# Genetic Architecture of Seed Yield and Its Component Characters Using Line × Tester Analysis in Pearl Millet [*Pennisetum glaucum* (L.) R. Br.]

पंक्ति × परीक्षक विश्लेषण का उपयोग करते हुए बाजरा [*पेनिसेटम ग्लॉकम* (एल.) आर. बीआर.] में बीज उपज और उसके घटक लक्षणों की आनुवांशिक संरचना


**KOMAL SHEKHAWAT**


## THESIS

*Doctor of Philosophy in Agriculture*

**(Genetics and Plant Breeding)**

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**DEPARTMENT OF GENETICS AND PLANT BREEDING**

**COLLEGE OF AGRICULTURE, BIKANER**

**SWAMI KESHWANAND RAJASTHAN AGRICULTURAL UNIVERSITY BIKANER (RAJASTHAN)-334006**

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**Thesis**

**Submitted to the**

**Swami Keshwanand Rajasthan Agricultural University, Bikaner**

in partial fulfillment of the requirement for the degree of

*Doctor of Philosophy in Agriculture*

**(Genetics and Plant Breeding)**

By

**KOMAL SHEKHAWAT**

**2021**

**Swami Keshwanand Rajasthan Agricultural University, Bikaner**

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***Place: Bikaner***
***Dated:*** ***(KOMAL SHEKHAWAT)***

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| S. No. | Abbreviation | Explanation | S. No. | Abbreviation | Explanation |
|---|---|---|---|---|---|
| 1 | % | Percent | 31 | h | Hour |
| 2 | $\mu$ | Population mean | 32 | Ha | Hectare |
| 3 | $\sigma^2$ | Variance | 33 | HM | Harmonic Mean |
| 4 | ºC | Degree celsius | 34 | i.e. | That is |
| 5 | AICPMIP | All India Coordinated Pearl Millet Improvement Project | 35 | ICRISAT | The International Crops Research Institute for the Semi-Arid Tropics, Hydrabad |
| 6 | AICRP | All India Coordinated Research Project | 36 | kg | Kilogram |
| 7 | AM | Arithmetic Mean | 37 | km | Kilometer |
| 8 | AMMI | Additive Main effect and Multiplicative Interaction | 38 | L x T | Line x Tester |
| 9 | ANOVA | Analysis of variance | 39 | M x F | Male x Female |
| 10 | ARS | Agricultural Research Station | 40 | M.S. | Mean Square |
| 11 | AU | Agriculture University | 41 | mg | Milligram |
| 12 | $b_i$ | Regrassion coefficient | 42 | mm | Millimeter |
| 13 | BSSH | Breadth of sunshine hours | 43 | MS line | Male Sterile line |
| 14 | C.D. | Critical Difference | 44 | NIL | Near Isogenic Lines |
| 15 | CCSHAU | Chaudhary Charan Singh Haryana Agricultural University | 45 | OPV | Open Pollinated Variety |
| 16 | CGMS | Cytoplasmic Genetic Male Sterility | 46 | ppm | Parts per million |
| 17 | cm | Centimeter | 47 | RARI | Rajasthan Agricultural Research Institute, Durgapura, Jaipur |
| 18 | $cm^2$ | Square centimeter | 48 | RBD | Randomized Block Design |
| 19 | CMS | Cytoplasmic Male Sterility | 49 | RIL | Recombinant Inbred Lines |
| 20 | d.f. | Degree of freedom | 50 | S.No. | Serial Number |
| 21 | D | Divergence Value | 51 | S.E. | Standerd Error |
| 22 | $D^2$ | Square of divergence value | 52 | S.S. | Sum of Squares |
| 23 | DAS | Days after sowing | 53 | $S^2d_i$ | Deviation from regrassion |
| 24 | *et al.* | And co-workers | 54 | SCA | Specific Combining Ability |
| 25 | $F_1$ | First Filial Generation | 55 | SEd | Standard error of deviation |
| 26 | Fe | Iron | 56 | SEm | Standard error of mean |
| 27 | G x E | Genotype x environment interaction | 57 | SKNAU | Sri Karan Narendra Agriculture University, Jobner, Jaipur |
| 28 | g | Gram | 58 | viz. | Namely |
| 29 | GCA | General Combining Ability | 59 | x | Cross between two parents |
| 30 | GM | Geomatric mean | 60 | Zn | Zinc |

# 1. INTRODUCTION

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is a major warm-season cereal grown on 26 million ha in the arid and semi-arid tropical (SAT) regions of Asia (more than 10 million ha) and Africa (15-16 million ha). Pearl millet is a staple food for the majority of poor farmers and also an important fodder crop for livestock population in arid and semi-arid regions of India. It is an important boorish grain crop belonging to the family *Poaceae (Gramineae)* and give out as staple food for the millions of people flourishing under hunger. The crop is able to booming under adverse conditions and also set up an important fodder crop for livestock population in arid and semi-arid regions of India.

Pearl millet is a highly cross pollinated crop with an outcrossing rate of more than 85%. It is a diploid (2n=14) in nature and originated in Africa (Vavilov, 1950). Pearl millet also known as cat tail, spiked or bulrush millet and localized known as bajra. Pearl millet is a $C_4$ plant species like sorghum, corn, sugarcane and switchgrass. This crop has high photosynthetic efficiency and capacity to produce more dry matter production. It's plants are highly heterozygous in nature because of its cross pollinating system due to protogynous nature. The protogynous flowering and wind-borne pollination favor making open pollinated varieties (OPVs) as the natural cultivar state of the crop.

It is very palatable bristly cereal with the best nutritional outline (rich in tryptophan and cysteine). Pearl millet grain contains 8.5 to 15% protein, 5.03 to 6.0% fat, 1.05 to 1.7% crude fibre and 65.5 to 70% carbohydrates. As a food crop, pearl millet grain take over the highest amount of calories per 100 gram (Burton *et al.*, 1972), which is mainly grant by carbohydrates, fats and proteins (Flech, 1981). It's mineral content is also close with other cereals.

Its grain is also used as cater for poultry and green fodder or stover (dry straw) is fed to cattle. Most important quality aspects of pearl millet forage are high protein (11.6%), low lignin, high dry matter yield, easy to digestible and retain less oxalic acid which is an anti-nutritional factor (Hanna *et al.*, 1999). Although, crude protein content (9.9-14%) in pearl millet stover is less than sorghum, but it is more than wheat and rice (Singh *et al*., 1977). The toxic component HCN is quantitatively less in green fodder of pearl millet in comparison to sorghum (Hanna *et al.*, 1999).

Pearl millet on large-scale is cultivated as dual purpose crop over large areas in Asia, Africa and Australia. India is the largest producer of pearl millet with an annual production of 8.60 million tonnes from an area of 6.93 million hectares with productivity of 1243 kg/ha Anonymous (2019-20)**.** Pearl millet is conventionally grown as rain fed crop mostly under low fertility and rainfall condition. However, it also responds well to irrigation and improved management conditions. In India, pearl millet is mainly grown in the state of Rajasthan, Uttar Pradesh, Gujarat, Maharashtra, Haryana, Karnataka, Tamil Nadu, Madhya Pradesh, and Andhra Pradesh.

Rajasthan hold first position in area and production of pearl millet in India. In Rajasthan, it is cultivated on 4.25 million hectares area with the production of 5.05 million tonnes and productivity 1190 kg/ha Anonymous (2019-20). Major pearl millet producing districts of Rajasthan are Alwar, Sikar, Bharatpur, Karauli, Jaipur, Dausa, Dholpur, Jhunjhunu, Sikar, Nagaur, Swai Madhopur, Barmer, Bikaner, Jaisalmer and Churu. The average productivity of pearl millet is far low (355 kg/ha) in Zone 1C (hyper arid and partially irrigated western plains) comprising Bikaner, Jaisalmer and four tehsils of Churu district because of low moisture and arid conditions prevailing in the zone. Therefore, it needs the attention to improve the productivity of the crop in the zone.

The breeding and advance work in pearl millet in the earlier days was neglected since; it was examine to be a crop of low value.

The improvements in this crop in India go ahead as early as in 1920. But, the real breakthrough was made when the first and the most widely used cytoplasmic male sterile line, Tift 23A, was released (Burton, 1965). This allowed grain hybrids to be developed in India with the production and extensive testing of single crosses with Tift 23A.

The basic reason in any crop improvement programme is to enlarge the quality and yield potential of the crop. The character grain yield has composite in nature, different factors affecting the yield must be think about and judge with regards to their contribution to yield. A successful breeding programme for yield improvement through the phenotypic selection is mainly dependent on the nature and magnitude of variation in the available material and role played by the environment in the expression of plant characters *i.e.* phenotype.

Manipulation of hybrid vigour is considered to be one of marvelous achievements of plant breeding in this crop. Cross-pollinated nature and accessibility of cytoplasmic male sterile line in pearl millet had made it achievable to exploit hybrid robustness on commercial scale. For the identification of potential hybrid combinations, prime importance is to study of magnitude and direction of heterotic behavior under diversified environmental condition.

The selection of right type of parents to be included in hybridization programme is a deciding step for the breeder. The use of superior genetically worthy parents ensures much better success of breeding programme. This would require considerable and complete genetically studies of subsist germplasm as well as newly evolved promising lines. The lines that perform well in combinations are eventually of greater importance to the plant breeder. Information on combining ability lay out the guide line to the plant breeder in selecting the elite parents and desirable cross combinations to be used in expression of systematic breeding programme and at the same time provides means of understanding the nature of gene action involved in the inheritance of numerous traits.

