76 | 2.70 | -42.03 | 2.44 | -4.42** |
| | B | -3.79 | -10.12 | -1.01 | 0.95 | 1.45 | 0.00 | -24.62 | 5.00 | 0.00 |
| AKV-8A X AKPR-386 | A | 2.46 | 26.81 | -32.52 | -31.11 | -6.41 | -10.00 | -75.51 | 1.89 | -7.87** |
| | B | -3.28 | 22.43** | -27.10 | -19.90 | -3.35 | -12.37 | -68.16 | 4.44 | -3.61** |
| AKV-8A X AKPR-227 | A | -1.70 | -11.52 | -20.51 | -32.84 | -5.18 | -15.41 | -37.19 | 0.2683** | -7.68** |
| | B | -7.20 | -14.50 | -14.13 | -21.92 | -2.09 | -17.63 | -18.33 | 2.78 | -3.42** |
| AKV-8A X AKPR-210 | A | 8.25 | -10.47 | -20.64 | -21.15 | -4.48 | 6.22 | -31.26 | 1.0813** | -3.84** |
| | B | 2.19 | -13.49 | -14.26 | -8.33 | -1.36 | 3.42** | -10.63 | 3.61 | 0.60 |

contd...

| Hybrids | | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters pr plant | 100 seed weight (gm) | Number of seeds per pod | Grain wt per plant (gm)) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| AKV-8A X AKPR-345 | A | 7.44** | 33.79** | -1.19 | -6.83 | 7.88** | 6.75** | -26.74 | 1.63 | -6.53** |
| | B | 1.43** | 29.17** | 6.74* | 8.326** | 11.33** | 2.89** | -4.74 | 4.17 | -2.21** |
| AKV-8A X AKPR-205 | A | 13.17** | 25.65** | -4.31 | -18.03 | 2.72 | -8.25 | -11.76 | 2.98 | -8.07** |
| | B | 6.84 | 21.42** | 3.38 | -4.70 | 6.07* | -11.57 | 14.72** | 5.56 | -3.82** |
| AKV-8A X AKPR-250 | A | 1.54** | 3.49 | -34.86 | -40.23 | -4.74 | -18.25 | -38.21 | 1.08 | -9.60** |
| | B | -4.13** | 0.00 | -29.63 | -30.50 | -1.63 | -21.20 | -19.67 | 3.61 | -5.42** |
| AKV-9A X AKPR-324 | A | 4.74** | 7.03 | -39.58 | -33.29 | 5.15** | -10.00 | -45.77 | 2.98 | -2.50** |
| | B | -1.12 | 3.37* | -34.73 | -22.44 | 8.52** | -13.25 | -29.49 | 5.56 | 2.01 |
| AKV-9A X AKPR-23 | A | 18.54** | 16.34** | 9.91** | 2.53 | -14.71 | -3.33 | 9.19 | 5.69 | -2.50** |
| | B | 11.90** | 12.31** | 18.73** | 19.21** | -11.97 | -6.75** | 41.97** | 8.33 | 2.01 |
| AKV-9A X AKPR-312 | A | 0.27 | 7.03 | -28.11 | -16.99 | -4.61 | -8.33 | -35.78 | -1.62** | -8.26** |
| | B | -5.34 | 3.37* | -22.34 | -3.49 | -1.45 | -11.57 | -16.50 | 0.83** | -4.02** |
| AKV-9A X AKPR-386 | A | 0.32 | 4.71 | -28.34 | -35.62 | -11.19 | -18.33 | -43.63 | -6.50** | -5.38** |
| | B | -5.30 | 1.18** | -22.58 | -25.14 | -8.34 | -21.20 | -26.71 | -4.16** | -1.01** |
| AKV-9A X AKPR-227 | A | 6.47** | 14.01 | -26.85 | -27.40 | -10.16 | -5.00 | -18.24 | -8.13** | -8.64** |
| | B | 0.52 | 10.12** | -20.98 | -15.58 | -7.25 | -8.43 | 6.30** | -5.83** | -4.42** |
| AKV-9A X AKPR-210 | A | 5.58** | 15.18 | -36.57 | -42.78 | 13.78** | -13.33** | -77.83 | -4.33** | -7.49** |
| | B | -0.32 | 11.30 | -31.48 | -33.47 | 17.50** | -16.39 | -71.18 | -1.94** | -3.22** |
| AKV-9A X AKPR-345 | A | 9.86** | 16.34** | -23.14 | -30.76 | -2.75 | 16.65 | -10.06 | -1.62** | -5.38** |
| | B | 3.71** | 12.31 | -16.97 | -19.50 | 0.45 | -1.93** | 16.94** | 0.83** | -1.01** |
| AKV-9A X AKPR-205 | A | 9.93** | 18.67** | -28.34 | -40.12 | -4.15 | -1.68** | -20.29 | -1.89** | -9.02** |
| | B | 3.77** | 14.67** | -22.58 | -30.38 | -1.00 | -5.30 | 3.63* | 0.55** | -4.82** |
| AKV-9A X AKPR-250 | A | 9.73** | 11.69 | -29.23 | -39.31 | 4.54 | -8.33 | -27.25 | 0.26** | -6.72** |
| | B | 3.59** | 7.93** | -23.55 | -29.44 | 7.89** | -11.57 | -5.40 | 2.78 | -2.41** |
| SE (m) ± | | 0.569 | 0.205 | 7.468 | 0.961 | 0.231 | 0.147 | 1.833 | 0.476 | 0.763 |
| CD at 5 % | | 1.598 | 0.58 | 20.96 | 2.69 | 0.65 | 0.41 | 5.14 | 1.33 | 2.14 |
| CD at 1 % | | 2.156 | 0.76 | 27.75 | 3.57 | 0.86 | 0.549 | 6.81 | 1.77 | 2.83 |

*** - Significant over check at 5 % level of significance    ** - Significant over check at 1 % level of significance    Others – Non-significant**

**N.B. Significance of useful Heterosis was tested on the deviation of F1 mean values from check variety (i.e. F1-check)**

Over check Maruti, standard heterosis for Number of branches per plant ranged from -20.24 per cent to 33.78 per cent (Table 4.4). Out of 36 hybrids only twenty one hybrids showed significant and positive standard heterosis for this trait. The maximum standard heterosis was shown by crosses AKV-2A X AKPR-23 (33.78%), AKV-2A X AKPR-210 (32.65%), AKV-8A X AKPR-345 (29.17 %), and AKV-2A X AKPR-345 (29.98%).

**3) Number of pods per plant**

Useful heterosis ranged form -54.961 per cent to 9.9070 per cent (Table 4.4) over check Asha for this character. Out of 36 hybrids only one hybrid shows significant and positive heterosis. The crosses AKV-9A X AKPR-23 (9.907 %) showed significant positive standard heterosis and cross AKV-4A X AKPR-312 (1.297 %) is show positive but non significant heterosis, all others show negative standard heterosis which is not desirable for this character

Useful heterosis ranged from -51.34 to 18.7324 per cent (Table 4.4) over check Maruti for this trait. Only three hybrids show significant positive heterosis. The crosses AKV-9A X AKPR-23 (18.7324%), AKV-4A X AKPR-312 (9.4310%), AKV-8A X AKPR-345 (6.7398),showed significant positive standard heterosis, , all other show negative standard heterosis which is not desirable for this character.

**4) No. of clusters per plant**

Useful heterosis ranged from -51.916 per cent to 2.531 per cent (Table 4.4) over check Asha for this trait. no one hybrid exhibited significant and positive standard heterosis for this trait. The cross AKV-9A X AKPR-23 (2.531 %) showed positive standard heterosis. all other show negative standard heterosis which is not desirable for this character.

Useful heterosis ranged from -44.092 per cent to 19.213 per cent (Table 4.4) over check Maruti for this character. Out of 36 hybrids only five hybrids showed positive heterosis but out of five only three hybrids AKV-9A X

AKPR-23 (19.213 %), AKV-8A X AKPR-345 (8.326 %), AKV-4A X AKPR-312 (3.225 %) showed significant and positive heterosis for this trait.

**5) 100 seed weight**

Useful heterosis ranged from -18.88 per cent to 13.78 per cent (Table 4.4) over check Asha. Only four hybrids exhibited significant heterosis for this character. Maximum positive useful heterosis was displayed by AKV-9A X AKPR-210 (13.78%) followed by AKV-8A X AKPR-345 (7.88 per cent), AKV-2A X AKPR-386 (5.53 per cent), AKV-9A X AKPR 324 (5.15 per cent).

Useful heterosis ranged from -16.23 to 17.50 per cent (Table 4.4) over check Maruti. Out of 36 hybrids eight hybrids shows significant and positive useful heterosis. Maximum useful heterosis was observed in hybrids AKV-9A X AKPR-210 (17.50%) followed by AKV-8A X AKPR-345 (11.33%), AKV-2A X AKPR-386 (8.884%), AKV-9A X AKPR-324 (8.52%), AKV-8A X AKPR-324 (8.34%).

**6) Number of seeds per pod**

For this trait useful heterosis ranged form -18.25 per cent to 26.17 per cent (Table 4.4) over check Asha. Out of 36 hybrids six hybrids showed significant positive useful heterosis. Maximum positive useful heterosis was observed in AKV-2A X AKPR-312 (26.11%) followed by AKV-2A X AKPR-23 (21.62%) and AKV-2A X AKPR-324 (15.41%).

Useful heterosis ranged from -21.20 per cent to 22.31per cent (Table 4.4) over check Maruti. Only six hybrids showed significant positive useful heterosis. Maximum positive useful heterosis was observed in AKV-2A X AKPR-312 (22.31per cent), followed by AKV-2A X AKPR-23 (15.79 per cent) and AKV-2A X AKPR-324 (12.37).

**7) Grain weight per plant**

Useful hetrosis for this character ranged from -85.479 per cent to 9.193 per cent (Table 4.4) over check Asha. Out of 36 hybrids only one hybrid AKV-9A X AKPR-23 (9.193%) showed significant and positive useful heterosis.

Useful heterosis ranged from -81.1196 per cent to 41.974 per cent (Table 4.4) over check Maruti. Only five hybrids exhibited significant and positive useful heterosis. Maximum positive useful heterosis was observed in cross AKV-9A X AKPR-23 (41.974 %) followed by AKV-9A X AKPR-345 (16.947%), AKV-8A X AKPR-205 (14.728%) and AKV-9A X AKPR-227 (6.307%).

**8) Days to 50% flowering**

For this character in pigeonpea negative heterosis is desirable. Standard heterosis ranged from -8.1301 per cent to 8.398 per cent (Table 4.4) over check Asha. Out of 36 hybrids 19 hybrids shows significant negative heterosis. Highest significant negative heterosis was observed in AKV-9A X AKPR-227 (-8.1301%) followed by AKV-9A X AKPR-386 (-6.5041%), AKV-9A X AKPR-210 (-4.3333%).

Useful heterosis ranged from -5.8333 to 11.108 per cent (Table 4.4) over check Maruti. Out of 36 hybrids, seven hybrids showed significant negative heterosis. Highest significant negative heterosis was observed in AKV-9A X AKPR-227 (-5.8333 %) followed by AKV-9A X AKPR-210 (-4.3333), AKV-9A X AKPR-386 (-4.1667%), MS-010 x AKPR-29 (-9.09%).

**9) Day to maturity**

Useful heterosis ranged from -9.60 per cent to 5.76 per cent (Table 4.4) over check Asha. Out of 36 hybrids, twenty five hybrids exhibited significant negative heterosis. Maximum negative heterosis was observed AKV-8A X AKPR-250 (-9.60 %) followed by AKV-9A X AKPR-205 (-9.02%), AKV-9A X AKPR-227 (-8.64%).

Useful heterosis ranged from -5.42 per cent to 10.64 per cent (Table 4.4) over check Maruti. Fifteen hybrids exhibited significant lowest heterosis. Highest negative heterosis marked by cross AKV-8A X AKPR-250 (-5.42 %) followed by AKV-9A X AKPR-205 (-6.72%), AKV-9A X AKPR-227(-4.42%).

### 4.1.5 Average heterosis (%)

Average heterosis can be defined as the superiority or inferiority of the $F_1$ hybrid over mid parental value. The percentage of Average heterosis over for the characters studied is given in Table 4.5. In pigeonpea, positive heterosis is desirable for all the characters except days to 50 per cent flowering and days to maturity for which negative heterosis is desirable. Character wise results of average heterosis observed in the 36 hybrids tested are presented here.

#### 1) Plant height per plant

The average heterosis for Plant height ranged from -6.19 per cent to 44.64 per cent (Table 4.4). Out of 36 hybrids, only thirty five hybrids revealed significant positive average heterosis. Maximum heterosis was depicted by hybrids AKV-4A X AKPR-312 (44.64%) followed by AKV-2A X AKPR-250 (39.46%) and AKV-4A X AKPR-250 (38.91 %). Only two hybrids AKV-2A X AKPR-210 (-6.19%) and AKV-2A X AKPR-386 (-5.64%) shows negative average heterosis which is undesirable for this character.

#### 2) Number of branches per plant

Average heterosis for this character ranged from -20.21 per cent to 52.24 per cent (Table 4.4). Only twenty three hybrids exhibited significant and positive average heterosis for this trait. The cross AKV-9A X AKPR-205 (52.24 %) showed highest average heterosis followed by crosses AKV-8A X AKPR-205 (39.35 %), AKV-9A X AKPR-23 (37.58 %). The crosses AKV-8A X AKPR-210 (-20.21%) and AKV-4A X AKPR-210 (-20.21%) shows the lowest negative average heterosis which is undesirable for this character.

