

**Line X tester analysis of yield and yield
contributing traits in Pearl millet. (*Pennisetum
glaucum* L.)**

THESIS



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CERTIFICATE – I

*This is to certify that the thesis entitled “Line X tester analysis of yield and yield contributing traits in Pearl millet.” (*Pennisetum glaucum* L.) submitted in partial fulfilment of the requirement of the degree of MASTER OF SCIENCE in Agriculture (Genetics & Plant Breeding) of the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior is a record of the bonafide research work carried out by madhavrav baghel under my guidance and supervision. The subject of the thesis has been approved by Students Advisory Committee and the Director of Instruction.*

No part of the thesis has been submitted for any degree or diploma or has been published. All the assistance and help received during the course of investigations have been duly acknowledged by the scholar.

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CERTIFICATE – II

*This is to certify that the thesis entitled “Line X tester analysis of yield and yield contributing traits in Pearl millet.” (*Pennisetum glaucum* L.) submitted by MADHAVRAV BAGHEL to the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior in partial fulfilment of the requirements for the degree of Master of Science in Agriculture in the Department of **Genetics & Plant Breeding** has been accepted after evaluation by the external examiner and approved by the Students Advisory Committee after an oral examination of the same.*

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Date : / / 2019

Place : Gwalior

(Madhavrav Baghel)

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Chapter - I

INTRODUCTION

Pearl millet (*Pennisetum glaucum* L.) belongs to the family poaceae and genus *Pennisetum*. It is a highly cross pollinated crop with protogynous flowering and wind borne pollination mechanism, which fulfills one of the essential biological requirements for hybrid development. Pearl millet is diploid ($2n=2x=14$) in nature and commonly known as bajra, cat tail millet and Bulrush millet in different part of the world. In India 9 to 10 million hectares of Pearl millet is grown annually, with an average 9.3 million tones production (AICPMIP, 2017). More than dozen states of India produce earl millet as a major crop, some of which are listed here, Rajasthan, Maharashtra, Gujarat, Uttar Pradesh, Haryana, Karnataka, Madhya Pradesh, Tamil Nadu, and Andhra Pradesh (AICPMIP, 2017 & Anonymous b, 2013-14). In Madhya Pradesh area under pearl millet is about 0.1959 million hectares. It produces seed yield approximately 397.8 million tons annually and productivity is approximately 2003 kg/ha (2013-14).The major growing district in MP are Morena, Bhind, Gwalior and some parts of Shivpuri and Jhabua.

Pearl millet is a principal source of energy, protein, vitamins and minerals for millions of poorest people in the regions where it is cultivated. It has 9 to 13% protein, more calories (360 kcal) than wheat and rice probably because of its higher oil content of 5%, of which 50% are polyunsaturated fatty acids. It is rich in calcium (38.0 mg/100g grain), niacin (3.5mg/100 g protein) lysine and tryptophan (0.47mg/100 g protein).

Pearl millet grain is gluten-free millet and it is the only grain that retains its alkaline properties after being cooked so it is ideal for people with gluten allergies. It is also cultivated as green fodder crop in some part of the country. The green fodder is more palatable because it does not have HCN content as that of sorghum.

The magnitude and direction of heterosis assume a great significance since it evaluates the prominent parental lines and their combinations for grain

yield, its attributes and quality characters. The exploitation of heterosis in Pearl millet was considered easy with its protogynous flowering and high out crossing rates. Selection made on phenotypic performance alone does not lead to expected success in hybrid breeding. The study on general combining ability of parents is essential for selection. Since general combining ability (gca) estimate the average performance of a line in crosses, reflects the breeding value of the line. The breeding value of the pollinator line depends on testers and interacts with the testing environments. Combining ability studies, therefore, aid in rejection of poor pollinators. The Line $\times$ Tester mating design developed by Kempthorne (1957) helps in evaluating the potential of new hybrids with their parents.

Knowledge of genetic divergence among genotypes, genetic variability, heritability and expected genetic advance association between characters cause and effect relationship are the prerequisites for precise evaluation and successful utilization of available material for the development of high yielding genotypes. The present study is being undertaken with the following objectives:

1. To estimate the genetic variability for various characters under study.
2. To estimate the heritability and genetic advance for various traits under study.
3. To estimate the general combining ability of parent and specific combining ability of their hybrids.
4. To estimate the heterosis with better parent.

Chapter-II

REVIEW OF LITERATURE

The relevant literatures related to various aspects of present study are reviewed under the following heads.

2.1 Genetic Variability

2.2 Heritability and genetic advance

2.3 Combining ability studies (GCA and SCA) and genetic component

2.4 Heterosis

2.1 Variability analysis:

Kulkarni *et al.* (2000) observed magnitude of phenotypic (PCV) (39.50%) and genotypic coefficient of variation (GCV) (24.83%) were highest for grain yield. Days to 50% flowering recorded (77.48%) heritability estimates. The minimum differences between GCV and PCV for days to 50% flowering, plant height, test weight and grain number/cm² indicated less environmental effect and was reflected in the high heritability estimates for these traits.

Borkhataria *et al.* (2005) studied the genotypic and phenotypic coefficient of variation (GCV and PCV), heritability, genetic advance (GA) and correlation for 7 characters days to flowering, number of effective tillers per plant, plant height, ear head length, ear head girth, 1000-seed weight and grain yield per plant). A wide range of variation was observed for all characters. Number of effective tillers per plant, 1000-seed weight and plant height had high heritability, high GCV and high GA, which indicate the role of fixable type of gene effects. Highly significant and positive correlation for ear head girth, number of effective tillers per plant, plant height and 1000-seed weight with grain yield indicated the major role of these characters in grain yield.

Sumathi *et al.* (2010) studied a field trial was laid out with 47 pearl millet genotypes and the observations were recorded on days to 50% flowering, plant height, number of tillers per plant, ear head length, ear head breadth, root

length, shoot length, root shoot ratio and seed yield per plant. The phenotypic co-efficient of variation (PCV) was greater than genotypic co-efficient of variation (GCV) for all the characters studied; this shows the influence of the environmental effect on the characters. The traits, number of tillers per plant, ear head length, root-shoot ratio and seed yield showed moderate PCV and GCV while the traits, days to 50% flowering, plant height, ear head breadth, root length and shoot length showed low PCV and GCV.

Shashi kant *et al.* (2012) studied a wide range of variability In pearl millet. The analysis of variance revealed significant differences among the genotypes for all the traits viz. standard germination (%), germination rate, days to 50% flowering, plant height (cm), ear length (cm), ear girth (cm), effective tillers (numbers/plant), total tillers (numbers/plant), dry fodder yield (g/plant), biological yield (g/plant), grain yield (g/plant), harvest index (%) and 1000-grain weight (g) which justify the presence of adequate variability with regard to the important traits under study.

Drabo *et al.* (2013) studied the genetic variability, and to estimate the broad sense heritability and the genetic advance. Analysis of variance revealed highly significant differences ($P < 0.01$) between the genotypes for all the characters studied except the number of productive tillers. The 12 significant characters were into four principal components each having eigen values greater than 1.00 and explained 76% of the total variation. The phenotypic coefficient of variation (PCV) was moderately higher than the genotypic coefficient of variation (GCV). High estimates of broad sense heritability (52-98%) were recorded for all the characters. All the characters, except stem width, recorded moderate to high genetic advance as per cent of the mean expected from selection of 5% best lines, coupled with high broad sense heritability.

Kumari Vinodhana *et al.* (2013) studied a high magnitude of variation in the experimental material of this study was reflected by high values of mean and range for almost all the characters. The results indicated that the genotypes 15010 recorded early flowering (38 days), ICTP 8203 recorded

highest mean value for thousand seed weight (14.50g) and seed yield potential (6.50), 5713 for panicle length (53.50 cm) and panicle thickness (10.25mm), 6510 for plant height (330.50cm) and green fodder yield potential (6.50), 18116 for total number of tillers (6.50) and productive tillers (5.00) and 18780 for spikelet density (7.50) which indicated that these genotypes can be selected as a parents in pearl millet improvement programme for the development of elite varieties/hybrids. The PCV and GCV estimates were found to be high for seed yield potential followed by green fodder yield potential, panicle length, spikelet density, thousand seed weight and total number of tillers which suggests that there is enough scope for selection based on these characters.

Subi *et al.* (2013) founded highly significant differences ($P \leq 0.01$) were observed for days to 50% flowering and days to maturity in the both seasons, for plant height, leaf area, number of grains/plant, 1000 grain weight and grain yield (t/ha) and panicle length. Also highly significant differences were observed for genotypes and genotypes $\times$ seasons interaction for days to 50% flowering and days to maturity. In general phenotypic coefficients of variation (PCV) estimates were higher than genotypic coefficients of variation (GCV) estimates for all the studied characters in all genotypes displaying the influence of environment effect on the studied characters. The combined results for heritability showed that the high estimates of heritability and genetic advance were scored for days to 50% flowering and days to maturity indicating that these characters were under the control of additive genetic effects.

Sathya *et al.* (2014) Studied in a RIL mapping population developed by crossing PT 6029 $\times$ PT 6129 was evaluated for various genetic variability parameters. Analysis of variance revealed high significant values for all the 11 characters studied. Phenotypic coefficient of variation (PCV) was higher than genotype coefficient of variation (GCV) for all the characters indicating the influence of environment on the characters. High PCV and GCV were observed for yield per plant and grain weight per ear head. The high heritability was recorded for all the traits except for days to 50% flowering, days to maturity and ear head girth. High heritability coupled with high genetic advance as per cent

of mean was observed for 1000 grain weight, number of productive tillers, single ear head grain weight, single ear head weight, single plant yield and plant height.

Sabiel *et al.* (2014) studied the Genotypic and phenotypic variability, heritability in a broad sense and genetic advance were estimated in a randomized complete block design with four replications. High genotypic coefficient of variation, heritability estimate (above 95 %) and genetic advance were recorded for grain yield (kg/ha) followed by straw yield (kg/ha) in both seasons. A number of heads/plant expressed low genetic advance with low heritability in both seasons. Highly significant and significant different among genotypes were found for all characters except number of heads/plant was observed non-significant. The high yielding genotypes were Dembi (Yellow), Sudan1 and SADC (Long) with grain yields of 499.8, 424.9 and 421.5 kg/ha, respectively. Grain yield kg/ha was significant and positively correlated with straw yield (kg/ha), plant height, number of heads/plant and 1000- grain weight, while significant and negative correlated with days to 95% maturity.

Kumar *et al.* (2015) studied the genetic variability, heritability and genetic advance in the pearl millet hybrids. The phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) in all the characters. The highest GCV associated with high heritability of with good genetic advance was observed for biological yield per plant followed by harvest index. The lowest variability associated with low heritability and low genetic advance as per cent of mean was observed for plant height

2.2 Heritability and Genetic advance:

Sharma *et al.* (2003) observed highly significant differences among the accessions for days to heading, plant height, number of tillers per plant and stem thickness. The genotypic and phenotypic coefficients of variation were more or less similar for all the characters. Broad sense heritability varied from 61% to 97%, confirming that genotypic variance contributed substantially to the total variance.

Bortkhataria *et al.* (2005) observed wide range of variation for days to flowering, number of effective tillers per plant, plant height, earhead length, earhead girth, 1000-seed weight and grain yield per plant in eighteen inbred lines (male parents) and 11 male sterile lines (female parents) and their 22 selected hybrids of pearl millet grown during kharif 1996, in Gujarat. Number of effective tillers per plant, 1000-seed weight and plant height had high heritability, high GCV and high GA, which indicate the role of fixable type of gene effects.

Varu *et al.* (2005) observed a wide range of genotypic and phenotypic variability for grain yield per plant, ear head girth, effective tillers per plant, ear head length, plant height, days to maturity and days to 50% flowering in 70 genotypes of pearl millet. High heritability and high genetic advance were observed for ear head girth, ear head length and plant height, indicating the prevalence of additive gene action.

Vidyadhar *et al.* (2006) conducted a study to estimate the heritable variation of yield components. The genotypic coefficient of variation (GCV) was higher for grain yield (48.14 kg), followed by tiller number (31.43) and fodder yield (23.28 kg), indicating that the observed variation was due to genetic influence. The estimates of higher heritability was observed for tiller number (96%) followed by grain yield (95%), days to 50% flowering (88%) and fodder yield (59%), while it was low for days to maturity (17%), plant height (9.8%), ear girth (7.5%) and ear length (5.9%).

Bhoite *et al.* (2008) had undertaken a study to determine the genotypic and phenotypic variation in 26 genotypes. A wide range of variability was observed for all the characters studied. Higher heritability coupled with genetic advance as percentage of mean was noticed for ear head girth, grain yield, plant height, fodder yield, days to maturity and days to 50% flowering indicating the presence of additive gene action and direct selection may be effective.

Sumathi *et al.* (2010) observed 47 pearl millet genotypes to assess the magnitude of variability and to understand the heritable component of variation

present in the biometrical characters. The phenotypic coefficient of variation (PCV) was greater than genotypic coefficient of variation (GCV) for all the characters under studied showing the influence of the environmental effect on the characters. High heritability was observed for all the traits under study. High heritability combined with high genetic advance (as per cent of mean) was observed.

Bhadalia *et al.* (2011) observed highly significant genotypic differences for all the ten characters studied. The characters, namely, days to 50% flowering, days to maturity, ear head length, ear head weight, plant height, 1000-grain weight, fodder yield per plant and grain yield per plant were less affected by environment showing close correspondence between genotypic co-efficient of variation and phenotypic co-efficient of variation. It was observed that the characters ear head weight, fodder yield per plant and grain yield per plant had high magnitude of phenotypic range, genotypic co-efficient of variation, phenotypic co-efficient of variation, heritability and genetic advance expressed as percentage of mean, which revealed role of fixable type of gene effects. Hence, these characters can be improved through simple selection process.

Govindaraj *et al.* (2011) observed high heritability for all the traits under study except seed weight which had moderate heritability. High value of heritability coupled with high genetic advance as per cent of mean were recorded for number of productive tillers, crude protein, crude fat, phytate, phosphorus, calcium, iron and zinc content, indicating the important role of additive gene action for the expression of these characters. Therefore, selection based on these characters could bring about desired improvement in yield as well as nutritional quality of pearl millet cultivars.

Chaudhary *et al.* (2012a) reported highly significant differences among the genotypes for all the nine characters studied. The relative magnitude of phenotypic co-efficient of variation (PCV) was slightly higher than corresponding genotypic co-efficient of variation (GCV) for all the characters

studied which indicated that these characters had interactions with environment to some extent. The variability analysis revealed that ear head weight, number of effective tillers per plant, fodder yield per plant and grain yield per plant had high magnitude of phenotypic range, genotypic co-efficient of variation, phenotypic co-efficient of variation, heritability and genetic advance expressed as percentage of mean thereby suggesting the importance of additive gene action. Hence, these characters can be improved through simple selection process.

Manga (2013) observed high estimates of phenotypic (PCV) and genotypic coefficients of variation (GCV) for days to flowering, plant height, effective tillers per plant, ear length, ear girth, ear head weight, grain yield, dry fodder yield, biomass, panicle harvest index, harvest index and 500 grain weight. High estimates of heritability were obtained for 500 grain weight, grain yield, ear head weight, biomass and plant height. Genetic advance as percent of mean, were found to be high for grain yield, ear head weight and biomass. These traits also recorded high GCV and heritability.

Subi *et al.* (2013) observed highly significant differences ($P \leq 0.01$) for days to 50% flowering and days to maturity in the both seasons, for plant height, leaf area, number of grains/plant, 1000 grain weight and grain yield (t/ha) in the summer season of 2009, for panicle length in the summer season of 2010. The phenotypic coefficients of variation (PCV) estimates were higher than genotypic coefficients of variation (GCV) estimates for all the studied characters in all genotypes displaying the influence of environment effect on the studied characters. The combined results for heritability showed that the high estimates of heritability and genetic advance were scored for days to 50% flowering and days to maturity indicating that these characters were under the control of additive genetic effects.

Vinodhana *et al.* (2013) reported the high heritability combined with high genetic advance was observed for plant height, total number of tillers, panicle length, panicle thickness, spikelet density, 1000 seed weight, green fodder yield

potential and seed yield potential which showed that these characters were controlled by additive gene effects and phenotypic selection for these characters were likely to be effective.

Bhadaliya *et al.* (2014) studied in 8x8 diallel set, including reciprocals, for grain yield and its 11 component traits in pearl millet. Both GCA and SCA variances were highly significant for all the characters. The ratio of GCA and SCA revealed preponderance of non-additive gene action in expression of all the characters viz., grain yield per plant, days to flowering, days to maturity, number of effective tillers per plant, ear head length, ear head girth, ear head weight, plant height, number grains per square cm, 1000-grain weight, dry fodder yield per plant and harvest index.

Santosh *et al.* (2017) worked on 54 germplasm lines of pearl millet for genetic variability, heritability and genetic advance along with the association of green fodder yield with component traits. The ANOVA showed highly significant differences among the genotypes for all the character studies. The PCV were slightly higher than GCV indicating little influence of environment on the expression of characters, some traits showed positive association with green fodder yield for which indirect selection can be made in future breeding programme to enhance green fodder yield.

2.3 Combining ability analysis

Lakshmana *et al.* (2003) reported that the estimates of general combining ability (GCA) revealed significant variation among the parents for plant height, ear length, number of days to maturity, and number of days to 50% flowering. The estimates of combining ability variances suggested the predominance of non-additive gene effects for most of the yield components. Among the male parents, IPC-1684 recorded significant positive combining ability effects for grain yield, and the greatest positive effects for fodder and grain yields. This line also showed significant negative effect for number of

days to 50% flowering and number of days to maturity. IPC-1684 and IPC-715 for fodder yield; IPC-715, IPC-735, IPC-828, IPC-1470 and IPC-1684 for ear length; and IPC-715, IPC-735, IPC-828 and IPC-1470 for plant height recorded significant positive GCA effect. Six of the 40 crosses (88004 A x IPC-1674, 843 A x IPC-828, 92666 A x IPC-1354, 92666 A x IPC-1674 and 94111 A x IPC-715) were superior, with significantly positive specific combining ability effects for grain yield.