Genotype and its interaction with prevailing environment is the basic factor set on the final yield. The genotype x environment interaction is particularly important in the pronouncement of quantitative characters, which are command by polygenic systems and are greatly modified by the environmental influences.

So that, in order to have unprejudiced estimates of various genetic components, it is imperious that the experiment should be repeated over different environments. The evaluation of genotype x environment interactions gives an idea of stability or buffering ability of the population under study. Genotype x environment interactions is of common phenomenon and often creates manifold difficulties in interpreting results and thus hampers the progress of breeding programme aiming at further genetic improvement in crop plants. Hence, the knowledge of magnitude and nature of genotype x environment interaction is very useful to a breeder for proper understanding and assessment of his material (Sprague, 1966).

Line x tester mating design has been substantial used in both self and cross pollinated species to realize the nature of gene action involved in expression of quantitative traits. It yields reliable information on the components of GCA and SCA variances and their effects. Thus it helps in the selection of suitable parents for hybridization as well as the choice of appropriate breeding procedures.

Moisture stress is major limiting factor in productivity of many crop species. Majority of the cultivation is still dependent on rainfall and conserved moisture. Crop naturally suffers from drought stress during the reproductive period of growth after depletion of stored water (Kumar, 2001). Hence development of drought tolerant/resistant varieties of pearl millet is essential to raise the production.

With this perspective, the present investigation was carried out in three environments using line x tester mating design in pearl millet with aforesaid objectives:

1. To estimate the combining ability variances and effects in $F_1$'s for yield and its contributing traits under different environments.
2. To estimate various components of genetic variation and to suggest suitable breeding strategy for improvement of yield and its contributing traits through line × tester analysis.
3. To estimate the magnitude of standard heterosis observed among the crosses under different environments.
4. To estimate the genotype x environment interaction and phenotypic stability of the hybrids for yield and its contributing characters.
5. To identify hybrids suitable for arid zone based upon above parameters.

# 2. REVIEW OF LITERATURE

Scientists of different corners of the world have carried out a few researches on combining ability, heterosis, phenotypic stability and stress indices in pearl millet and some other important crops of grass family and valuable information was reported. The relevant literature related to the present investigation **"Genetic Architecture of Seed Yield and Its Component Characters Using Line × Tester Analysis in Pearl Millet [*Pennisetum glaucum* (L.) R. Br.]"** are reviewed below under following headings:

1. Combining ability and gene action
2. Standard heterosis
3. Phenotypic stability (genotype x environment interaction)
4. Moisture stress indices

## 1. Combining ability and gene action

Fisher (1918) was first recognized the importance of biometrical techniques to study the genetics of quantitative characters and Fisher *et al.* (1932) partitioned total genetic variance into three parts *viz.,* additive (which arises from average effect of genes), dominance (which arises from allelic interactions) and epistatic (which arises from non-allelic interactions).

Combining ability may be defined as the ability of a genotype to transmit superior attributes to its crosses. This is of mainly two types. The concept of combining ability in terms of genetic variation was first given by Sprague and Tatum (1942) using single crosses in maize crop. General combining ability indicates the average performance of a line in a series of cross combination, whereas, specific combining ability shows those effects in some definite combinations which significantly departed from what would be expected on the basis of average performance of the lines involved (Sprague and Tatum, 1942).

Combining ability studies are useful in assessing the ability of parents and thus, helps in selecting parents which, when crossed, would give rise to more desirable segregants during hybridization programme. It also helps in characterizing the nature and magnitude of a systematic breeding approach. The method of line x tester analysis developed by Kempthorne (1957) is one such design, which has been extensively used both in self as well as cross pollinated crops.

Yadav *et al.* (2005) analyzed an experimental material comprising 42 crosses of pearl millet developed by crossing seven lines and six testers in line x tester mating design. Sufficient amount of genetic variability was present in the material as was evident from highly significant mean square values in case of lines, testers and lines x tester for all the characters. The estimates of general predictability ratio revealed that both additive and non-additive gene effects were equally important for all the characters studied. The estimate of gca effects revealed that lines HMS 9A, ICMA 95555 and testers H 90/4-5, G 73- 107 and CSSC 46-2 were the good general combiners not only for grain yield, but also for most of its component traits, and cross combinations HMS 9A x CSSC 46-2 and ICMA 95555 x CSSC 46-2 showed high positive sca effects and per se performance for grain yield and most of its contributing traits.

Shanmuganathan *et al.* (2006) evaluated a diallel set of 11 pearl millet genotypes in terms of general combining ability (GCA) effects of parents and specific combining ability (SCA) effects of cross combinations. The analysis of variance of diallel progenies exhibited significant genotypic differences. Different analyses *i.e.* combining ability analysis and genetic component analysis showed that both additive and non additive gene effect were significant. Four parents had negative GCA estimates. Crosses with low SCA effects were also identified and their further use in breeding programme has been suggested.

Izge *et al.* (2007) conducted a nursery experiment in pearl millet to estimate combining ability. Both additive and non-additive genetic effects were involved in the control of the traits, but non-additive genetic effect was the most important in that regard. The parents, BONKOK- SHORT, DMR 43, DMR22 and LCIC 9702 were identified as the best general combiners in terms of GCA effects. The hybrids DMR 22 x LCIC 9702, DMR 43 x LCIC 9702, DMR 22 x LCIC 9703-27 and D2P 29 x EX-BORNO were observed to have recorded the highest SCA effects in various traits.

Eldie *et al.* (2009) carried out an experiment in Sudan which consisted of four male, 15 female parents and their 60 crosses following line x tester arrangement. Combining ability analysis showed that parents, ICMA 97333, ICMA 96222, Baladi yellow, SADC togo and Topcross P1 were good combiners for high grain yield as well as for most of the other traits measured in this study. Assessment of SCA effects for grain yield at Wad Medani revealed that hybrid Baldai white x ICMA 97333 had maximum positive SCA effects and high per se performance followed by SADC togo x ICMA 96222; while at Elgedarif Topcross x ICMA 99111 had the highest positive SCA effects followed by ICMV 155 x ICMA 99111. However, ICMV 155 x ICMA 99111 exhibited the highest SCA in combined analysis across sites.

Khandagale *et al.* (2014) conducted an experiment with 50 hybrids of pearl millet which were developed through line x tester mating design using five male sterile lines and ten restorers as parental material. Significant differences were observed for all the ten characters studied. Among females, 732A was found best general combiner for grain yield and had significant GCA effects for days to 50% flowering, days to maturity, 1000-grain weight and plant height while, in male parent, PT 4801 was the best general combiner followed by PT 4108 and PT 4563 for grain yield per plant. The cross ICMA

88004 x PT 4639 was the best specific combiner for grain yield per plant followed by ICMA 91222 x PT 4520 and ICMA 99222 x PT 4801.

Singh and Sharma (2014) conducted an experiment with four male sterile lines (female parents) and nine inbreds (male parents) of pearl millet. In general combining ability analysis, GIB 144 recorded maximum GCA effects for yield, stem thickness, leaf area, panicle length, panicle girth and 1000-grain weight, dry weight per plant and harvest index followed by ICMA 93222, GIB 3346 and ICMA 95333. In specific combining ability analysis seven crosses *viz.,* ICMA 93222 x GIB 78, ICMA 96111 x GIB 129, ICMA 93222 x GIB 144, ICMA 93222 x GIB 129, ICMA 97333 x GIB 157, ICMA 97333 x GIB 135 and ICMA 95333 x GIB 157 were identified as the best specific combiners for yield and major yield components.

Rafiq *et al.* (2016) carried out an investigation to study the combining ability of different cytoplasms of alloplasmic iso-nuclear lines of pearl millet. The results revealed that the lines with $A_4$ cytoplasm are significantly better general combiner for grain yield per plant, panicle weight, 1000 grain weight and productive tillers per plant than the lines with $A_1$ and $A_5$ cytoplasm. Among male parents, NB 527 was the best general combiner followed by NB 799, NB 714 and NB612 for grain yield per plant. The $A_4$ cytoplasm hybrids ICMA05666 × NB647, ICMA 05666 × NB8 12 and ICMA 05666 × NB 827 were best specific combiner for grain yield per plant followed by CMA 07999 × NB 652 and ICMA 99444 × NB5 26 belongs to $A_5$ and $A_1$ cytoplasm, respectively.

Jeeterwal *et al.* (2017) undertaken an investigation to study the combining ability in pearl millet using 10x10 diallel set, excluding reciprocals, for grain yield and its 12 component traits. The ratio of GCA and SCA variance revealed preponderance of non- additive gene action in expression of all the characters. Among the Parent RIB-3135 followed by RIB-335/74, MIR-5252 and RIB-192 were found to be uniformly best parent across the environments for grain yield per plant. The crosses *viz.,* P5 x P9 in all the environments followed by P4 x P6 in $E_1$, P5 x P10 followed by P1 x P2 in $E_2$ and P6 x P7 followed by P2 x P6 in $E_3$ were the most promising having good SCA, coupled with high per se performance for grain yield and some of its components.

Krishnan *et al.* (2017) conducted an experiment to assess the combining ability effects of 35 hybrids resulted from line x tester mating design involving seven lines and five tester parents along with the standard check (GHB 558). The analysis of variance for combining ability revealed that specific combining ability variance for m x f interaction were highly significant for all characters. The magnitude of sca variances was higher than the gca variances for all the characters indicated non-additive gene action in the inheritance of these traits. The female ICMA 96222 had high per se performance and good general combing ability for days to flowering, days to maturity, ear head length, test weight, grain yield per plant, harvest index and protein content. The cross ICMA 06777 x 18805 R had good x average combiner parents, high per se performance, significant positive specific combining ability effect for grain yield per plant, test weight, ear head length and harvest index. The cross ICMA 96222 x 18488 R had good x good combiner parent, significant positive specific combining ability effect for grain yield per plant, test weight, ear head length and protein content.