**Table 4.5 : Average Heterosis (%)**

| Sr.No. | Crosses | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters per plant | 100 seed weight (gm) | Number of seeds per pod | Grain wt. per plant (gm) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 | AKV-2A X AKPR-324 | 21.29 ** | 17.05 ** | 37.56 ** | 20.51 ** | 4.2** | 19.63 ** | -9.35 | 15.94 | 6.85 |
| 2 | AKV-2A X AKPR-23 | 10.40 ** | 35.23 ** | 41.76 ** | 17.85 ** | 7.06 * | 18.92 ** | 63.41 ** | 7.63 | 1.88 |
| 3 | AKV-2A X AKPR-312 | 27.72 ** | -4.05 | 55.65 ** | -2.1 | 5.29 | 19.61 ** | 53.28 ** | 4.08 | 2.05 |
| 4 | AKV-2A X AKPR-386 | -5.64 | -9.83 | 40.32 ** | -7.84 | 12.91 ** | 0 | -41.47 | 8.45 | 10.47 |
| 5 | AKV-2A X AKPR-227 | 8.35 ** | -20.43 | -2.34 | -18.59 | -8.07 | -6.31 | 107.75 ** | 8.73 | 8.09 |
| 6 | AKV-2A X AKPR-210 | -6.19** | 16.26 ** | -8.21 | -1.13 | 0.77** | 13.46 * | 64.11 ** | -2.2 | -2.34 |
| 7 | AKV-2A X AKPR-345 | 24.72 ** | 17.71 ** | 32.60 ** | 0** | -2.89 | -12.73 | 63.09 ** | 1.65 | 3.26 |
| 8 | AKV-2A X AKPR-205 | 16.46 ** | 9.09 | 22.34 ** | 17.36 ** | -9.2 | 2.91 | 73.88 ** | 1.96 | 0.3 |
| 9 | AKV-2A X AKPR-250 | 39.46 ** | 4.35** | 64.49 ** | 42.41 ** | 3.83* | 6.67 | 40.39 ** | 3.79 | 3.88 |
| 10 | AKV-4A X AKPR-324 | 22.77 ** | 32.92 ** | 53.95 ** | 27.25 ** | 4.61 | 13.46* | 23.86 ** | 13.48 | 5.31 |
| 11 | AKV-4A X AKPR-23 | 24.91 ** | 10.56 | 22.65 ** | 8.11 * | -3.2 | -9.26 | -3.55** | 7.65 | 0.7 |
| 12 | AKV-4A X AKPR-312 | 44.64 ** | 15.19 | 126.93 ** | 69.91 ** | 14.01 | 13.13 | -41.13 | 8.33 | 1.66 ** |
| 13 | AKV-4A X AKPR-386 | 8.71 ** | -5.06 | 41.96 ** | 19.10 ** | 12.46 | 4.67 | 51.74 ** | 6.76 | 12.27 |
| 14 | AKV-4A X AKPR-227 | 29.67 ** | -8.77 | 14.65** | 0.29 | 17.29 ** | 0 | -42.11 | 5.85 | 8.82 |
| 15 | AKV-4A X AKPR-210 | 1.44 ** | -20.21 | 34.26 ** | 14.37 ** | -0.22 | 14.85* | 20.12 ** | -1.59 | 0.66 |
| 16 | AKV-4A X AKPR-345 | 6.71 ** | 11.86 ** | -26.78 | -13.84 | -2.72 | 0.93 | -12.36 | 4.92 | -0.41** |
| 17 | AKV-4A X AKPR-205 | 10.26 ** | 26.67 ** | 9.92** | 10.97 * | 4.1 | 16.00 * | 42.04 ** | 4.72 | 3.14 |
| 18 | AKV-4A X AKPR-250 | 38.91 ** | 11.24 * | 66.69 ** | 50.63 ** | 10.73 | 13.73 * | 28.73 ** | 7.16 | -1.11** |
| 19 | AKV-8A X AKPR-324 | 30.66 ** | 26.51 ** | 24.45 ** | 27.82 ** | 14.53 ** | -9.91 | 69.17 ** | 14.45 | 11.54 ** |
| 20 | AKV-8A X AKPR-23 | 20.97 ** | -14.46 | 34.97 ** | 48.96 ** | 2.5 | -13.04 | 49.86 ** | 9.78 | 5.67 ** |

contd....

| Sr.No. | Crosses | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters per plant | 100 seed weight (gm) | Number of seeds per pod | Grain wt. per plant (gm) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 21 | AKV-8A X AKPR-312 | 33.87 ** | -1.84 | 124.30 ** | 76.50 ** | 14.51 | 7.55 | 111.11 ** | 7.08 | 2.47 |
| 22 | AKV-8A X AKPR-386 | 6.00 ** | 33.74 ** | 30.23 ** | 23.14 ** | 7.93 | -12.28 | 7.77 | 6.67 | -1.03** |
| 23 | AKV-8A X AKPR-227 | 16.78 ** | -13.64 | 73.91 ** | 19.79 ** | 6.09 | -18.26 | 166.73 ** | 6.63 | 0.21** |
| 24 | AKV-8A X AKPR-210 | 4.83 ** | -20.21 | 44.18 ** | 34.78 ** | 0 | 9.26* | 100.06 ** | -2.61 | -5.92 |
| 25 | AKV-8A X AKPR-345 | 20.73 ** | 26.37 ** | 55.51 ** | 39.69 ** | 19.13 ** | 12.28 ** | 187.77 ** | 4.02 | -0.41** |
| 26 | AKV-8A X AKPR-205 | 30.87 ** | 39.35 ** | 107.80 ** | 56.86 ** | 7.27 ** | 2.8 | 169.40 ** | 7.19 | -3.72** |
| 27 | AKV-8A X AKPR-250 | 28.56 ** | 2.3 | 36.05 ** | 14.51 | 6.60 | -10.09 | 83.10 ** | 5.37 | -5.89 ** |
| 28 | AKV-9A X AKPR-324 | 24.22 ** | 26.90 * | 27.79 ** | 19.46 ** | 10.90 ** | 9.09 | 22.92 ** | 12.09 | 2.83 |
| 29 | AKV-9A X AKPR-23 | 37.58 ** | 37.93 * | 99.93 ** | 76.34 ** | -4.35 | 12.62 | 150.52 ** | 10.01 | 1.09 |
| 30 | AKV-9A X AKPR-312 | 31.49 ** | 29.58 * | 74.57 ** | 68.94 ** | 7.31 | 17.02 | 59.96 ** | 3.86 | -1.65** |
| 31 | AKV-9A X AKPR-386 | 3.66 ** | 26.76 | 37.42 ** | 15.20 ** | -1.2 | -3.92 | 59.19 ** | -1.15** | 1.65 * |
| 32 | AKV-9A X AKPR-227 | 26.31 ** | 26.45 ** | 58.88 ** | 29.62 ** | -2.91 | 10.68 | 125.65 ** | -1.31** | -0.83** |
| 33 | AKV-9A X AKPR-210 | 2.13 ** | 15.12 ** | 14.55** | -2.08 | 15.34 ** | 8.33 | -52.88 | -6.98 | -9.48** |
| 34 | AKV-9A X AKPR-345 | 23.28 ** | 24.22 ** | 20.34 ** | 3.9** | 3.81 | 19.61 ** | 135.82 ** | 1.68 | 0.82* |
| 35 | AKV-9A X AKPR-205 | 26.95 ** | 52.24 ** | 54.50 ** | 14.73 | -3.11 | 24.21 * | 75.42 ** | 3.13 | -4.72** |
| 36 | AKV-9A X AKPR-250 | 38.70 ** | 25.49 ** | 46.78 ** | 16.41 | 13.02 ** | 13.40 | 56.70 ** | 5.56 | -2.9** |
| | SE (m) ± | 0.492 | 0.177 | 6.467 | 0.832 | 0.200 | 0.127 | 1.587 | 0.412 | 0.661 |
| | CD AT 5 % | 1.3838 | 0.4984 | 18.1573 | 2.3372 | 0.5641 | 0.3591 | 4.4569 | 1.1592 | 1.8572 |
| | CD AT 1 % | 1.832 | 0.6599 | 24.0387 | 3.0943 | 0.7469 | 0.4754 | 5.9006 | 1.5348 | 2.4588 |

**Note :**

*** - Significant at 5 % level of significance**

**** - Significant at 1 % level of significance**

**Others - Non-significant**

**N.B. Significance of useful Heterosis was tested on the deviation of F1 mean values from check variety (i.e. F1-MP)**

**3) Number of pods per plant**

Average heterosis ranged form -26.78 per cent to 126.93 per cent (Table 4.4). Out of thirty one hybrids thirty three hybrids shows significant and positive heterosis. The cross AKV-4A X AKPR-312 (126.93 %) shows highest significant positive heterosis followed by AKV-8A X AKPR-312 (124.30 %). The cross AKV-4A X AKPR-345 (-26.78%) shows lowest negative average heterosis which is not desirable for this character.

**4) No. of clusters per plant**

Average heterosis ranged from -18.59 per cent to 76.50 per cent (Table 4.4). Twenty eight hybrids exhibited significant and positive average heterosis for this trait. The cross AKV-8A X AKPR-312 (76.50 %) showed maximum positive average heterosis followed by AKV-9A X AKPR-23 (76.34%), AKV-4A X AKPR-312 (69.91%). The cross AKV-4A X AKPR-345 (-13.84%) shows minimum negative heterosis which is undesirable for this characters.

**5) 100 seed weight**

Average heterosis ranged from -8.07 per cent to 19.13 per cent (Table 4.4). Twenty seven hybrids exhibited significant and positive heterosis for this character. Maximum positive average heterosis was displayed by AKV-8A X AKPR-345 (19.13 %) and minimum negative average heterosis was displayed by AKV-2A X AKPR-227 (-8.07%) which is undesirable for this character.

**6) Number of seeds per pod**

For this trait average heterosis ranged form -18.26 per cent to 24.21 per cent (Table 4.4). Out of 36 hybrids twenty seven hybrids shows significant positive average heterosis. Maximum positive average heterosis was observed in AKV-9A X AKPR-205 (24.21 %) and lowest average heterosis was observed in AKV-8A X AKPR-227 (-18.26%) which is not desirable for this character.

**7) Grain weight per plant**

Average hetrosis for this character ranged from -52.88 per cent to 187.77 per cent (Table 4.4). Out of 36 hybrids thirty hybrids showed significant and positive average heterosis. Maximum heterosis was observed in hybrids AKV-8A X AKPR-345 (187.77 %) followed by AKV-8A X AKPR-205 (169.40), AKV-8A X AKPR-227 (166.73). AKV-9A X AKPR-210 (-52.88) shows negative average heterosis which is undesirable for this character.

**8) Days to 50% flowering**

For this character in pigeonpea negative heterosis is desirable. Average heterosis ranged from -1.31per cent to 15.94 per cent (Table 4.5). Out of 36 hybrids only three hybrids shows significant negative heterosis. Highest significant negative heterosis was observed in AKV-9A X AKPR-227 (-1.31%) followed by AKV-9A X AKPR-386 (-1.15%) remaining all are non significant for the character.

**9) Day to maturity**

Useful heterosis ranged from -9.48 per cent to 11.54 per cent (Table 4.5). Out of 36 hybrids, four hybrids exhibited significant heterosis. Maximum negative heterosis was observed in AKV-9A X AKPR-210 (-9.48) followed by AKV-8A X AKPR-250 (-5.89 %), AKV-9A X AKPR-205 (-4.72%). Cross AKV-8A X AKPR-324 (11.54) shows highest positive heterosis which is not desirable for this character.

**4.1.heterobeltosis (%)**

Heterobeltosis can be defined as the superiority of the hybrid over better parent. The percentage of better heterosis estimated for the characters studied is given in Table 4.6. In pigeonpea, positive heterosis is desirable for all the characters except days to 50 per cent flowering and days to maturity for which negative heterosis is desirable. Character wise results of Better heterosis observed in the 36 hybrids tested are presented here.

**1) Plant height per plant**

Heterobeltosis ranged from -22.45 per cent to 43.05 per cent (Table 4.6). Twenty six of the 36 hybrids revealed significant positive better heterosis. Maximum positive better heterosis was depicted by hybrid AKV-4A X AKPR-312 (43.05 %) and minimum better heterosis displayed by AKV-2A X AKPR-210 (-22.45 %) which is not desirable for this character.

**2) Number of branches per plant**

Heterobeltosis for this character ranged from -30.56 per cent to 45.71 per cent (Table 4.6). Sixteen hybrids exhibited significant and positive better heterosis for this trait. The cross AKV-2A X AKPR-23 (25.26) and AKV-2A X AKPR-210 (9.26) exhibited significant and positive better heterosis. AKV-9A X AKPR-205 (45.71 %) showed highest better heterosis. And the cross AKV-4A X AKPR-210 (-30.56 %), shows lowest negative better heterosis which is not desirable for this character.

**3) Number of pods per plant**

Heterobeltosis ranged form -34.49 per cent to 91.30 per cent (Table 4.6) for this character. Out of 36 hybrids twenty nine hybrids shown significant and positive heterosis. The cross AKV-9A X AKPR-23 (91.30 %) shows maximum positive better heterosis. The cross AKV-4A X AKPR-345 (-34.49 %) showed minimum negative heterosis which is not desirable for this character.

**4) No. of clusters per plant**

Heterobeltosis ranged from -23.75 per cent to 65.79 per cent (Table 4.6). Twenty four hybrids exhibited significant and positive better heterosis for this trait. The cross AKV-9A X AKPR-23 (65.79 %) showed maximum positive

Table 4.6 : Heterobeltosis (%)

| Sr.No. | Crosses | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters pr plant | 100 seed weight (gm) | Number of seeds per pod | Grain wt per plant (gm) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 | AKV-2A X AKPR-324 | 16.83 | 8.42 | 23.74 | 17.18 | 3.52 | 16.36 ** | -31.50 | 4.99 | 1.15 |
| 2 | AKV-2A X AKPR-23 | 4.36 | 25.26 * | 35.83 | 16.64 | 1.56 | 17.86 ** | 24.51 ** | 1.84 | -1.91 |
| 3 | AKV-2A X AKPR-312 | 20.60 | -12.63 | 21.98 | -15.65 | -0.39 | 10.91 | 24.38 | -2.89 | -4.96 |
| 4 | AKV-2A X AKPR-386 | -18.49 | -17.89 | 39.20 | -10.31 | 7.97 | 0 | -46.09 | 1.05 | 2.67 |
| 5 | AKV-2A X AKPR-227 | 4.39 | -22.11 | -14.45 | -20.61 | -9.62 | -7.14 | 86.30 * | -0.26 | -0.57 |
| 6 | AKV-2A X AKPR-210 | -22.45 | 9.26 * | -12.63 | -2.59 | -3.46 | 7.27 | 19.13 ** | -3.33 | -4.22 |
| 7 | AKV-2A X AKPR-345 | 14.63 | 16.49 | 12.69 ** | -11.58 | -3.36 | -12.73 * | 38.63 | -3.15 | -3.24 |
| 8 | AKV-2A X AKPR-205 | 9.62 | -5.26 | 7.97 | 7.06 | -13.22 | -3.64 | 28.90 ** | -4.46 | -4.39 |
| 9 | AKV-2A X AKPR-250 | 36.40 | 1.05 | 50.89 * | 29.77 | 2.04 | 1.82 | 2.7 | -2.89 | -0.38 |
| 10 | AKV-4A X AKPR-324 | 10.81 | 32.10 | 31.49 | 23.62 | -5.44 | 13.46 * | 23.84 ** | 4.64 | 0.78 |
| 11 | AKV-4A X AKPR-23 | 10.79 | 9.88 | 20.64 | 7.1 | -7.45 | -12.50 * | -4.68 | 3.83 | -1.95 |
| 12 | AKV-4A X AKPR-312 | 43.05 | 13.75 | 70.52 ** | 46.29 | 9.30 | 7.69 | -46.40 | 3.01 | -4.30 |
| 13 | AKV-4A X AKPR-386 | -11.28 | -6.25 | 32.88 * | 15.81 | 6.66 | 1.82 | 21.96 ** | 1.37 | 5.47 |
| 14 | AKV-4A X AKPR-227 | 17.06 | -14.29 | -4.47 | -2.29 | 8.31 | -3.57 | -52.39 | -1.09 | 1.17 |
| 15 | AKV-4A X AKPR-210 | -20.48 | -30.56 | 32.97 * | 12.78 | -12.71 | 11.54 | 13.10 ** | -4.62 | -2.39 |
| 16 | AKV-4A X AKPR-345 | -7.77 | 2.06 | -34.49 | -23.75 | -11.16 | -1.82 | -24.16 | 1.91 | -5.66 |
| 17 | AKV-4A X AKPR-205 | -2.60 | 18.75 | -7.78 | 1.14 | -9.12 | 11.54 | 38.03 ** | 0 | -0.59 |
| 18 | AKV-4A X AKPR-250 | 32.59 | 5.62 | 44.99 ** | 37.14 | 2.3 | 11.54 | 22.63 ** | 2.19 | -4.10 |
| 19 | AKV-8A X AKPR-324 | 20.61 | 23.53 | 12.74 | 24.85 | 6.06 | -15.25 ** | 19.88 * | 4.26 | 5.96 |
| 20 | AKV-8A X AKPR-23 | 9.69 | -16.47 | 28.36 | 40.19 ** | 0.57 | -15.25 ** | 6.97 | 4.52 | 2.12 |