Manga and Dubey (2004) performed a diallel analysis study involving 9 restorer lines of pearl millet, which revealed that restorers 'CZI 1676-2', 'CZI 98/9', 'CZI 9613-1' and 'CZI 9621' not only showed high mean performance but also had significantly high positive general combining ability effects for grain yield. These restorers along with 'CZI 98/6' and 'CZI 96/1604' produced hybrid combinations with high mean performance and specific combining ability effects.

Shanmuganathan *et al.* (2005) recorded data for grain and stover yield and associated characters days to 50% flowering, plant height, number of tillers per plant, number of productive tillers, number of leaves, leaf length and breadth, panicle length and width, stem diameter, and 1000-grain weight). The variances due to general combining ability (GCA) and specific combining ability (SCA) were significant. GCA variances were higher in magnitude than SCA variances for all characters except leaf breadth, indicating the preponderance of additive gene action. For leaf breadth, both GCA and SCA variances were equal, indicating the prevalence of both additive and non-additive gene action. IP20381 was the best combiner for plant height, number of tillers, number of productive tillers, number of leaves, leaf length, stem diameter, grain yield and stover yield. IP19125 was also a good combiner for these characters, in addition to panicle length and width. The per se performance of the parents provided a fairly good indication of their combining ability in most cases, except for panicle width. IP20381 x PT5665 had the highest SCA and per se value for plant height, number of tillers, number of productive tillers and grain yield. IP20381 x GP15071 had the highest SCA and per se value for number of

leaves and panicle width. In general, hybrids having high SCA effects have high per se performance.

Bhanderi *et al.* (2007) studied combining ability in 8x8 diallel set, excluding reciprocals, for grain yield and its 12 attributes in pearl millet. Both GCA and SCA variances were highly significant for all characters. The predictability ratio of GCA and SCA revealed preponderance of additive genetic variance for plant height, ear head length, ear head girth and 1000 grain weight, whereas, non-additive genetic variance for days to 50 per cent flowering, days to maturity, number of effective tillers per plant, fodder yield per plant, harvest index and grain yield per plant, while, both were equally important for number of nodes, ear head weight and threshing index. The parents like J-2420, J-2441, J-2440 and J-2340 were identified as good general combiners for grain yield per plant and some other components. Majority of their crosses had also displayed significant and desirable SCA effects, coupled with high per se performance for grain yield per plant. The hybrids *viz.*, J-2420 x J-2480, J-2340 x J-2440 and J-2440 x J-2420 were the most promising having good SCA. Analyses of crosses revealed majority of the superior crosses were involved high x low; and few cases high x high or low x low general combiners.

Izge *et al.* (2007) identified ACC-1022-1-2SPT and SOSAT-C88 as the best parents in total grain yield considering their per se performance. The parents BONKOK-SHORT, DMR 43, DMR22 and LCIC9702 were identified as the best general combiners in terms of general combining ability (GCA) effects. The hybrids DMR22 x LCIC9702, DMR43 x LCIC9702, DMR22 x LCIC9703-27, D2P29 x EX-BORNO recorded the highest SCA effects in various traits. Similarly, the hybrids D2P29 x DMR43, DMR22 x LCIC9702, DMR43 x LCIC9702, BONKOK-SHORT x SOSAT-C88 and D2P29 x EX-BORNO were the highest in terms of per se performance. It has been observed however, that some hybrids with high specific combining ability (SCA) effects were also high in per se performance. A fair general parallelism existed in most cases between the GCA effects and the performance of the parental lines per se.

Patel *et al.* (2008a) found that non-additive gene action solely governed most of the traits, while the preponderance of additive gene action was observed for ear head length, ear head girth, and test weight. No parent was a good general combiner for grain yield. The cross combination ICMA 96555 x 187 SB followed by JMSA 101 A x 217 SB was the best specific combiner for grain yield.

Patel *et al.* (2008b) indicated that only non additive gene action governed most of the fodder yield attributes from the analysis of combining ability variances. For the expression of days to maturity, both additive and non additive gene action were responsible. The estimates of general combining ability effects indicated that none of the parents was good general combiner for fodder yield. The estimates of specific combining ability revealed that only JMSA-101 A x 217 SB exhibited highest significant and positive SCA effect for fodder yield.

Dangariya *et al.* (2009) studied a 10 x 10 half diallel excluding reciprocals was evaluated to study the combining ability and gene action involved in respect of yield and its attributers in pearl millet. Analysis of variance indicated highly significant differences among mean squares due to general and specific combining ability for all characters studied. The estimates of general combining ability (GCA) effects indicated that the parents D-23, SB-220 and J-2467 emerged as good general combiners for grain yield and its components. Out of 45 crosses combinations only five combinations such as J-2467 x J-2474, J -2454 x J-108, SB -220 x D-23, J- 2475 x D-23 and J -2340 x D -23 showed significant and positive specific combining ability (SCA) effects for grain yield and other yield attributing characters.

Chotaliya *et al.* (2010) studied Combining ability analysis was carried out in a 10 x 10 diallel set, The hybridization programme to exploit their GCA effects for grain yield and some important attributing traits. The hybrids viz., J-2467x J-2474, J-2454 x J-108, J-2480 x D-23, J-2475 x D-23 and J-2340 x J-2480 were the most promising having good SCA, coupled with high *per se*

performance and heterobeltiosis for grain yield. Analyses of crosses revealed majority of the superior crosses were involved high x high or high x low; and few cases low x low general combiners.

Vagadiya *et al.* (2010) studied combining ability in a line x tester fashion for grain yield and 13 component traits using four male sterile lines and 12 restorers in pearl millet. The predictability ratio of GCA and SCA revealed the preponderance of non-additive gene action in the inheritance of all the traits viz., grain yield per plant, days to flowering, length of protogyny, number of nodes per plant, plant height, ear head girth, ear head length, number of effective tillers per plant, ear heads weight per plant, days to maturity, 1000-grain weight, harvest index, threshing index and fodder yield per plant. Female parent JMSA-20073 and male parents J-2290, J-2498 and H-77/833-2 were identified as the best general combiners for grain yield per plant along with many other component traits. Majority of their crosses had depicted significant and desirable SCA effects, coupled with high per se performance for grain yield. Among the 48 crosses, 19 displayed significant and positive SCA effects for grain yield. Of these, three hybrids viz., ICMA-95444 x J-2405, JMSA-20073 x J-2474 and ICMA-98444 x J-2498 were the most promising having good specific combining ability effects in addition to high per se performance and heterobeltiosis for grain yield. These cross combinations also registered significant SCA effects in desired direction for many of the yield attributing characters.

Bhadaliya *et al.* (2014) studied in 8x8 diallel set, including reciprocals, for grain yield and its 11 component traits in pearl millet. Both GCA and SCA variances were highly significant for all the characters. The ratio of GCA and SCA revealed preponderance of non-additive gene action in expression of all the characters viz., grain yield per plant, days to flowering, days to maturity, number of effective tillers per plant, ear head length, ear head girth, ear head weight, plant height, number grains per square cm, 1000-grain weight, dry fodder yield per plant and harvest index.

Patel *et al.* (2014) conducted the experimental material consisted of ten restorer lines and their 45 F1s developed through half diallel mating design. The analysis of variance for combining ability revealed that mean squares due to parents and F1s were significant for all characters studied except number of effective tillers per plant, thereby suggesting the importance of both additive and non additive gene effects. AIB-34 was only good general combiner for grain yield per plant. While, in case of hybrids, AIB-9 x AIB-34 and AIB-9 x AIB-29 were good specific combiners for grain yield per plant, number of effective tillers per plant and average ear head weight.

Singh *et al.* (2014) studied Combining ability analysis in pearl millet. The analysis of variance for combining ability analysis using data pooled over three environments on parents and F1's revealed that variance due to GCA and SCA were significant for all the characters under study. This indicates those both additive and non additive genes are involved in the inheritance of these characters. The parents 76-80, 41-50 and 71-75 emerged as good general combiners for dual purpose (grain and dry fodder yield). Therefore, these parents could be used intensively in hybridization programme to develop inbred with several desirable characters and grain yield improvement in pearl millet. Some promising crosses 26-30 x 41-50, 26-30 x RIB-135-144, 41-50 x 61-70, 41-50 x RIB- 135-144, RIB-20 x 71-75 and 76-80 x 51-60 were identified having high SCA effects in desirable direction for dual purpose (grain and dry fodder yield) and other related desirable traits.

Mungra *et al.* (2015) studied the combining ability and gene action for grain yield and 14 quantitative traits in pearl millet. The ratio of GCA variance and SCA variance indicated the predominance of non-additive gene action for the characters days to 50% flowering, length of protogyny, number of nodes per plant, plant height, number of productive tillers per plant, ear head weight per plant, days to maturity, 1000-grain weight, dry fodder yield per plant, grain yield per plant, harvest index and threshing index and additive gene action for ear head girth and ear head length. Among the lines, ICMA-04111, ICMA-92777 and ICMA-05333 and the testers J-2534, J-2454 and J-2507 displayed high

GCA effect for grain yield per plant and for some desirable traits. Significant and positive SCA effect for grain yield per plant was displayed by the cross ICMA-05333 x J-2527 followed by ICMA-05333 x J-2340, JMSA-20064 x 283-SB-11, ICMA-92777 x STPT-115, ICMA-04999 x J-2539 and JMSA-20071 x J-2507.

Kanatti et al.(2016) Crossed of two broad based and diverse populations of pearl millet with 14 diverse inbred lines in each of two experiments to produce 56 top cross hybrids, which were evaluated along with their parental lines for grain Fe and Zn densities. Results showed that there was highly significant and moderately high positive correlation between the top cross hybrid performance per se (a measure of GCA) produced with the two testers, both for Fe and Zn densities in both experiments.

Solanki *et al.* (2017) analyzed of variance revealed significant difference among all the hybrids for all the characters studied. Ratio of GCA and SCA variances was below unity for all the characters which indicate of greater role of non-additive genetic variance in the inheritance of these traits. The per cent contribution of lines to total variance in hybrids were higher in magnitude as compared to testers for the characters ear head length (cm), test weight (g) and harvest index while testers were higher for the characters days to 50% flowering, days to maturity, plant height (cm), no. of effective tillers/plant, ear head diameter, biological yield/plant (g) and seed yield/ plant (g) and lines × testers were higher for characters viz. harvest index, ear head diameter (cm) and ear head length.

2.4 Heterosis

Ramamoorthi and Govindarasu (2000) studied the magnitude of heterosis over better parent in 10 pearl millet hybrids produced by crossing 5 inbred lines without reciprocals. The heterosis for grain yield/plant ranged from -10.43 to 21.30% over the better.

Blummel and Rai (2003) conducted a study to assess heterosis in 42 *Pennisetum glaucum* top-cross hybrids for stover quality traits. Significant positive as well as negative heterosis effects were observed for grain yield and stover yield. Positive heterosis trends were observed in 32 hybrids for grain yield and in 12 hybrids for stover yield.

Manga and Dubey (2004) observed good amount of heterosis for grain yield, earliness, productive tillers per plant, ear length, ears per ha, ear weight, 1000-grain weight, threshing ratio, harvest index and biomass. On the basis of high heterosis (96.2-300.7%) for grain yield, parents 'CZI 9621', 'CZI 98/6', 'CZI 98/9', 'CZI 96/1604', 'CZI 9613-1', 'CZI 1676-2' and 'CZI 962' were found to be promising, and produced high-yielding hybrids when crossed with male-sterile lines. Crosses showing high mean performance and heterosis for grain yield were 'CZI 9621' x 'CZI 98/6' (1645 kg/ha), 'CZI 96/1604' x 'CZI 98/6' (1616 kg/ha), 'CZI 9624' x 'CZI 98/9' (1603 kg/ha), 'CZI 962' x 'CZI 9621' (1431 kg/ha), and 'CZI 9613-1' x 'CZI 9621' (1381 kg/ha).

Shanmuganathan *et al.* (2005) recorded data for grain and stover yield and associated characters (days to 50% flowering, plant height, number of tillers per plant, number of productive tillers, number of leaves, leaf length and breadth, panicle length and width, stem diameter, and 1000-grain weight). The mean squares of parents and hybrids were significant for all characters studied. Parents vs. hybrids interaction mean squares indicated the existence of heterotic effects for all characters except panicle width.

Bhandari *et al.* (2007) reported that the hybrids viz., J-2420 x J-2480, J-2340 x J-2440 and J-2440 x J-2420 were the most promising with high per se performance and heterobelteosis for grain yield.

Izge *et al.* (2007) reported that considerable higher parent heterosis was exhibited among the hybrids in almost all the traits. Higher parent heterosis of 85.13 and 114.05 for yield per plant and total grain yield per hectare, respectively, was obtained. There is therefore a great potential for the production of hybrid pearl millet cultivars with increased total grain yield. The preponderance of non-additive genetic effect and the tremendous levels of higher parent

heterosis observed among the traits in the parents and the hybrids studied would be a great asset in choosing pearl millet cultivars for inters crossing and development of cultivars and hybrids for commercial production.

Scheffler *et al.* (2008) studied heterosis (H) for each population cross was determined or grain yield. The population cross, BS10 (FR) C14 by BS29(R)C3, the greatest grain yield at the F1 (8.30 t ha⁻¹) and F2 (6.71 t ha⁻¹) generations, the lowest estimate of ID (1.59 t ha⁻¹), but the estimate of H (1.90 t ha⁻¹) was similar to the average estimate of H (1.74 t ha⁻¹) for all crosses. BS10(FR)C14 is a selected strain within the Iowa Stiff Stalk Synthetic heterotic group, whereas BS29(R)C3 is an adapted strain of Suwan-1 a tropical cultivar that originated in Thailand. BSSS(R)C14 (0.63* t ha⁻¹) and BS13(S)C9 (0.54* t ha⁻¹), The data provide information on the relative performance of the populations assigned to the respective heterotic groups of the U.S. Corn Belt, and that BS29(R)C3 includes germplasm that could enhance the genetic variation of the non-Iowa Stiff Stalk Synthetic heterotic group.

Vetriventhan *et al.* (2008) reported that the extent of hybrid vigour in F1 for grain yield and its components. Highest and significant negative relative heterosis, heterobeltiosis and standard heterosis was observed in the cross ICMA 94111A x PT 5259 and the same combination showed negative relative heterosis, heterobeltiosis and standard heterosis for the trait plant height. The cross combination 'ICMA 94111A x PT 5423' showed higher magnitude of positive relative heterosis and heterobeltiosis for the trait total number of tillers. Highest and significant positive standard heterosis was recorded in 'ICMA 88004A x PT' 5164 for total number of tillers. The hybrid cross 'ICMA 94111A x PT 5423' was showed highest and significant relative heterosis, heterobeltiosis and standard heterosis for total productive tillers. The hybrid ICMA 88004A x PT 5181 recorded highest and significant positive standard heterosis for ear head length and 100 grain weight, ICMA 88004A x PT 5200 for ear head girth. 13 hybrids recorded highly significant standard heterosis for grain yield per plant. among 150 hybrids studied, seven hybrids namely ICMA 88004 A x PT 5164, ICMA 88004 A x PT 5200, ICMA 88004 A x PT 5232, ICMA 88004 A x PT 5130,

ICMA 88004 A x PT 5173, 732 A x PT 5172 and ICMA 88004 A x PT 5809 were selected as best crosses since they expressed high standard heterosis over standard hybrid (MBH163) for many of the traits studied for high grain yield.

Chotaliya *et al.* (2009) crossed ten diverse inbreds in a diallel fashion, excluding reciprocals, to study the magnitude of heterosis and to identify new restorers in pearl millet. The degree of heterosis varied from cross to cross for all the characters studied. The high magnitude of heterobeltiosis was found for grain yield per plant, fodder yield per plant, plant height, number of effective tillers per plant, ear head weight, 1000 grain weight and harvest index, while moderate heterosis over better parent was exhibited for ear head girth, ear head length and number of nodes. Days to 50 per cent flowering and days to maturity displayed the least heterotic values. The maximum positive heterosis for grain yield per plant was observed to be 194.65 and 153.22 per cent over mid and better parent, respectively. The cause of heterosis in grain yield might be due to heterosis in its yield attributing traits, mainly, 1000 grain weight, fodder yield per plant, plant height, number of effective tillers per plant, ear head weight, ear head length, and harvest index. The crosses viz., J-2480 x D-23, J-2467 x J-2474 and J-2467 x D-23 depicted high heterosis, per se performance, coupled with high SCA and involved both or at least one good combiner parents. Such crosses have potential to throw desirable transgressive segregants in the segregating material for the development of high yielding inbred lines in pearl millet.

Vagadiya *et al.* (2010) estimated the nature and magnitude of heterosis for grain yield and its attributing traits involving four CMS lines and 12 restorers in pearl millet. The magnitude of heterosis varied from cross to cross for all the characters studied. The high level of heterosis was observed for grain yield per plant and ear head length, while moderate heterosis was found for length of protogyny, plant height and harvest index. The number of effective tillers per plant and ear head girth exhibited the least heterosis. Maximum positive heterosis for grain yield per plant over better parent and standard check (GHB-719) was observed to be 105.71 and 11.30 per cent, respectively. The cause of heterosis in grain yield might be due to its component traits, mainly, ear head

length, plant height and harvest index. Three most promising hybrids viz., JMSA-20072 x J-2290, JMSA-20073 x H- 77/833-2 and ICMA-98444 x J-2498 having high heterosis, *per se* performance, coupled with high SCA effects and involved both or at least one good combiner parents for grain yield.

Vagadiya *et al.* (2010a) reported that 19 hybrids manifested higher heterosis over the better parent for most of the yield attributes and grain yield.

Davda *et al.* (2012) observed heterosis in both directions for most of the characters. The high standard heterosis was obtained for grain yield, harvest index, days to 50 per cent flowering, days to maturity and length of protogyny; medium level of heterosis was found for plant height and threshing index, and low for number of nodes per plant. Early hybrids viz., ICMA-98333 x IPC-1518, JMSA-2005 x IPC-1501 and ICMA-00777 x IPC-1518 were the best heterotic hybrids for grain yield and its three or more component traits.