Kumar *et al.* (2017a) carried out a study to assess the combining ability and gene action for grain yield and 10 quantitative traits in pearl millet. In results, both GCA and SCA variances were highly significant for all characters. The estimates of general combining ability (GCA) effects indicated that the parents RMS 7A, ICMA 843-22, ICMA 04999, ICMA 93333 and JMSA 20042 (females) and BIB-40, BIB-75 and BIB- 186 (males) emerged as good general combiners for grain yield and its components. The cross combinations such as RMS

21A x BIB-186, ICMA92777 x BIB-65, ICMA 04999 x BIB-76, ICMA 06999 x BIB-40, RMS 7A x BIB-75, ICMA 92777 x BIB-40, ICMA 92777 x BIB-66, ICMA 97111 x BIB-186, ICMA 04999 x BIB-65, JMSA 20042 x BIB-40, JMSA 20042 x BIB-66, RMS 7A x BIB-76, ICMA 06999 x BIB-76 and RMS 6Ax BIB-186 showed significant and positive specific combining ability (SCA) effects for grain yield and other yield attributing characters.

Siddique *et al.* (2017) undertook a study to explore the genetic architecture of pearl millet through combining ability analysis in a 5 x 5 diallel fashion. In results both GCA and SCA mean squares were significant for grain yield, plant height, panicle length and days to flowering. However, these were non-significant for number of productive tillers and panicle girth. General combining ability estimates revealed that genotype MGP-322 was good general combiner for all the traits under study except for days to flowering for which MGP-335 and 13RBS-01 were good general combiners but these were poor general combiners for all other traits under study. The crosses MGP-322 x MGP- 328, MGP-322 x MGP-335, MGP-328 x 13RBS-13, 13RBS-01 x 13RBS-13 and MGP-322 x 13RBS-01 were best specific combiners for grain yield and some other attributes respectively. All these crosses involved at least one good general combiner except MGP-328 x 13RBS-13.

Solanki *et al.* (2017) conducted an experiment to study combining ability along with inheritance of grain yield and component characters of pearl millet. The analysis of variance revealed significant difference among all the hybrids for all the characters studied. Among the female parents, RMS 6A, ICMA 92777 and JMSA 20073 were identified as good general combiners for grain yield per plant and some other component traits. Amongst male parents, H77/833-2 and RIB 57SO5 were good general combiner for most of the characters. Among the fifty hybrids, nine hybrids showed the best performance with significantly positive SCA effect for grain yield.

Badurkar *et al.* (2018) conducted an experiment to assess combing ability in pearl millet using four CGMS lines and five restorer male parents and found that the ratio of $\sigma^2$gca/$\sigma^2$sca was less than unity for all the traits indicated the preponderance of non-additive gene effects in the expression of traits. The CGMS line MS 92888, MS 95111and restorer parent R 156 and R 177 were found good general combiners for grain yield and other related traits. In general for grain yield and its related traits the hybrids *viz.,* MS 95111 x R 189 and MS 93333 x R 177 were found better.

Gavali *et al.* (2018) conducted an experiment with 48 hybrids which were developed through line x tester mating design using four male sterile line and twelve restores as parental material along with two hybrids as standard checks. Significant differences were observed for all the ten characters studied. Among the females, DHLB-25A was found best general combiner for grain yield and had significant GCA effects for six other characters. For earliness, DHLB-21A was good general combiner as it had significant GCA effects. The lines, DHLB-22A and DHLB-23A were good general combiner for grain iron content (ppm). Among male parents, S16/105, S-16/85 and S-16/93 were found to be good general combiner for most of the characters under study. The cross DHLB-21 x S-16/107 was the best specific combiner for grain yield per plant followed by DHLB-25A x S16/109 and DHLB-25A x S-16/93. The cross combination DHLB-22A x S-16/109 was the best specific combiner for grain iron content (ppm) followed by DHLB-23 x S-16/89.

Ladumor *et al.* (2018) carried out a line × tester analysis involving 4 testers and 7 lines of pearl millet to identify crosses and good combiners for developing new hybrids to achieve high grain yield per plant. The variance due to GCA and SCA showed that the non-additive components were pre-dominant for the expression of days to flowering, days to maturity, plant height (cm), number of effective tillers per plant (no.), dry fodder yield per plant (g), grain yield per plant (g) and Fe content (ppm) Whereas, additive components were predominant for the expression of ear head length (cm), ear head diameter (cm), dry fodder yield (g), test weight (g), harvest index and Zn content (ppm). Among the female parents ICMA 10222 and JMSA5 20171 were identified as good general combiner for grain yield per plant and some other component traits. Among the male parents 128-SB17, 160-SB-17 and 153-SB-17 were good general combiner for most of the characters. Among the 28 hybrids, two crosses (JMSA5 20171 × 153-SB-17 and ICMA1 12444 × 118SB-17) were identified as good specific combiners based on significant and positive sca effect for grain yield per plant.

Saini *et al.* (2018) evaluated 56 hybrids which were generated through line × tester mating design using 8 lines and 7 testers as parental material along with 2 standard checks in terms of combining ability in pearl millet. Mean sum of squares due to lines were significant for all the characters, while the mean sum of squares due to testers was significant for all the characters except number of effective tillers and biological yield per plant. The interaction effects were found to be significant for all the traits except grain yield/ plant, biological yield/ plant and harvest index. It is concluded from the present investigation that the crosses JMSA 20042 × BIB 19 followed by ICMA 97111 × BIB 16, ICMA 93333 × BIB 31 and ICMA 843-22 × BIB 4 were identified as potential crosses for commercial exploitation of heterosis in pearl millet as these crosses exhibited highest magnitude of standard heterosis and sca effects.

Santosh *et al.* (2018) carried out a line x tester analysis using four lines and twelve testers to study the combining ability and gene action for grain yield and other morpho-nutritional traits in pearl millet.

Analysis of variance for combining ability revealed significant differences among the lines, testers and lines x testers for all the characters except for mean squares due to lines for days to 50% flowering, days to maturity, ear head girth, number of grain per sq. cm, grain Zn content (mg/kg) and due to testers for grain Fe content (mg/kg). Among the lines, DHLB-18A and the testers K-13/991, K-13/999 and K-13/1005 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 DHLB-17A x K-13/1005 (average x good) followed by DHLB-16A x K13/1008, DHLB-15A x K-13/1017 and DHLB-15A x K-13/995.

Shruti *et al.* (2020) study was carried out with line × tester analysis to generate information on magnitude of heterobeltiosis and standard heterosis, gene effects, combining ability effect of parents and hybrids for grain yield, grain weight and grain minerals (iron, zinc, copper and manganese). The partitioning of variance due to parental genotypes revealed that lines and testers significantly differed for studied traits. The per se performance of hybrids was higher than parents in desired directions for most of the characters suggesting the possibility of heterotic hybrids. The potence ratio was less than 1 for all traits except Fe. The analysis of variance for combining ability revealed importance of both additive and non-additive components of genetic variance. On the basis of per se performance and combining ability analysis cross ICMA 98444 × AIB 220 may be directly exposed for commercial cultivation and may be advanced for development of parental genotypes. The genetic relationships identified among the male sterile/restorer lines may be useful in designing strategies to improve the genetic variation in the context of pearl millet breeding and to develop heterotic crosses.

Anita *et al.* (2020) investigation was carried out to study combining ability along with inheritance of grain yield and its component traits in 100 hybrids of pearl millet which were generated through line x tester mating design using 5 male sterile lines and 20 restorers as parental material at ICRISAT, Hyderabad during summer, 2018. These hybrids were evaluated in randomized block design with 3 replications in 3 environments during *Kharif,* 2018 at Rajasthan Agricultural Research Institute, Durgapura (Jaipur). In results, the ratio of variance due to GCA and SCA indicated that predominance of non-additive gene action for all the characters studied except ear girth. GCA effects revealed that parents like ICMA 04999 and ICMA-843-22 (female), RIB-192, RIB-15270, RIB-494 and MIR-525-2 (male) were good general combiners for grain yield and some contributing characters. On the basis of SCA effects the crosses namely ICMA-843-22 x RIB-3135-18, ICMA-04999 x J-2290, ICMA-93333 x RIB-15270 were identified as superior for grain yield and related traits over the environment.

Kumawat *et al.* (2020a) five male sterile lines (RMS 7A from Rajasthan Agricultural Research Institute, Jaipur, Rajasthan and ICMA 843-22, ICMA 88004, ICMA 93333 and ICMA 97111 from ICRISAT, Patancheru, Hyderabad) were crossed with ten restorer lines (BIB-343, BIB-359, BIB-383, BIB-391, BIB-399, BIB-407, BIB-415, BIB-423, BIB-439 and BIB-451 from AICRP on Pearl Millet, Bikaner, Rajasthan) in line x tester mating design at ICRISAT, Patancheru, Hyderabad, during summer-2018 to develop 50 $F_1$ hybrids. These 50 $F_1$ hybrids (crosses) along with three standard check (HHB 67 Improved, RHB-177 and MPMH-17) hybrids were evaluated in randomized block design with three replications under three environments created by differentiating number of irrigations during *Kharif*-2018 at Agricultural Research Station ($E_1$) and College of Agriculture ($E_2$ and $E_3$), Bikaner. From the results of GCA effects, it was revealed that a number of parents *via.* ICMA 843-22, RMS 7A (female parents), BIB-423, BIB-343 and BIB-451 (male parents) were found to be better general combiner for grain yield and most of its component characters. In case of SCA effects, the hybrids *viz.,* RMS-7A x BIB-407, ICMA 843-22 x BIB- 343, ICMA 843-22 x BIB-451, ICMA 88004 x BIB-423 and ICMA 93333 x BIB-439 were identified as superior for grain yield and related traits. The hybrids with high SCA effects involving good x good general combiners were ICMA 843-22 x BIB-343, ICMA 843-22 x BIB-451 and ICMA 843- 22 x BIB-423 for grain yield and related traits therefore, it was expected that these hybrids may offer desirable transgressive segregants in the later generations.