| Sr.No. | Crosses | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters pr plant | 100 seed weight (gm) | Number of seeds per pod | Grain wt per plant (gm) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 21 | AKV-8A X AKPR-312 | 32.05 | -5.88 | 76.80 ** | 59.11 ** | 12.66 | -3.39 | 59.21 ** | 0.53 | -4.23 |
| 22 | AKV-8A X AKPR-386 | -11.77 | 28.24 | 30.20 | 20.16 | 5.02 | -15.25 ** | -9.09 | 0 | -7.69 |
| 23 | AKV-8A X AKPR-227 | 7.82 | -16.48 | 53.37 ** | 16.67 | 0.43 | -20.34 ** | 119.72 ** | -1.60 | -7.50 |
| 24 | AKV-8A X AKPR-210 | -16.31 | -28.70 | 36.22 * | 26.30 | -10.46 | 0 | 36.91 ** | -4.36 | -8.07 |
| 25 | AKV-8A X AKPR-345 | 6.59 | 18.56 | 31.31 ** | 18.18 ** | 11.49 | 8.47 | 126.07 ** | -0.27 | -6.35 |
| 26 | AKV-8A X AKPR-205 | 18.18 | 27.06 | 84.64 ** | 50.21 | -4.15 | -6.78 | 87.75 ** | 1.06 | -7.88 |
| 27 | AKV-8A X AKPR-250 | 25.69 | 0 | 25.70 | 9.53 | 0.96 | -16.95 ** | 26.15 ** | -0.8 | -9.42 |
| 28 | AKV-9A X AKPR-324 | 14.83 | 13.58 | 15.11 | 16.57 | 6.24 | 3.85 | 22.25 ** | 2.98 | -2.31 |
| 29 | AKV-9A X AKPR-23 | 24.92 | 23.46 | 91.30 ** | 65.79 ** | -5.94 | 3.57 | 148.85 ** | 5.69 | -2.31 |
| 30 | AKV-9A X AKPR-312 | 29.50 | 17.95 | 36.96 | 52.44 | 5.23 | 17.02 * | 46.35 ** | -1.63 | -8.08 |
| 31 | AKV-9A X AKPR-386 | -13.61 | 15.38 | 36.53 | 12.30 | -2.03 | -10.91 | 28.46 ** | -6.50 | -5.19 |
| 32 | AKV-9A X AKPR-227 | 16.79 | 7.69 | 39.35 | 26.10 | -4.84 | 1.79 | 86.33 ** | -8.13 | -8.46 |
| 33 | AKV-9A X AKPR-210 | -18.37 | -8.33 | 8.87 | -8.33 | 6.70 | 6.12 | -55.85 | -9.49 | -11.56 |
| 34 | AKV-9A X AKPR-345 | 8.98 | 3.09 | 2.15 | -12.17 | 0.54 | 10.91 | 104.99 ** | -1.63 | -5.19 |
| 35 | AKV-9A X AKPR-205 | 14.80 | 45.71 | 36.52 | 9.98 | -10.57 | 22.92 ** | 69.60 ** | -1.90 | -8.85 |
| 36 | AKV-9A X AKPR-250 | 35.81 | 7.87 | 34.82 | 11.46 | 10.83 | 10 | 48.55 ** | 0.27 | -6.54 |
| | SE (m) ± | 0.569 | 0.205 | 7.468 | 0.961 | 0.231 | 0.147 | 1.833 | 0.476 | 0.763 |
| | CD AT 5 % | 1.598 | 0.5754 | 20.9664 | 2.6989 | 0.6515 | 0.4146 | 5.1465 | 1.3385 | 2.1445 |
| | CD AT 1 % | 2.156 | 0.7618 | 27.7577 | 3.5731 | 0.8625 | 0.549 | 6.8136 | 1.7721 | 2.8391 |

**Note :**

*** - Significant at 5 % level of significance**

**** - Significant at 1 % level of significance**

**Others - Non-significant**

**N.B. Significance of useful Heterosis was tested on the deviation of F1 mean values from check variety (i.e. F1-BP)**

heterobeltosis. The cross AKV-4A X AKPR-345 (-23.75 %) showed minimum negative heterosis which is not desirable for this character.

**5) 100 seed weight**

Heterobeltosis ranged from -13.22 per cent to 12.66 per cent (Table 4.6). Ten one hybrids exhibited significant and positive heterosis for this character. Maximum positive better heterosis was displayed by AKV-8A X AKPR-312 (12.66 %). The cross AKV-2A X AKPR-205 (-13.22 %) showed minimum negative heterosis which is not desirable for this character

**6) Number of seeds per pod**

For this trait Heterobeltosis ranged form -20.34 per cent to 22.92 per cent (Table 4.6). Out of 36 hybrids twelve hybrids shows significant positive better heterosis. Maximum positive better heterosis was observed in AKV-9A X AKPR-205 (22.92 %). The cross AKV-8A X AKPR-227 (-20.34 %) showed minimum negative heterosis which is not desirable for this character.

**7) Grain weight per plant**

Heterobeltosis for this character ranged from -55.85 per cent to 148.85 per cent (Table 4.6). Out of 36 hybrids twenty seven hybrids showed significant and positive better heterosis. Maximum heterosis was observed in hybrids AKV-9A X AKPR-23 (148.85 %). The cross AKV-9A X AKPR-210 (-55.85 %) showed minimum negative heterosis which is not desirable for this character.

**8) Days to 50% flowering**

For this character in pigeonpea negative heterosis is desirable. Better heterosis ranged from -9.49 per cent to 5.69 per cent (Table 4.6). Out of 36 hybrids fourteen hybrid showed significant negative heterosis. Highest significant negative heterosis was observed in AKV-9A X AKPR-210 (-9.49) followed by AKV-9A X AKPR-227 (-8.13 %), AKV-9A X AKPR-386 (-6.50%).

### 9) Day to maturity

Heterobeltosis ranged from -11.56 per cent to 5.47 per cent (Table 4.5). Out of 36 hybrids, twenty six hybrid exhibited significant negative heterosis. Maximum negative heterosis was observed in AKV-9A X AKPR-210 (-11.56 %) followed by AKV-9A X AKPR-205 (-8.85 %), AKV-9A X AKPR-227 (-8.46 %) which is desirable for this character.

### 4.1.7 Analysis of variance for combining ability

Line x tester analysis of 36 hybrids obtained by crossing 4 CMS lines with 9 testers was carried out and the total variance due to hybrids was partitioned into portions attributable to females (lines), males (testers), interaction, females x males (lines x testers) and error sources. The components of variances attributable to lines and testers were used as a measure of general combining ability effects and the variance due to interaction between lines and testers was use as a measure of specific combining ability effects. Analysis of variance for combining ability is presented in Table 4.7.

The variance due to females was highly significant for Plant height, number of clusters per plant and days to maturity. The variance due to males was highly significant for plant height per plant and number of clusters per plant. However, the magnitude of variance was higher in females as compared to that in males for all the traits except Number of branches per plant and Days to 50 percent flowering. The variance females x males was highly significant for all the traits studied indicated the presence of significant differences between males and females

### 4.1.8 General combining ability effects of parents

The estimates of general combining ability effect of the female and male parents are presented in Table 4.8. In pigeonpea, positive gca effects are desirable for all the traits studied except days to 50% flowering and days to

**Table 4.7: Analysis of variance for combining ability**

| Source of variation | d.f. | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters per plant | 100 seed weight (gm) | Number of seeds per pod | Grain per plant (gm) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Replications | 2 | 5.176 *** | 0.090 | 1.022 | 2.111 | 0.007 | 63.306 | 19.400 *** | 3.861 *** | 27.032 |
| Females (Lines) | 3 | 165.111 ** | 1.680 | 371.358 | 465.861 ** | 0.276 | 29609.120 | 285.147 | 1.740 | 13101.500 * |
| Males (Testers) | 8 | 106.488 ** | 3.313 | 242.466 | 220.125 * | 0.187 | 24490.910 | 160.958 | 2.492 | 4644.912 |
| Females x Males (Lines x Testers) | 24 | 20.007 ** | 2.128 ** | 339.229 ** | 86.181 ** | 0.336 ** | 27620.87 ** | 126.292 ** | 1.643 ** | 3414.400 ** |
| Error | 70 | 0.576 | 0.100 | 1.084 | 1.254 | 0.066 | 226.106 | 2.371 | 0.150 | 11.038 |

Note
* - Significant at 5 % level of significance
** - Significant at 1 % level of significance
Others - Non-significant

maturity for which negative gca effects are desirable. Character wise gca effects of female and male parents are presented here.

**1) Plant height per plant (cm)**

All the parents exhibited significant gca effect for this character. The study revealed that among females, AKV-9A (4.551) was the best general combiner for the trait followed by AKV-8A (1.093). This female showed significant positive gca effects. Significant negative gca effects were exhibited by AKV-4A (-4.131) and AKV-2A (-1.513) and were poor general combiner for the trait.

AKPR-250 (6.497) revealed the highest significant positive gca effect and was the best general combiner among the males followed by AKPR-23 (3.561), for plant height. AKPR-386 (-7.636) and AKPR-227 (-4.998) showed highest significant negative gca effect respectively.

**2) Number of branches per plant**

All the parents exhibited significant gca effect for this character. Among the females, AKV-2A (0.222) was found to be the best general combiner for this trait followed by AKV-9A (0.185). These female showed significant positive gca effects.

Among males AKPR-345 (0.865) displayed the highest significant gca effects and hence was the best general combiner among the males for number of branches per plant followed by AKPR-324 (0.531) and AKPR-205 (0.331). Whereas, AKPR-227 (-0.819), AKPR-312 (-0.485) and AKPR-386 (-0.385) show highest significant negative gca effects, respectively.

**3) Number of pods per plant**

The study revealed that among females. AKV-8A (36.741) was the best general combiner for this trait; this parent shows significant gca effects.

**Table 4.8 : General combining ability effects of parents**

| Parents | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters per plant | 100 seed weight (gm) | Number of seeds per pod | Grain wt per plant (gm) | Days to 50% percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| **Females (Lines)** | | | | | | | | | |
| AKV-2A | -1.51 ** | 0.22 ** | -43.25 ** | -4.07 ** | 0.16 ** | 0.11 ** | -17.64 ** | 1.63 ** | 4.63 ** |
| AKV-4A | -4.13 ** | -0.30 ** | -1.67 ** | 0.04 | -0.38 ** | 0.02 ** | -17.95 ** | -0.04 ** | 1.97 ** |
| AKV-8A | 1.09 ** | -0.10 ** | 36.74 * | 3.88 ** | 0.14 ** | -0.13 ** | 8.08 ** | 1.89 ** | -1.80 ** |
| AKV-9A | 4.55 ** | 0.18 ** | 8.1 | 0.14 | 0.07 ** | 0.01 | 27.51 ** | -3.48 ** | -4.80 ** |
| SE (gi) | 0.189 | 0.068 | 2.489 | 0.320 | 0.077 | 0.049 | 0.611 | 0.158 | 0.254 |
| CD AT 5 % | 0.376 | 0.135 | 4.941 | 0.636 | 0.153 | 0.097 | 1.213 | 0.315 | 0.505 |
| CD AT 1 % | 0.498 | 0.179 | 6.542 | 0.842 | 0.203 | 0.129 | 1.606 | 0.417 | 0.669 |
| **Males (Testers)** | | | | | | | | | |
| AKPR-324 | 1.69 ** | 0.53 ** | -48.93 ** | 0.33 | 0.55* | 0.08 ** | -13.35 ** | 5.17 ** | 7.72 ** |
| AKPR-23 | 3.56 ** | 0.06 * | 65.47 * | 6.60 ** | -0.93 ** | 0.01 | 14.20 ** | 4.84 ** | 3.55 ** |
| AKPR-312 | -2.94 ** | -0.48 ** | 58.54 * | 4.02 ** | -0.01 ** | 0.11 ** | -14.04 ** | -0.40 ** | -4.02 ** |
| AKPR-386 | -7.64 ** | -0.38 ** | -1.94 ** | -3.45 ** | -0.10 ** | -0.19 ** | -33.58 ** | -1.32 ** | 3.22 ** |
| AKPR-227 | -4.99 ** | -0.81 ** | -61.26 ** | -4.99 ** | -0.32 ** | -0.19 ** | -1.09 ** | -3.49 ** | -1.36 ** |
| AKPR-210 | -0.60 ** | -0.10 ** | -31.93 ** | -2.09 ** | 0.53 ** | 0.10 ** | -6.44 ** | -1.49 ** | 2.05 ** |
| AKPR-345 | 3.16 ** | 0.86 ** | 27.57 | 1.50 * | -0.03 ** | 0.08 ** | 9.56 ** | -1.07 ** | -3.52 ** |
| AKPR-205 | 1.25 ** | 0.33 ** | -21.83 ** | -1.98 ** | 0.06 * | 0.05 ** | 33.70 ** | -1.74 ** | -4.11 ** |
| AKPR-250 | 6.49 ** | -0.01 ** | 14.30 | 0.069 | 0.26 ** | -0.06 ** | 11.03 ** | -0.49 ** | -3.52 ** |
| SE (gj) | 0.284 | 0.102 | 3.734 | 0.4807 | 0.116 | 0.073 | 0.916 | 0.238 | 0.382 |
| CD AT 5 % | 0.564 | 0.203 | 7.412 | 1.9031 | 0.230 | 0.146 | 1.819 | 0.473 | 0.758 |
| CD AT 1 % | 0.747 | 0.269 | 9.813 | 2.5195 | 0.304 | 0.194 | 2.408 | 0.626 | 1.003 |

Note :

* - Significant at 5 % level of significance

** - Significant at 1 % level of significance

Others - Non-significant

Significant negative gca effects were exhibited by AKV-2A (-49.59) and AKV-4A (-1.670) and were poor general combiner for the trait.

AKPR-23 (65.478) showed highest significant positive gca effects and hence was the best general combiner among the males for number of pods per plant, followed by AKPR-312 (58.544). Whereas, AKPR-227 (-61.264), AKPR-324 (-48.931), AKPR-210 (-31.931), AKPR-205 (-21.831), AKPR-386 (-1.946) showed highest significant negative gca effects, respectively.

**4) Number of clusters per plant**

Among the females AKV-8A (3.887) was the best general combiner for this trait which is significant positive gca effects. AKV-2A (-4.069) exhibited significant negative gca effects and were poor general combiner for the trait.

Among the male AKPR-23 (6.602), AKPR-312 (4.019) and AKPR-345 (1.502) displayed the highest significant positive gca effects. AKPR-227 (-4.998) exhibited significant negative gca effects followed by AKPR-386 (-3.448), AKPR-210 (-2.098), AKPR-205 (-1.981).

**5) 100 Seed weight (gm)**

Among the females, AKV-2A (0.162) was found to be the best general combiner for this character. This showed significant positive gca effect. AKV-4A (-0.377) exhibited significant negative gca effects and was poor general combiner for the trait.

Among males AKPR-324 (0.555) displayed the highest significant positive gca effects and hence was the best general combiner among the males for 100 seed weight, followed by AKPR-210 (0.531), AKPR-250 (0.264) and AKPR-205 (0.065). Whereas, AKPR-23 (-0.937) showed highest significant negative gca effect followed by AKPR-227 (-0.326).