Jethva *et al.* (2012) carried out the heterosis study for grain yield and its attributes in pearl millet (*Pennisetum glaucum* (L.) R.Br.) through Line x tester mating design in three different seasons. In general, it is inferred that the magnitude of heterosis effect was high for grain yield per plant, fodder yield per plant, 1000-seed weight, ear head weight, harvest index and number of effective tillers per plant; moderate for ear head length and threshing index and low for ear head girth. The hybrids ICMA 95222 x J 2372 and JMSA 101 x J 2296 exhibited the highest, significant and positive heterotic effect and mean performance for grain yield per plant and some of its important component traits.

Bhadalia *et al.* (2013) observed high magnitude of standard heterosis for grain yield plant⁻¹, number of effective tillers plant⁻¹, ear head weight and harvest index; while moderate to low heterosis over standard check hybrid (GHB-744) was found for rest of the traits under study. The highest positive heterosis for grain yield plant⁻¹ over better parent and standard check was observed to be 77.82 and 42.91 per cent, respectively. The cause of heterosis in grain yield might be due to heterosis in its component traits, mainly, ear head weight and harvest index. The crosses viz., J-2454 x J-2467, J-2454 x J-2511 and J-2340 x J-2511 displayed high *per se* performance, high positive and significant

standard heterosis, heterobeltiosis along with high SCA had involved at least one good combiner parent.

Singh *et al.* (2013) Studied on heterosis for seed yield and its component traits. The heterosis over better parent was found significant in desirable direction for number of capsules on main raceme in JP 96 x JI 368; for length of main raceme, effective length of main raceme and number of capsules on main raceme in cross JP 96 x JI 372; and for oil content in cross JP 101 x SKI 215. Inbreeding depression was observed significant for shelling outturn, seed yield per plant and 100-seed weight in JP 96 x JI 368; for length and effective length of main raceme, number of capsules per plant and oil content in cross JP 96 x JI 372; and for days to maturity, plant height, number of nodes and 100-seed weight in cross JP 101 x SKI 215. In majority of cases, a close agreement was seen between the observed and the expected values of relative heterosis, heterobeltiosis and inbreeding depression in all the three castor crosses with few exemptions.

Manoj kumar *et al.* (2017) reported that 10 CMS lines were crossed with six testers in a line x tester design to study the extent of heterosis in pearl millet for yield and its component traits. Heterosis was observed in both directions for most of the characters. The standard heterosis for grain yield per plant ranged from - 18.42 to 355.96 per cent. Highest and significant positive standard heterosis for grain yield per plant was recorded in ICMA 04999 x BIB-76 (355.96) followed by JMSA 20042 x BIB-40 (315.26), ICMA 04999 x BIB-40 (300.7) and ICMA 04999 x BIB -65 (294.91).

Chapter-III

MATERIALS AND METHOD

The experimental materials used and methods adopted during the present investigation entitled “Line X tester analysis of yield and yield contributing traits in Pearl millet.” (*Pennisetum glaucum* L.).

Location:

Experiment was conducted at the Research Farm of College of Agriculture, Gwalior located in the Gird region (Agro climatic zone VI wheat-pearl millet crop zone). The Gwalior is situated at an altitude of 211.52 meter above mean sea level, 26° 13' N Latitude and 78° 14' E Longitude. The soil is sandy loam, low in available nitrogen, medium in phosphorus and high in potash with pH of 8.5

Climate:

The summer is hot and dry, May and June are the hottest months and minimum and maximum temperature varies from 46°C to 29.5°C, respectively. December and January constitutes the cooler months of the year and minimum temperature ranges from 4°C to 12.3°C. The average rainfall ranges between 115 to 180 mm most of which is received in the months of July, August and September with few showers in winter months.

During investigation, maximum temperature was ranging from 40.2°C to 44.4°C and minimum temperature from 22.5°C to 26.9°C. The total rainfall received was 174 mm from February to May 2015 during the summer season. Overall season was favourable for crop growth.

Table 3.1: Weekly meteorological data during the crop season (2017-18)

STD Week	STD Week period	Temperature		Relative humidity (%)		Rainfall (mm)	Evapo-ration (mm.)
No.		Max	Min	Morn	Even	Weekly	Weekly
30	July(23-29-2017)	32.0	25.7	87.1	74.6	4.2	3.2
31	July-Aug.(30-5-2017)	34.5	26.6	81.7	58.3	0	4.7
32	Aug.(6-12-2017)	32.5	26.5	79.6	77.3	92.2	2.3
33	Aug.(13-19-2017)	34.7	27.3	78.0	58.0	0	6.6
34	Aug.(20-26-2017)	35.7	26.3	86.0	56.7	19	3.9
35	Aug.-Sep.(27-2-2017)	31.1	24.9	91.6	74.7	196.2	2.1
36	Sep.(3-9-2017)	34.5	25.5	82.4	56.4	1.6	4.4
37	Sep.(10-16-2017)	36.3	26.2	80.3	52.7	0	4.7
38	Sep.(17-23-2017)	33.9	24.7	85.6	59.6	72.3	3.3
39	Sep.(24-30-2017)	35.5	23.4	81.3	50.6	0	4.9
40	Oct.(1-7-2017)	36.1	21.1	86.7	39.7	0	4.5
41	Oct.(8-14-2017)	36.7	21.7	82.7	33.6	0	4.6

Experimental material

The experimental material consisted of 4 male sterile lines and 10 inbred and their 40 crosses. The parents were crossed in line x tester mating design during Kharif season of 2017. The pedigree of lines and testers are listed in table: 3.2

The experiment was laid down in a randomized block (RBD) design with 2 replications. Each entry was sown in single row adopting a row spacing of 50 cm. And plant spacing of 15 cm. The material was planted on 23th July; 2017. The recommended package of practices of pearl millet crop was followed during the conduct of experiment.

Table: 3.2. Detail of experimental material used for present investigation

S.No.	Male sterile line	S.No.	Tester
1	RP-81	1	PDRLT-106
2	RP-98555	2	PDRLT-115
3	ICMA-96666	3	PDRLT-117
4	ICMA- 05333	4	PDRLT-110
		5	PDRLT-116
		6	R-15081
		7	R-15155
		8	R-15248
		9	R-15468
		10	R-15545
S.No.	Cross	S. No.	Cross
1	RP-81 X PDRLT-106	21	RP-81X R-15081
2	RP-98555 X PDRLT-106	22	RP-98555 X R- 15081
3	ICMA- 96666 X PDRLT-106	23	ICMA-96666 X R-15081
4	ICMA-05333 X PDRLT-106	24	ICMA-05333 X R-15081
5	RP-81X PDRLT-115	25	RP-81X R-15155
6	RP98555 X PDRLT-115	26	RP-98555 X R-15155
7	ICMA- 96666 X PDRLT-115	27	ICMA-96666 X R-15155
8	ICMA-05333 X PDRLT-115	28	ICMA-05333 X R-15155
9	RP-81X PDRLT-117	29	RP-81 X R-15248
10	RP-98555 X PDRLT-117	30	RP-98555 X R-15248
11	ICMA-96666 X PDRLT-117	31	ICMA-96666 X R-15248
12	ICMA-05333 X PDRLT-117	32	ICMA-05333 X R-15248
13	RP-81 X PDRLT-110	33	RP-81 X R-15468
14	RP-98555 X PDRLT-110	34	RP-98555 X R-15468
15	ICMA-96666 X PDRLT-110	35	ICMA-96666 X R-15468
16	ICMA- 05333 X PDRLT-110	36	ICMA-05333 X R-15468
17	RP-81X PDRLT-116	37	RP-81X R-15545
18	RP-98555 X PDRLT-116	38	RP-98555 X R-15545
19	ICMA- 96666 X PDRLT-116	39	ICMA- 96666 X R-15545
20	ICMA-05333 X PDRLT-116	40	ICMA-05333 X R-15545

Observations recorded:

Observations were recorded on five plants basis. The observations were recorded on Plant height (cm), number of productive tillers per plant, number of nods per plant, flag leaf length (cm), panicle length, days to 50% flowering, grain yield per plant (g), days to maturity and Harvest index (%).

Days to 50% flowering:

The number of days was taken from date of sowing to the date of stigma emergence on the main panicle of 50 per cent plant in each row.

Days to maturity:

Numbers of days were counted from the date of sowing to maturity of the plant.

Reproductive phase:

Reproductive phase were counted from days to maturity minus days to 50% flowering.

Number of productive tillers per plant:

Total number of panicle bearing tillers of 5 randomly selected plants were counted and averaged.

Number of nodes per plant:

The total number of nodes on the main tiller was counted before harvesting.

Flag leaf length (cm):

It is length of flag leaf from base to the tip of the leaf that was measured by scale in centimetre.

Plant height (cm):

Plant height was measured from the base of the plant to top of the panicle of main tiller at the maturity stage.

Panicle length:

It is measure from base of panicle to tip of panicle in centimetre.

Harvest index (%): Harvest index (%) was calculated by the formula:

$$HI (\%) = \frac{\text{Seed yield per plant (g)}}{\text{Biological yield per plant (g)}} \times 100$$

Grain yield per plant (g):

Grain yield of five plants were recorded in grams and their average was computed and designated as single plant grain yield.

Fodder yield per plant:

After complete drying of stock (fodder). The weight was recorded for each genotype in gram per plant.

Statistical procedures:

(I) Analysis of variance: The mean of each character were analyzed following the procedure given by Panse and Sukhatme (1967) for randomized block design.

(a) The model of randomized complete block design is expressed as follows:

$$y_{ij} = \mu + g_i + b_j + e_{ij}$$

Where,

μ = General mean effect

g_i = Effect of the i^{th} genotype

b_j = Effect of j^{th} replication over the genotype

e_{ij} = Random error associated with each observation

The skeleton of analysis of variance for parents and crosses explained as follows:

Table: 3.3 Analysis of variance for crosses and parents in randomized block design.

Source of variance	Degree of freedom	Mean sum of square
Replications	$(r - 1)$	MSS_r
Genotypes	$(g - 1)$	MSS_t
Parents	$(p - 1)$	MSS_p
Crosses	$(c - 1)$	MSS_c
C vs R	1	$MSS_p \text{ vs. } MSS_c$
Error	$(r - 1)(t - 1)$	MSS_e
Total	$(rt - 1)$	

Where, r = number of replications, g = number of genotypes, p = number of parents, c = number of crosses,

(b) Standard error of mean, critical difference and coefficient of variation:

(i) **Standard error of mean:** Standard error of mean was calculated using the following formula,

$$S.E(m) \pm = \sqrt{\frac{MSS_e}{r}}$$

Where,

$S E(m) \pm$	=	Standard error of difference
MSSe	=	Error mean sum of squares
r	=	Number of replications

(ii) **Standard error of difference:** Standard error of difference was calculated using the following formula,

$$S.E.m(d) \pm = \sqrt{\frac{2 \text{ MSSe}}{r}}$$

Where,

$S E(m) \pm$	=	Standard error of difference
MSSe	=	Error mean sum of squares
r	=	Number of replications

(iii) **Critical difference:** It was calculated as formula given below

$$C. D. (5\%) = S E(d) \times 't' \text{ value at 5\% level of significance}$$

Where,

C. D	=	Critical difference
$S E(d) \pm$	=	Standard error difference
't'	=	t table value at error degree of freedom at 5% level

of significance.

(II) Estimation of phenotypic and genotypic coefficients of variation:

The phenotypic and genotypic coefficients of variation in per cent were computed by the following formulae given by Burton (1952).

$$GCV\% = \frac{\text{Genotypic standard deviation}}{\text{Mean}} \times 100$$

$$PCV\% = \frac{\text{Phenotypic standard deviation}}{\text{Mean}} \times 100$$

Where,

PCV = Phenotypic coefficient of variation

GCV = Genotypic coefficient of variation

The coefficient of variation were categorized as proposed by Sivasubramanian and Madhava Menon (1973)

- 0-10% - Low
- 10-20% - Moderate
- >20% - High

(III) ESTIMATION OF HERITABILITY AND GENETIC ADVANCE:

Heritability in per cent in broad sense was estimated by the following formula given by Singh and Choudhary (1977):

$$\text{Heritability (h}^2\text{)} = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}} \times 100$$

$$\text{Genotypic variance} = \frac{M_t - M_e}{r}$$

$$\text{Phenotypic variance} = \text{genotypic variance} + M_e$$

Where, M_t = Treatment mean sum of square,

M_e = Error mean sum of square

, r = Number of replications

Heritability values are catagorised as low, moderate and high (Robinson *et al.*, 1949) and are given below,

- 0-30% - Low
- 30-60% - Moderate
- > 60% - High

The estimates of expected genetic advance from selection, $G(s)$, was obtained by the formula suggested by Robinson *et al.* (1949).

$$G(s) = k \times h^2 \times \sigma_p$$

where,

k = Selection differential in standard deviation units which is 2.06 for 5% selection intensity,

h^2 = Heritability in broad sense, and

σ_p = Phenotypic standard deviation

Genetic advance was expressed as percentage of mean by using the formula suggested by Johnson *et al.* (1955).

$$\text{Genetic advance as percentage of mean} = \frac{\text{Genetic advance}}{\text{Grand mean}} \times 100$$

Genetic advance as percent of mean was classified as low, moderate and high (Johnson *et al.*, 1955) and values are given below:

- 0-10% - Low
- 10-20% - Moderate
- > 20% - High

(IV) COMBINING ABILITY ANALYSIS:

Combining ability analysis: When the data were found significant for a given character in randomized block design, it was subjected to combining ability analysis according to the procedure given by Kempthorne (1957). The format for the analysis of variance along with the expectation of mean squares is given in table 4.

Table 3.4: Format for line × tester analysis

Source	d.f.	M.S.	Expected mean square
Lines	f-1	M1	$\sigma_e^2 + r(\text{Cov F.S.} - 2\text{Cov H.S.}) + rm$ (CovH.S.)
Testers	m-1	M2	$\sigma_e^2 + r(\text{Cov F.S.} - 2\text{Cov H.S.}) + r$ f(CovH.S.)
Line × Tester	(f-1)(m-1)	M3	$\sigma_e^2 + r(\text{Cov F.S.} - 2\text{Cov H.S.})$
Error	(r-1)(fm+f+m-1)	M4	σ_e^2

Where, r = number of replications, f = lines, m = testers, Cov H.S. = Covariance of Half-sibs, Cov F.S. = Covariance of full-sibs

Significance of various sum of squares were tested by means of F test as given below. Mean square for line × tester was first tested against error mean square. Thus,

$$F = \frac{M3}{M4}$$

If the mean sum of squares for line $\times$ tester was found non-significant, the sum of squares for error and line $\times$ tester were pooled accompanied by pooling of corresponding degree of freedom.

The new mean square was then used as denominator to test the significance of lines and testers. If the mean sum of squares for line $\times$ tester was significant, it was employed as denominator for F test of lines and testers. Thus,

$$\text{F test for lines} = \frac{M1}{M3} \text{ and } \text{F test for testers} = \frac{M2}{M3}$$

3. Estimation of covariance and variance components: When the mean squares of the lines and testers were found significant, estimates of covariance of half-sibs were calculated as:

$$\text{Cov. (H.S.) lines} = \frac{M1 - M3}{rm}$$

$$\text{Cov. (H.S.) testers} = \frac{M2 - M3}{rf}$$

However, when the mean squares for both lines and testers were significant, averages estimate of Cov. (H.S.) calculated following King *et al.* (1961)

$$\text{Cov. (H.S.) average} = \frac{M1 + M2 - 2M3}{r(f + m)}$$

Covariance of full-sibs was calculated as:

$$\text{Cov. (F.S.)} = \frac{M1 + M2 - 3M4 + ry(6 - m - f)}{3r}$$

The σ_{gca}^2 , σ_{sca}^2 , σ_A^2 and σ_D^2 were calculated as under

$$\sigma_{gca}^2 = \text{Cov. H.S.}$$

$$\sigma_{sca}^2 = \text{Cov. F.S.} - 2 \text{ Cov.H.S.}$$

$$\sigma_A^2 = 4 (\sigma_{gca}^2)$$

$$\sigma_D^2 = 4 (\sigma_{sca}^2)$$

4. Estimation of general (gi and gj) and specific (sij)

combining ability effects: The general combining ability for i^{th} line or j^{th} tester and specific combining ability effects (for ij^{th} cross) were computed as shown below:

GCA effects:

$$g_i \text{ (lines)} = \frac{y_{i..}}{rm} - \frac{y_{...}}{rfm}, \quad i = 1, 2, 3, 4$$

$$g_j \text{ (testers)} = \frac{y_{.j.}}{rf} - \frac{y_{...}}{rfm}, \quad j = 1, 2, 3, \dots, 12$$

SCA effects:

$$s_{ij} = \frac{y_{ij.}}{r} - \frac{y_{i..}}{rf} - \frac{y_{.j.}}{rm} + \frac{y_{...}}{rfm}$$

Where,

$y_{...}$ = total of all hybrids

$y_{i..}$ = total of i^{th} female parent over all males and replications

$y_{.j.}$ = total of j^{th} male parent over all females and replications

$y_{ij.}$ = $(ij)^{th}$ combination total over all replications

5. Standard errors for general and specific combining ability

effects: Standard errors required testing the significance of gca effects and sca effects were calculated as:

$$S.E. (g_i) = \sqrt{\frac{M4}{rm}} \text{ and } S.E. (g_j) = \sqrt{\frac{M4}{rf}}$$

The significance of g_i and g_j was tested by means of 't' test using the following formula.

$$t \text{ (for } g_i) = \frac{g_i - 0}{S.E.(g_i)} \text{ and } t \text{ (for } g_j) = \frac{g_j - 0}{S.E.(g_j)}$$

The values of the ratio so obtained were referred to 't' table at error degrees of freedom.