Patil *et al.* (2021) evaluated 60 hybrids produced by crossing four male sterile lines with ten diverse inbred lines in L x T mating design in RBD with two replications to study combining ability effects. The analysis of variance for combining ability revealed that mean squares due to parents and crosses were significant for all characters studied indicated significant differences for all characters. However, $\sigma^2$ gca / $\sigma^2$ sca ratio depicted preponderance of non additive gene action for all the characters except days to 50% flowering, days to maturity, earhead length and earhead girth, thereby suggesting the importance of both additive and non additive gene effects. Among the parents S-19/12, S-19/11, S-19/13, S-16/769A and DHLB-23A was good general combiner for grain yield per plant; while hybrids S-16/704A x S-19/12 followed by S-16/760A x S-19/05, DHLB-23A x S-19/04 were good specific combiners for grain yield per plant.

## 2. Standard heterosis

Heterosis is usually defined as superiority of the hybrid over the average performance of the parents and has been reported in species including pearl millet. Shull (1914) coined the term heterosis during working on maize. The heterosis is measured over mid, better parent and commercial checks. Superiority of hybrid over better parent actually is a measure of over dominance and has often been taken as a synonym of heterobeltiosis. Measurement of superiority of hybrid over check is termed as standard heterosis, has an economic importance and is now widely used for expression of heterosis.

The most important aspect for the economic exploitation of hybrid vigour is to study the extent of heterosis present for agriculturally important traits and the feasibility of its commercial use. Burton (1951) first reported the presence of heterosis in pearl millet. After that various researchers have reported a sizable amount of heterosis for all the characters in pearl millet as its utilization is possible owing to the availability of cytoplasmic-genetic male sterility (CGMS). The available information on magnitude of standard heterosis in pearl millet is reviewed here.

Vetriventhan *et al.* (2008) conducted an experiment comprising five male sterile lines and 30 inbred testers of pearl millet and their 150 hybrids at Millet Breeding Station, Tamil Nadu Agricultural University, Coimbatore during 2005-2007 for studying the extent of hybrid vigour in $F_1$ 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. Highest and significant positive standard heterosis was recorded in ICMA 88004A x PT 5164 for total number of tillers; while hybrid ICMA 94111A x PT 5423 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.

Chotaliya *et al.* (2009) crossed ten diverse inbreds in a diallel fashion excluding reciprocals to study the magnitude of heterosis in pearl millet. 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 be194.65 and 153.22 per cent over mid and better parent, respectively.

Vagadiya *et al.* (2010) carried out a study to estimate the nature and magnitude of heterosis for grain yield and its attributing traits through line x tester fashion 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. 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. Three most promising hybrids were JMSA-20072 x J- 2290, JMSA-20073 x H77/833-2 and ICMA-98444 x J-2498 having high heterosis.

Jethva *et al.* (2012) studied heterosis for grain yield and its attributes in pearl millet through line x tester mating design in three different seasons. The degree of heterobeltiosis and standard heterosis varied for all the hybrids and for all the characters studied. In general, it was 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.

Singh *et al.* (2014) had undertaken a study for genetic analysis of forage yield and quality traits in pearl millet under two environments. A set of 15 CMS lines and 4 populations as testers were crossed in all possible combinations to obtain 60 top cross hybrids. Hybrids 220A × Giant bajra, 01555A × NDFB-2 and 408A × GFB-1 exhibited high positive significant heterosis under both the environments.

Parmar *et al.* (2015) studied the extent of heterobeltiosis and standard heterosis for grain yield per plant and quality traits in pearl millet using line × tester analysis involving 5 lines and 14 testers. ICMA 91777 x J 2466 was the best heterotic cross, which possessed significantly highest standard heterosis for grain yield per plant. For grain yield per plant, ICMA 91777 x J 2441, ICMA 91777 x J 2467, ICMA 91777 x J 2466, ICMA 91777 x J 2462 and JMSA 101 x J 2450 were the five best crosses exhibited significantly positive heterobeltiosis.

Kapadia *et al.* (2016) investigated heterotic effects between the crosses of selected forage pearl millet lines. Most of the hybrids exhibited significant and positive heterosis over check (RBC-2) for green fodder yield. Hybrid ICMA-01777 x J-2500 exhibited maximum standard heterosis for green fodder yield per plant followed by ICMA-01777 x J-2290 and ICMA-01777 x MJC-2 and large number of crosses registered heterotic effects in negative direction. The hybrids ICMA-05888 x J- 2500, ICMA-01777 x J-2290 and ICMA-01777 x MJC-2 recorded highest per se performance.

Lubadde *et al.* (2016) conducted an experiment in pearl millet using North Carolina II mating design to study gene effects and heterosis for yield and yield- related traits and rust resistance. In results, high better parent heterosis was observed for most of the traits including grain yield and rust resistance. The traits were also characterized by relatively low levels of narrow sense heritability.

Patel *et al.* (2016) evaluated an experimental material consisting 16 parents, 60 crosses and two standard checks. In results, highest significant positive heterobeltiosis and standard heterosis for grain yield were observed in the hybrid ICMA 98444 × J 2526 and ICMA 96222 × AIB-2, respectively. The majority of yield and yield contributing characters had a more numbers of hybrids founds significant positive heterobeltiosis and standard heterosis under study.

Acharya *et al.* (2017) conducted a study to estimate magnitude of heterosis for grain yield per plant and its thirteen yield attributing components in pearl millet using 60 entries comprised of five male sterile lines and nine restorer lines as well as their 45 hybrids developed through line x tester mating design along with standard check hybrid (GHB 732). Considering per se performance of hybrids, the superior cross combinations for grain yield per plant were JMSA 20102 x J-2496 (19.56 g), JMSA 20102 x J-2479 (18.13 g) and JMSA 20102 x J2500 (15.53 g). These cross combinations also had high per se performance for one or more yield contributing traits. Out of twenty eight significant heterotic cross combinations over better parents, nineteen showed positive and significant standard heterosis for grain yield per plant.

Bhasker *et al.* (2017) conducted a study to determine heterosis for grain yield and its component traits in bajra through line x tester mating design using five lines and eight testers along with two checks, PHB-3 and GHB-558. Heterosis was observed in both directions for most of the characters. Maximum range of standard heterosis was obtained for 1000 grain weight, fodder yield per plot, number of productive tillers per plant, plant height, panicle length, grain yield per plant and panicle diameter.

Chittora and Patel (2017) carried out an experiment which comprised of six male sterile lines, eight inbred testers, their 48 hybrids and two standard checks (GHB-538 and GHB-558) of pearl millet to study the extent of hybrid vigour in $F_1$ for grain yield and its component traits. The cross JMSA-9904 x AIB-15 showed highest and significant standard heterosis for total effective tillers, ear head girth, grain yield per plant and harvest index. Among 48 hybrids studied, three hybrids namely JMSA-9904 x AIB-15, JMSA-9904 x AIB-30 and ICMA99555 xAIB-30 selected as best crosses since they expressed high standard heterosis over standard hybrid for many of the traits studied for high grain yield.

Kapoor and Singh (2017) conducted a study in which, a set of 15 CMS lines of bajra was top crossed to four populations as testers to obtain 60 top cross hybrids. The hybrids were evaluated for magnitude of heterosis over commercial hybrid PHBF-1 and composite FBC-16. In results, only one cross 308A x Giant Bajra (6.2%) manifested positive heterosis over best check (PHBF-1). Few hybrids, namely, 315A x RBC- 2, 543A x NDFB-2 and 04777A x GFB-1 had similar per se performance as of commercial checks.

Karvar *et al.* (2017) evaluated 48 hybrids produced by line (4) x tester (12) crossing programme. Maximum positive standard heterosis for grain yield per plant over hybrid check (Aadishakti) was observed in DHLB-16A x S-16/08 (36.88%) followed by DHLB-14A x S-16/06 (34.74%) and DHLB-16A x S-16/07 (26.29%). The range of standard heterosis over check (Aadishakti) was -49.28 per cent (DHLB-14A x S-16/10) to 36.88 per cent (DHLB-16A x S-16/08).

Kumar *et al.* (2017b) crossed ten MS lines with six testers in line x tester design to study the extent of heterosis in pearl millet for yield and its component traits. In results, 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). Among 60 hybrids studied, eighteen hybrids namely RMS

6A x BIB65, RMS 7A x BIB-40, RMS 7A x BIB-75, RMS 21A x BIB-186, ICMA 832-22 x BIB- 65, ICMA 83222 x BIB- 186, ICMA 92777 x BIB- 66,ICMA 971111 x BIB- 186, ICMA 93333 x BIB- 66, ICMA 93333 x BIB-75, ICMA 93333 x BIB- 186, ICMA 04999 x BIB- 65, ICMA 04999 x BIB-76, ICMA 04999 x BIB- 186, JMSA 20042 x BIB-40, JMSA 20042 xBIB- 65, JMSA 20042 x BIB- 66 and JMSA 20042 x BIB- 76 were selected as best crosses since they expressed high standard heterosis for many of the traits studied for high grain yield.