**P6) Number of seeds per pod**

Among the females AKV-2A (0.109) showed highest significant positive gea effects followed by AKV-4A (0.020). AKV-8A (-0.135) exhibited significant negative gca effects and was poor general combiner for the trait.

AKPR-312 (0.119) exhibited highest significantly positive gca effect and was the best general combiner for character number of seeds per pod. AKPR-386 (-0.198) shows significant negative gea effect.

**7) Grain weight per plant (gm)**

Among the females, AKV-9A (27.514) was found to be the best general combiner for grain weight per plant followed by AKV-8A (8.079) (Table 4.5). Both the females exhibited highly significant positive gca effects. AKV-4A (-17.949), AKV-2A (-17.643) exhibited significant negative gca effects.

AKPR-205 (33.703) exhibited the highest and highly significant positive gca effect and was the best general combiner among the males, followed by AKPR-23 (14.201). Whereas, AKPR-386 (-33.579) exhibited significant negative gca effects and were poor general combiner for grain weight per plant.

**8) Days to 50% flowering**

Among the females AKV-9A (-3.481) was found to be the best general combiner for earliness. These females revealed significant negative gca effects. AKV-8A (1.889), AKV-2A (1.630) showed significant positive gca effects.

Among the males, AKPR-227 (-3.491) showed highest significant negative gca effect and was the best general combiner among the males followed by AKPR-205 (-1.741), AKPR-210 (-1.491) and AKPR-386 (-1.324) for earliness. AKPR-324 (5.176) and AKPR-23 (4.843) exhibited significant positive gca effect and was the poor general combiner for day to 50% flowering.

**9) Days to maturity**

Among the females, AKV-9A (-4.806) was found to be the best general combiner for character days to maturity. It showed significant negative gca effects. AKV-2A (4.639) and AKV-4A (1.972) exhibited significant positive gca effects.

AKPR-205 (-4.111) Revealed the highest significant negative gca effect and was the best general combiner among the males, followed by AKPR-312 (-4.028). Whereas, AKPR-324 (7.722) and AKPR-23 (3.556) exhibited significant positive gca effect and was poor general combiner for days to maturity.

### 4.9.1 Specific combining ability effect of crosses

The estimates of specific combining ability effects of the 36 crosses are presented in Table 4.9 In pigeonpea, positive sca effects are desirable for all the traits studied except days to 50% flowering and days to maturity for which negative sca effect are desirable. Character wise sca effects of the 36 crosses are presented here.

**1) Plant height per plant (cm)**

Out of the 36 crosses, only 17 hybrids revealed significant positive sca effects. AKV-2A X AKPR-345 (17.00), recorded the highest and highly significant positive sca effect followed by AKV-9A X AKPR-23 (15.627), AKV-2A X AKPR-250 (13.168), AKV-4A X AKPR-227 (12.741). Fifteen hybrids showed significant negative sca effects and the rest all showed non-significant sca effects.

**2) Number of branches per plant**

Only eight hybrids were marked to reflect significant positive sca effects for number of branches per plant. AKV-8A X AKPR-386 (1.504) was the best specific cross combination. It exhibited the highest significant positive sca effect followed by AKV-2A X AKPR-210 (1.494), AKV-2A X AKPR-23 (1.394), AKV-9A X AKPR-227 (0.915). Ten hybrids showed significant negative sca effects and the rest all showed non-significant sca effect.

**3) Number of pods per plant**

Out of 36 hybrids, only 16 hybrids revealed highly significant positive sca effects. The cross combination AKV-9A X AKPR-23 (162.466) marked the highest significant positive sca effect and hence was the best specific cross combination, followed by AKV-8A X AKPR-205 (129.909), AKV-4A X AKPR-312 (123.945), AKV-8A X AKPR-345 (100.500).

Seventeen hybrids showed significant negative sca effect which is undesirable for number of pods per plant. The remaining crosses show non-significant sca effects.

**4) Number of clusters per plant**

Out of 36 hybrids, only 15 hybrids revealed highly significant positive sca effects. The cross combination AKV-9A X AKPR-23 (11.761) marked the highest significant positive sca effect and hence was the best specific cross combination, followed by AKV-2A X AKPR-250 (8.702), AKV-8A X AKPR-345 (7.713), AKV-4A X AKPR-250 (7.257). Twelve hybrids showed significant negative sca effects which is undesirable for number of clusters per plant. The remaining crosses showed non-significant sca effects.

**5) 100 Seed weight (g)**

Out of the 36 hybrids, only 8 hybrids revealed significant positive sca effect. AKV-9A X AKPR-210 (1.343) recorded the highest and highly significant positive sca effect followed by AKV-4A X AKPR-227 (1.339), AKV-8A X AKPR-345 (1.169), AKV-2A X AKPR-23 (1.065). Nine hybrids showed significant

**Table 4.9: Specific combining ability effects for crosses**

| Sr.No. | Crosses | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters pr plant | 100 seed weight (gm) | Number of seeds per pod | [illegible] per plant (gm)) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 | AKV-2A X AKPR-324 | 3.16 ** | -0.14 | 40.79 ** | 4.03 ** | -0.06 | 0.37 * | -15.63 ** | 2.12 ** | -3.38 ** |
| 2 | AKV-2A X AKPR-23 | -11.55 ** | 1.39 ** | 9.18 | -1.56 | 1.06 ** | 0.57 ** | 0.79 | -1.54** | -4.55 ** |
| 3 | AKV-2A X AKPR-312 | -0.13 | -0.45 * | -72.61 ** | -11.11 ** | -0.07 | 0.14 | 12.92 ** | -2.29 ** | -2.30 ** |
| 4 | AKV-2A X AKPR-386 | -7.78 ** | -0.88 ** | 46.07 ** | -1.78 | 0.94 ** | 0.05 | -25.06 ** | 3.62 ** | 3.77 ** |
| 5 | AKV-2A X AKPR-227 | -9.55 ** | -0.72 ** | -76.00 ** | -3.83 ** | -0.78 ** | -0.14 | 14.88 ** | 4.12 ** | 2.69 ** |
| 6 | AKV-2A X AKPR-210 | -5.21 ** | 1.49 ** | -67.67 ** | 0.60 | 0.02 | 0.02 | 32.48 ** | 1.12 * | -0.38 |
| 7 | AKV-2A X AKPR-345 | 17.01 ** | 0.19 | 90.49 ** | 2.13 * | -0.38 | -0.69 ** | -11.36 ** | -1.96 ** | 0.19 |
| 8 | AKV-2A X AKPR-205 | 0.88 | -0.80 ** | -39.63 ** | 2.82 ** | -0.64 ** | -0.32 * | -6.23 ** | -1.96 ** | -1.22 |
| 9 | AKV-2A X AKPR-250 | 13.17 ** | -0.07 | 69.36 ** | 8.70 ** | -0.08 | -0.01 | -2.78 | -2.96 ** | 5.19 ** |
| 10 | AKV-4A X AKPR-324 | -3.58 ** | 0.65 ** | 82.48 ** | 2.25 * | -0.53 * | 0.13 | 30.57 ** | -2.21 *** | -5.38 ** |
| 11 | AKV-4A X AKPR-23 | 1.46 * | -0.08 | -73.32 ** | -9.07 ** | -0.46 | -0.47 ** | -20.66 ** | -1.88 ** | -5.88 ** |
| 12 | AKV-4A X AKPR-312 | 11.85 ** | 0.60 ** | 123.94 ** | 6.50 ** | 0.23 | -0.10 | -27.01 ** | -2.54 ** | -2.30 ** |
| 13 | AKV-4A X AKPR-386 | 9.10 ** | -0.56 ** | 40.83 ** | 3.30 ** | 0.30 | 0.21 | 49.12 ** | 1.70 ** | 7.11 ** |
| 14 | AKV-4A X AKPR-227 | 12.74 ** | 0.07 | -42.38 ** | -1.47 | 1.34 ** | 0.08 | -44.91 ** | 0.62 | 4.36 ** |
| 15 | AKV-4A X AKPR-210 | 1.75 ** | -0.84 ** | 71.15 ** | 2.02 * | -0.56 * | 0.04 | 27.12 ** | -0.21 | 5.61 ** |
| 16 | AKV-4A X AKPR-345 | -18.84 ** | -0.21 | -179.08 ** | -7.50 ** | -0.81 ** | -0.20 | -32.17 ** | 1.12 * | -5.13 ** |
| 17 | AKV-4A X AKPR-205 | -16.41 ** | 0.05 | -94.41 ** | -3.29 ** | 0.39 | 0.09 | 2.09 | 1.03 * | 4.11** |
| 18 | AKV-4A X AKPR-250 | 1.93 ** | 0.32 | 70.78 ** | 7.25 ** | 0.09 | 0.21 | 15.77 ** | -0.63 | -2.47 ** |
| 19 | AKV-8A X AKPR-324 | 6.43 ** | 0.32 | -82.32 ** | -3.65 ** | 0.25 | -0.31 * | 1.26 | 0.78 | 10.05** |
| 20 | AKV-8A X AKPR-23 | -5.54 ** | -1.48 ** | -98.33 ** | -1.12 | -0.17 | -0.24 | -39.13 ** | -0.80 | 7.55 ** |

contd....

| Sr.No. | Crosses | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters per plant | 100 seed weight (gm) | Number of seeds per pod | Grain wt per plant (gm)) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 21 | AKV-8A X AKPR-312 | -2.72 ** | -0.33 | 23.43 ** | 1.53 | 0.05 | 0.12 | 10.92 ** | -0.14 | 4.14 ** |
| 22 | AKV-8A X AKPR-386 | 2.89 ** | 1.50 ** | -71.17 ** | -1.33 | -0.38 | -0.03 | -32.15 ** | 0.11 | -9.11 ** |
| 23 | AKV-8A X AKPR-227 | -6.83 ** | -0.26 | 65.27 ** | -0.78 | -0.02 | -0.23 | 7.02 ** | 0.36 | -4.19 ** |
| 24 | AKV-8A X AKPR-210 | 5.72 ** | -0.91 ** | 35.14 ** | 3.04 ** | -0.80 ** | 0.27 | 23.45 ** | 0.53 | -0.94 |
| 25 | AKV-8A X AKPR-345 | 0.59 | 0.65 ** | 100.50 ** | 7.71 ** | 1.16 ** | 0.62 ** | 15.89 ** | -0.47 | -0.03 |
| 26 | AKV-8A X AKPR-205 | 12.24 ** | 0.72 ** | 129.91 ** | 4.73 ** | 0.48 * | 0.05 | 19.76 ** | -0.22 | -2.11 ** |
| 27 | AKV-8A X AKPR-250 | -12.79 ** | -0.21 | -102.42 ** | -10.12 ** | -0.56 * | -0.23 | -7.03 ** | 2.11 ** | -5.36 ** |
| 28 | AKV-9A X AKPR-324 | -6.01 ** | -0.83 ** | -40.96 ** | -2.64 ** | 0.33 | -0.18 | -16.20 ** | -1.47 ** | -1.27 |
| 29 | AKV-9A X AKPR-23 | 15.62 ** | 0.16 | 162.46 ** | 11.76 ** | -0.43 | 0.14 | 59.00 ** | 0.56 | 2.88 ** |
| 30 | AKV-9A X AKPR-312 | -8.99 ** | 0.18 | -74.76 ** | 3.08 ** | -0.20 | -0.15 | 3.15 | 4.23 ** | 0.47 |
| 31 | AKV-9A X AKPR-386 | -4.21 ** | -0.05 | -15.73 * | -0.19 | -0.86 ** | -0.24 | 8.01 ** | 0.48 | -1.77 * |
| 32 | AKV-9A X AKPR-227 | 3.63 ** | 0.91 ** | 53.10 ** | 6.09 ** | -0.52 * | 0.29 | 23.01 ** | -4.60 ** | -2.86 ** |
| 33 | AKV-9A X AKPR-210 | -2.27 ** | 0.26 | -38.62 ** | -5.67 ** | 1.34 ** | -0.34 * | -83.05 ** | -4.43 ** | -4.27 ** |
| 34 | AKV-9A X AKPR-345 | 1.24 * | -0.63 ** | -11.90 | -2.34 * | 0.02 | 0.28 | 27.65 ** | -1.77 ** | 4.97 ** |
| 35 | AKV-9A X AKPR-205 | 3.27 ** | 0.03 | 4.14 | -4.25 ** | -0.23 | 0.18 | -15.62 ** | 1.14 * | -0.77 |
| 36 | AKV-9A X AKPR-250 | -2.31 ** | -0.03 | -37.72 ** | -5.84 ** | 0.55 * | 0.03 | -5.95 ** | 1.48 ** | 2.63 ** |
| | SE (Sij) | 0.56 | 0.20 | 7.46 | 0.96 | 0.23 | 0.14 | 1.83 | 0.47 | 0.76 |
| | CD AT 5 % | 1.12 | 0.40 | 14.82 | 1.90 | 0.46 | 0.29 | 3.63 | 0.94 | 1.51 |
| | CD AT 1 % | 1.49 | 0.53 | 19.62 | 2.52 | 0.60 | 0.38 | 4.81 | 1.25 | 2.01 |

**Note :**

*** - Significant at 5 % level of significance**

**** - Significant at 1 % level of significance**

**Others - Non-significan**

negative sca effects and the remaining crosses exhibited non-significant sca effect.

**6) Number of seeds per pod**

Out of 36 hybrids only three hybrids revealed significant positive sca effects. The cross AKV-8A X AKPR-345 (0.619) marked the highest and highly significant positive sca effect and hence was the best specific cross combination, followed by AKV-2A X AKPR-23 (0.574), AKV-2A X AKPR-324 (0.374).

Five hybrids showed significant negative sca effects which is undesirable for number of seeds per pod. The remaining crosses showed non-significant sca effects.

**7) Grain weight per plant (g)**

Out of 36 hybrids, only sixteen hybrids revealed highly significant positive sca effects and can be considered worthwhile fourteen hybrids exhibited significant negative sca effects which is not desirable. The remaining crosses revealed non-significant sca effects.

AKV-9A X AKPR-23 (59.006) recorded the highest and highly significant positive sca effect followed by AKV-4A X AKPR-386 (49.199), AKV-2A X AKPR-210 (32.479), AKV-4A X AKPR-324 (30.573).

**8) Days to 50% flowering**

Out of the 36 crosses, only twelve hybrids revealed significant negative sca effect which is desirable for days to 50% flowering. The cross combination AKV-9A X AKPR-227 (-4.602) marked the highest significant negative sca effect and hence was the best specific cross combination and can be considered worth while. Another cross combination AKV-9A X AKPR-210 (-4.435), AKV-2A X AKPR-250 (-2.963), AKV-4A X AKPR-312 (-2.546) showed significant negative sca effects.

Eleven hybrids revealed positive significant sca effect, which is undesirable for days to 50% flowering. Remaining crosses exhibited non-significant sca effects.

**9) Days to maturity**

Out of the 36 hybrids, only fifteen hybrids revealed significant negative sca effect, which is desirable for days to maturity. The cross combination AKV-8A X AKPR-386 (-9.111) showed the highest significant negative sca effect and was the best specific cross combination followed by AKV-4A X AKPR-23 (-5.889), AKV-4A X AKPR-324 (-5.389) AKV-8A X AKPR-250 (-5.361).

thirteen hybrids revealed positive significant sca effects, which is undesirable remaining crosses exhibited non-significant sca effects.