The significance of difference between GCA effects of two lines (or testers) was tested against the standard error for difference as:

$$\text{S.E. (gi-gj) for tester} = \sqrt{\frac{2M4}{rf}} \text{ and S.E. (gi-gj) for line} = \sqrt{\frac{2M4}{rm}}$$

The standard error for specific combining ability is calculated as below:

$$\text{S.E. (s}_{ij}) = \sqrt{\frac{M4}{r}}$$

Significance of difference between SCA effects of two crosses was tested against the standard error which was computed as:

$$\text{S.E. (s}_{ij} - \text{s}_{ki}) = \sqrt{\frac{M4}{r}}$$

(V) COMPUTATION OF HETEROSIS: —

(i) **Heterosis over better parents:** The heterosis over better parents was estimated as formula mentioned below (Fonseca and Patterson, 1968).

$$h = \frac{\bar{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

Where, $\bar{F}_1$ = Mean of $\bar{F}_1$ hybrid

$\overline{BP}$ = Mean of the superior parents of the particular cross under study.

Test of significance for heterosis: Test of significance of heterosis over commercial check was calculated by applying t- test

$$t = \frac{\bar{F}_1 - \overline{CC}}{SE(H)}$$

Where, $SE(H) = \sqrt{(2s^2/r)}$

S^2 = Error mean sum of square r = no. of replication

Test of significance of heterosis over better parents and standard parent was done by applying t-test

$$t = \frac{\bar{F}_1 - \overline{BP}}{SE(H)}$$

Where, $SE(H) = \sqrt{(2s^2/r)}$

S^2 = Error mean sum of square r = no. of replication



Chapter - V

DISCUSSION

The present investigation entitled “Line X tester analysis of yield and yield contributing traits in Pearl millet.” (*Pennisetum glaucum* L.) was undertaken to study combining ability, for grain yield and its components in F_1 generation and their parents of Pearl millet through line x tester analysis . Phenotypic and genotypic coefficient of variation, heritability, genetic advance, combining ability and heterosis estimated for parents and their crosses. Result of experiment consisting 10 testers, 4 male sterile lines and 40 crosses grown in a RBD with two replications were discussed in the light of review made in this topics in order to upgrade the genetic improvement of Pearl millet cultivars.

5.1 Analysis of variance and Mean performance:

Parents were significantly varied for days to 50% flowering, days to maturity, reproductive phase, effective tillers per plant, number of nodes per plant, flag leaf length, plant height, panicle length, harvest index, grain yield per plant, fodder yield per plant, thereby, indicating significant variation in the population. Mean performance showed significant mean values in ‘PDRLT-116’ (42.5) and ‘PDRLT-117’ (42.5) for early days to 50% flowering, ‘PDRLT-110’ (109.5) for early days to maturity, ‘ICMA-96666’ (73.5) for late reproductive phase, ‘RP-81’ (2.4) for maximum effective tillers per plant, ‘PDRLT-106’ (7.7) for maximum number of nodes per plant, ‘ICMA-96666’ (47.5) for long flag leaf length, ‘R-15248’ (195.0) for tallest plant height ‘R-15155’ (28.7) for maximum panicle length, ‘R-15468’ (36.0) for maximum harvest index, ‘PDRLT-115’ (22.9) for highest grain yield per plant, ‘PDRLT-116’ (237.5) for higher fodder yield indicating promising parents for respective traits.

Crosses were significantly varied for days to 50% flowering, days to maturity, reproductive phase, number of nodes per plant, flag leaf length, plant height, panicle length, harvest index, grain yield per plant, fodder yield per plant.

Promising crosses identified were 'ICMA-05333 X PDRLT-106' (40.5), 'ICMA-053333 X PDRLT-115' (40.5), 'ICMA-96666 X PDRLT-116' (41.0), 'ICMA-9666 X PDRLT-117' (41.5), 'ICMA-96666 X PDRLT-110' (41.5) for early days to 50% flowering; 'RP-98555 X PDRLT-110' (106.5), 'RP-81 X PDRLT-110'(107.0), 'ICMA-96666 X PDRLT-116' (107.5) for early days to maturity, 'ICMA-05333 X PDRLT-106' for late reproductive phase, 'RP-98555 X R-15081' (2.8), 'RP-98555 X R-15155' (2.7), 'RP-81 X R-15468' (2.7) for maximum effective tillers per plant, 'RP-98555 X R-15468' (8.3), 'RP-98555 X R-15155' (8.1) and 'RP-81 X PDRLT-116' (8.1) for maximum number of nodes per plant, 'RP-98555 X PDRLT-116' (47.5) and 'ICMA-9666 X R-15155' (47.5) for long flag leaf length, 'RP-81 X PDRLT-116' (204.3), 'RP-98555 X R-15468' (204.3) and 'RP-81 X R-15468' (203.4) for tallest plant height. 'ICMA-96666 X R-15155' (30.7), 'RP-98555 X R-15155'(29.7) for maximum panicle length, 'RP-81 X R-15468'(36.7), 'RP-81X R-15155'(36.7) for maximum harvest index, 'ICMA-05333 X R-15155'(23.1), 'RP-81 X R-15081'(23.1), 'RP-98555 X PDRLT-106'(23.0), 'ICMA-96666 X PDRLT-106' (22.9) for higher grain yield per plant, 'R-15468 X RP-9855'(242.5), 'RP-98555 X R-15545'(240.0) for higher fodder yield per plant. The similar results were also reported earlier by Shashi kant *et al.* (2012), Kumari Vinodhana *et al.* (2013).

5.2 Phenotypic and Genotypic Coefficient of Variation (PCV and GCV): In general, estimates of phenotypic coefficient of variation (PCV) were higher compared to genotypic coefficient of variation for all characters. The close resemblance was noticed for corresponding estimates of PCV and GCV in almost all the characters. High PCV and GCA were recorded for plant height, fodder yield, flag leaf length, panicle length, days to 50 % flowering and harvest index, reproductive phase and moderate PCV and GCV were recorded for effective tillers per plant, number of nodes per plant, grain yield per plant and days to maturity. Similar results were reported by Bortkhataria *et al.* (2005), Sumathi *et al.*(2010), Kumar *et al.*(2015).

Heritability (BS) and genetic advance(GA): High heritability in broad sense were observed for plant height (99.6%) followed by flag leaf length (99.5%), harvest index (95.51%), days to 50% flowering (94.8%), reproductive phase

(91.40%), fodder yield per plant (90.66%), days to maturity (90.11%), moderate for panicle length (86.82%), number of nodes per plant (81.91) and effective tillers per plant, moderate heritability estimates for grain yield per plant (59.43%). Similar results were reported by Sharma *et al.* (2003), Varu *et al.* (2005), Vidhyadhar *et al.* (2006), Sumathi *et al.* (2010)

Genetic advance were found to be high for effective tillers per plant (35.98%) followed by, panicle length (22.73%), number of nodes per plant (22.35%), flag leaf length (20.53%), harvest index (19.09%), plant height (18.25%), days to 50% flowering (16.76%), reproductive phase (12.40%) fodder yield per plant (11.97%). Lower genetic advance recorded for grain yield per plant (7.44%) and days to maturity (4.66%). Similar results were reported by Bhoite *et al.* (2008), Sumathi *et al.* (2010), Bhadalia *et al.* (2013), Manga *et al.* (2013), Subi *et al.* (2013).

5.3 Genetic components:

The Genetic components viz., σ^2_{gca} and σ^2_{sca} and lower ratio " $\sigma^2_{gca} / \sigma^2_{sca}$ " showed the predominance of non-additive components in the inheritance of all characters. Similar results were reported by Shanmunganathan *et al.* (2005), Patel *et al.* (2008a), Bhadaliya *et al.* (2014), Mungra *et al.* (2015)

5.4. Combining ability:

Variance due to gca were significant for days to 50% flowering, days to maturity, reproductive phase, effective tillers per plant, nodes per plant, flag leaf length, plant height, panicle length, harvest index, grain yield per plant and fodder yield per plant. Whereas, sca were significant for days to 50% flowering, days to maturity, reproductive phase, number of nodes per plant, flag leaf length, plant height, panicle length, grain yield per plant and fodder yield per plant. Similar results were reported by Lakshmana *et al.* (2003), Shanmuganathan *et al.* (2005), Bhandari *et al.* (2007), Dangariya *et al.* (2009), Chotaliya *et al.* (2010), Patel *et al.* (2014), Solanki *et al.* (2017)

5.4 General and specific combining ability effects:

5.4.1 General combining ability effects:

The estimates of GCA effects revealed that 'ICMA-05333' showed positive significant GCA effects for grain yield per plant, days to maturity, reproductive phase, panicle length, harvest index and significant but negative effect for days to 50% flowering, thereby, suggesting good general combiner for these traits. 'PDRLT-117' recorded significant positive GCA effect for grain yield per plant, nodes per plant, harvest index and significant negative effect for days to 50% flowering and days to maturity, thereby, suggesting good general combiner. 'PDRLT-116' also had significant positive gca effect for grain yield per plant, effective tillers per plant, plant height, panicle length and desirable negative significant gca effect for days to 50% flowering and days to maturity, indicating this parent as good combiner for these traits. 'R-15081' showed positive significant GCA effect for grain yield per plant, plant height, days to maturity, reproductive phase, nodes per plant, flag leaf length, harvest index and also showed significant negative effect for days to 50% flowering indicating this parent as a good general combiner for these traits. 'R-15155' identified as good general combiners for grain yield per plant, effective tillers per plant, plant height, flag leaf length, harvest index. 'R-15545' recorded significant positive GCA effect for grain yield per plant, reproductive phase, nodes per plant, flag leaf length, harvest index, indicating this parent as a good general combiner for these traits. Rests of the parents were poor combiner for grain yield per plant. Similar result in pearl millet for grain yield and its components traits also reported by Laksmana *et al.*(2003), Bhanderi *et al.*(2007), Dangariya *et al.*(2009), Vagadiya *et al.*(2010).

5.4.2 Specific combining ability effects:

Significant SCA effects revealed that cross 'RP-98555 X PDRLT-106' was good specific combiner for grain yield per plant and nodes per plant. Cross 'ICMA-96666 X PDRLT-106' recorded good specific combiner for grain yield per plant, flag leaf length, plant height and fodder yield per plant because and this trait also showed desirable negative significant effect for days to maturity, Cross 'ICMA-96666 X PDRLT-110' identified as good specific combiner for grain yield per plant, effective tillers per plant and harvest index. Cross 'ICMA-05333 X

PDRLT-110' showed significant positive sca effect for grain yield per plant and flag leaf length. Cross 'RP-81 X R-15081' was only good specific combiner for grain yield per plant. Cross 'RP-81 X R-15248' recorded good specific combiner for grain yield per plant and panicle length. Cross 'ICMA-05333 X R-15545' identified as good specific combiner for grain yield per plant. Present results are in agreement with those of Laksmana *et al.*(2003), Bhanderi *et al.*(2007), Dangariya *et al.*(2009), Vagadiya *et al.*(2010), Mungra *et al.*(2015),

5.5 Heterosis: Out of 40 crosses, only 16 showed significant and positive heterosis over better parent for grain yield and its contributing traits. Cross 'RP-98555X PDRLT-106' was recorded significant positive heterosis over better parents for grain yield per plant (15.08%), panicle length (4.86%), and fodder yield (353.54%). Cross 'ICMA-96666 X PDRLT-106' showed significant positive heterosis over better parent for grain yield per plant (9.99%), reproductive phase (23.23%), harvest index (2.48%) and fodder yield (370.71%). Cross 'RP-98555 X PDRLT-117' recorded significant positive heterosis over better parent for grain yield per plant (13.98%), plant height (342.94%) and fodder yield per plant(407.06%), Cross 'ICMA-05333 X PDRLT-117 ' showed significant positive heterosis over better parent for grain yield per plant (4.31%), plant height (316.47%) and these cross also showed significant negative effect for days to 50% flowering (-4.71%) Cross 'RP-81 X PDRLT 116 ' was identified significant positive heterosis over better parent for grain yield per plant (5.74%), plant height (380.59%) and fodder yield (347.06%). 'RP-98555 X PDRLT-116'showed significant positive heterosis over better parent for grain yield per plant (13.33%), plant height (355.53%), fodder yield per plant (372.94%). cross'PDRLT-116 X ICMA-05333' was recorded significant positive heterosis over better parent for grain yield per plant (2.83%), panicle length (4.22%), plant height (350.82%), nodes per plant (87.53%) and this cross also showed negative effect for days to 50% flowering (-4.71%). cross'R-15081 X ICMA-05333 was identified significant positive heterosis over better parent for grain yield per plant (3.65%), nodes per plant (87.76%), flag leaf length (85.19%), plant height (325.37%), harvest index

(16.74%) and also showed negative effect for days to 50% flowering (-3.23%), 'ICMA-05333 X R-15155' showed significant positive heterosis over better parent for grain yield per plant (5.43%), tillers per plant (5%), nodes per plant (13.04%), plant height (274.69%), panicle length (41.43%). Cross 'R-15468 X RP-81' was showed significant positive heterosis over better parent for grain yield per plant (9.1%), tillers per plant (15%), plant height (346.92%), fodder yield per plant (452.97%) and also showed significant negative effect for days to 50% flowering (-6.9%) and days to maturity (-6.78%), 'ICMA-05333 X R-15468' also showed significant positive heterosis over better parent for grain yield per plant (52.04%), tillers per plant (23.53%), nodes per plant (3.73%), plant height (295.27%), panicle length (5.29%) and fodder yield per plant (342.56%) and negative effect for days to 50% flowering (-4.4%) and days to maturity (-3.43%) . Cross 'RP-81 X R-15545' was recorded significant positive heterosis over better parent for grain yield per plant (57.29%), effective tillers per plant (10%), nodes per plant (87.37%), fodder yield per plant (405.26%) and also showed significant negative effect for days to 50% flowering (-6.9%). cross 'R-15545 X RP-98555' was identified significant positive heterosis over better parent for grain yield per plant (3.79%), tillers per plant (37.5%), nodes per plant (15.74%), plant height (6.39%), fodder yield per plant (402.11%) and these cross also showed significant positive heterosis for days to 50% flowering (-6.59%), cross 'ICMA-96666 X R-15545' was recorded significant positive heterosis over better parent for grain yield per plant (4.23%), effective tillers per plant (11.76%) and fodder yield (378.95%), cross 'ICMA-05333 X R-15545' showed significant positive heterosis over better parent for grain yield per plant (13.45%), tillers per plant (47.06%), nodes per plant (88.22%), flag leaf length (4.4%), panicle length (4.75%), harvest index (22.58%) and fodder yield per plant (13.45%). Heterosis for grain yield and its contributing traits is in agreement with Blummel and Rai.(2003), Vetriventham *et al.*(2008), Chotaliya *et al.*(2009), Vagadiya *et al.*(2010a), Jethva *et al.*(2012), Manoj kumar *et al.*(2017).

Chapter-IV

RESULTS

The results obtained from the present investigation entitled “Line X tester analysis of yield and yield contributing traits in Pearl millet.” (*Pennisetum glaucum* L)”undertaken with using the line x tester mating design.

4.1 Analysis of variance:

Analysis of variance for seed yield per plant and its contributing traits is presented in Table 4.1. All the 11 characters studied showed significant mean sum of square due to genotypes, viz:days to 50% flowering, days to maturity, reproductive phase, effective tillers per plant, nodes per plant,flag leaf length,plant height,panicle length,harvest index, grain yield per plant,fodder yield per plant. It indicates that there was considerable variability for these characters in the present material consisting parents and crosses thus combining ability analysis may yield significance of genetic components for these traits.Parents showed significant variation for days to 50% flowering, days to maturity, reproductive phase, effective tillers per plant,no of nodes per plant,flag leaf length,plant height,panicle length,harvest index, grain yield per plant,fodder yield per plant., whereas,crosses were significant for days to 50% flowering, days to maturity, reproductive phase, no of nodes per plant ,flag leaf length, plant height, panicle length, harvest index, grain yield per plant, fodder yield per plant. The mean sums of squares due to crosses vs. parents were significant for days to 50% flowering, days to maturity, reproductive phase, flag leaf length,plant height,panicle length, grain yield per plant.

4.2 Mean performance:The mean performance of parents and their 40 crosses made in Line X Tester mating design have been described for different characters and presented in table 4.2.All genotypes showed significant variation.

Table 4.1: Analysis of variance for yield and its attributing characters of parents and their different crosses in pearl millet.

source	Df	Days to 50% flowering	Days to maturity	Reproductive phase	Effective tillers per plant	No. Of nodes/ plant	Flag leaf length	Plant height	Panicle length	Harvest index	Grain yield/ plant	Fodder yield/ plant
Replication	1	0.45	63.79**	50.70**	0.02	0.96	22.23**	245.10**	18.01**	8.31**	5.91*	1358.23**
Treatment	53	29.50**	15.14**	37.94**	0.31	1.45*	32.32**	519.05**	17.53**	19.11**	2.72**	384.15**
Parents	13	3433.69**	21176.8**	7610.92**	5.50**	72.45**	2802.72**	50846.03**	895.56**	1678.92**	706.70**	78652.90**
C vs P	1	32.31**	316.04**	71.12**	0.64	0.01	79.01**	318.91**	16.71**	0.05	7.63**	0.27
Crosses	39	34.04**	8.64**	42.12**	0.35	1.79*	33.05**	532.31**	16.78**	19.34**	2.63**	387.98**
Lines	3	227.55**	12.08**	186.91**	0.22	4.15**	64.98**	4.22**	36.65**	2.18	3.46*	185.93**
Testers	9	26.20**	15.61**	53.90**	0.26	1.43	23.23**	1398.59**	24.41**	28.42**	1.24	335.88**
L X T	27	15.15**	5.94**	22.10**	0.39	1.65	32.78**	302.22**	12.03**	18.22**	3.01**	427.79**
Error	53	0.77	0.79	1.70	0.05	0.14	0.08	6.65	1.24	0.44	0.69	18.82

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

Days to 50% flowering: Parents were significantly varied for days to 50% flowering and ranging from 42.5(PDRLT-116 and PDRLT-117) to 52.5 (RP-81) days, whereas, crosses were significantly varied and ranging from 40.5 (ICMA-05333 X PDRLT-115) to 52.5 (RP-81 X PDRLT-116) days .Among parents, 'PDRLT-117' and 'PDRLT-116' showed significantly early in days to 50% flowering, whereas 'ICMA-9666' showed significantly late in days to 50% flowering, Out of 9 crosses,' ICMA-05333 X PDRLT-106', 'ICMA-05333 X PDRLT-117',' RP-81 X PDRLT-110',' ICMA-05333 X PDRLT-116',' ICMA-05333 X R-15081' , ' ICMA-9666X R-15248', 'ICMA-05333 X R-15248',' ICMA-9666X R-15468' were significantly early in days to 50% flowering whereas, ' ICMA-9666 X PDRLT-116', 'ICMA-9666 X PDRLT-110' and 'ICMA-9666 X PDRLT-117' showed significantly late in days to 50% flowering.