Badhe *et al.* (2018) obtained forty eight hybrid combinations by crossing four male sterile lines with twelve newly developed inbred of a diverse origin to estimate heterobeltiosis and standard heterosis for grain yield per plant and other related characters. The best hybrids were DHLB-15A x K-13/973 and DHLB-16A x K-13/1017, which showed standard heterosis and heterobeltiosis for many traits including grain yield. Only a few hybrids recorded significant heterobeltiosis and standard heterosis in a desirable direction for plant height and number of productive tillers per plant.

Kanfany *et al.* (2018) conducted an experiment with a set of 17 inbred lines crossed with Sosat C 88 and Souna 3 following a line × tester mating design in bajra. In results, the top cross hybrids performed better than the inbred lines and OPVs. The top five genotypes across the two locations showed evidence of heterosis for grain yield in pearl millet. A maximum standard heterosis of 20% for grain yield was observed providing advantage of growing hybrids compared to the local cultivars.

Kumawat *et al.* (2020) conducted an experiment with five male sterile lines (RMS 7A from Rajasthan Agricultural Research Institute, Jaipur, Rajasthan and ICMA 843-22, ICMA 88004, ICMA 93333 and ICMA 97111 from ICRISAT, Patancheru, Hyderabad) were crossed with ten restorer lines (BIB- 343, BIB-359, BIB-383, BIB-391, BIB-399, BIB-407, BIB-415, BIB-423, BIB-439 and BIB-451 from AICRP on Pearl Millet, Bikaner, Rajasthan) in line x tester mating design at ICRISAT, Patancheru, Hyderabad, during summer-2018 to develop 50 $F_1$ hybrids. These 50 $F_1$ hybrids (crosses) along with three standard check (HHB 67 Improved, RHB-177 and MPMH-17) hybrids were evaluated in randomized block design with three replications under three environments created by differentiating number of irrigations during *Kharif*-2018 at Agricultural Research Station ($E_1$) and College of Agriculture ($E_2$ and $E_3$), Bikaner. From the results of Standard heterosis the hybrids *viz.,* ICMA 843-22 x BIB-343, ICMA 843-22 x BIB-451, RMS 7A x BIB-407, ICMA 843-22 x BIB-423 and ICMA 88004 x BIB-423 showed high and significant standard heterosis for grain yield and its contributing characters over the environments.

## 3. Phenotypic stability (genotype x environment interaction)

A phenotype is the consequence of interplay of a genotype and its environment. A specified genotype does not exhibit the same phenotypic characteristics under all environments as well as different genotypes respond differently to a specified environment. This variation arising from the lack of correspondence between the genetic and non-genetic effects is known as the genotype x environment (G x E) interaction which is generally considered as an impediment in plant breeding, as it baffles breeder in judging the real potential of a genotype when grown in different locations or in different seasons.

The interaction between genotype and environment has long been recognized by Fisher and Mackenzie (1923) and Sprague and Federer (1951) showed how variance component could be used to separate the effect of genotypes, environments and their interactions by equating the observed mean squares in the analysis of variance to their expectations on the random model. Genotype x environment interaction has been a major challenge in obtaining a clear understanding of variability. Therefore, the detection and measurement of magnitude of G x E interactions are of major importance to the plant breeder to obtain the unbiased estimate of genetic variance.

The statistical analysis for genotype x environment interaction and stability is generally carried out according to the procedure outlined by Eberhart and Russell (1966) for seed yield and its component characters. Eberhart and Russell (1966) emphasized the need of considering both linear ($b_i$) and non linear ($S^2d_i$) components for g x e interaction for judging the phenotypic stability of a genotype. Thus, a variety having higher mean performance and unit regression with least deviation from regression (approaching zero) would be considered as stable genotype.

Yahaya *et al.* (2006) studied genotype x environment interaction in pearl millet for grain yield by growing 90 genotypes consisting of 81 hybrids and 9 inbred parents at 5 locations for 2 years. Genotype x environment interaction was accounted for non-linear regression on the environment means. Although the linear portion was significant, its magnitude was smaller than that of the non-linear component indicating the significance of environmental effects on the genotypes. Six hybrids were found to be stable across the environments. They yielded above the average mean yield of all the genotypes under test with a slope of unity and the mean square due to deviation from regression equal to zero.

Munawar *et al.* (2007) evaluated seven pearl millet varieties for stability of grain yield performance in a total of 25 environments across years and locations during 2000-2004. Pearl millet variety PARC MS-1 produced the highest mean grain yield of 2223 kg $ha^{-1}$ indicating response to only favourable environments and was less stable across the locations. Based on the parameters of stability, pearl millet genotypes with adaptive stable yield performance across this set of environments are PARC MS-5, PARC MS-2, PARC MS-3 and PARC MS-6. These appear to be broadly adapted across 25 test environments. The cultivars PARC MS-4 and PARC MS-1 proved to be suitable for higher yielding while the cultivar DBR-3 was more suitable for low yielding environments. The highest yielding environments were Yousafwala (in 2002) and Umerkot (in 2001) and the lowest yielding one was Kohat (in 2001).

Abuali and Abdelmula (2008) evaluated fifteen genotypes of pearl millet at two locations to estimate the grain yield stability. The genotypes had a mean value higher than the average mean (38.8 g), regression coefficient above unity and deviation from regression not significantly different from zero was JM 23, JM 30, JM 44 and JM 25 and was considered sensitive to environmental change and therefore could be recommended for favourable conditions. However, the genotypes JM 3 and Medalakawyia, which had a mean value higher than the average mean (38.8 g), deviation from regression not significantly different from zero and a regression coefficient ($b_i$) below the unity could be recommended under unfavourable conditions.

Dakheel *et al.* (2009) evaluated sixteen pearl millet genotypes under irrigation with three levels of saline water. Stability parameters were computed for fresh and dry matter yield, plant height and leafiness. Pooled analysis of variance revealed significant mean differences among genotypes and environments. The genotypes IP6106(B2), IP13150, HHVBC Tall (B2), ICMV 7704(B1), MC94C2(B2), ERaj pop and ICMV155 Brist (B10) had the above average yield of green and dry matter and leafiness but $b_i$ values greater than 1 showing their performance was better under low and medium salinity levels. IP6106 (B2) was the most stable genotype with highest fresh and dry matter yield with bi values close to unity and small $S^2d_i$.

Pabale and Pandya (2010) tested twenty four genotypes (hybrids) of pearl millet under eight environments in Gujarat. The models of Eberhart and Russell (1966), Perkins and Jinks (1968) and Freeman and Perkins (1971) applied to study genotype x environment interaction and were compared for their efficiency empirically. The genotypes GHB- 788, GHB-832 and GHB-840 were observed as most stable and widely adapted over environments in all three models. On the basis of simplicity and computational convenience, Eberhart and Russell (1966) model was recommended.

Rajpurohit *et al.* (2012) evaluated 45 crosses of pearl millet at four locations with respect to phenotypic stability. The analysis of variance for phenotypic stability revealed that genotypes as well as environments were highly significant for all the characters. Amongst parents, D 23 was found stable for grain yield per plant and also exhibited average stability for high dry fodder yield per plant and tall plant height. Parent H 77/833-2 was stable across environments for shorter plant height, higher number of effective tillers per plant whereas for days to 50% flowering it showed stability for poor environments.

Gebre (2014) evaluated 16 pearl millet genotypes at four locations and studied the magnitude of genotype x environment interaction for yield and yield related traits. Combined analysis of variance showed that the genotype x environment interaction were highly significant for grain yield and other traits, indicating differential response of genotypes across testing locations and the need for stability analysis. Stability analysis revealed that Weioto was the most suitable environment and gave highest mean grain yield. The lowest yield was observed at Jinka. Genotypes SOSATC88 (8), ICMP97774 (6), MCSRC (5) and ICMV95490 (13) also produced high mean average yield.

Mustapha and Bakari (2014) applied AMMI Model and GGE biplots in possessing the stability and adaptability of patterns of g x e interaction in pearl millet varieties. The combined ANOVA and AMMI analysis for grain yield of forty pearl millet genotypes at 4 environments showed that environments, genotype and g x e interaction revealed highly significant ($P<0.001$) variations. The analysis also show that pearl millet grain yield was significantly affected by environment, which explained 33.20% of the total treatment variation, whereas the genotype and g x e were significant accounted for 22.72% and 44.01% respectively.

Bhuri *et al.* (2015) evaluated 55 genotypes (parents and $F_1$'s) of pearl millet in three environments. Results revealed that genotypic expression was influenced by the environments significantly for twelve morphological characters and grain yield per plant. Crosses 41-50 x RIB-20 followed by 31-40 x 101-105, 26-30 x 101-105, 26-30 x 71-75, RIB-20 x 71-75 and 71-75 x RIB-135-144 showed absolute stability for grain yield per plant.

Singh and Singh (2015) evaluated twenty seven accessions of pearl millet germplasm of African origin along with check HHB in eightenvironments for eight quantitative traits. Seven accessions namely, EC 539227, EC 539241, EC 468904, EC 539254, EC 539259, EC 468900,and EC468896 were identified to be promising based on regression analysis, whereas accessions EC 539299, EC 541536, EC 468904, EC 539227, EC 468898, EC 541540 and EC 539251 were identified as potential ones by using crossover and non-crossover interactions concepts against standard check HHB 67. Of these accessions EC 468904 was identified as high yielding accession having specific adaptability and responsiveness to higher nitrogen regimes both by regression analysis and crossover and non-crossover interactions concept.