## 4.2 Discussion

In recent past, emphasis is being given on the breeding hybrids in pigeonpea. Possibilities of hybrid pigeonpea seed production on commercial scale had been feasible with available genetic male sterility (Reddy et al., 1978) and considerably high amount of pod set on male sterile with pollination. ICPH-8 is the first ever pigeonpea hybrid released for cultivation in India in 1989 (Asthana et al., 1991). ICRISAT along with India Council of Agricultural Research (ICAR) released world's first genetic male sterility (GMS) based pigeonpea hybrid ICPH-8. The work of development of new pigeonpea hybrids from various parental lines is in progress at pulses Research Unit, Dr. PDKV, Akola during last fifteen years, Two GMS based pigeonpea hybrids i.e. AKPH-4101 and AKPH-2022 released at Dr. PDKV, Akola.

The seed production bottlenecks of GMS-based hybrids encouraged the breeder to breed a more efficient cytoplasmic-nuclear male sterility (CMS) system. So far five primary CMS system derived from various inter specific crosses have been reported in pigeonpea. These are designed as. i) A1 cytoplasm, derived from *Cajanus sericeus* ii) A2 cytoplasm, derived from *Cajanus scarabaeiodes* iii) A3 cytoplasm, derived from *Cajanus volubils.* iv) A4 cytoplasm, derived from *Cajanus cajanifolius* v) A5 cytoplasm, derived from cultivated pigeonpea (Saxena *et al.*, 2006). In order to make use of these cytoplasmic male sterilities in commercial hybrid seed production, fertility restoration were observed with germplasm line ICP-10875, at Pulses Research Unit, Dr. PDKV, Akola (Patel, 2000).

Yield is a complex character influenced by different yield components. In pigeonpea plant height, flowering duration, number of pods and seed size are the important yield component (Upadhaya, 1980). It has been reported by various workers that grain yield in pigeonpea is positively correlated with days to flowering (Veeeraswamy *et al.*, 1973), Plant height (Sindhu *et al.*, 1985), pods per plant (Munoz and Abbrams, 1971) and seed size (Sindhu *et al.*, 1985). Pod per plant, seeds per pod 100 seed weight and days to flower are reported to have higher direct effects on grain yield (Shoran, 1982 and Sindhu *et al.*, 1985).

The use of heterosis has achieved a greater importance in the production of agricultural crops. Line x tester analysis is extensively used in self and cross pollinated species to understand the nature of gene action involved in the expression of quantitative traits and to select the parents for further breeding procedure.

The concept of combining ability proposed by Sprague and Tatum (1942) is considered to be landmark in the development of breeding procedures. It helps in selection of parents for hybridization by way of knowing the nature and magnitude of gene action in terms of general and specific combining ability effects.

Selection of parents based only on per se performance may be misleading. Parents to be selected for hybridization should have good general combining ability, adaptability, phenotypic stability, and genetic diversity along with their superior agronomic performance. Specific combining ability is an effective mean for isolating superior cross combinations for exploitation of heterosis.

Line x tester analysis (Kempthorne, 1957) is one of the biometrical methods which provide valid information on combining ability (gca and sca) effects of the parents. The estimates of combining ability effects and the magnitude of desirable heterosis help the breeder in making decision in respect of selecting promising breeding material to be used in crop improvement programme. The magnitude of heterosis is of more importance than its frequency of occurrence.

The present study "line x Tester analysis in pigeonpea" was therefore undertaken to estimate the gca and sca effects, the extent of heterosis for seed its components and to find out promising high yielding hybrid combinations.

The results obtained in the present investigation are discussed in the light of previous studies reported by various workers under following sub heads.

4.2.1 *Per se* performances

4.2.2 Heterosis

4.2.3. Combining ability analysis

4.2.4 GCA and SCA effects

**4.2.1 *Per se* performance**

In the present investigation it was found that among the females, AKV-4A recorded highest mean performance for grain yield per plant, number of clusters per plant, number of pods per plant.

Among the males, AKPR-210 recorded highest mean performance for grain yield per plant and also shows desirable mean performance for yield contributing characters like number of pods per plant and number of cluster per plant, 100 seed weight, and number of branches per plant.

Among the hybrids, only AKV-9A X AKPR-23 exhibited the highest and significantly grain weight per plant, plant height, number of pods per plant, number of clusters per plant, followed by AKV-9A X AKPR-345, AKV-8A X AKPR-205.

#### 4.2.2. Heterosis

The heterosis plays an important role for increasing the productivity of crop without much increase in the cost of production. Therefore it is of great importance to plant breeders. The aim of the present study was to identify superior cross combinations which will exhibit good amount of heterosis for grain yield and its component traits.

Considerable amount of useful heterosis in desirable direction was observed for plant height per plant, number of branches per plant, number of pods per plant, number of clusters per plant, number of seeds per pod, 100 seed weight, grain weight per plant, days to 50% flowering, days to maturity (Table 4.6).

The highest useful heterosis in desirable direction was recorded for plant height in AKV-9A X AKPR-23 (18.538%, 11.903%), for number of branches in AKV-2A X AKPR-23 (38.44%, 33.78%), for number of pods in AKV-9A X AKPR-23 (9.907%, 18.7324%), for number of clusters per plant in AKV-9A X AKPR-23 (2.531%, 19.213%), for 100 seed weight in AKV-9A X AKPR-210 (13.78%, 17.50%), for number of seeds per pod in AKV-2A X AKPR-312 (26.11%, 22.31%), for grain weight in AKV-9A X AKPR-23 (9.193%, 16.947%), for days to 50% flowering in AKV-9A X AKPR-227 (-8.1301%, -5.8333%), for

**Hybrid : AKV-9A X AKPR-23**

**Table 4.10. Significant useful heterosis in desirable direction for various characters**

| Sr. No. | Character | Range of heterosis % | | Crosses | Useful heterosis % | |
|---|---|---|---|---|---|---|
| | | Asha | Maruti | | Asha | Maruti |
| 1 | Plant height per plant | -7.032 to18.538 | -12.236 to 1.903 | AKV-9A X AKPR-23 | 18.54 | 11.90 |
| | | | | AKV-2A X AKPR-345 | 15.556 | 9.09 |
| | | | | AKV-2A X AKPR-250 | 15.26 | 8.80 |
| 2 | Number of branches per plant | -17.45 to 38.44 | -20.24 to 33.78 | AKV-2A X AKPR-23 | 38.44 | 33.78 |
| | | | | AKV-2A X AKPR-210 | 37.27 | 32.65 |
| | | | | AKV-8A X AKPR-345 | 33.79 | 29.17 |
| | | | | AKV-2A X AKPR-345 | 31.47 | 26.98 |
| 3 | Number of pods per plant | -54.961 to 9.9070 | -51.34 to 18.7324 | AKV-9A X AKPR-23 | 9.907 | 18.7324 |
| | | | | AKV-4A X AKPR-312 | 1.297 | 9.4310 |
| | | | | AKV-8A X AKPR-345 | 13.967 | 8.326 |
| 4 | Number of clusters per plant | -51.916 to 2.531 | -44.092 to 19.213 | AKV-9A X AKPR-23 | 2.531 | 19.213 |
| | | | | AKV-8A X AKPR-345 | -6.83 | 8.326 |

contd....

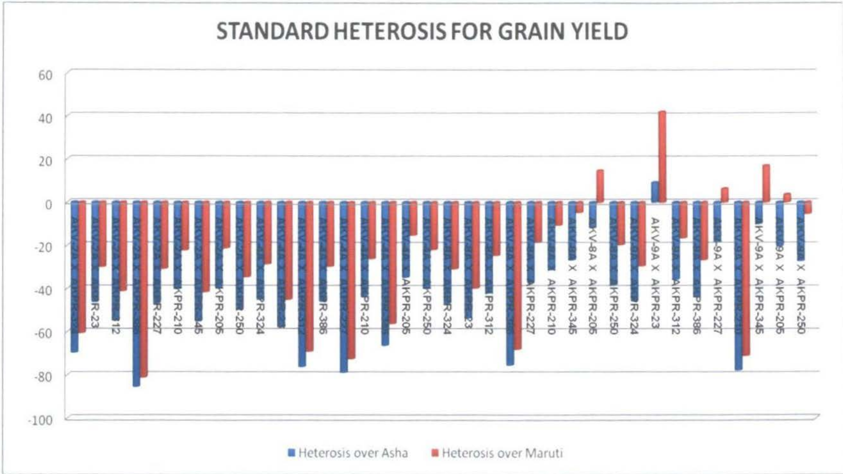


**Fig. 1- Standard heterosis for grain yield per plant over both checks**

| Sr. No. | Character | Range of useful heterosis % | | Crosses | Useful heterosis % | |
|---|---|---|---|---|---|---|
| | | Asha | Maruti | | Asha | Maruti |
| 5 | 100 seed weight | -18.88 | -16.23 to 17.50 | AKV-9A X AKPR-210 | 13.78 | 17.50 |
| | | | | AKV-8A X AKPR-345 | 7.88 | 11.33 |
| | | | | AKV-2A X AKPR-386 | 5.53 | 8.88 |
| 6 | Number of seeds per pod | -18.25 to 26.11 | -21.20 to 22.31 | AKV-2A X AKPR-312 | 26.11 | 22.31 |
| | | | | AKV-2A X AKPR-23 | 21.62 | 15.79 |
| | | | | AKV-2A X AKPR-324 | 15.41 | 12.31 |
| 7 | Grain weight per plant | -85.479 to 9.193 | -81.11 to 41.97 | AKV-9A X AKPR-23 | 9.193 | 16.947 |
| 8 | Days to 50 % flowering | -8.1301 to 8.398 | -5.833 to 11.108 | AKV-9A X AKPR-227 | -8.1301 | -5.8333 |
| | | | | AKV-9A X AKPR-386 | -6.5041 | -4.1667 |
| | | | | AKV-9A X AKPR-210 | -4.3333 | -4.3333 |
| 9 | Days to maturity | -9.60 to 5.76 | -5.42 to 10.64 | AKV-8A X AKPR-250 | -9.60 | -5.42 |
| | | | | AKV-9A X AKPR-205 | -9.O2 | -6.72 |
| | | | | AKV-9A X AKPR-227 | -8.64 | -4.42 |

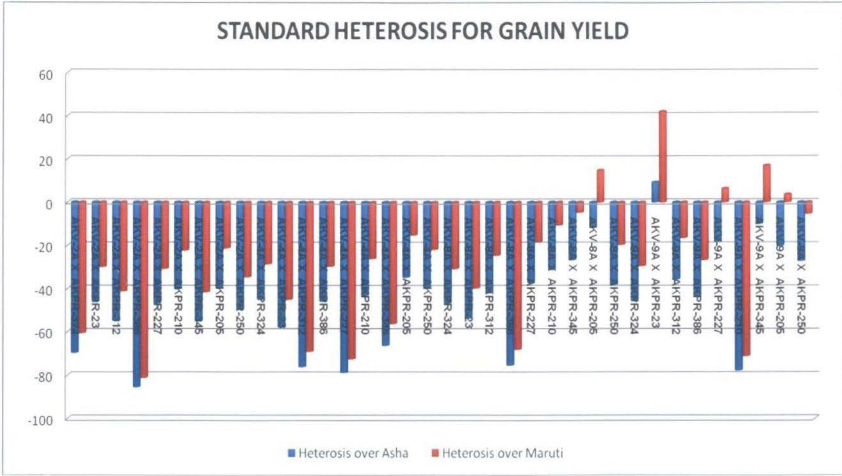


**Fig. 1- Standard heterosis for grain yield per plant over both checks**

days to maturity in AKV-8A X AKPR-250 (-9.60%,-5.42%) over checks Asha and Maruti, respectively.

Useful heterosis for these characters in pigeonpea was also reported earlier by several researchers, Reddy *et al.* (1979), Venkateswarlu *et al.* (1981). Marekar *et al.* (1982), Jain and Saxena (1990), Tuteja *et al.* (1992), Malik *et al.* (1995), Khapre *et al.* (1996), Narladkar and Khapre (1996), Verulkar and Singh (1997), Manivel and Rangaswamy (1998), Singh *et al.* (1999), Pandey and Singh (2002), Aher *et al.* (2006), Wanjari *et al.* (2007), Anantha Raju *et al.* (2007)

The highest average heterosis in desirable direction was recorded for plant height in AKV-4A X AKPR-312 (44.64%), for number of branches in AKV-9A X AKPR-205 (52.24 %), for number of pods in AKV-4A X AKPR-312 (126.93 %), for number of clusters per plant in AKV-8A X AKPR-312 (76.50 %), for 100 seed weight in AKV-8A X AKPR-345 (19.13 %), for number of seeds in AKV-9A X AKPR-205 (24.21 %), for grain weight in AKV-8A X AKPR-345 (187.77 %), for days to 50% flowering in AKV-9A X AKPR-227 (-1.31%), for days to maturity in AKV-9A X AKPR-386 (-1.15%).

The highest heterobeltosis in desirable direction was recorded for plant height in AKV-4A X AKPR-312 (43.05 %), for number of branches in AKV-2A X AKPR-23 (25.26), for number of pods in AKV-9A X AKPR-23 (91.30 %), for number of clusters per plant in AKV-9A X AKPR-23 (65.79 %), for 100 seed weight in AKV-8A X AKPR-312 (12.66 %), for number of seeds in AKV-9A X AKPR-205 (22.92 %), for grain weight in AKV-9A X AKPR-23 (148.85 %), for days to 50% flowering in AKV-4A X AKPR-210 (-4.62), for days to maturity in AKV-9A X AKPR-210 (-11.56 %).

However, the selection of superior crosses should necessarily be based not only on the magnitudes of useful heterosis but also on actual yield. Performance least it might result in crosses with high heterotic response but with poor actual yields (Ranga Rao, 1982).

In case of pigeonpea higher mean values are desirable for all the characters except days to 50% flowering and days to maturity. For the trait plant height (AKV-9A X AKPR-23, AKV-2A X AKPR-345), number of branches (AKV-2A X AKPR-23, AKV-2A X AKPR-210), number of pods (AKV-9A X AKPR-23, AKV-4A X AKPR-312), number of clusters per plant (AKV-9A X AKPR-23, AKV-8A X AKPR-345), 100 seed weight (AKV-9A X AKPR-210), number of seeds (AKV-2A X AKPR-23, AKV-8A X AKPR-345 ), grain weight (AKV-9A X AKPR-23), Days to 50 % flowering (AKV-9A X AKPR-227, AKV-9A X AKPR-386) and days to maturity (MS AKV-8A X AKPR-250, AKV-9A X AKPR-205) revealed comparatively higher percentage of useful heterosis and also higher mean performance. Hence these crosses could be used for further breeding programme aimed at improvement in pigeonpea either by exploitation of hybrid vigour or thought selection in segregating population. Along with the extent of heterosis the knowledge about the combining ability of the genotypes is also required to evaluate them on the basis of their genetic value. This helps in selection of suitable parents for hybridization or for varietal breeding.

### 4.2.3 Combining ability analysis

Combining ability analysis (Table 4.7) revealed that mean squares for females (lines) were highly significant for plant height per palnt, number of clusters per plant and days to maturity. This indicates the presence of genetic variability in females for these traits. Males (Testers) showed genetic variation for all the traits except plant height and number of clusters per plant. The magnitude of variance was higher in females as compared to males. The variance due to interaction between females and males was highly significant for all the triats studied.