Days to maturity: Parents were significantly varied for days to maturity and ranging from 109.5 (PDRLT-110) to 118.5 (R-15468) days, whereas, crosses were significantly varied and ranging from 106.5 (RP-98555 X PDRLT-110) to 114.5 (RP-98555 X R-15081) days. Among parents, 'PDRLT-110' showed significantly early in days to maturity. Out of 40 cross, only 'RP-98555 X PDRLT-110' and 'RP-81 X PDRLT-106' recorded significantly early for days to maturity crosses, whereas, 'ICMA-9666 X PDRLT-116' showed significantly late in maturity.

Reproductive phase:Parents were significantly varied for reproductive phase and ranging from 64.5 (PDRLT-106) to 73.5 (ICMA-96666) days, whereas, crosses were significantly varied and ranging from 55.5 (RP-81 X PDRLT-106) to 74.0 (ICMA—05333 X PDRLT-1106) days. Among parents, 'RP-98555', 'ICMA-05333' and 'R-15248' were showed significantly early in reproductive phase.Only four parent viz., 'ICMA-96666', 'R-15468', PDRLT-117 and PDRLT-116 proved significantly superior in terms of late to reproductive phase. Cross 'ICMA-05333' X R-15468, 'ICMA-05333 X PDRLT-115' and 'RP-98555 X R-15468' were recorded significantly early reproductive phase , whereas, 'ICMA-05333 X PDRLT-106 ', 'ICMA-05333 X R-15248 ', 'ICMA-96666X R-15468' and 'ICMA-96666 X R-15545' were showed significantly late in reproductive phase

Effective tillers per plant: Parents were significantly varied for effective tillers per plant and ranging from 1.3 (R-15155) to 2.4 (RP-81) for tillers per plant. Crosses were significantly varied and ranging from 1.3 (ICMA-05333 X PDRLT-116) to 2.8 (RP-98555 X R-15081). Parents 'RP-81' showed significantly maximum number of tillers per plant. Among crosses, 'RP-98555X R-15081' showed significantly highest number of tillers per plant, whereas, cross 'RP-81X R-15155' and 'RP-81 X R-15468' were showed significantly less number of tillers per plant.

No. of nodes per plant: Parents were significantly varied for no of nodes per plant and ranging from 6.0 (PDRLT-117) to 7.7 (PDRLT-106) for Node per plant. Crosses were significantly varied and ranging from 5.1 (ICMA-05333 X PDRLT-110) to 8.3 (RP-98555 X R-15468). Parents 'PDRLT-106' showed significant for node per plant. Cross, 'RP-98555X R-15468' showed significantly maximum node per plant, whereas, 'RP-98555 X R-15555' and 'RP-98555 X R-15468' recorded significantly lowest node per plant.

Flag leaf length: Parents were significantly varied for flag leaf length and ranging from 34.5 (PDLRT-117) to 47.5 cm (ICMA-96666) for Flag leaf length. Crosses were significantly varied and ranging from 32.5 (ICMA-05333 X PDRLT-116) to 47.5 cm (RP-98555 X PDRLT-116). Parents 'ICMA-96666' showed significant for long Flag leaf length. Among crosses 'RP-98555 X PDRLT-116' and 'ICMA-96666 X R-15155' showed significant for Flag leaf length.

Plant height: Plant height were significantly varied for plant height and ranging from 144.1 (PDRLT-106) to 197cm (R-15248) for different parents. Crosses were significantly varied and ranging from 144.1(RP-81 X PDRLT-106) to 204.3cm (ICMA-96666 X R-15468). Parents, 'R-15248', showed significantly tallest plant as compared to other parents, whereas, 'PDRLT-116' and 'R-15248' recorded significantly dwarf plant. Among crosses 'RP-98555' X PDRLT-116, 'RP-81X R-15468', 'ICMA-05333 X R-15081', 'RP-81 X R-15081' showed significantly tallest plants, whereas 'ICMA-96666 X R-15155' and 'RP-98555X R-15155' showed significantly dwarf plants.

Panicle length: Parents were significantly varied for panicle length and ranging from 18.0 (PDRLT-115) to 28.7 cm (R-15155) for panicle length. Crosses were significantly varied and ranging from 19.7 (ICMA-05333 X PDRLT-106) to 30.7 cm (ICMA-96666 X R-15155). Parents 'R-15155' showed significantly maximum panicle length as compared to other parent, whereas, 'PDRLT-110' and 'ICMA-05333' showed significantly minimum panicle length. Among crosses, 'R-15155 X ICMA96666' and 'RP-98555 X R-15155' showed significantly longest panicle length, whereas, 'RP-98555 X PDRLT-110' significantly short panicle length.

Harvest index: Parents were significantly varied for harvest index and ranging from 26.8% (R-15081) to 36.0 % (R-15468) for Harvest index. crosses were significantly varied and ranging from 25.7 (RP-98555 X PDRLT-110) to 37.8 % (ICMA-05333 X R-15468). Parents 'R-15468' showed significantly maximum Harvest index as compared to other parent, whereas 'R-15248', 'PDRLT-117' and 'RP-81' was significantly minimum Harvest index. Among cross 'ICMA-05333X R-15468' showed significantly harvest index.

Grain yield per plant: Parents were significantly varied for grain yield and ranging from 19.7 (PDRLT-106) to 22.9 g (PDRLT-115) for Grain yield per plant. crosses were significantly varied and ranging from 19.3 (RP-98555X PDRLT-110) to 23.1 g (ICMA-05333 X R-15155). Parents 'PDRLT-115' and 'R-15155' showed significantly highest grain yield per plant compared to other parent, whereas, 'ICMA-05333' was lowest grain yield per plant. Among crosses 'ICMA-05333' X R-15155', 'RP-81X 'R-15081', 'RP-98555X 'PDRLT-110', 'ICMA-05333 X PDRLT-116' showed significantly higher grain yield per plant compared to other plant, whereas, 'RP-81X R-15248 ', 'ICMA-96666X R-15468', 'RP-81 X PDRLT-116' and 'ICMA-9666 X PDRLT-110' was significantly lower grain yield per plant.

Fodder yield per plant: Parents were significantly varied for fodder yield per plant and ranging from 185.5 (ICMA-05333) to 237.5 (PDRLT-116) for fodder yield per plant. crosses were significantly varied and ranging from 190.0 (RP-98555X PDRLT-116) to 242.5 (RP98555 X R-15468). Parents 'PDRLT-116', 'RP-

81', 'PDRLT-106' and 'PDRLT-115' showed significantly higher fodder yield per plant compared to other parent, whereas, 'R-15248', 'PDRLT-117' and 'R-15155' was significantly lower fodder yield per plant. Among crosses 'RP98555 X R-15468', 'RP-98555 X R-15545', 'ICMA-9666 X R-15545' showed significantly higher fodder yield per plant, whereas, 'RP-81 X PDRLT-106', 'RP-98555 X R-151555' recorded significantly lower grain yield per plant.

4.3. GENETIC VARIABILITY

Phenotypic and genotypic coefficient of variation: In general, the estimates of phenotypic coefficient of variation (PCV) were higher than the estimates of genotypic coefficient of variation (GCV) for all the traits under the study indicating that the substantial influence of the environment in the expression of these traits. The estimates of phenotypic and genotypic coefficient of variation are presented in table 4.3. the highest Phenotypic coefficient of variation (PCV) were recorded for plant height (119.13%), fodder yield (95.40%), flag leaf length (63.26%), panicle length (62.39%) days to 50% flowering (57.76%), harvest index (55.08%), reproductive phase (54.15%) and moderate PCV for no of nodes per plant (34.36%), effective tillers per plant (32.19%), grain yield per plant (28.17%).

The highest genotypic coefficient of variation (GCV) were observed for the plant height (119.12%), fodder yield per plant (90.83%), flag leaf length (63.26%), panicle length (58.14%), days to 50% flowering (56.26%), harvest index (53.83%), reproductive phase (51.77%) and moderate GCV for grain yield per plant (21.72%), days to maturity (25.28%), effective tillers per plant (28.05%), no of nodes per plant (31.10%).

Table 4.2: Analysis of Mean performance for yield and its attributing characters of parents and their different crosses in Pearl millet

Genotype	Days to 50% Flowering	days to maturity	Reproductive phase	Effective tillers per plant	No. of nodes/Plant	Flag leaf length	Plant height	Panicle length	Harvest Index	Grain yield/Plant	Fodder yield/Plant
RP-81× PDRLT-106	51.5	107.0	55.5	2.5	6.3	44.5	144.1	23.0	29.8	20.1	214.5
RP-98555× PDRLT-106	47.5	113.0	65.5	1.8	7.6	36.5	128.3	25.9	28.1	23.0	224.5
ICMA-96666× PDRLT-106	48.5	109.5	61.0	1.5	5.3	43.5	163.5	23.7	29.9	22.9	233.0
ICMA-05333× PDRLT-106	40.5	114.5	74.0	1.7	6.3	35.0	170.9	20.9	33.9	20.0	219.5
RP-81× PDRLT115	50.0	114.0	64.0	2.0	6.1	36.5	165.4	19.7	30.8	20.0	200.5
RP-98555× PDRLT-115	42.5	112.0	69.5	2.6	6.2	38.5	174.5	25.8	35.1	22.7	205.5
ICMA-96666× PDRLT-115	45.5	113.5	68.0	1.7	5.9	41.5	189.4	21.9	27.6	22.5	220.0
ICMA05333× PDRLT-115	40.5	112.5	72.0	2.6	7.3	35.5	169.6	26.7	29.6	21.1	239.5
RP-81× PDRLT-117	51.5	111.0	59.5	2.2	7.4	36.5	175.5	23.9	35.1	20.5	238.5
RP-98555× PDRLT-117	43.0	110.0	67.0	1.7	5.8	39.5	188.3	20.9	36.9	22.8	215.5
ICMA96666× PDRLT-117	41.5	109.0	67.5	1.7	7.8	34.5	183.7	21.9	31.7	21.4	220.0
ICMA05333× PDRLT-117	40.5	110.5	70.0	1.7	7.3	36.5	177.0	21.5	29.9	23.0	233.0
RP-81× PDRLT-110	40.5	108.0	67.0	2.0	7.0	39.5	178.0	21.1	27.2	20.0	230.5
RP98555× PDRLT-110	43.5	106.5	63.0	1.4	6.5	37.5	184.4	28.8	25.7	19.3	238.0
ICMA-96666× PDRLT-110	41.5	109.5	68.0	2.2	5.5	34.5	171.3	26.1	35.9	22.1	220.0
ICMA05333× PDRLT-110	43.0	112.0	69.0	1.7	5.1	41.5	175.0	25.3	30.7	22.7	225.0
RP-81× PDRLT-116	52.5	108.0	55.5	2.2	8.1	37.5	204.3	24.2	34.1	22.1	230.5
RP-98555× PDRLT-116	44.5	111.5	67.0	2.4	6.6	47.5	193.6	24.7	35.2	22.7	190.0
ICMA-96666× PDRLT-116	41.0	107.5	66.5	2.4	6.9	40.5	173.3	22.9	25.9	20.9	201.0
ICMA-05333× PDRLT-116	40.5	111.5	71.0	1.3	5.3	32.5	191.6	28.1	30.7	22.7	219.0

RP-81× R-15081	49.5	112.0	62.5	1.5	7.8	35.5	200.6	19.8	33.9	23.1	210.5
RP-98555× R-15081	45.0	114.5	69.5	2.8	7.0	46.5	202.5	27.8	34.8	20.8	199.0
ICMA96666× R-15081	43.5	110.5	67.0	1.6	7.8	39.5	188.1	20.8	34.8	21.4	238.0
ICMA05333× R-15081	40.5	111.0	70.5	1.9	7.1	40.5	202.1	25.7	35.9	22.9	232.5
RP-81× R-15155	52.0	112.5	60.5	2.7	6.0	35.5	173.1	24.2	36.7	21.9	207.0
RP98555× R-151555	50.5	113.5	63.0	1.4	8.1	45.5	196.2	29.7	29.7	20.9	215.5
ICMA96666× R-15155	42.5	111.0	68.5	2.4	6.8	47.5	194.6	30.7	32.9	21.4	234.0
ICMA05333× R-15155	49.5	112.0	62.5	2.1	5.4	39.5	183.6	28.7	35.2	23.1	196.0
RP81× R-15248	48.5	113.0	64.5	1.7	7.8	37.5	195.6	26.0	28.8	22.0	223.0
RP98555× R-15248	45.5	110.0	64.5	2.4	6.6	41.5	176.3	25.1	29.9	20.1	217.5
ICMA96666×R-15248	40.5	111.0	70.5	1.8	7.9	43.5	158.1	19.8	31.7	19.4	232.0
ICMA05333× R-15248	40.5	113.0	72.5	1.7	6.4	45.5	186.1	23.7	31.0	22.2	230.0
R15468×RP-81	52.5	110.0	69.5	2.7	6.9	38.5	203.4	23.0	32.9	21.2	226.0
RP98555× R-15468	43.5	111.0	72.0	2.3	8.3	36.5	197.3	24.9	34.9	21.8	242.5
ICMA96666× R-15468	40.5	110.0	72.5	2.1	7.8	44.5	204.3	25.9	33.9	22.1	216.5
ICMA05333× R-15468	42.5	112.5	71.5	2.2	4.6	43.5	179.9	27.7	37.8	21.0	200.0
RP81× R-15545	48.0	111.5	70.0	1.5	7.8	37.5	170.8	21.9	31.9	21.0	210.0
RP98555 × R-15545	49.0	113.5	72.5	1.9	6.4	45.5	177.4	24.8	30.7	22.8	240.0
ICMA96666× R-15545	42.0	114.5	72.5	2.5	7.0	41.5	194.3	25.8	34.7	20.3	238.5
ICMA05333× R-15545	45.5	113.0	67.5	1.7	6.0	35.5	177.7	20.7	32.0	22.9	227.5
RP-81	52.5	118.0	65.5	2.4	6.9	41.5	168.4	20.8	35.6	20.9	235.0
RP-98555	46.5	116.5	71.0	1.7	6.4	45.5	166.8	24.7	33.9	20.0	212.5
ICMA-96666	43.5	117.0	73.5	1.7	6.7	47.5	186.5	21.2	29.2	20.8	209.0
ICMA-05333	45.5	116.5	71.0	2.0	6.2	38.5	176.8	27.0	30.8	22.1	185.5
PDRLT-106	49.5	114.0	64.5	2.2	7.7	40.5	144.1	22.8	27.1	19.7	235.0

PDRLT-115	46.5	112.0	65.5	2.0	7.4	37.5	179.7	18.0	31.9	22.9	235.5
PDRLT-117	42.5	115.0	72.5	1.9	6.0	34.5	183.4	21.0	35.8	19.9	220.5
PDRLT-110	44.5	109.5	65.0	1.9	6.2	41.5	185.3	27.7	30.1	21.1	229.0
PDRLT-116	42.5	114.5	72.0	1.6	7.3	43.5	193.4	22.0	33.7	19.8	237.5
R-15081	47.5	113.5	66.0	1.7	6.9	45.5	197.0	20.0	26.8	21.8	210.0
R-15155	49.0	115.5	66.5	1.3	7.1	38.5	183.6	28.7	31.7	22.9	224.5
R-15248	45.0	116.5	71.5	2.0	6.6	41.5	195.0	25.8	35.7	20.1	220.5
R-15468	45.5	118.5	73.0	1.5	6.4	42.5	177.3	23.9	36.0	20.2	228.5
R-15545	47.5	115.5	68.0	1.7	6.3	45.5	150.2	24.7	33.0	21.8	217.5
Mean	45.4	112.3	67.6	2.0	6.7	40.3	180.6	24.1	32.2	21.5	221.4
SE(M)	0.4	0.4	0.9	0.0	0.1	0.0	3.3	0.6	0.2	0.3	9.4
CD 5%	1.2	1.2	2.6	0.1	0.2	0.1	10.2	1.9	0.7	1.1	28.7
CV %	1.9	0.8	1.9	11.3	5.6	0.7	1.4	4.6	2.1	3.9	2.0

4.4.1. Heritability (Broad sense heritability): The estimates of broad-sense heritability % have been presented in Table 4.3. High heritability was observed for plant height (99.96%), flag leaf length (99.5%), harvest index (95.15%), days to 50% flowering (94.88%) , reproductive phase (91.40%), fodder yield per plant (90.66%), days to maturity (90.11%) panicle length (86.82%), no of nodes per plant (81.91%), effective tillers per plant (75.93%), while moderate heritability exhibited for grain yield per plant (59.43%) showed moderate heritability.

4.4.2. Genetic advance: The estimates of expected genetic advance (Table 4.3) revealed that the maximum genetic advance as per cent of mean was recorded for effective tillers per plant (35.98) followed by no of nodes per plant (22.35), panicle length (22.73), flag leaf length (20.35). The moderate genetic advance were recorded for harvest index (19.09), plant height (18.25), days to 50% flowering (16.76), reproductive phase (12.40) fodder yield per plant (11.97) and lower for grain yield per plant (7.44) and days to maturity (4.66).