Sumathi *et al.* (2017) evaluated a set of 27 pearl millet hybrids that newly developed using $A_1$ cytoplasmic male-sterile lines over three (two wet and one dry) crop seasons (hereafter refer to as environments) to predict genotype x environment interaction for grain yield and its component traits, and to identify the high yielding stable hybrids through AMMI and cluster analysis method for possible adaption. Based on these two models of stability analysis, hybrids

TNBH 05 03, TNBH 39 and TNBH 05 45 were identified for stable performance in all the environments.

Dadarwal *et al.* (2018) studied genotype x environment interaction in pearl millet for grain yield by growing 57 genotypes consisting of 54 hybrids along with three standard checks under three different environments. Among the crosses RMS 6A x BIB-27 and ICMA 04999 x BIB15 had higher grain yield per plant and showed stability for better management conditions and poor management conditions, respectively.

Lagat *et al.* (2018) evaluated thirty six pearl millet genotypes at two locations to study the magnitude of genotype x environment interaction and phenotypic stability for yield and its component traits and to identify the most stable high yielding genotypes. The environment 'Marigat' was the most suitable environment and gave highest mean grain yield of 3620 kg/ha. Based on the parameters of stability, three stable (widely adapted) and high yielding genotypes (EUP 34, EUP 18, and EUP 9) were identified. They also out yielded the standard open pollinated variety check, Kat PM2. Genotypes EUP 32 was the highest yielding across all sites followed by EUP 35 and could be recommended for further multi-location evaluation in warmer environment and possible release for commercial production.

Pawar *et al.* (2018) assessed the stability of grain iron (Fe) and zinc (Zn) content in a set of 68 pearl millet genotypes grown at four environments. Significant genotype x environment interactions was observed for both grain Fe and Zn indicating differential nutrient accumulation by the genotypes. Additive main effects and multiplicative interaction (AMMI) analysis indicated that the first two principal components were significant and contributed more than 75% of g × e sum of squares. None of parents or hybrids was found consistently stable for all the characters in any environment. They suggested that the stable parent S-12/30088 could be used as sources for further genetic improvement of micronutrients.

Singhal *et al.* (2018) assessed the stability of Fe and Zn content in recombinant inbred lines (RILs) developed for grain Fe and Zn content. A mapping population consisting of 210 RILs along, with parents and checks, was assessed in three consecutive years (2014–16) under rainfed conditions at the same experimental location. Significant differences were observed in genotype, environment and genotype x environment interaction mean squares for all variables, particularly grain micronutrients. Among the 210 RILs, RIL 69, RIL 186, RIL 191, RIL 149 and RIL 45 were found to be more stable with higher mean micronutrient content, additive main effects and multiplicative interaction stability value and genotype selection index under rain fed condition.

Kumawat *et al.* (2020b) conducted an experiment with five male sterile lines (RMS 7A from Rajasthan Agricultural Research Institute, Jaipur, Rajasthan and ICMA 843-22, ICMA 88004, ICMA 93333 and ICMA 97111 from ICRISAT, Patancheru, Hyderabad) were crossed with ten restorer lines (BIB-343, BIB-359, BIB-383, BIB-391, BIB-399, BIB-407, BIB-415, BIB-423, BIB-439 and BIB-451 from AICRP on Pearl Millet, Bikaner, Rajasthan) in line x tester mating design at ICRISAT, Patancheru, Hyderabad, during summer-2018 to develop 50 $F_1$ hybrids. These 50 $F_1$ hybrids (crosses) along with three standard check (HHB 67 Improved, RHB-177 and MPMH-17) hybrids were evaluated in randomized block design with three replications under three environments created by differentiating number of irrigations during *Kharif*-2018 at Agricultural Research Station ($E_1$) and College of Agriculture ($E_2$ and $E_3$), Bikaner. From the results of Phenotypic stability analysis (G x E interaction) Joint consideration of mean performance and stability parameters revealed that the hybrids *viz.,* RMS 7A x BIB-407, RMS 7A x BIB-451, ICMA 843-22 x BIB-343, ICMA

843-22 x BIB-383, ICMA 843-22 x BIB-415 and ICMA 88004 x BIB-423 were found stable and depicted predictable genotype x environment interaction for eight or more characters over the environments.

### 4. Moisture stress indices

Yadav and Bhatnagar (2001) evaluated thirty pearl millet cultivars at 22 locations that were grouped as stress, non-stress or intermediate environments. Five selection indices *viz.,* arithmetic mean (AM), geometric mean (GM), AM (standard units), stress susceptibility index (SSI) and drought response index (DRI) were calculated for each genotype to determine correlation between selection indices and yield under stress (YS), non-stress (YNS), and average conditions (YAV). Results indicated that DRI might be useful for identifying cultivars with high performance under stress particularly when days to flower differ considerably among test entries.

Golbashy *et al.* (2010) studied the effect of drought stress on yield and its components on 28 hybrids of maize along with 6 commercial control hybrids at the Khorasan Razavi Agricultural Research and Natural Resources Institute Mashhad, Iran in 2010. The mean grain yield of SC500 hybrid in the normal irrigation condition and N11 hybrid in the stress condition was highest. In order to identify the tolerant genotypes, drought resistance indices were calculated. SC500 and SC250 hybrids were the best genotypes under normal condition and H11 and SC250 showed the best behaviour under drought stress condition. It was reported that STI and GMP indices have a similar ability to separate drought sensitive and tolerant genotypes.

Bonea and Urechean (2011) evaluated 20 Romanian maize hybrids in terms of drought tolerance/susceptibility based on six indices *viz.,* mean productivity (MP), geometric mean productivity (GMP), stress tolerance (TOL), stress susceptibility index (SSI), stress tolerance index (STI) and harmonic mean (HAR). The best indices for both conditions (irrigated and non-irrigated) proved to be MP, GMP, STI and HAR. The TOL and SSI were good predictors for non-irrigation conditions only. The hybrids Neptun, Oana, Ileana, Rapsodia, Campion and Cocor were the most tolerant at severity of water stress.

Kharrazi and Rad (2011) studied seven genotypes of sorghum in both drought and normal conditions. Drought tolerance indices including stability tolerance index (STI), mean productivity (MP), geometric mean productivity (GMP), stress susceptibility index (SSI) and tolerance index (TOL) were calculated for each genotype. The maximum value of STI (0.687), MP (658.95) and GMP (624.94) were recorded for genotype KGS 3.

Khodarahmpour and Hamidi (2011) performed an experiment in order to find the best drought tolerant inbred lines of maize at the Agricultural College of Islamic Azad University, Shoushtar Branch, Iran during 2010. Five stress tolerance indices, including mean productivity (MP), stress tolerance (TOL), stress susceptibility (SSI), stress tolerance index (STI) and geometric mean productivity (GMP) were used in study. Data analysis revealed that the MP, GMP and STI indices were the more accurate criteria for selection of drought tolerant and high yielding inbred lines. Based on the STI, GMP and MP indices, K166B proved to be the most drought tolerant line. Based on the results of the study, the inbred line K166B was recommended for future breeding programmes for production of drought tolerant hybrids.

Moradi *et al.* (2012) studied the effect of drought stress on morpho-physiologic characteristics, yield and yield components of 8 new hybrids of corn and KSC704 commercial hybrid as control resistant to drought and warm. The grain yields of studied hybrids, stress tolerance index (STI), stress susceptibility index (SSI), tolerance index (TOL), mean productivity (MP), geometric mean productivity (GMP), harmonic mean (HM) and golden mean (GM) were estimated. Results showed that among drought tolerance indices, MP, GMP, STI and HM were the best indices for corn and KSC704 hybrid and H4 had the highest tolerance to drought in Mashhad weather condition.

Kiani (2013) tested six pure lines of maize under irrigated and rainfed conditions. Genetic variation was found between the genotypes for yield potential ($Y_p$), stress yield ($Y_s$), tolerance index (TOL), geometric mean productivity (GMP), harmonic mean (HM) and stress tolerance index (STI). Stress tolerance index was corrected using a correction coefficient and thus a modified stress tolerance index (MSTI) was introduced as the optimal selection criterion for drought tolerant genotypes. The results of three-D plotting indicated that the most desirable genotype for both irrigated and rain fed conditions was the genotype K1515, for non-stressed conditions was K18 and for stress conditions were K104/3, K760/7 and K126/10.

Radhouane (2013) evaluated three ecotypes of pearl millet under drought stress (17% of irrigation requirement) and optimum (well watered) conditions to study their responses to drought and to identify the traits that are associated with drought adaptation. Results showed that deficient irrigation reduced plant height and this reduction was more severe for genotype with long stem. Pearl millet ecotypes differed significantly for all traits studied under stress as well under non-stress conditions. Comparison among ecotypes showed that the effect of the drought was much more severe for KS ecotype, which is the most productive ecotype under favourable conditions. The least productive ecotype in favourable conditions was least vulnerable to drought.

Shahrabian and Soleymani (2014) investigated possibility of using stress susceptibility index (SSI), tolerance index (TOL), yield stability index (YSI), yield index (YI), stress tolerance index (STI), geometric mean productivity (GMP), harmonic mean (HARM) and mean productivity (MP) to identify genotypic performance of some maize cultivars under normal and stressed condition. The results indicated that SSI index which showed the lowest negative correlation with dry matter yield can be used as the best index for maize breeding programs to introduce drought tolerant hybrids. It was found that SC 647 showed the best behavior under drought stress condition based on TOL and SSI. A higher STI, GMP and HARM values were attained for $ko_6$. It can be suggested that $ko_6$ should be cultivated in moderate stressful environment of Iran.