### 4.2.4 GCA and SCA effects

The significant gca effect of the parents in desirable direction for various characters as depicted by the parents are shown pictorially in Table 4.11

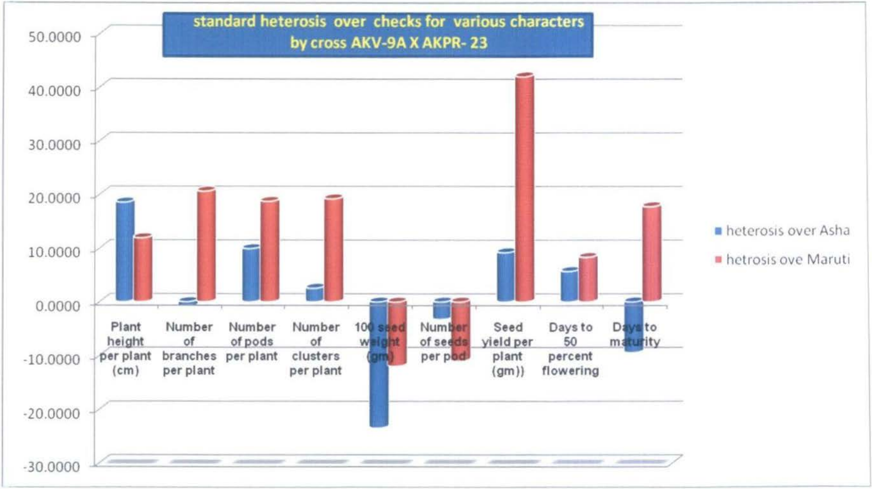


Fig. 2- Standard heterosis over both checks for grain yield per plant by cross AKV-9A X AKPR- 23

reveals that none of the parents was found to have significant desirable gca effect simultaneously for all characters.

However, AKPR-23 and AKPR-205 among the male parents (Testers) were found to possess significant gca effect for most of the yield contributing characters. Hence these genotypes were recognized as the best parental material among the available genotypes.

The males and females revealed differences from one another in respect of their gca effects for all the characters indicating genetic variability among them for these characters.

Table 4.12 reveals the sca effects of crosses for various characters studied. In pigeonpea, the positive sca values are desirable for all the traits studies except days to 50% flowering and days to maturity for which negative sca values are desirable.

The highest desirable sca effect was observed for plant height in AKV-2A X AKPR-345 (17.009), for number of branches per plant in AKV-8A X AKPR-386 (1.504), for number of pods AKV-9A X AKPR-23 (162.466), for number of clusters per plant AKV-9A X AKPR-23 (11.761), for 100 seed weight AKV-9A X AKPR-210 (1.343), for number of seeds per pod AKV-8A X AKPR-345 (0.619), for grain weight per plant AKV-9A X AKPR-23 (59.006), for days to 50% flowering AKV-9A X AKPR-227 (-4.602) and for days to maturity AKV-8A X AKPR-386 (-9.111).

A very few crosses viz., AKV-8A X AKPR-345, AKV-8A X AKPR-205, AKV-8A X AKPR-205, AKV-4A X AKPR-312, AKV-4A X AKPR-324, AKV-4A X AKPR-250, revealed significant desirable sca effects simultaneously for majority of the characters studied.

It was observed that the crosses with high specific combining ability for seed yield had also average to high specific combining ability for one or more other yield components suggesting that the improvement in grain yield could be obtained by improving its component characters. Similar results were reported by Narladkar and Khapre (1997), Wanjari *et al.* (1998), Singh and Srivastava (2001), Pawar and Tikka (2003), and Sunilkumar *et al.* (2003), Banu *et al.* (2006), Anantha, R.P. and Muthian, A.R. (2007), Baskaran Muthiah (2009), Kumar *et al.* (2009), Vaghela *et al.* (2009), Singh and Singh (2009).

Five promising crosses were selected on the basis of mean performance, heterotic response and sca effects of the crosses (Table 4.13) The crosses AKV-9A X AKPR-23, AKV-9A X AKPR-23, AKV-8A X AKPR-205, AKV-9A X AKPR-227, AKV-9A X AKPR-205 were the most promising among the 36 crosses studied. These crosses revealed the significant desirable useful heterosis and significant desirable sca effects.

The promising crosses showing high mean performance, high magnitude of heterosis with high sca effects and involving good general combiners could be successfully exploited for hybrid vigor. The promising heterotic crosses involving one parent with good gca and another with poor or even negative gca effect may give desirable transgressive segregates which will help in the development of varieties and inbred line (Amalraj, 1989).

**Table 4.11. Significance gca effects of parents in desirable direction for various characters**

| Parents | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters per plant | 100 seed weight (gm) | Number of seeds per pod | Seed yield per plant (gm)) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Females (Lines) | | | | | | | | | |
| AKV-2A | | ** | | | ** | ** | | | |
| AKV-4A | | | | | | ** | | ** | |
| AKV8A | ** | | * | ** | ** | | ** | | ** |
| AKV-9A | ** | ** | | | ** | | ** | ** | |
| Males (Testers) | | | | | | | | | |
| AKPR-324 | ** | ** | | | * | ** | | | |
| AKPR-23 | ** | * | * | ** | | | ** | | |
| AKPR-312 | | | * | ** | | ** | | ** | ** |
| AKPR-386 | | | | | | | | ** | |
| AKPR-227 | | | | | | | | ** | ** |
| AKPR-210 | | | | | ** | ** | | ** | |
| AKPR-345 | ** | ** | | * | | ** | ** | ** | ** |
| AKPR-205 | ** | ** | | | * | ** | ** | ** | ** |
| AKPR-250 | ** | | | | ** | | ** | ** | ** |

* - Significant at 5 % level of significance

** - Significant at 1 % level of significance

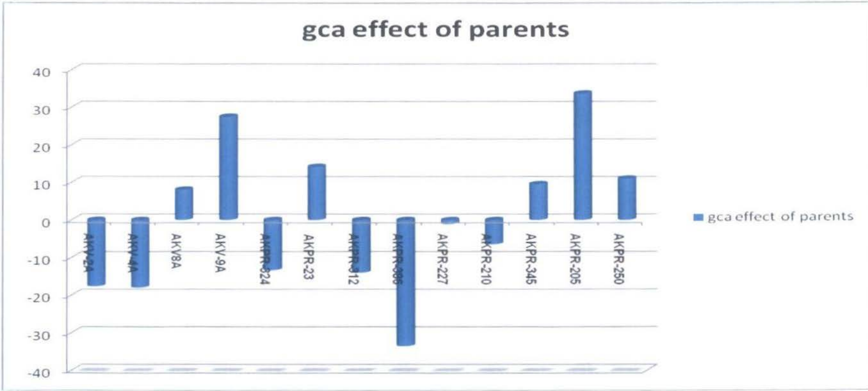


Fig. 3- gca effects of parents for grain yield per plant

**Table 4.12 Specific combining ability effects of crosses**

| Sr. No. | Crosses | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters per plant | 100 seed weight (gm) | Number of seeds per pod | Seed yield per plant (gm)) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 | AKV-2A X AKPR-324 | ** | | ** | ** | | * | | | ** |
| 2 | AKV-2A X AKPR-23 | | ** | | | ** | ** | | ** | ** |
| 3 | AKV-2A X AKPR-312 | | | | | | | ** | ** | ** |
| 4 | AKV-2A X AKPR-386 | | | ** | | ** | | | | |
| 5 | AKV-2A X AKPR-227 | | | | | | | ** | | |
| 6 | AKV-2A X AKPR-210 | | ** | | | | | ** | | |
| 7 | AKV-2A X AKPR-345 | ** | | ** | * | | | | ** | |
| 8 | AKV-2A X AKPR-205 | | | | ** | | | | ** | |
| 9 | AKV-2A X AKPR-250 | ** | | ** | ** | | | | ** | |
| 10 | AKV-4A X AKPR-324 | | ** | ** | * | | | ** | ** | ** |
| 11 | AKV-4A X AKPR-23 | * | | | | | | | ** | ** |
| 12 | AKV-4A X AKPR-312 | ** | ** | ** | ** | | | | ** | ** |
| 13 | AKV-4A X AKPR-386 | ** | ** | ** | ** | | | ** | | |
| 14 | AKV-4A X AKPR-227 | ** | | | | ** | | | | |
| 15 | AKV-4A X AKPR-210 | ** | | ** | * | | | ** | | |
| 16 | AKV-4A X AKPR-345 | | | | | | | | | ** |
| 17 | AKV-4A X AKPR-205 | | | | | | | | | |
| 18 | AKV-4A X AKPR-250 | ** | | ** | ** | | | ** | | ** |
| 19 | AKV-8A X AKPR-324 | ** | | | | | | | | |
| 20 | AKV-8A X AKPR-23 | | | | | | | | | |

contd...

| Sr. No. | Crosses | Plant height per plant (cm) | Number of branches per plant | Number of pods per plant | Number of clusters pr plant | 100 seed weight (gm) | Number of seeds per pod | Seed yield per plant (gm)) | Days to 50 percent flowering | Days to maturity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 21 | AKV-8A X AKPR-312 | | | ** | | | | ** | | |
| 22 | AKV-8A X AKPR-386 | ** | ** | | | | | | | ** |
| 23 | AKV-8A X AKPR-227 | | | ** | | | | ** | | ** |
| 24 | AKV-8A X AKPR-210 | ** | | ** | ** | | | ** | | |
| 25 | AKV-8A X AKPR-345 | | ** | ** | ** | ** | ** | ** | | |
| 26 | AKV-8A X AKPR-205 | ** | ** | ** | ** | * | | ** | | ** |
| 27 | AKV-8A X AKPR-250 | | | | | | | | | ** |
| 28 | AKV-9A X AKPR-324 | | | | | | | | ** | |
| 29 | AKV-9A X AKPR-23 | ** | | ** | ** | | | ** | | |
| 30 | AKV-9A X AKPR-312 | | | | ** | | | | | |
| 31 | AKV-9A X AKPR-386 | | | | | | | ** | | * |
| 32 | AKV-8A X AKPR-205 | ** | ** | ** | ** | | | ** | ** | ** |
| 33 | AKV-9A X AKPR-210 | | | | | ** | * | | ** | ** |
| 34 | AKV-9A X AKPR-345 | * | | | | | | ** | ** | |
| 35 | AKV-9A X AKPR-205 | ** | | | | | | | | |
| 36 | AKV-9A X AKPR-250 | | | | | * | | | | |

* - Significant at 5 % level of significance

** - Significant at 1 % level of significance

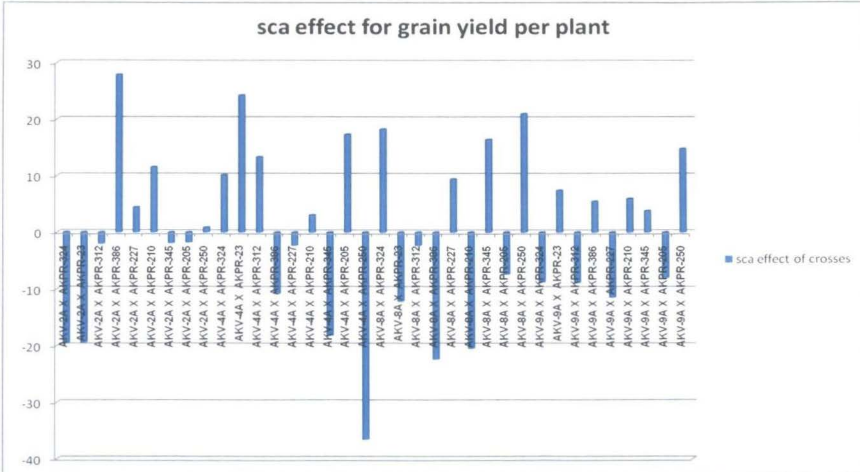


Fig. 4- sca effects of crosses for grain yield per plant

**Table 4.13 Yield performance, heterosis, gca effects and sca effects in promising hybrids**

| Sr. No. | Crosses | Grain yield per plant (g) | Heterosis (%) | | sca effects | gca effects with type of parents | Significant gca effects for other characters in desirable direction | Significant sca effects for other characters in desirable direction |
|---|---|---|---|---|---|---|---|---|
| | | | Asha | Maruti | | | | |
| 1. | AKV-9A X AKPR-23 | 204.15** | 9.19** | 41.97** | 59.01 ** | 27.51 ** x 14.21 ** <br> H H | $P_1$ : 1,2,5,7,8,9 <br> $P_2$ : 1,2,3,4,7,8,9 | 1,2.3,4,6 |
| 2. | AKV-9A X AKPR-345 | 168.17 | -10.06 | 16.94** | 27.65 ** | 27.51 ** x 9.57 ** <br> H H | $P_1$ : 1,2,5,7,8,9 <br> $P_2$ : 1,2,4,6,7,8,9 | 1,5,6,7,8 |
| 3. | AKV-8A X AKPR-205 | 164.98 | -11.76 | 14.72** | 19.76 ** | 8.08 ** x 33.70 ** <br> H H | $P_1$ : 1,3,4,5,7,9 <br> $P_2$ : 1,6,9,10 | 1,2,3,4,5,6,7,8, 9 |
| 4. | AKV-9A X AKPR-227 | 180.13 | -18.23 | 6.307** | 23.01 ** | 27.51 ** x -1.09 ** <br> H L | $P_1$ : 1,2,5,7,8,9 <br> $P_2$ : 8,9 | 1,2,3,4,6,7,8,9 |
| 5. | AKV-9A X AKPR-205 | 149.03 | -20.29 | 3.63* | -15.62 ** | 27.514 **x 33.70 ** <br> H H | $P_1$ : 1,2,5,7,8,9 <br> $P_2$ : 1,6,9,10 | 1,23,6,9 |

H : High gca
L : Low gca
$P_1$ & $P_2$ : Female parent and male parent of the concerned cross, respectively
* : Significant at 5 % level of significance
** : Significant at 1 % level of significance
1 : Plant height per plant (cm), 2 : Number of branches per plant, 3 : Number of pods per plant, 4 : number of clusters per plant, 5 : 100 seed weight (g), 6 : Number of seeds per pod, 7 : Grain weight per plant (g),
8 : Days to 50% flowering, 9 : Days to maturit

# CHAPTER V

# SUMMARY AND CONCLUSIONS

The Present investigation entitled "Line x Tester analysis in pigeonpea" was undertaken to estimate the combining ability effects and extent of heterosis for various characters in pigeonpea to find out superior hybrid combinations.

Line x Tester model was selected for the study. The experimental material comprised of 4 females (lines) viz., AKV – 2, AKV – 4 AKV – 8A, AKV – 9A and 9 males (Testers) viz., AKPR-324, AKPR-23, AKPR-312, AKPR-386, AKPR-227, AKPR-210, AKPR-345, AKPR-205, AKPR-250 and their 36 hybrids along with the variety 'Asha' and Maruti as standard check. The parents and crosses were randomized separately and sown in single block in kharif 2008-2009 at the field of Pulse Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

The result showed that, parent AKPR-210 (220.34cm) and cross AKV-9A X AKPR-23 (201.926cm) were the tallest genotypes. AKPR-210 (7.2) and cross AKV-2A X AKPR-23 (7.933) recorded maximum number of branches per plant. Among the parents AKPR-345 (483.27) and cross AKV-9A X AKPR-23 (705.9) recorded maximum number of pods per plant. AKPR-345 (45.47) and cross AKV-9A X AKPR-23 (59.133) exhibited maximum number of pods per plant. Among the parents AKPR-210 (12.148) and cross AKV-9A X AKPR-210 (12.960) recorded maximum 100 seed weight. AKV8A (3.93) and cross AKV-2A X AKPR-312 and AKV-9A X AKPR-345 (4.66) showed maximum number of seeds per pod. Among the parents AKPR-210 (93.87) and cross AKV-9A X AKPR-23 (204.15) recorded highest grain weight per plant. The result showed that AKPR-324 (104.00) and cross AKV-9A X AKPR-227 (113.00) were earlier for days to 50% flowering. AKPR-227 (146.66) and cross AKV-8A X AKPR-250 (174.00) was earlier for day to maturity.