4.5 Line X tester and combining ability analysis: Analysis of variances for combining ability showed in table 4.1 indicates that variances due to testers were significantly differ for days to 50% flowering, days to maturity, reproductive phase, flag leaf length, plant height, panicle length, harvest index, grain yield per plant, fodder yield. Whereas, variance due to line were significant for days to 50% flowering, days to maturity, reproductive phase, number of nodes per plant, flag leaf length, plant height, panicle length, grain yield, fodder yield. Variance due to Line X tester were significantly differ for days to 50% flowering, days to maturity, reproductive phase, flag leaf length, plant height, panicle length, harvest index, grain yield , fodder yield. Thus it is indicated significance of both GCA and SCA variances in the present material.

4.5.1 Genetic components: The genetic component's magnitudes are presented in Table 4.3.1 showed that the due to lines, tester and L X T variances and ratio of genetic components " $\sigma^2_{gca} / \sigma^2_{sca}$ " showed that the non-additive components of variances were higher as compared to additive components of variances for all the characters.

4.5.2 General combining ability effects: Character wise GCA effects are presented in Table 4.3.

Days to 50% flowering: The lines 'RP-81' (4.61) and 'RP-98555' (0.41) showed significant positive value of GCA effect and the tester 'PDRLT-106, R-15155' and 'R-15545' evidenced significant positive value for GCA effect, 1.96, 3.59, 1.09, respectively, whereas, the lines 'ICMA-96666', (-2.34) and 'ICMA-05333' (-2.69) showed significant negative value of GCA effect and the tester 'PDRLT-115', 'PDRLT-117', 'PDRLT-110', 'PDRLT-116', 'R-15248' and 'R-15468' demonstrated significant negative value for GCA effect, -0.41, -0.91, -2.91, -0.41, -1.29 and -0.29 respectively.

Days to maturity: The lines 'ICMA-05333' (0.97) showed significant positive value of GCA effect and the tester 'PDRLT-115', 'R-15081', 'R-15155', 'R-15248' and 'R-15545', showed significant positive value of GCA effect, 1.72, 0.72, 0.97, 0.47 and 1.85 respectively, whereas, line, 'RP-81' (-0.58) and 'ICMA-96666', (-0.68) showed significant negative value of GCA effect and the tester 'PDRLT-106', 'PDRLT-117', 'PDRLT-110', 'PDRLT-116' and 'R-15468', showed significant negative value of GCA effect, -0.28, -1.15, -2.28, -1.65 and -0.40 respectively.

Reproductive phase: The lines 'ICMA-96666' (1.09) and 'ICMA-05333' (2.94) showed significant positive value of GCA effect and the tester 'PDRLT-115', 'R-15081', 'R-15248', 'R-15468' and 'R-15545', showed significant positive value of GCA effect, 1.26, 0.26, 0.89, 4.26, 3.51 respectively, whereas, line, 'RP-81' (-4.26) showed significant negative value of GCA effect and the tester 'PDRLT-106', 'PDRLT-117', 'PDRLT-110', 'PDRLT-116' and 'R-15155', showed significant negative value of GCA effect, -3.11, -1.11, -0.36, -2.11, and -3.49 respectively.

Effective tillers per plant: The tester 'PDRLT-115', 'PDRLT-116', 'R-1515' and 'R-15468' showed significant positive value of GCA effect, 0.22, 0.07, 0.15 and 0.32 respectively, whereas, the lines, 'ICMA-05333' (-0.14) recorded significant negative value for GCA effect and the tester 'PDRLT-106', 'PDRLT-117', 'PDRLT-110', 'R-15081', 'R-15248', 'R-15545' showed significant negative value for GCA effect, -0.13, -0.18, -0.19, -0.05, -0.10, and -0.10 respectively.

Table 4.3: Estimates of PCV, GCV, broad sense heritability genetic advance for yield and its attributes in pearl millet

Character	Mean	Range	PV	GV	PCV (%)	GCV (%)	Heritability (%)	Genetic Advance	Genetic advance as % of mean
Days to 50% Flowering	45.4	46.5	15.14	14.36	57.76	56.26	94.88	7.60	16.76
Days to maturity	112.3	112.5	7.97	7.17	26.63	25.28	90.11	5.23	4.66
Reproductive phase	67.6	64.5	19.82	18.12	54.15	51.77	91.40	8.38	12.40
Effective tillers per plant	2.0	2.0	0.20	0.15	32.19	28.05	75.93	0.70	35.98
No. of nodes/Plant	6.7	6.75	0.79	0.65	34.36	31.10	81.91	1.50	22.35
Flag leaf length	40.3	40	16.20	16.12	63.26	63.26	99.50	8.27	20.53
Plant height	180.6	166.4	256.28	256.19	119.13	119.12	99.96	32.96	18.25
Panicle length	24.1	23.85	9.38	8.14	62.39	58.14	86.82	5.47	22.73
Harvest Index	32.2	30.67	9.77	9.33	55.08	53.83	95.51	6.15	19.09
Grain yield/Plant	21.5	20.89	1.70	1.01	28.17	21.72	59.43	1.59	7.44
Fodder yield/Plant	221.4	215	201.48	182.66	95.40	90.83	90.66	26.50	11.97

PV = Phenotypic Variance, GV =Genotypic variance, PCV =Phenotypic coefficient of variance, GCV = Genotypic Coefficient of varianc

Table 4.4: Analysis of Genetic components for yield and its attributing characters of parents and their different crosses in pearl millet

covariences	Days to 50% Flowering	days to maturity	Reproductive phase	Effective tillers per plant	No. of nodes/Plant	Flag leaf length	Plant height	Panicle length	Harvest Index	Grain yield/Plant	Fodder yield/Plant
Cov HS (Line)	13.274	0.38	10.30	-0.01	0.16	2.01	-18.63	1.54	-1.00	0.03	-15.12
Cov HS (Tester)	0.690	0.60	1.99	-0.01	-0.01	-0.60	68.52	0.77	0.64	-0.11	-5.74
Cov HS (Average)	0.510	0.08	0.54	0.00	0.00	0.03	6.29	0.13	0.04	-0.01	-0.76
Cov FS	253.398	26.80	239.53	0.44	5.53	93.43	1424.09	60.07	32.59	3.72	554.13
Genetic components											
σ^2_{gca} (Lines)	0.510	0.08	0.54	0.00	0.00	0.03	6.29	0.13	0.04	-0.01	-0.76
σ^2_{gca} (Testers)	2.040	0.30	2.18	0.00	0.02	0.12	25.17	0.54	0.17	-0.03	-3.05
σ^2_{gca} (Parents)	1.020	0.15	1.09	0.00	0.01	0.06	12.59	0.27	0.08	-0.02	-1.53
σ^2_{sca}	7.186	2.57	10.20	0.17	0.75	16.35	147.79	5.40	8.89	1.16	204.49
$\sigma^2_{gca} / \sigma^2_{sca}$	0.141	0.06	0.11	-0.01	0.01	0.00	0.09	0.05	0.01	-0.01	-0.01
σ^2_A	866.72	399.11	1601.78	-5.78	-3.94	-317.2	43258.79	544.40	375.82	-69.76	-4160.17
σ^2_D	7.19	2.57	10.20	0.17	0.75	16.35	147.79	5.40	8.89	1.16	204.49

Number of nodes per plant: The lines 'RP-81'(0.38), showed significant positive value of GCA effect and the tester 'PDRLT-117', 'R-15081', 'R-15248', R-15468 and R-15545, showed significant positive value of GCA effect (0.34, 0.68, 0.43, 0.15 and 0.04 respectively) whereas, line, 'ICMA-05333'(-0.66) showed significant negative value of GCA effect and the tester PDRLT-106, PDRLT-115, PDRLT110, PDRLT-116 and R-15155, showed significant negative value of GCA effect,-0.13, -0.38, -0.71, -0.02 and -0.17 respectively.

Flag leaf length: The lines 'RP-98555'(1.74) and 'ICMA-96666'(1.34) showed significant positive value of GCA effect and the tester 'PDRLT-106', 'R-15081', 'R-15155', 'R-15248', 'R-15468' and 'R-15545' were recorded significant positive value for GCA effect 0.11 ,2.24 ,2.24, 0.99 and 0.24 respectively,. Whereas, the lines 'RP-81'(-1.86) and 'ICMA-05333'(-1.21) showed significant negative value for GCA effect and the tester 'PDRLT-115' , 'PDRLT-117', 'PDRLT-110' and 'PDRLT-116' showed significant negative value for GCA effect , -1.76,-3.01,-1.51 and -0.26.

Plant height: The lines 'RP-98555'(0.28) and 'ICMA-05333'(0.47) showed significant positive value of GCA effect and the tester 'PDRLT-116', 'R-15081', 'R-15155' and 'R-15468' recorded significant positive value for GCA effect, 9.10, 16.73, 5.30 and 14.6 respectively, Whereas, the lines 'RP-81'(-0.52) and ICMA-05333(-0.24) showed significant negative value of GCA effect. The tester 'PDRLT-106', 'PDRLT-115', 'PDRLT-117', 'PDRLT-110', 'R-15248' and 'R-15545' showed significant negative value for GCA effect, -29.88,-6.86,-0.47,4.43,-2.57 and -1.53 respectively.

Panicle length: The line 'RP-98555'(1.50) and 'ICMA-05333'(0.56) showed significant positive value of GCA effect and the tester 'PDRLT-110','PDRLT-116','R-15155' and 'R-15468', recorded significant positive value for GCA effect, 0.97,0.65,4.0 and 1.01 respectively, whereas, the lines, 'RP-81'(-1.76) showed significant negative value of GCA effect and the tester 'PDRLT-106', 'PDRLT-115','PDRLT-117' and 'R-15081' showed significant negative value for GCA effect,-0.98, -0.83, -2.29, -0.80, -0.71 and -1.03 respectively.

Harvest index: The lines 'ICMA-05333'(0.47) significant positive value of GCA effect and the tester 'PDRLT-117','R-15081','R-15155','R-15468' and 'R-15545', showed significant positive value for GCA effect, 1.19, 2.65, 1.42, 2.65 and 0.15 respectively, whereas, the lines, 'ICMA-96666'(-0.30) illustrated significant negative value of GCA effect and the tester 'PDRLT-106','PDRLT-115','PDRLT-110','PDRLT-116' and 'R-15248' showed significant negative value for GCA effect, -1.75,-1.40,-2.34,-0.71 and -1.85 respectively.

Grain yield per plant: The lines 'ICMA-05333'(0.54) showed significant positive value of GCA effect and the tester 'PDRLT-117','PDRLT-116', 'R-15081', 'R-15155' and 'R-15545' showed significant positive value for GCA effect, 0.31,0.46,0.42,0.22, and 0.12 respectively, whereas, the lines, 'RP-81'(-0.43) illustrated significant negative value for GCA effect and the tester 'PDRLT-106', 'PDRLT-115', 'PDRLT-110', 'R-15248' and 'R-15468' showed significant negative value for GCA effect, -0.15,-0.03,-0.59,-0.68 and -0.08 respectively.

Fodder yield per plant: The lines, 'ICMA-96666'(3.95) showed significant positive value of GCA effect, whereas, the line, 'RP-81'(-2.25) and 'RP-98555'(-2.55) showed significant negative value of GCA effect and the tester 'PDRLT-116'(-11.23) showed significant negative value of GCA effect.

4.5.3 Specific combining ability effects: The SCA effects for seed yield and its contributing traits are given in Table 4.3.3 Results of SCA effects presented character wise as under.

Days to 50% flowering: The crosses: 'ICMA-96666 × PDRLT-106', 'RP-81 × PDRLT-115', 'ICMA-96666 × PDRLT-115', 'RP-81 × PDRLT-117', 'ICMA-96666 × PDRLT-110', 'ICMA-05333 × PDRLT-110', 'RP-81 × PDRLT-116', 'ICMA-05333 × R-15155', 'RP-98555 × R-15248', 'RP-81 × R-15468', 'RP-98555 × R-15545' and 'ICMA-05333 × R-15545', showed significant positive value for SCA effect.(3.84, 0.76, 3.21, 2.76, 1.71, 3.56, 3.26, 3.56, 1.34, 3.14, 2.56 and 2.06 respectively). Whereas, the cross combinations 'ICMA-05333 × PDRLT-106', 'RP-98555 × PDRLT-115', 'ICMA-05333 × PDRLT-115', 'RP-98555 × PDRLT-117', 'PDRLT-110 × RP-81', 'ICMA-96666 × PDRLT-116', 'ICMA-05333 × PDRLT-

116', 'ICMA-05333×R-15081', 'RP-81×R-15155', 'ICMA-96666 × R-15155', 'RP-98555×R-15468', 'ICMA-96666×R-15468', 'RP-81×R-15545' and 'ICMA-9666 × R-15545' illustrated significant negative value for SCA effect.(-.3.81,-2.54,-1.44,-1.54,-6.24,-1.24,-1.44,-1.24,-3.79,-1.66,-1.91,-2.74 and -1.79 respectively).

Days to maturity: the crosses 'ICMA-05333×PDRLT-106', 'RP-81×PDRLT-115', 'RP-81×PDRLT-117', 'ICMA-05333×PDRLT-110', 'RP-98555×R-15081', 'RP-81×R-15545', 'RP-98555×R-15545', 'RP-81×R-15248' and 'ICMA-96666 × R-15545' illustrated significant positive value of SCA effect. (2.53, 1.58, 1.45, 2.03, 2.23, 0.83, 0.98, 1.83 and 2.05 respectively), whereas , the crosses 'RP-81×PDRLT-106', 'ICMA-96666 × PDRLT-106', 'RP-98555 × PDRLT-115', 'ICMA-05333 ×PDRLT-115', 'RP-98555 × PDRLT-110', 'ICMA-96666 × PDRLT-116', 'R-15081 × ICMA-05333', 'RP-98555 × R-15248' showed significant negative value for SCA effect (-3.43, -0.82, -1.27, -1.47, -2.77, -1.45, -1.97, -2.02 respectively).

Reproductive phase: the crosses 'ICMA-05333 × PDRLT-106', 'RP-98555 × PDRLT-110', 'ICMA-05333 × PDRLT-116', 'RP-98555 × R-15081', 'ICMA-96666 × R-15155', 'RP-81 × R-15468', 'RP-81 × R-15545' illustrated significant positive value of SCA effect. (7.06, 4.51, 3.06, 1.89, 3.79, 2.39, 3.64), whereas , the crosses 'RP-81 × PDRLT-106', 'ICMA-96666 × PDRLT-106', 'RP-81 × PDRLT-117', 'RP-98555 × PDRLT-110', 'RP-81 × PDRLT-116', 'ICMA-05333 × R-15155', 'RP-98555 × R-15248', 'ICMA-05333 × R-15468' and 'ICMA-05333 × R-15545' showed significant negative value for SCA effect (-4.24, -4.09, -2.24, 3.99, -5.24, -4.06, -3.74,-2.81, and -6.06 respectively).

Effective tillers per plant: the crosses 'RP-81 × PDRLT-106', 'RP-98555 × PDRLT-115', 'ICMA-05333 × PDRLT-115', 'ICMA-96666 × PDRLT-110', 'ICMA-96666 × PDRLT-116', 'RP-98555 × R-15081', 'RP-81 × R-15155', 'RP-98555 × R-15248' and , ' ICMA-96666 × R-15545', illustrated significant positive value of SCA effect. (0.53, 0.31, 0.52, 0.40, 0.34, 0.78, 0.46, 0.43 and 0.61 respectively) whereas the crosses 'ICMA-96666 × PDRLT-106', 'RP-81 × PDRLT-115', ' ICMA-96666 × PDRLT-115', ' RP-98555 × PDRLT-110', ' ICMA-05333 × PDRLT-116', 'R-15081 × RP-81', 'R-15081 × ICMA-96666', 'RP-98555 × R-15155', and

'RP-81 × R-15545' showed significant negative value for SCA effect (-0.36, -0.32, -0.57, -0.48, -0.63, -0.54, -0.34, -0.82, and -0.49 respectively).

Number of nodes per plant: the cross combinations 'RP-98555 × PDRLT-106', 'ICMA-05333 × PDRLT-106', 'ICMA96666 × PDRLT-117', 'ICMA05333 × PDRLT-117', 'RP-81 × PDRLT-110', 'RP-81 × PDRLT-116', 'RP-98555 × R-15155', 'ICMA-96666 × R-15248', 'RP-98555 × R15468', 'ICMA-96666 × R-15468', and 'RP-81 × R-15545' illustrated significant positive value for SCA effect. (1.03, 0.60, 0.60, 0.89, 0.60, 1.01, 1.38, 0.57, 1.25, 0.79 and 0.60 respectively) whereas the crosses 'ICMA96666 × PDRLT-106', 'RP-81 × PDRLT-115', 'ICMA-96666 × PDRLT-115', 'RP-98555 × PDRLT-117', 'ICMA-96666 × PDRLT-110', 'ICMA-05333 × PDRLT-116', 'RP-98555 × R-15081', 'RP-81 × R-15155', 'RP-98555 × R-15248' and 'ICMA-05333 × R-15468' showed significant negative value for SCA effect. (-1.19, -0.63, -0.57, -1.44, -0.65, -0.75, -0.58, -0.94, -0.73, -1.63 and -0.54 respectively).