Yadav *et al.* (2014) tested 45 $F_1$ hybrids of pearl millet along with parents for heat tolerance and related traits at seedling stage. Field screening and laboratory screening techniques were simultaneously used for the evaluation of $F_1$ hybrids and their parents. Heat tolerance was measured as seedling thermo tolerance index (STI) and seed to seedling thermo tolerance index (SSTI) under field conditions, but membrane thermo stability (MTS) in the laboratory. The hybrid H77/29-2× CVJ-2-5-3-1-3 showed highest STI value followed by H77/833-2 × 96AC-93. The hybrid H77/833-2 × 96AC-93 had the highest worth for SSTI. These three indices were highly correlated among themselves. STI values were invariably high, whereas SSTI has lower values as it also covers the effect of under soil mortality (USM).

Abraha *et al.* (2015) identified drought tolerant Eritrean sorghum landraces and assessed efficiency of drought tolerance indices using twenty five sorghum accessions. Seven tolerance indices including stress tolerance index (STI), mean productivity (MP), geometric mean productivity (GMP), stress susceptibility index (SSI), tolerance index (TOL), yield index (YI), and yield stability index (YSI) were estimated for each genotype based on grain yield under drought stress ($Y_s$) and irrigated conditions ($Y_{ir}$). Significant correlations between $Y_{ir}$ and $Y_s$ with GMP, MP, STI and YI indicated that these indices were good predictors of drought tolerance among genotypes. Based on the tolerance indices, accessions EG 885, EG 469, EG 481, EG 849, Hamelmalo, EG 836 and EG 711 were identified as superior genotypes for post flowering drought tolerance.

Arisandy *et al.* (2017) informed that tolerance indices and morphological traits related to drought stress tolerance would be useful for identifying potential maize hybrids tolerant to drought on the basis of their study. Results showed that harmonic mean (HM) and modified stress tolerance index ($k_2$STI) can be used for selection adaptive maize hybrids to drought stress, stress tolerance index (STI) used for selection adaptive maize hybrids to normal environment and drought stress and stress susceptibility index (SSI) and modified stress tolerance index ($k_1$STI) used for selection tolerant maize hybrids to drought stress. Adaptive maize hybrids on normal environment and drought stress based on stress tolerance index (STI) were H32, H13 and H21. Drought tolerant maize hybrids based on stress susceptibility index (SSI) were T11, H17 and H15.

Jukanti *et al.* (2017) evaluated fourteen pearl millet cultivars under two environments in such a way that the flowering was not/minimally affected by high temperature stress (non-stress-NST) and the flowering largely coincided with high temperature (≥42$^0$C), impacting the seed set and grain yield (stress-ST). The data on different parameters including grain yield was recorded and different stress indices were estimated. Based on heat tolerance/susceptibility indices, seed set and grain yield, cultivars CZH 233, CZP 9603, CZI 2011/5 and CZMS 21A were the best performing genotypes.

El-Sabagh *et al.* (2018) evaluated the response of maize hybrids to drought tolerance indices including stress susceptibility index (SSI), stress tolerance index (STI), geometric mean productivity (GMP), tolerance index (TOL), mean production (MP), yield index (YI), yield stability index (YSI), drought resistance index (DI), yield stability index (YSI) and stress susceptibility percentage (SSP). In case of stress tolerance indices, genotypes with high values of STI, GMP, YI, YSI, DI and MP can be recognized as drought tolerant hybrids. Among the tested maize hybrids, 70 May 80, Aaccel and Indaco were selected as drought tolerant genotypes on the basis of STI, GMP, YI, YSI, DI and MP.

Kumawat *et al.* (2020) conducted the experiment to identify $F_1$ hybrids suitable for drought-affected areas in pearl millet on stress indices. Fifty $F_1$ hybrids (which were developed at ICRISAT, Hyderabad during summer, 2018) along with three standard checks were laid down in Randomized Block Design with three replications in two different environments. Six stress indices *viz.,* stress tolerance (TOL), stress susceptibility index (SSI), stress tolerance index (STI), mean productivity (MP), geometric mean productivity (GMP) and yield index (YI) were calculated to screen the hybrids for moisture stress tolerance based on grain as well as dry stover yield (biological yield) per plant. Based on grain yield, dry stover yield and stress indices, the hybrids *viz.,* ICMA 843-22 x BIB- 343, ICMA 843-22 x BIB-423, RMS 7A x BIB-407, ICMA 843-22 x BIB-451 and ICMA 88004 x BIB-423 were identified as most tolerant for moisture stress conditions and recommended for drought affected areas. These hybrids can also be used for stress breeding as well as developing moisture stress tolerant populations.

# 3. MATERIAL AND METHODS

The present investigation entitled **"Genetic Architecture of Seed Yield and Its Component Characters Using Line × Tester Analysis in Pearl Millet [*Pennisetum glaucum* (L.) R. Br.]"** was undertaken to obtain the information on combining ability, standard heterosis, and phenotypic stability for grain yield and its component traits in pearl millet [*Pennisetum glaucum* (L.) R. Br.] under different moisture regimes created by different irrigation levels.

## 3.1 Experimental material

The experimental material for the present study was generated by using eleven male sterile lines (female) and seven restorer lines (male pollinator) of pearl millet. These lines were crossed in line x tester mating design to develop 77 $F_1$ hybrids at The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad during summer-2019. The main characteristics of the parents used for generating the experimental material are presented in Table 3.1.1.

## Table 3.1.1 Description of the parental material

| S. No. | Name | Source | Characteristics |
|---|---|---|---|
| | | **Females ( MS lines)** | |
| **1** | ICMA - 04999 | ICRISAT, Patancheru, Hyderabad | Erect, medium maturity, medium tall, medium compact and conical shape of panicle. |
| **2** | ICMA - 88004 | ICRISAT, Patancheru, Hyderabad | Erect, extra early, tall, panicle completely exerted, conical and semi-compact heads |
| **3** | ICMA - 93333 | ICRISAT, Patancheru, Hyderabad | Late maturity, tall, medium tillering, thin stem, thick, medium long, compact and cylindrical heads |
| **4** | ICMA - 97111 | ICRISAT, Patancheru, Hyderabad | Extra early, medium tall, high tillering, medium long and thick cylindrical heads |
| **5** | ICMA - 97444 | ICRISAT, Patancheru, Hyderabad | Erect, early maturity, short height, panicle diameter medium, small length panicle and conical shape heads. |
| **6** | ICMA - 98222 | ICRISAT, Patancheru, Hyderabad | Erect, medium maturity, short height, panicle diameter thick, small length panicle, conical shape and seed colour grey. |
| **7** | ICMA - 10444 | ICRISAT, Patancheru, Hyderabad | Erect, medium maturity, short height, panicle thick, medium long length panicle with conical shape. |
| **8** | ICMA - 30199 | ICRISAT, Patancheru, Hyderabad | Erect, early maturity, short height, panicle diameter thick, panicle length small, conical shape panicle. |
| **9** | ICMA – 30200 | ICRISAT, Patancheru, Hyderabad | Erect late maturity, short height, panicle diameter thick, small length panicle and conical shape. |
| **10** | ICMA – 30201 | ICRISAT, Patancheru, Hyderabad | Erect, medium maturity, tall height, panicle diameter thick, small length panicle, conical shape |
| **11** | ICMA – 30209 | ICRISAT, Patancheru, Hyderabad | Erect medium maturity, short height, panicle diameter thick, small length panicle, conical shape and high tillering. |
| | | **Males ( Testers)** | |
| **1** | BIB – 481-500 | ARS, Bikaner | High tillering, tall and early maturity. |
| **2** | BIB – 501-510 | ARS, Bikaner | Medium tillering, dwarf, early maturity, and thin head diameter. |
| **3** | BIB – 511-520 | ARS, Bikaner | Medium tillering, medium tall and medium maturity. |
| **4** | BIB – 531-540 | ARS, Bikaner | Low tillering, dwarf and thick head. |
| **5** | BIB – 551-560 | ARS, Bikaner | High tillering, medium tall and long head |
| **6** | BIB – 561-570 | ARS, Bikaner | Low tillering, thin stem and head. |
| **7** | BIB – 571-580 | ARS, Bikaner | High tillering, thick stem, medium maturity and thick head. |

## 3.2 Experimental layout

Three sets of experiments were laid out during *Kharif*-2019 at research farm, ARS, Bikaner ($E_1$, $E_2$ and $E_3$). The research farms are situated between $27^0$11' N latitude and $71^0$54' E longitudes at an altitude of 228.5 meters above mean sea level. This region falls under agro-climatic zone 1C of Rajasthan. The climate of the region is typically hyper-arid which is characterized by extremes of temperature during summer and winter with aridity of atmosphere and salinity of rhizosphere. The average rainfall is about 260 mm which is mostly received during July-September. The meteorological data on maximum and minimum temperature, relative humidity, wind velocity, rainfall and rainy days during the crop growing period are given in Appendix-I. The three environments thus created are presented in Table 3.2.1.