The phenomenon of heterosis was of general occurrence for all the traits. However, considerable amount of heterosis in desirable direction was observed for all the traits except number of seeds per pod.

The highest useful heterosis in desirable direction was recorded for plant height in AKV-9A X AKPR-23 (18.538%, 11.903%), for number of branches in AKV-2A X AKPR-23 (38.44%, 33.78%), for number of pods in AKV-9A X AKPR-23 (9.907%, 18.7324%), for number of clusters per plant in AKV-9A X AKPR-23 (2.531%, 19.213%), for 100 seed weight in AKV-9A X AKPR-210 (13.78%, 17.50%), for number of seeds per pod in AKV-2A X AKPR-312 (26.11%, -22.31%), for grain weight in AKV-9A X AKPR-23 (9.193%, 16.947%), for days to 50% flowering in AKV-9A X AKPR-227 (-8.1301%, -5.8333%), for days to maturity in AKV-8A X AKPR-250 (-9.60%, -5.42%) over check Asha and Maruti, respectively.

The highest average heterosis in desirable direction was recorded for plant height in AKV-4A X AKPR-312 (44.64%), for number of branches in AKV-9A X AKPR-205 (52.24 %), for number of pods in AKV-4A X AKPR-312 (126.93 %), for number of clusters per plant in AKV-8A X AKPR-312 (76.50 %), for 100 seed weight in AKV-8A X AKPR-345 (19.13 %), for number of seeds in AKV-9A X AKPR-205 (24.21 %), for grain weight in AKV-8A X AKPR-345 (187.77 %), for days to 50% flowering in AKV-9A X AKPR-227 (-1.31%), for days to maturity in AKV-9A X AKPR-386 (-1.15%).

The highest heterobeltosis in desirable direction was recorded for plant height in AKV-4A X AKPR-312 (43.05 %), for number of branches in AKV-2A X AKPR-23 (25.26), for number of pods in AKV-9A X AKPR-23 (91.30 %), for number of clusters per plant in AKV-9A X AKPR-23 (65.79 %), for 100 seed weight in AKV-8A X AKPR-312 (12.66 %), for number of seeds in AKV-9A X AKPR-205 (22.92 %), for grain weight in AKV-9A X AKPR-23 (148.85 %), for days to 50% flowering in AKV-4A X AKPR-210 (-4.62), for days to maturity in AKV-9A X AKPR-210 (-11.56 %).

The General combining ability effects revealed that AKPR-250 (6.497) was the best general combines for plant height. AKPR-345 (0.865) was the best general combiner for number of branches per plant. For number of pods per plant AKPR-23 (65.478) was best general combiner. For the trait number of cluster per plant, parent AKPR-23 (6.602) was best general combiner. AKPR-324 (0.555) was the best general combiner for 100 seed weight. For number of seeds per pod AKPR-312 (0.119) was the best general combiner. AKPR-205 (33.703) was the best general combiner for grain weight per plant. AKPR-227 (-3.491) was the best general combiner for days to 50% flowering. AKV-9A (-4.806) was the best general combiner for days to maturity.

The highest desirable sca effect was observed for plant height in AKV-2A X AKPR-345 (17.009), for number of branches per plant in AKV-8A X AKPR-386 (1.504), for number of pods AKV-9A X AKPR-23 (162.466), for number of clusters per plant AKV-9A X AKPR-23 (11.761), for 100 seed weight AKV-9A X AKPR-210 (1.343), for number of seeds per pod AKV-8A X AKPR-345 (0.619), for grain weight per plant AKV-9A X AKPR-23 (59.006), for days to 50% flowering AKV-9A X AKPR-227 (-4.602) and for days to maturity AKV-8A X AKPR-386 (-9.111).

Five promising crosses were identified on the basis of mean performance, useful heterosis and estimates of gca and sca effects AKV-9A X AKPR-23 was the best hybrid with highest useful heterosis (9.193%, 41.974%), respectively over standard check Asha and Maruti, high sca effect (59.006) involving good general combiners and hence can be successfully exploited for hybrid vigor. Similarly the hybrid AKV-9A X AKPR-345 can exploited for heterosis. The remaining three hybrids viz., AKV-8A X AKPR-205, AKV-9A X AKPR-227, and AKV-9A X AKPR-205 involving one parent with good gca effect and the second with poor or even negative gca effect can be advanced to further generations to obtain desirable transgressive sergeants and improvement by pedigree or recurrent selection.

Thus, from the study it is concluded that, among all hybrid studied, AKV-9A X AKPR-23 showed positive significant useful heterosis over both check Asha and Maruti for grain yield. Among the female parents (lines) AKV-9A and AKV-8A and AKPR-205 and AKPR-23 among the male parents (Testers) were found to possess significant positive gca effect for yield and for most of the yield contributing characters. Thus the study revealed the detail understanding of the extent of useful heterosis observed within the available genetic variability and on idea about the combining ability of the parents for various characters studied. The study would help in determining the breeding strategy for further improvement in pigeonpea.

# CHAPTER VI

# IMPLICATIONS

The promising crosses showing high mean performance, high magnitudes of useful heterosis with high sca effects and involving good general combines could be successfully exploited for hybrid vigor. The promising heterotic crosses involving one parent with good gca and another with poor or even negative gca effect may give desirable transgressive segregates which will help in the development of varieties and inbred line.

The present study may be useful for selecting good combiners for grain yield per plant. The female AKV-9A and AKV-8A and AKPR-23 and AKPR-205 among the male parent showed good gca effect can be further utilized in pigeonpea experimental hybrid development program for exploitation or their good general combining ability. Similarly the cross AKV-9AxAKPR-23 showed superior performance for grain yield and yield contributing characters. So, this cross can be commercially exploited using heterosis breeding after its thorough evaluation in multiplication traits.

## CHAPTER VII

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# VITA

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**Place :** Akola

**Date :** 28/05/2010

**Signature of Student**

Table 1: Weekly Weather data for the year 2009 recorded at Meteorological Observatory Department of Agronomy Dr. PDKV., Akola