Flag leaf length: The cross combinations 'RP-81 × PDRLT-106', 'ICMA-96666 × PDRLT-106', 'ICMA-96666 × PDRLT-115', 'RP-81 × PDRLT-117', 'RP-98555 × PDRLT-117', 'ICMA-05333 × PDRLT-117', 'RP-81 × PDRLT-110', 'ICMA-05333 × PDRLT-110', 'RP-98555 × PDRLT-116', 'RP-98555 × R-5081', 'ICMA-05333 × R-15081', 'RP-98555 × R-15155', 'ICMA-96666 × R15155', 'ICMA-05333 × R-15248', 'ICMA-96666 × R-15468' and 'RP-98555 × R15545' exhibited significant positive value for SCA effect. (6.49, 2.292, 1.6, 1.61, 1.01, 0.96, 3.11, 4.46, 6.26, 4.26, 1.21, 1.76, 4.16, 4.71, 2.41 and 3.76 respectively) whereas the crosses 'RP-81 × PDRLT-106', 'ICMA-05333 × PDRLT-106', 'RP-98555 × PDRLT-115', 'ICMA-05333 × PDRLT-115', 'ICMA-96666 × PDRLT-117', 'RP-98555 × PDRLT-110', 'ICMA-96666 × PDRLT-110', 'ICMA-05333 × PDRLT-116', 'RP-81 × RP-15081', 'RP-81 × R-15155', 'ICMA-05333 × R-15155', 'RP-81 × R-15248', 'RP-98555 × R-15248', 'RP-98555 × R-15468', 'RP-81 × R-15545', 'ICMA-05333 × R-15545' showed significant negative value for SCA effect. (-5.11, -3.66, -1.24, -1.29, -3.59, -2.49, -5.09, -5.79, -3.14, -2.34, -4.64, -1.29, -2.64, -5.99, 0.64, -3.29, correspondingly).

Table.4.5: Analysis of GCA effects for yield and its attributing characters of different parents in pearl millet

Entries	Days to 50% Flowering	Days to maturity	Reproductive phase	Effective tillers per plant	No. of nodes/Pla nt	Flag leaf length	Plant height	Panicle length	Harvest Index	Grain yield/Pla nt	Fodder yield/Pla nt
Lines											
RP-81	4.61**	-0.58**	-4.26**	0.09	0.38**	-1.86**	-0.52	-1.67**	-0.08	-0.43**	-2.25**
RP-98555	0.41**	0.27	0.24	0.07	0.16	1.74**	0.28	1.50**	-0.10	0.08	-2.55**
ICMA-96666	-2.34**	-0.68**	1.09**	-0.01	0.12	1.34**	0.47	-0.40	-0.30**	-0.19	3.95**
ICMA-05333	-2.69**	0.97**	2.94**	-0.14**	-0.66**	-1.21**	-0.24	0.56**	0.47**	0.54**	0.85
SE(L)+-	0.20	0.20	0.29	0.05	0.08	0.06	0.58	0.25	0.15*	0.19	0.97
Tester											
PDRLT-106	1.96**	-0.28**	-3.11**	-0.13**	-0.37**	0.11**	-29.88**	-0.98**	-1.75	-0.15**	1.53
PDRLT-115	-0.41**	1.72**	1.26**	0.22**	-0.38**	-1.76**	-6.86**	-0.83**	-1.40**	-0.03**	-4.97
PDRLT-117	-0.91**	-1.15**	-1.11**	-0.18**	0.34**	-3.01**	-0.47	-2.29**	1.19**	0.31**	5.40
PDRLT-110	-2.91**	-2.28**	-0.36**	-0.19**	-0.71**	-1.51**	-4.43	0.97**	-2.34**	-0.59**	7.03
PDRLT-116	-0.41**	-1.65**	-2.11**	0.07**	-0.02**	-0.26**	9.10**	0.65**	-0.71**	0.46**	-11.23**

R-15081	-0.41**	0.72**	0.26**	-0.05**	0.68**	0.74**	16.73**	-0.80**	2.65**	0.42**	-1.35
R-15155	3.59**	0.97**	-3.49**	0.15**	-0.17**	2.24**	5.30**	4.00**	1.42**	0.22**	-8.22
R-15248	-1.29**	0.47**	0.89**	-0.10**	0.43**	2.24**	-2.57**	-0.71**	-1.85**	-0.68**	4.28
R-15468	-0.29**	-0.40**	4.26**	0.32**	0.15**	0.99**	14.62**	1.01**	2.65**	-0.08**	-0.10
R-15545	1.09**	1.85**	3.51**	-0.10**	0.04**	0.24**	-1.53**	-1.03**	0.15**	0.12**	7.65
SE(T)+-	0.01	0.01	0.05	0.00	0.00	0.00	0.69	0.02	0.00	0.01	5.53

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

Plant height: Cross combinations 'ICMA-96666 × PDRLT-106', 'ICMA-05333 × PDRLT-106', 'ICMA-96666 × PDRLT-115', 'RP-98555 × PDRLT-117', 'RP-98555 × PDRLT-110', 'RP-81 × PDRLT-116', 'RP-98555 × R-15081', 'ICMA-05333 × R-15081', 'RP-98555 × R-15155', 'ICMA-96666 × R-15155', 'RP-81 × R-15248', 'ICMA-05333 × R-15248', 'RP-81 × R-15468', 'ICMA-96666 × R-15468', 'ICMA-96666 × R-15545' illustrated significant positive value of SCA effect.(11.34, 19.45, 14.21, 6.87, 6.93, 14.10, 3.92, 3.99, 9.04, 7.25, 7.34, 7.68, 7.64, 13.79 respectively) whereas the crosses 'RP-81 × PDRLT-106', 'RP-98555 × PDRLT-106', 'RP-81 × PDRLT-115', 'ICMA-05333 × PDRLT-115', 'RP-81 × PDRLT-117', 'ICMA-05333 × PDRLT-117', 'ICMA-9666 × PDRLT-110', 'ICMA-96666 × PDRLT-116', 'ICMA-96666 × R-15081', 'RP-81 × R-15155', 'ICMA-96666 × R-15248', 'ICMA-05333 × R-15468', 'RP-81 × R-15545' exhibited significant negative value for SCA effect.(-7.07, -23.72, -8.84, -4.88, -5.13, -3.86, -6.36, -17.90, -10.72, -13.25, -21.37, -16.10, -8.77 accordingly).

Panicle length: Cross combinations 'ICMA-05333 × PDRLT-115', 'RP-81 × PDRLT-117', 'RP-98555 × PDRLT-110', 'ICMA-05333 × PDRLT-116', 'RP-98555 × R-15081', 'ICMA-05333 × R-15081', 'ICMA-96666 × R-15155', 'RP-81 × R-1528', 'ICMA-05333 × R15468' , 'ICMA-96666 × R-15545' illustrated significant positive value of SCA effect.(2.64, 3.53, 2.00, 2.56, 2.78, 1.61, 2.77, 4.0, 1.80, 2.90 respectively) whereas the crosses 'ICMA-05333 × PDRLT-106', 'RP-81 × PDRLT-115', 'RP-98555 × PDRLT-117', 'RP-81 × PDRLT-110', 'RP-98555 × PDRLT-116', 'RP-81 × R-15081', 'ICMA-96666 × R-15081', 'RP-81 × R-151555', 'ICMA-96666 × R-15248', 'RP-98555 × R-15468', 'ICMA-05333 × R-15545' exhibited significant negative value for SCA effect.(-3.06, -2.18, -2.69, -2.58, -1.77, -1.68, -2.06, -2.33, -2.46, -3.47, -1.99, -3.16 accordingly).

Harvest index: Cross combinations 'ICMA-05333 × PDRLT-106' , 'RP-98555 × PDRLT-115', 'RP-81 × PDRLT-117', 'RP-98555 × PDRLT-117', 'ICMA-96666 × PDRLT-110', 'RP-81 × PDRLT-116', 'RP-98555 × PDRLT-116', 'RP-98555 × R-15155', 'ICMA-05333 × R15155, 'ICMA-96666 × R-15248', 'ICMA-05333 × R15468', 'ICMA-96666 × R-15545' illustrated significant positive value of SCA effect, whereas the crosses 'RP-98555 × PDRLT-106', 'ICMA-05333 × PDRLT-

115', 'ICMA-96666 × PDRLT-117', 'RP-81 × PDRLT-110', 'RP-98555 × PDRLT-110', 'ICMA-96666 × PDRLT-116', 'ICMA-05333 × PDRLT-116', 'RP-98555 × R-151555', 'RP-81 × R-15248', 'RP-81 × R-15468', 'RP-98555 × R-15545' exhibited significant negative value for SCA effect.(-2.24, -2.87, -1.63, -1.43, -2.58, -4.08, -5.25, -1.22, -3.81, -1.50, -1.89, -1.50 accordingly).

Grain yield per plant: Crosses 'RP-98555 × PDRLT-106', 'ICMA-96666 × PDRLT-106', 'ICMA-96666 × PDRLT-110', 'ICMA-96666 × PDRLT-110', 'RP-81 × R-15081', 'RP-81 × R-15248', 'ICMA-05333 × R-15545' exhibited significant positive value for SCA effect.(1.47, 1.57, 1.25, 1.15, 1.45, 1.53, 0.62) whereas 'ICMA-05333×PDRLT-106', 'RP-81 × PDRLT-115', 'RP-98555 × PDRLT-110', 'RP-98555 × R-15081', 'ICMA-96666 × R-15248' showed significant negative value for SCA effect.(-2.06, -1.57, -1.28, -1.36).

Fodder yield per plant: Cross combinations 'ICMA-96666 × PDRLT-106', 'ICMA-05333 × PDRLT-115', 'RP-81 × PDRLT-117', 'RP-98555 × PDRLT-110', 'RP-81 × PDRLT-116', 'ICMA-05333 × PDRLT-116', 'ICMA-96666 × R-15081', 'ICMA-05333 × R-15081', 'ICMA-96666 × R-151555', 'RP-81 × R-15468', 'RP-98555 × R-15468', 'RP-98555 × R15545', 'ICMA-05333 × R-15545' illustrated significant positive value of SCA effect(6.17, 22.28, 12.18, 22.63, 8.03, 14.05, 11.65, 4.92, 16.93, 7.0, 23.80, 13.55, 5.55 respectively) whereas the crosses 'RP-81 × PDRLT-106', 'RP-81 × PDRLT-115', 'RP-98555 × PDRLT-115', 'RP-98555 × PDRLT-117', 'RP-81 × R-15081', 'RP-98555 × R-15081', 'ICMA-9666 × R-15468' exhibited significant negative value for SCA effect.(-6.13, -13.63, -8.33, -8.70, -17.58, -18.45, -8.75 accordingly).

Table 4.6: Analysis of SCA effects for yield and its attributing characters of different crosses in Pearl Millet

	Crosses	Days to 50% Flowering	days to maturity	Reproductive phase	Effective tillers per plant	No. of nodes/P plant	Flag leaf length	Plant height	Panicle length	Harvest Index	Grain yield/Plant	Fodder yield/Plant
1	RP-81× PDRLT-106	-0.11	-3.43**	-4.24**	0.53**	-0.44	6.49**	-7.07**	1.32	-0.54	-0.98	-6.13**
2	RP-98555× PDRLT-106	0.09	1.73**	1.26	-0.14	1.03**	-5.11**	-23.72**	1.05	-2.24**	1.47**	4.17
3	ICMA-96666×PDRLT-106	3.84**	-0.82	-4.09**	-0.36**	-1.19**	2.29**	11.34**	0.70	-0.22	1.57**	6.17**
4	ICMA-05333×PDRLT-106	-3.81**	2.53**	7.06**	-0.03	0.60**	-3.66**	19.45**	-3.06**	3.00**	-2.06**	-4.22
5	RP-81× PDRLT115	0.76**	1.58**	-0.11	-0.32**	-0.63**	0.36	-8.84**	-2.18**	0.07	-1.16*	-13.63**
6	RP-98555× PDRLT-115	-2.54**	-1.27*	0.89	0.31*	-0.36	-1.24**	-0.50	0.80	4.43**	1.07	-8.33**
7	ICMA-96666×PDRLT-115	3.21**	1.18	-1.46	-0.51**	-0.57**	2.16**	14.21**	-1.25**	-2.87**	1.12	-0.33
8	ICMA05333× PDRLT11	-1.44	-1.47**	0.69	0.52**	1.56**	-1.29**	-4.88**	2.64**	-1.63**	-1.02	22.28**
9	RP-81× PDRLT-117	2.76**	1.45**	-2.24**	0.28	-0.05	1.61**	-5.13**	3.53**	1.84**	-0.95	14.00**
10	RP-98555× PDRLT-117	-1.54**	-0.40	0.76	-0.19	-1.44**	1.01**	6.87**	-2.69**	3.59**	0.79	-8.70**
11	ICMA96666× PDRLT11	-0.29	-0.45	0.41	-0.11	0.60**	-3.59**	2.13	0.26	-1.43**	-0.38	-10.70**

12	ICMA05333×PDRLT-117	-0.94	-0.60	1.06	0.02	0.89	0.96**	-3.86**	-1.10	-4.00	0.54	5.40
13	RP-81× PDRLT-110	-6.24**	-0.42	4.51**	0.05	0.60**	3.11**	1.38	-2.58**	-2.58**	-0.59	4.38
14	RP98555× PDRLT-110	0.96	-2.77**	-3.99**	-0.48**	0.31	-2.49**	6.93**	2.00**	-4.08**	-1.81**	12.18**
15	ICMA-96666×PDRLT-110	1.71**	1.18	0.16	0.40**	-0.65**	-5.09**	-6.36**	1.20	6.32**	1.25**	-12.33**
16	ICMA05333×PDRLT-110	3.56**	2.03**	-0.69	0.03	-0.26	4.46**	-1.95	-0.61	0.34	1.15*	-4.22
17	RP-81× PDRLT-116	3.26**	-1.05	-5.24**	0.03	1.01**	-0.14	14.10**	0.89	2.67**	0.45	22.63**
18	RP-98555× PDRLT-116	-0.54	1.60**	1.76	0.26	-0.33	6.26**	2.64	-1.77**	3.80**	0.50	-17.58**
19	ICMA-96666×PDRLT-116	-1.29**	-1.45**	0.41	0.34**	0.07	-0.34	-17.90**	-1.68**	-5.25**	-1.01	-13.08**
20	ICMA-05333×PDRLT-116	-1.44**	0.90	3.06**	-0.63**	-0.75**	-5.79**	1.16	2.56**	-1.22**	0.06	8.03**
21	RP-81× R-15081	0.26	0.58	-0.61	-0.54**	0.01	-3.14**	2.82	-2.06**	-0.90	1.45**	-7.25**
22	RP-98555× R-15081	-0.04	2.23**	1.89*	0.78**	-0.58**	4.26**	3.92**	2.78**	0.04	-1.28**	-18.45**
23	ICMA96666× R-15081	1.21	-0.82	-1.46	-0.34**	0.27	-2.34**	-10.72**	-2.33**	0.24	-0.45	14.05**
24	ICMA05333× R-15081	-1.44**	-1.97**	0.19	0.09	0.30	1.21**	3.99**	1.61**	0.62	0.28	11.65**
25	RP-81× R15155	-1.24*	0.83**	1.14	0.46**	-0.94**	-4.64**	-13.25**	-2.46**	3.19**	0.49	-3.88

26	RP98555× R-151555	1.46**	0.98**	-0.86	-0.82**	1.38**	1.76**	9.04**	-0.12	-3.81**	-0.98	4.92
27	ICMA96666× R15155	-3.79**	-0.57	3.79**	0.26	0.07	4.16**	7.25**	2.77**	-0.44	-0.20	16.93**
28	ICMA05333× R15155	3.56**	-1.22	-4.06**	0.09	-0.50	-1.29**	-3.04	-0.19	1.06**	0.69	-17.98**
29	RP81× R15248	0.14	1.83**	0.76	-0.29	0.26	-2.64**	17.07	4.00**	-1.50**	1.53**	-0.38
30	RP98555× R15248	1.34**	-2.02**	-3.74**	0.43**	-0.73**	-2.24**	-3.03	-0.06	-0.37	-0.93	-5.58
31	ICMA96666×R-15248	-0.91**	-0.07	1.41	-0.09	0.57**	0.16	-21.37**	-3.47**	1.65**	-1.36**	2.42
32	ICMA05333× R15248	-0.56**	0.28	1.56	-0.06	-0.10	4.71**	7.34**	-0.48	0.22	0.76	3.53
33	RP81× R15468	3.14**	-0.30	2.39**	0.28	-0.41	-0.39	7.68**	-0.72	-1.89**	0.09	7.00**
34	RP98555× R15468	-1.66**	-0.15	0.39	-0.09	1.25**	-5.99**	0.78	-1.99**	0.15	0.21	23.80**
35	ICMA96666× R15468	-1.91**	-0.20	0.04	-0.21	0.79**	2.41**	7.64**	0.91	-0.69	0.73	-8.70**
36	ICMA05333× R15468	0.44	0.65	-2.81**	0.02	-1.63**	3.96**	-16.10**	1.80**	2.43**	-1.03	-22.10**
37	RP81× R15545	-2.74**	-1.05	3.64**	-0.49**	0.60**	-0.64**	-8.77**	0.27	-0.37	-0.32	-16.75
38	RP98555× R15545	2.46**	0.10	1.64	-0.07	-0.54**	3.76**	-2.92	0.00	-1.50	0.97	13.55**
39	ICMA96666× R15545	-1.79**	2.05**	0.79	0.61**	0.05	0.16	13.79**	2.90**	2.69**	-1.26	5.55**
40	ICMA05333× R15545	2.06**	-1.10	-6.06**	-0.06	-0.11	-3.29**	-2.10	-3.16**	-0.82	0.62**	-2.35
	SE(SCA)+-	0.62	0.63	0.16	0.16	0.27	0.20	1.82	0.79	0.47	0.59	3.07

*, **significant at 5 and 1% level, respective

4.6 Heterosis: The estimates of heterosis over better parents (heterobeltiosis) for seed yield per plant and its contributing traits are presented in Table 4.7. Heterosis over mid-parents and over better parents show significant for the 10 characters are as follows.

Days to 50% flowering: heterosis over the better parent ranged from -10.99 % to 23.53 % for Days to 50% flowering. Maximum significant positive heterosis was noticed in cross 'RP-81 × PDRLT-116' (23.53%), 'RP-81 × PDRLT-117' (21.18%), 'ICMA-96666 × R-15468' (15.38%). Whereas the crosses 'ICMA-05333 × PDRLT-115' (-10.99%), 'ICMA-05333 × PDRLT-106' (-10.99%), 'RP-98555 × R-15155' (-10.99%), 'RP-98555 × R-15468' (-10%), 'RP-81 × PDRLT-110' (-8.99%) showed significant negative heterosis.