| | | Actual | | | | 2009 | | | | | | | | | | Normal | | 1971-2000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weeks | Dates | T MAX (°C) | | T MIN (°C) | | BSH (hrs) | | WS (km/hr) | | RH I (%) | | RH II (%) | | Evap (mm) | | RF (mm) | | CRF (mm) | Rainy Days | |
| | | N | A | N | A | N | A | N | A | N | A | N | A | N | A | N | A | | N | A |
| | 2009 | | | | | | | | | | | | | | | | | | | |
| 1 | 1-7 Jan | 29.0 | 30.3 | 10.3 | 13.7 | 8.7 | 3.8 | 4.9 | 1.6 | 78 | 65 | 30 | 29 | 4.2 | 4.4 | 1.7 | 0.0 | 0.0 | 0.2 | 0.0 |
| 2 | 8-14 | 29.2 | 31.0 | 11.3 | 16.9 | 8.6 | 3.8 | 6.3 | 2.1 | 71 | 75 | 30 | 33 | 4.5 | 4.8 | 3.4 | 0.0 | 0.0 | 0.2 | 0.0 |
| 3 | 15-21 | 29.9 | 31.6 | 11.6 | 15.0 | 8.9 | 5.9 | 5.4 | 2.5 | 69 | 59 | 28 | 21 | 4.8 | 6.1 | 0.9 | 0.0 | 0.0 | 0.1 | 0.0 |
| 4 | 22-28 | 30.8 | 33.6 | 11.8 | 14.0 | 9.1 | 7.0 | 5.5 | 1.2 | 67 | 56 | 27 | 19 | 5.2 | 5.9 | 1.1 | 0.0 | 0.0 | 0.2 | 0.0 |
| 5 | 29-4 Feb | 31.1 | 34.8 | 12.1 | 15.9 | 9.3 | 7.2 | 5.8 | 1.8 | 61 | 49 | 25 | 16 | 5.6 | 6.3 | 2.8 | 0.0 | 0.0 | 0.2 | 0.0 |
| 6 | 5-11 | 31.3 | 34.4 | 11.9 | 16.7 | 9.1 | 6.4 | 5.6 | 2.7 | 59 | 43 | 23 | 17 | 5.9 | 6.8 | 4.9 | 0.0 | 0.0 | 0.4 | 0.0 |
| 7 | 12-18 | 32.5 | 33.5 | 13.4 | 15.7 | 9.4 | 4.8 | 6.1 | 1.7 | 56 | 44 | 22 | 18 | 6.6 | 6.6 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 | 19-25 | 33.0 | 36.4 | 13.8 | 20.7 | 9.5 | 5.7 | 6.5 | 2.5 | 57 | 41 | 22 | 18 | 7.3 | 8.5 | 3.3 | 0.0 | 0.0 | 0.5 | 0.0 |
| 9 | 26-4 Mar | 34.7 | 38.1 | 14.8 | 19.0 | 9.6 | 8.6 | 7.0 | 3.2 | 50 | 41 | 17 | 16 | 8.1 | 9.4 | 3.4 | 0.0 | 0.0 | 0.3 | 0.0 |
| 10 | 5-11 | 36.1 | 37.9 | 16.7 | 21.0 | 9.6 | 7.7 | 6.8 | 3.8 | 44 | 34 | 18 | 18 | 9.0 | 10.4 | 2.1 | 0.0 | 0.0 | 0.3 | 0.0 |
| 11 | 12-18 | 37.3 | 36.7 | 17.5 | 20.9 | 9.6 | 6.7 | 6.9 | 4.2 | 42 | 41 | 17 | 22 | 9.5 | 9.5 | 2.5 | 0.8 | 0.8 | 0.3 | 0.0 |
| 12 | 19-25 | 38.5 | 38.2 | 18.3 | 21.2 | 9.6 | 7.7 | 6.9 | 4.5 | 37 | 34 | 13 | 14 | 10.5 | 10.7 | 0.3 | 1.5 | 2.3 | 0.1 | 0.0 |
| 13 | 26-1 Apr | 39.0 | 39.6 | 19.7 | 22.3 | 9.6 | 8.8 | 7.6 | 4.1 | 36 | 28 | 15 | 14 | 11.3 | 11.7 | 2.9 | 0.0 | 2.3 | 0.3 | 0.0 |
| 14 | 2-8 Apr | 40.1 | 41.1 | 21.1 | 23.4 | 9.8 | 6.9 | 7.9 | 2.1 | 36 | 28 | 15 | 21 | 11.7 | 11.3 | 0.6 | 0.0 | 2.3 | 0.1 | 0.0 |
| 15 | 9-15 | 40.8 | 40.6 | 22.5 | 21.8 | 9.9 | 8.9 | 9.3 | 3.7 | 34 | 26 | 12 | 16 | 13.4 | 12.1 | 0.3 | 0.0 | 2.3 | 0.1 | 0.0 |
| 16 | 16-22 | 41.7 | 43.4 | 23.5 | 26.7 | 10.2 | 8.5 | 9.1 | 5.7 | 34 | 26 | 14 | 12 | 13.7 | 15.9 | 0.3 | 0.0 | 2.3 | 0.0 | 0.0 |
| 17 | 23-29 | 42.1 | 43.0 | 24.8 | 24.7 | 10.1 | 8.9 | 10.2 | 6.2 | 37 | 24 | 14 | 9 | 14.4 | 14.1 | 0.0 | 0.0 | 2.3 | 0.1 | 0.0 |
| 18 | 30- 6 May | 42.7 | 44.9 | 26.0 | 28.8 | 9.9 | 8.9 | 11.4 | 8.5 | 38 | 30 | 14 | 12 | 15.4 | 17.3 | 0.3 | 0.0 | 2.3 | 0.2 | 0.0 |
| 19 | 7-13 | 42.6 | 43.2 | 26.5 | 29.2 | 10.1 | 9.0 | 12.7 | 11.2 | 43 | 34 | 17 | 13 | 16.4 | 18.4 | 0.3 | 0.0 | 2.3 | 0.1 | 0.0 |
| 20 | 14-20 | 42.6 | 41.8 | 27.3 | 26.9 | 9.7 | 7.8 | 14.6 | 10.5 | 48 | 58 | 18 | 27 | 17.3 | 14.1 | 1.8 | 21.8 | 24.1 | 0.2 | 2.0 |
| 21 | 21-27 | 42.4 | 41.7 | 27.4 | 28.3 | 9.8 | 6.5 | 15.7 | 11.1 | 50 | 57 | 20 | 26 | 17.0 | 13.8 | 4.1 | 20.3 | 44.4 | 0.5 | 2.0 |
| 22 | 28-3 Jun | 41.9 | 41.7 | 27.6 | 28.6 | 9.7 | 6.3 | 16.2 | 15.3 | 56 | 51 | 23 | 25 | 16.3 | 17.8 | 5.7 | 0.0 | 44.4 | 0.5 | 0.0 |
| 23 | 4-10 | 39.0 | 39.8 | 25.8 | 28.3 | 8.0 | 4.6 | 14.9 | 16.8 | 62 | 56 | 30 | 31 | 13.4 | 17.2 | 18.3 | 0.0 | 44.4 | 1.2 | 0.0 |
| 24 | 11-17 | 38.2 | 41.6 | 25.5 | 28.9 | 7.5 | 7.2 | 15.4 | 15.5 | 71 | 55 | 42 | 27 | 11.1 | 17.6 | 43.3 | 0.0 | 44.4 | 2.0 | 0.0 |
| 25 | 18-24 | 35.3 | 40.8 | 24.9 | 27.0 | 7.1 | 5.3 | 15.1 | 13.3 | 76 | 60 | 50 | 28 | 9.1 | 14.4 | 52.3 | 2.4 | 46.8 | 2.2 | 0.0 |
| 26 | 25-1Jul | 34.1 | 33.6 | 24.2 | 24.5 | 5.3 | 3.6 | 13.4 | 9.2 | 80 | 82 | 55 | 59 | 7.3 | 7.8 | 38.2 | 143.2 | 190.0 | 2.3 | 4.0 |
| 27 | 2-8 | 33.5 | 32.8 | 24.4 | 24.5 | 5.2 | 3.7 | 12.9 | 4.1 | 81 | 90 | 58 | 65 | 6.8 | 4.7 | 34.7 | 77.1 | 267.1 | 2.4 | 5.0 |
| 28 | 9-15 | 32.3 | 30.2 | 23.7 | 24.1 | 3.8 | 1.4 | 12.0 | 7.5 | 84 | 89 | 62 | 71 | 5.5 | 3.4 | 52.2 | 48.0 | 315.1 | 2.8 | 4.0 |
| 29 | 16-22 | 32.0 | 28.6 | 23.9 | 23.6 | 3.3 | 1.2 | 11.2 | 4.9 | 84 | 86 | 65 | 78 | 5.6 | 3.1 | 58.6 | 57.2 | 372.3 | 2.6 | 3.0 |
| 30 | 23-29 | 31.7 | 30.3 | 23.3 | 23.6 | 4.3 | 3.1 | 11.9 | 4.3 | 85 | 85 | 64 | 60 | 5.3 | 4.0 | 44.2 | 30.0 | 402.3 | 2.6 | 4.0 |
| 31 | 30-5 Aug | 31.1 | 32.2 | 23.1 | 24.0 | 3.6 | 3.4 | 11.7 | 7.5 | 88 | 81 | 66 | 52 | 4.6 | 5.9 | 49.3 | 0.0 | 402.3 | 2.5 | 0.0 |
| 32 | 6-12 | 30.2 | 32.1 | 22.9 | 24.0 | 3.5 | 2.3 | 11.6 | 7.2 | 87 | 84 | 69 | 56 | 4.2 | 4.8 | 59.9 | 4.2 | 406.5 | 2.9 | 0.0 |
| 33 | 13-19 | 30.5 | 32.8 | 22.8 | 24.9 | 4.4 | 3.7 | 11.7 | 7.7 | 86 | 77 | 66 | 49 | 4.5 | 6.3 | 40.6 | 0.0 | 406.5 | 2.2 | 0.0 |
| 34 | 20-26 | 30.5 | 31.1 | 22.6 | 22.8 | 4.3 | 2.5 | 11.0 | 4.2 | 88 | 94 | 66 | 73 | 4.3 | 3.8 | 46.7 | 65.7 | 472.2 | 2.0 | 3.0 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 35 | 27-2 Sep | 30.4 | 30.2 | 22.7 | 23.5 | 4.4 | 2.8 | 10.6 | 6.5 | 86 | 91 | 64 | 68 | 4.2 | 3.5 | 47.1 | 2.9 | 475.1 | 2.4 | 0.0 |
| 36 | 3-9 | 31.1 | 30.3 | 22.5 | 23.3 | 5.7 | 3.2 | 9.1 | 10.1 | 85 | 93 | 61 | 67 | 4.7 | 4.0 | 28.5 | 30.2 | 505.3 | 1.5 | 1.0 |
| 37 | 10-16 | 32.2 | 33.2 | 22.4 | 22.9 | 7.1 | 5.4 | 9.0 | 6.0 | 85 | 85 | 56 | 43 | 5.1 | 5.2 | 18.9 | 0.0 | 505.3 | 1.1 | 0.0 |
| 38 | 17-23 | 33.4 | 35.2 | 22.3 | 22.8 | 7.2 | 7.1 | 8.5 | 2.7 | 83 | 81 | 53 | 34 | 5.3 | 5.7 | 24.6 | 2.1 | 507.4 | 1.4 | 0.0 |
| 39 | 24-30 | 33.7 | 34.3 | 21.9 | 24.5 | 7.6 | 5.6 | 5.4 | 5.5 | 83 | 83 | 50 | 49 | 4.9 | 6.5 | 24.4 | 6.8 | 514.2 | 1.5 | 2.0 |
| 40 | 1-7 Oct | 33.9 | 32.2 | 20.2 | 23.7 | 8.1 | 4.1 | 7.5 | 4.3 | 81 | 90 | 45 | 60 | 5.5 | 4.3 | 21.8 | 67.8 | 582.0 | 1.1 | 4.0 |
| 41 | 8-14 | 34.1 | 32.9 | 18.7 | 19.8 | 4.2 | 8.1 | 4.1 | 4.4 | 76 | 90 | 40 | 33 | 5.3 | 5.1 | 16.0 | 0.0 | 582.0 | 0.9 | 0.0 |
| 42 | 15-21 | 33.9 | 34.9 | 18.1 | 17.8 | 8.4 | 7.8 | 4.4 | 1.5 | 74 | 81 | 36 | 23 | 5.5 | 5.7 | 3.1 | 0.0 | 582.0 | 0.4 | 0.0 |
| 43 | 22-28 | 33.1 | 33.8 | 18.5 | 14.7 | 8.4 | 6.7 | 4.1 | 1.6 | 73 | 74 | 36 | 19 | 5.3 | 5.6 | 10.0 | 0.0 | 582.0 | 0.6 | 0.0 |
| 44 | 29-4 Nov | 33.0 | 34.4 | 15.8 | 14.3 | 8.7 | 6.8 | 4.7 | 1.6 | 72 | 70 | 31 | 17 | 5.3 | 6.4 | 2.3 | 0.0 | 582.0 | 0.3 | 0.0 |
| 45 | 5-11 | 32.4 | 31.0 | 14.8 | 19.1 | 8.6 | 4.1 | 4.5 | 2.1 | 70 | 81 | 30 | 50 | 5.2 | 4.9 | 3.7 | 5.0 | 587.0 | 0.3 | 1.0 |
| 46 | 12-18 | 31.7 | 29.3 | 13.7 | 21.7 | 8.6 | 3.6 | 4.6 | 1.6 | 70 | 92 | 30 | 58 | 4.9 | 3.5 | 1.1 | 97.8 | 684.8 | 0.2 | 3.0 |
| 47 | 19-25 | 31.0 | 27.5 | 13.1 | 13.1 | 8.6 | 7.9 | 4.4 | 1.1 | 71 | 89 | 30 | 35 | 4.6 | 3.8 | 10.1 | 0.0 | 684.8 | 0.3 | 0.0 |
| 48 | 26-2 Dec | 30.3 | 28.8 | 12.4 | 12.2 | 8.8 | 7.2 | 4.6 | 1.3 | 71 | 82 | 31 | 29 | 4.3 | 4.0 | 6.8 | 0.0 | 684.8 | 0.3 | 0.0 |
| 49 | 3-9 | 29.8 | 29.6 | 11.2 | 13.5 | 8.7 | 5.4 | 4.7 | 1.0 | 70 | 85 | 29 | 33 | 4.3 | 3.5 | 1.3 | 0.0 | 684.8 | 0.2 | 0.0 |
| 50 | 10-16 | 29.4 | 30.5 | 10.3 | 15.1 | 8.8 | 4.9 | 4.5 | 0.8 | 70 | 88 | 27 | 34 | 4.2 | 3.4 | 1.3 | 0.0 | 684.8 | 0.2 | 0.0 |
| 51 | 17-23 | 29.5 | 29.0 | 10.6 | 14.7 | 8.7 | 5.1 | 4.7 | 2.1 | 69 | 86 | 29 | 36 | 4.3 | 3.3 | 0.9 | 0.7 | 685.5 | 0.1 | 0.0 |
| 52 | 24-31 | 29.2 | 27.4 | 10.7 | 12.2 | 8.6 | 4.8 | 4.8 | 1.7 | 70 | 76 | 31 | 33 | 4.3 | 3.8 | 2.6 | 14.0 | 699.5 | 0.2 | 1.0 |
| | 2010 | | | | | | | | | | | | | | | | | | | |
| 1 | 1-7 Jan | 29.0 | 27.2 | 10.3 | 10.8 | 8.7 | 6.8 | 4.9 | 1.2 | 78 | 81 | 30 | 25 | 4.2 | 4.0 | 1.7 | 0.0 | 0.0 | 0.2 | 0.0 |
| 2 | 8-14 | 29.2 | 28.2 | 11.3 | 13.5 | 8.6 | 5.1 | 6.3 | 2.4 | 71 | 86 | 30 | 37 | 4.5 | 3.3 | 3.4 | 30.9 | 30.9 | 0.2 | 2.0 |
| 3 | 15-21 | 29.9 | 27.5 | 11.6 | 10.8 | 8.9 | 7.3 | 5.4 | 1.0 | 69 | 85 | 28 | 30 | 4.8 | 3.5 | 0.9 | 0.0 | 30.9 | 0.1 | 0.0 |
| 4 | 22-28 | 30.8 | 29.4 | 11.8 | 10.2 | 9.1 | 7.6 | 5.5 | 0.9 | 67 | 69 | 27 | 22 | 5.2 | 4.7 | 1.1 | 0.0 | 30.9 | 0.2 | 0.0 |
| 5 | 29-4 Feb | 31.1 | 30.2 | 12.1 | 13.5 | 9.3 | 5.4 | 5.8 | 1.9 | 61 | 71 | 25 | 27 | 5.6 | 4.7 | 2.8 | 0.0 | 30.9 | 0.2 | 0.0 |
| 6 | 5-11 | 31.3 | 30.6 | 11.9 | 15.2 | 9.1 | 4.1 | 5.6 | 2.7 | 59 | 66 | 23 | 26 | 5.9 | 5.1 | 4.9 | 0.0 | 30.9 | 0.4 | 0.0 |
| 7 | 12-18 | 32.5 | 32.5 | 13.4 | 17.6 | 9.4 | 4.6 | 6.1 | 1.9 | 56 | 66 | 22 | 28 | 6.6 | 5.3 | 0.1 | 0.3 | 31.2 | 0.0 | 0.0 |
| 8 | 19-25 | 33.0 | 33.3 | 13.8 | 16.5 | 9.5 | 6.5 | 6.5 | 2.5 | 57 | 52 | 22 | 24 | 7.3 | 6.6 | 3.3 | 1.0 | 32.2 | 0.5 | 0.0 |
| 9 | 26-4 Mar | 34.7 | 36.4 | 14.8 | 16.5 | 9.6 | 8.0 | 7.0 | 2.3 | 50 | 48 | 17 | 16 | 8.1 | 7.9 | 3.4 | 0.0 | 32.2 | 0.3 | 0.0 |
| 10 | 5-11 | 36.1 | 36.7 | 16.7 | 19.7 | 9.6 | 6.8 | 6.8 | 4.6 | 44 | 53 | 18 | 24 | 9.0 | 9.3 | 2.1 | 2.4 | 34.6 | 0.3 | 0.0 |
| 11 | 12-18 | 37.3 | 37.2 | 17.5 | 18.6 | 9.6 | 6.6 | 6.9 | 3.2 | 42 | 62 | 17 | 23 | 9.5 | 8.0 | 2.5 | 13.5 | 48.1 | 0.3 | 1.0 |
| 12 | 19-25 | 38.5 | 40.9 | 18.3 | 21.7 | 9.6 | 6.6 | 6.9 | 2.5 | 37 | 42 | 13 | 23 | 10.5 | 10.4 | 0.3 | 0.0 | 48.1 | 0.1 | 0.0 |
| 13 | 26-1 Apr | 39.0 | 40.5 | 19.7 | 24.5 | 9.6 | 6.0 | 7.6 | 5.9 | 36 | 55 | 15 | 32 | 11.3 | 13.0 | 2.9 | 0.0 | 48.1 | 0.3 | 0.0 |

| Table 2. Monthly Weather data for the year 2009-2010 Recorded at Meteorological Observatory Department of Agronomy Dr PDKV., Akola | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Actual | 2009 and 2010 | | | | | | | Normal | 1971-2000 | | | | | | |
| Month | T MAX (°C) | | T MIN (°C) | | BSH (hrs) | | Ws (km/hr) | | RHI (%) | | RHII (%) | | Evap (mm) | | RF (mm) | | CRF (mm) | Rainy Days | |
| 2009 | N | A | N | A | N | A | N | A | N | A | N | A | N | A | N | A | | N | A |
| JANUARY | 29.8 | 31.9 | 11.4 | 15.2 | 8.8 | 5.3 | 5.3 | 1.8 | 68 | 62 | 29 | 25 | 4.8 | 5.4 | 9.0 | 0.0 | 0.0 | 0.9 | 0 |
| FEBRUARY | 32.5 | 35.0 | 13.3 | 17.4 | 9.4 | 6.2 | 6.2 | 2.1 | 57 | 44 | 22 | 18 | 6.6 | 7.4 | 10.2 | 0.0 | 0.0 | 0.8 | 0 |
| MARCH | 37.3 | 38.1 | 17.8 | 21.0 | 9.6 | 7.9 | 7.2 | 4.0 | 41 | 35 | 19 | 17 | 6.0 | 10.5 | 9.5 | 2.3 | 2.3 | 0.7 | 0 |
| APRIL | 41.2 | 42.2 | 23.2 | 24.2 | 10.0 | 8.4 | 9.0 | 4.4 | 35 | 26 | 14 | 14 | 13.7 | 13.4 | 3.1 | 0.0 | 2.3 | 0.4 | 0 |
| MAY | 42.5 | 42.7 | 27.0 | 28.4 | 9.9 | 7.9 | 14.2 | 11.0 | 46 | 46 | 18 | 20 | 16.8 | 16.1 | 16.6 | 42.1 | 44.4 | 1.1 | 4 |
| JUNE | 37.2 | 39.2 | 25.6 | 27.4 | 7.2 | 5.2 | 14.9 | 14.4 | 71 | 62 | 41 | 35 | 10.9 | 14.9 | 150.5 | 141.2 | 185.6 | 7.9 | 3 |
| JULY | 32.5 | 30.7 | 23.7 | 24.0 | 4.5 | 2.5 | 11.9 | 2.2 | 84 | 87 | 61 | 66 | 5.5 | 4.0 | 212.2 | 216.7 | 402.3 | 12.6 | 17 |
| AUGUST | 30.4 | 31.7 | 23.0 | 23.8 | 4.1 | 2.9 | 11.4 | 6.7 | 87 | 85 | 68 | 60 | 4.4 | 5.0 | 215.7 | 72.3 | 474.6 | 9.3 | 3 |
| SEPTEMBER | 32.5 | 33.2 | 22.2 | 23.4 | 6.6 | 5.2 | 7.9 | 5.9 | 84 | 86 | 57 | 50 | 5.0 | 5.2 | 111.1 | 39.6 | 514.2 | 7.5 | 3 |
| OCTOBER | 33.7 | 33.6 | 18.6 | 18.6 | 8.4 | 6.7 | 4.8 | 2.9 | 76 | 82 | 39 | 32 | 5.5 | 5.3 | 52.3 | 67.8 | 582.0 | 2.3 | 4 |
| NOVEMBER | 31.6 | 30.0 | 14.1 | 16.6 | 8.7 | 5.8 | 4.7 | 1.4 | 70 | 84 | 31 | 41 | 4.8 | 4.4 | 20.0 | 102.8 | 684.8 | 1.2 | 4 |
| DECEMBER | 28.3 | 29.0 | 10.6 | 13.6 | 8.8 | 5.1 | 4.6 | 1.3 | 70 | 84 | 30 | 34 | 4.3 | 3.5 | 8.4 | 14.7 | 699.5 | 0.9 | 1 |
| 2010 | | | | | | | | | | | | | | | | | | | |
| JANUARY | 29.8 | 28.2 | 11.4 | 11.3 | 8.8 | 6.7 | 5.3 | 1.4 | 68 | 79 | 29 | 28 | 4.8 | 4.1 | 9.0 | 30.9 | 30.9 | 0.9 | 2 |
| FEBRUARY | 32.5 | 32.2 | 13.3 | 16.1 | 9.4 | 5.4 | 6.2 | 2.3 | 57 | 62 | 22 | 25 | 6.6 | 5.7 | 10.2 | 1.3 | 32.2 | 0.8 | 0 |
| MARCH | 37.3 | 38.6 | 17.8 | 20.6 | 9.6 | 6.6 | 7.2 | 3.6 | 41 | 51 | 19 | 24 | 6.0 | 9.8 | 9.5 | 15.9 | 48.1 | 0.7 | 1 |