Days to maturity: heterosis over the better parent ranged from 28.42 % to 162.35 % for days to maturity. Maximum significant positive heterosis was noticed in crosses 'RP-98555' × PDRLT-116 (162.35%), 'ICMA-96666 × PDRLT-116' (162.35%), 'RP-81 × PDRLT-117' (161.18%), 'ICMA-05333 × PDRLT-117' (160%), 'RP-98555 × PDRLT-117' (158.82%), 'ICMA-96666 × PDRLT-117' (156.47%). Whereas, among the none of this cross showed significant negative heterosis for days to maturity.

Reproductive phase: Heterosis over the better parent is ranged from -56.84% to 59.34%. Maximum significant positive heterosis were noticed 'ICMA-96666 × R-15468' (59.34%), 'ICMA-96666 × PDRLT-117' (56.67%), 'ICMA-96666 × PDRLT-116' (56.47%), 'ICMA-05333 × PDRLT-110' (55.06%). Whereas, only one cross 'ICMA-05333 × R-15081' (-56.84%) showed negative heterosis.

Effective tillers per plant: heterosis over the better parent ranged from -96.87% to 95.05 % for effective tillers per plant. Maximum significant positive heterosis was noticed in crosses 'ICMA-96666 × PDRLT-110' (95.06%) and 'RP-98555 × R-15081' (64.71%). Whereas, these crosses 'ICMA-96666 × PDRLT-106' (-96.87%), 'R-98555 × PDRLT-110' (-96.85%), 'RP-98555 × PDRLT-106' (-96.36%), 'ICMA-96666 × PDRLT-115' (-96.34%), 'ICMA-05333 × R-15248' (-96.22%) showed negative heterosis.

Number of nodes per plant: Heterosis over better parent ranged from -89.89% to 88.98 % for number of effective tillers per plant. Maximum significant positive heterosis was noticed in crosses 'ICMA-96666 × R-15155' (88.98%), 'ICMA-05333 × R-15545' (88.37%), 'ICMA-05333 × R-15081'(87.76%), 'ICMA-05333 × PDRLT-106'(87.53%), 'RP-81 × R-15545'(87.37%). Whereas, these crosses 'R-15468 × RP-81'(-89.89%), 'ICMA-96666 × PDRLT-106'(-89.29%), 'ICMA-96666 × PDRLT-115'(-87.31%), 'RP-81 × PDRLT-106'(-87.24%), 'RP-98555 × R-15155'(-86.22%) showed significant negative heterosis for no. of nodes per plant.

Flag leaf length: heterosis over the better parent ranged from -27.37% to 85.19 % for flag leaf length. Maximum significant positive heterosis was noticed 'ICMA-05333 × PDRLT-116'(85.19%), 'ICMA-05333 × R-15468'(21.05%). whereas these crosses showed significant negative heterosis 'ICMA-96666 × PDRLT-117' (-27.37%), 'R-81 × R-15081' (-25.26%), 'RP-98555 × R-15545'(-25.26%), 'ICMA-05333 × PDRLT-116'(-23.53%), 'ICMA-96666 × PDRLT-110'(-22.47%).

Plant height: Heterosis over the better parent is ranged from -23.09% to 380.59 % for plant height. Maximum significant positive heterosis was noticed 'RP-81 × PDRLT116'(380.59%), 'RP-98555 × PDRLT-118 (355'.09%), 'ICMA-05333 × PDRLT-116'(350.82%), 'RP-81 × R15468'(346.92%), 'RP-98555 × PDRLT-117' (342.94%). Whereas, these crosses 'RP-98555 × PDRLT-106' (-23.09%), 'PDRLT-106 × RP-81'(-14.4%), 'ICMA-96666 × PDRLT-106'(-12.33%), 'ICMA-9666 × PDRLT-110'(-8.18%) showed significant negative heterosis for these trait.

Panicle length: Heterosis over the better parent is ranged from -56.11% to 42.33%. Maximum significant positive heterosis was noticed 'R-15248 × RP-81'(42.33%), 'ICMA-05333 × R-15155'(41.33%), 'ICMA-96666 × R-15155 ' (37.55%), Whereas, these crosses 'RP-98555 × R-15248' (-56.11%), 'RP-81 × PDRLT-106'(53.54%), 'ICMA-96666 × PDRLT-106' (-52.22%), 'RP-81 × PDRLT-110'(-52.7%), 'RP-81 × R-15155' (-50.61%) showed maximum negative heterosis.

Harvest index: heterosis over the better parent is ranged from -42.3% to 25.57% for harvest index. Maximum significant positive heterosis was noticed 'RP-98555

× R-15468 '(25.57%), 'ICMA-96666 × PDRLT-110'(22.84%), 'ICMA-05333 × R-15545'(22.58%), 'RP-98555 × R-15081' (19.12%), 'ICMA-05333 × R-15081' (16.74%). Whereas, the crosses 'RP-98555 × PDRLT-110 '(-42.3%), 'RP-98555 × R-15155'(-39.99%), ICMA-96666 × PDRLT-116 (-38.99%), 'ICMA-05333 × PDRLT-115'(-36.26%) shows maximum significant negative heterosis for seed yield per plant.

Grain yield per plant: heterosis over the better parent is ranges from -57.29% to 57.29 % for grain yield per plant. Maximum positive heterosis was noticed 'RP-98555 × R-15545'(57.29%) and 'ICMA-05333 × R-15468'(52.04%) showed significant positive heterosis. Whereas 'RP-98555 × R-15155'(-57.28%), 'RP-81 × PDRLT-115'(-57.01%), 'RP-98555 × PDRLT-110'(-56.04%), 'ICMA-96666 × R-15155'(-56.23%), 'RP-98555 × R-15081'(-56.13%) and 'RP-98555 × PDRLT-115'(-54.61%) was showed maximum significant negative heterosis for this trait

Fodder yield per plant: heterosis over the better parent is ranges from -11.91% to 452 % for grain yield per plant. Maximum positive heterosis was noticed 'RP-81 × R-15468'(452.97%), ' ICMA-96666 × PDRLT-117'(448.24%) and 'RP-81 × PDRLT-110'(434.83%) showed significant positive heterosis ,Whereas, 'ICMA-05333 × R-15081'(-11.91%) and 'PDRLT-116 × ICMA-05333'(-10.43%) was showed significant negative heterosis for this traits.

Table.4.7: estimation of Heterosis for grain yield and its contributing traits of pearl millet

	heterosis (BP)	Days to 50% Flowering	days to maturity	Reproductive phase	Effective tillers per plant	No. of nodes/Plant	Flag leaf length	Plant height	Panicle length	Harvest Index	Grain yield/Plant	Fodder yield/Plant
1	RP-81× PDRLT-106	4.04**	116.16**	12.12	4.17**	-87.24**	7.23**	-14.4**	-53.54**	-16.26**	-4.02**	333.33**
2	RP-98555× PDRLT-106	2.15**	128.28**	32.32**	-96.36**	-84.75**	-19.78**	-23.09**	4.86**	-17.07**	15.08**	353.54**
3	ICMA-96666×PDRLT-106	11.49**	121.21**	23.23**	-96.87**	-89.29**	-12.12**	-12.33**	-52.22**	2.48**	9.99**	370.71**
4	ICMA-05333×PDRLT-106	-10.99**	131.31**	49.49**	-96.57**	-87.27**	-9.09**	-3.31	-22.63**	10.15**	-9.54**	343.43**
5	RP-81× PDRLT115	7.53**	145.16**	37.63**	-16.67**	-86.88**	-12.05**	255.59**	-5.53**	13.58**	-57.01**	331.18**
6	RP-98555× PDRLT-115	-8.6**	140.86**	49.96**	-94.41**	-86.77**	-15.38**	275.27**	4.45**	3.67**	-51.12**	341.94**
7	ICMA-96666×PDRLT-115	4.6**	144.09**	46.24**	-96.34**	-87.31**	-12.63**	-1.55	3.07**	-5.39**	-51.58**	373.12**
8	ICMA05333×PDRLT11	-10.99**	141.94***	54.84**	-94.41**	-84.41**	-7.79**	204.73**	-0.93	-36.26**	-54.61**	415.05**
9	RP-81× PDRLT-117	21.18**	161.18**	-9.16	-8.33**	7.25**	-12.05**	312.82**	-43.76**	-17.31**	-1.7**	1.49
10	RP-98555× PDRLT-117	1.18	158.82**	-5.63	-96**	-9.38**	-13.19**	342.94**	-15.59**	-13.22**	13.98**	407.06**
11	ICMA96666×PDRLT11	-2.35**	156.47**	58.82**	-96**	16.42**	-27.37**	-1.5	3.3**	-25.53**	2.77**	448.24**
12	ICMA05333×PDRLT-117	-4.71**	160**	-1.41	-15**	17.74**	-14.12**	316.47**	-20.22**	-3.04**	4.31**	-1.91

13	RP-81× PDRLT-110	-8.99**	142.7**	50.46**	-18.75**	1.45**	-4.82**	300**	-52.7**	-26.68**	-55.04**	434.83**
14	RP98555× PDRLT-110	-2.25**	139.33**	41.57**	-96.85**	1.56**	-17.58**	314.27**	-35.28**	-42.3**	-56.65**	394.38**
15	ICMA-96666×PDRLT-110	-4.6**	146.07**	52.81**	95.06**	-17.91**	-22.47**	-8.18**	-41.35**	22.84**	-50.36**	405.62**
16	ICMA05333×PDRLT-110	-3.37**	151.69**	55.06**	-15**	-17.74**	-6.74**	293.15**	-43.26**	-0.89	-48.96**	442.35**
17	RP-81× PDRLT-116	23.53**	154.12**	-15.27	-8.33**	-80.94**	-9.64**	380.59**	-43.06**	-4.35**	5.74**	347.06**
18	RP-98555× PDRLT-116	4.71**	162.35**	-5.63	41.18**	-84.59**	4.4**	355.53**	0	-17.21**	13.33**	372.94**
19	ICMA-96666×PDRLT-116	-3.53**	152.94**	56.47**	41.18**	83.76**	-4.71**	307.65**	-46.12**	-38.99**	0.48	415.29**
20	ICMA-05333×PDRLT-116	-4.71**	162.35**	0	-35**	87.53**	-23.53**	350.82**	4.22**	-0.18	2.83**	-10.43**
21	RP-81× R-15081	-3.53**	135.79**	-4.58	37.5**	13.04**	-25.26**	322.32**	-4.81**	-4.94**	-51.46**	-6.35**
22	RP-98555× R-15081	-4.71**	141.05**	46.32**	64.71**	-85.33**	2.2**	326.32**	12.55**	2.66**	-56.13**	401.05**
23	ICMA96666× R-15081	4.21**	132.63**	41.05**	-5.88**	83.58**	-16.84**	295.89**	-1.89	19.12**	-54.95**	389.47**
24	ICMA05333× R-15081	-3.23**	28.42**	-56.84**	-5**	87.76**	85.19**	325.37**	-4.64**	16.74**	3.65**	-11.91**
25	RP-81× R15155	0	129.63**	-7.63	12.5**	-83.47**	-14.46**	253.27**	-50.61**	3.12**	-55.32**	339.8**
26	RP98555× R-151555	-10.99**	131.63**	28.57**	-17.65**	-86.22**	0	300.41**	-39.93**	-39.37**	-57.28**	377.55**
27	ICMA96666× R15155	6.12**	126.53**	39.8**	41.18**	88.98**	-19.39**	4.34	37.55**	-32.89**	-56.23**	300**
28	ICMA05333× R15155	8.6**	128.57**	27.55**	5**	13.04**	-9.64**	274.69**	41.43**	-36.08**	5.43**	-5.11

29	RP81× R15248	-2.3**	151.11**	-1.53	29.17*	-85.78**	-8.79**	334.56**	42.33**	-33.6**	0.43	383.33**
30	RP98555× R15248	8.79**	144.44**	-9.15	41.18**	0.72	-8.42**	291.67**	-56.11**	-29.58**	-6.71**	415.56**
31	ICMA96666×R-15248	7.78**	146.67**	56.67**	-96**	29.69**	1.11**	251.33**	-12.26**	-31.02**	0.82	411.11**
32	ICMA05333× R15248	1.11	151.11**	2.11	-96.22**	16.42**	-15.38**	313.53**	-44.56**	-27.73**	-53.43**	-3.83
33	RP81× R15468	-6.9**	-6.78	6.11	15**	-89.89**	-19.75**	346.92**	0.61	-23.3**	9.1**	452.97**
34	RP98555× R15468	-10**	-4.72	1.41	12.5**	12.32**	-6.32**	3333.52**	-43.19**	25.57**	-51.47**	375.82**
35	ICMA96666× R15468	15.38**	-5.98	59.34**	35.29**	0	-4.4**	9.54**	2.78**	-17.03**	-53.76**	339.56**
36	ICMA05333× R15468	-4.4**	-3.43	0.7	23.53**	3.73**	-21.05**	295.27**	5.29**	-10.47**	52.04**	342.56**
37	RP81× R15545	-6.9**	134.74**	6.87	10**	87.37**	-4.21**	1.43	0.4	-9.28**	57.29**	405.26**
38	RP98555× R15545	-6.59**	138.95**	52.63**	37.5**	15.74**	-12.63**	6.39**	-45.68**	-26.87**	3.79**	402.11**
39	ICMA96666× R15545	1.05	141.05**	52.63**	11.76**	28.41**	-25.26**	4.18	-23.19**	-32.65**	4.23**	378.95**
40	ICMA05333× R15545	5.38**	137.89**	42.11**	47.06**	88.22**	4.4**	0.54	4.75**	22.58**	13.45**	415.47**
	SE(H)+-	0.880	9.812	9.938	0.221	0.379	0.283	2.579	1.111	0.662	0.831	4.337

Chapter – VI

SUMMARY, CONCLUSION AND SUGGESTION FOR FURTHER WORK

Summary:

The present investigation entitled “Line X tester analysis of yield and yield contributing traits in pearl millet.” (*Pennisetum glaucum* L.) was undertaken to obtain the information on the Phenotypic and genotypic coefficient of variation, heritability, genetic advance, combining ability and heterosis for grain yield and its attributes. Experiment was carried consisting 4 male sterile line, 10 tester and 40 crosses in a Randomized Block Design with 2 replications under normal sown condition at experimental Research Farm, College of Agriculture, Gwalior, (M.P.) during *kharif* seasons 2017-2018. The genetic analysis was carried out by adopting Kempthorne (1957). Heterosis over better parents in F_1 crosses. Phenotypic and genotypic coefficient of variation, heritability, genetic advance and were also determined for all the traits under study.

Both high GCV & PCV were recorded for plant height, fodder yield per plant, flag leaf length, panicle length, reproductive phase, harvest index. High heritability and genetic advance was recorded for flag leaf length, plant height, effective tillers per plant, nodes per plant, panicle length and harvest index indicated presence of additive components. The lower ratio “ $\sigma^2_{gca} / \sigma^2_{sca}$ ” showed the predominance of non-additive components in the inheritance of all characters. Among the parents, ‘ICMA-05333’, ‘R-15081’, ‘R-15155’ and ‘R-15545’ showed significant positive GCA effect for seed yield per plant and its attributing traits, and thus identified as good general combiner in pearl millet. Among the 40 crosses, 7 crosses viz., ‘RP-98555 X PDRLT-106’, ‘ICMA-96666 X PDRLT-106’, ‘ICMA-96666 X PDRLT-110’, ‘ICMA-05333 X PDRLT-110’, ‘RP-81 X R-15081’, ‘RP-81 X R-15248’, ‘ICMA-05333 X R-15545’, recorded good specific combiner for grain yield. The best cross combinations includes ‘RP-98555 X PDRLT-106’, ‘ICMA-96666 X PDRLT-106’, ‘RP-98555 X PDRLT-117’, ‘ICMA-96666 X PDRLT-117’, ‘ICMA-05333 X PDRLT-117’,

'RP-81 X PDRLT-116', 'RP-98555 X PDRLT-116', 'ICMA-05333 X PDRLT-116', 'ICMA-05333 X R-15081', 'ICMA-05333 X R-15155', 'RP-81 X R-15468', 'ICMA-05333 X R-15468', 'RP-81 X R-15545', 'ICMA-05333 X R-15545' exhibited significant positive heterosis. Only 2 crosses, 'RP-98555 X PDRLT-106', 'ICMA-96666 X PDRLT-106' recorded promising for high SCA and heterosis along with higher grain yield.

Conclusion:

1. High estimates of heritability, genetic advance and significant gca and sca variance revealed that flag leaf length, plant height, panicle length, harvest index and effective tillers per plant were equally under the control of additive gene action and non additive gene action.
2. Grain yield and fodder yield were predominantly under the control of non-additive gene action. But both traits were showed significant contribution of additive gene action.
3. 'ICMA-05333, R-15081, R-15155 and R-15545 identified as good general combining parents for seed yield per plant along with various yield components could be used in future pearl millet genetic improvement.
4. 'RP-98555 X PDRLT-106', 'ICMA-96666 X PDRLT-106', 'ICMA-96666 X PDRLT-110', 'ICMA-05333 X PDRLT-110', 'RP-81 X R-15081', 'RP-81 X R-15248', 'ICMA-05333 X R-15545' were good specific combiner for seed yield per plant and attributing traits and may be exploited in the development of hybrids.
5. 'RP-98555 X PDRLT-106' and 'ICMA-96666 X PDRLT-106' recorded promising for high SCA and heterosis along with higher grain yield, could be exploited as promising hybrid.

Suggestions for further work:

1. Good general combiners like 'ICMA-05333, R-15081, R-15155 and R-15545 could be used in the development of high yielding varieties through the simple / recurrent selection from promising segregating cross generations.

2. New recombinant promising single plants may be selected in F_2 generations of good crosses 'RP-98555 X PDRLT-106' and 'ICMA-96666 X PDRLT-106' involving one of the good general combining parents for seed yield could be lead varietal improvement through the recurrent selection, inter-mating and bi-parental crossing.

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