**Table 3.2.1 Environments created for the present study**

| Location | Environment | Fertilizer (N:P:K/ha) | Irrigation (No.) |
|---|---|---|---|
| Bikaner | Environment-1 ($E_1$) | 80:40:0 | Normal moisture condition (Three) |
| | Environment-2 ($E_2$) | 60:30:0 | Limited moisture condition (Two ) |
| | Environment-3 ($E_3$ ) | 40:20:0 | Moisture stress condition (One) |

Pearl millet faces drought at critical stages which affects its productivity to a great extent in North-Western Rajasthan. Low rainfall pattern at critical stages have urged the need to create above three different environments on the basis of irrigations at critical stages [tillering (25-30 DAS), flowering (45-50 DAS) and grain filling (60-65 DAS)] which is expected to be useful in planning of breeding strategies to develop suitable hybrids for such an harsh environment with unique adaptation. In all the three sets of environments pre-sowing irrigation was given to facilitate germination of seeds. In $E_1$, all the three irrigations were provided at all critical stages. In $E_2$, only two irrigations were provided at critical stage first (tillering) and second (flowering). In $E_3$, only one irrigation was provided at critical stage first (tillering). If any rain occurred it was treated as common factor in all the environments.

The experimental material comprised 80 hybrids including three commercially cultivated hybrids (RHB-177, HHB-67 Improved and BHB-1602) as checks in each replication. Checks were included only for computation of standard heterosis. The three checks included are presented in Table 3.2.2.

**Table 3.2.2 Standard checks included for the present study**

| S.No. | Standard check | Source | Characteristics |
|---|---|---|---|
| 1 | HHB 67 Improved | HAU, Hisar | Early maturing, medium tall, thin stem, medium sized grey colour seed |
| 2 | RHB-177 | AICPMIP, SKNAU, Jaipur | Early maturing, medium tall, cylindrical bristled ear heads, resistant to downy mildew and light yellow anthers |
| 3 | BHB- 1602 | SKARU, Bikaner | Early maturing, tall, high tillering |

## 3.3 Characters studied and observational procedure

Ten randomly selected plants were tagged before completion of flowering to be unbiased about the plant selection from each plot of each replication for recording the observations. Every care was taken to select only competitive plants and border plants were avoided. All the observations except days to 50% flowering and days to maturity (which were based on whole plot) were recorded on these selected plants and averaged to obtain the plot mean. Details of the procedure followed for recording data on different characters are described below:

1. **Days to 50% flowering:** The number of days taken from the date of sowing to the date when stigma had appeared on the ears of the main tillers of the 50% plants in a plot.
2. **Days to maturity:** The number of days taken from the date of sowing to the date when grains on the ear head mature

Fig 3.1: Generation of Experimental material in Line × Tester mating Design

Fig3.2: Evaluation of resultant hybrids at Agriculture Research Station Bikaner during *Kharif* 2019

**3. Plant height (cm):** Plant height was measured in centimetres at the time of maturity from the base of the plant to the tip of ear on the main tiller.

**4. Productive tillers per plant:** The number of tillers bearing ear head including main tiller were counted at the time of maturity.

**5. Ear head length (cm):** The ear head length was measured in centimetre from the base of the ear to its tip.

**6. Ear head diameter (cm):** The ear head diameter in millimetres was measured at middle of the ear of main tiller with the help of vernier calliper at the time of maturity.

**7. Test weight (g):** A random sample of thousand seeds was drawn from the threshed seed of each hybrid in each replication and weighed in grams.

**8. Ear Head Weigth (g):** The weight of ten randomly selected and tagged plants head.

**Dry stover yield per plant (g):** Ten randomly selected and tagged plants including all plant parts above ground were dried in sunlight and weighed in grams and averaged.

**10. Grain yield per plant (g):** The ear heads of the ten tagged plants were threshed together, weighed and averaged to obtain grain yield per plant.

**11. Harvest index (%):** Harvest index computed by using following formula as suggested by Singh and Stoskoff (1971).

$$\text{Harvest index\%} = \frac{\text{Grain yield per plant (g)}}{\text{Biological yield per plant(g)}} \times 100$$

**12. Threshing index (%):** Threshing index computed by using following formula as grain weight divided by ear head weight.

$$\text{Threshing index (\%)} = \frac{\text{Grain weight per plant}}{\text{Ear head weight per plant}} \times 100$$

**13. Grain iron (Fe) content (%):** Only some of the superior hybrids over the checks were tested for grain iron (Fe) content at ICRISAT, Hyderabad and the values are presented in appendix-II. This observation was not included in statistical analysis.

**14. Grain zinc (Zn) content (%):** Only some of the superior hybrids over the checks were tested for grain zinc (Zn) content at ICRISAT, Hyderabad and the values are presented in appendix-II. This observation was not included in statistical analysis.

## 3.4 Statistical analysis

Replication wise mean values were subjected to following statistical analyses:

1. Analysis of variance
2. Combining ability analysis
3. Estimation of standard heterosis
4. Phenotypic stability analysis
5. Calculation of moisture stress indices

### 3.4.1 Analysis of variance

The mean values of different $F_1$s (hybrids) for all the characters were subjected to analysis of variance as described by Panse and Sukhatme, (1985) separately for individual environment as well as for pooled data over environments to determine the significance of differences between genotypes, environments and genotype x environment interaction effects. The analysis of variance for individual environment and data pooled over environments is presented in Table 3.4.1 and 3.4.2, respectively based on the following models:

The model used for the analysis of variance for individual environment is

Fig 3.3: Recording the post flowering  phenotypic observations in experimental material

$$Y_{ij} = \mu + r_j + g_i + e_{ij}$$

Where,

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

$\mu$ = general mean

$r_j$ = effect of $j^{th}$ replication

$g_i$ = effect of $i^{th}$ genotype

$e_{ij}$ = random error associated with particular measurement.

**Table 3.4.1: Analysis of variance for individual environment**

| Sources of variations | d. f. | M. S.S. | Expectations of M.S.S. |
|---|---|---|---|
| Replication<br>Genotypes<br>Error | (r-1)<br>(g-1)<br>(r-1) (g-1) | Mr<br>$\sigma^2_r$<br>Mg<br>$\sigma^2_g$<br>Me | $\sigma^2_e$ + g<br><br>$\sigma^2_e$ + r<br><br>$\sigma^2_e$ |
| Total | r g - 1 | | |

Where,

r and g are the number of replications and genotypes respectively. The "F" values so obtained were tested at 5 per cent and 1 per cent level of significance.

S.E. (Diff.) = (2 x Error MSS / No. of replications)$^{1/2}$

**Mathematical model for pooled analysis**

$$Y_{ijk} = \mu + n_k + r_j + g_i + (gn)_{ki} + e_{ijk}$$

Where,

$Y_{ijk}$ = mean performance of $i^{th}$ genotype in $j^{th}$ replication at the $k^{th}$ environment

$\mu$ = general mean

$n_k$ = effect of $k^{th}$ environment

$r_j$ = a random effect associated with $j^{th}$ replication at the $k^{th}$ environment

$g_i$ = effect of $i^{th}$ genotype

$(gn)_{ki}$ = effect of $i^{th}$ genotype at the $k^{th}$ environment and

$e_{ijk}$ = error component associated with the $i^{th}$ genotype in the $j^{th}$ replication at the $k^{th}$ environment

The data of each character were pooled over environments and the pooled analysis of variance was performed. The structure of analysis of variance for pooled analysis is given below in Table – 3.4.2

**Table 3.4.2: ANOVA based on the data pooled over three environments**

| **Source of variation** | **d. f.** | **M.S.S.** | **Expected M.S.S.** |
|---|---|---|---|
| Environment | (s-1) | Ms | $\sigma^2{}_e + rg\sigma^2{}_s$ |
| Replications | (r-1) | Mr | $\sigma^2{}_e + gs\sigma^2{}_r$ |
| Replications/Env. | (r-1) s | Mrs | $\sigma^2{}_e + g\sigma^2{}_{rs}$ |
| Genotypes | (g-1) | Mg | $\sigma^2{}_e + r\sigma^2{}_{gs} + rs\sigma^2{}_g$ |
| Genotype x Env. | (g-1)(s-1) | Mgs | $\sigma^2{}_e + r\sigma^2{}_{gs} + r\sigma^2{}_{gs}$ |
| Pooled Error | s(g-1)(r-1) | Me | $\sigma^2{}_e$ |

Where,

s = number of environments

g = number of genotypes

$\sigma^2{}_{gs}$ = variance due to genotype x environment Interaction

$\sigma^2{}_g$ = variance due to genotype

$\sigma^2{}_r$ = variance due to replication

### 3.4.2 Combining ability analysis

Combining ability analysis was computed as per Kempthorne (1957) and ANOVA form is presented in Table 3.4.3 and 3.4.4

Mathematical model for combining ability in single environment:

$Y_{ijk} = \mu + g_i + g_j + s_{ij} + r_k + e_{ijk}$

Where,

| | | |
|---|---|---|
| $Y_{ijk}$ | = | mean value of $ij^{th}$ cross in $k^{th}$ replication |
| $\mu$ | = | general mean |
| $g_i$ | = | gca effect of $i^{th}$ line |
| $g_j$ | = | gca effect of $j^{th}$ tester |
| $s_{ij}$ | = | sca effect due to $ij^{th}$ cross combination |
| $r_k$ | = | effect due to $k^{th}$ replication, and |
| $e_{ijk}$ | = | random error associated with $ij^{th}$ cross in $k^{th}$ replication |

**Table 3.4.3 Analysis of variance for combining ability in single environment**

| Source of variation | d. f. | M.S | Expectations of M.S. | Expectations of covariances |
|---|---|---|---|---|
| **Replication** | (r-1) | | | |
| **Crosses** | (lt-1) | | | |
| **line** | (l-1) | $M_1$ | $\sigma^2_e + r\sigma^2_{lt} + rt\sigma^2_l$ | $\sigma^2_e$ + r [cov.(F.S.) – 2 Cov.(H.S.) + rt cov.(H.S.)] |
| **tester** | (t-1) | $M_2$ | $\sigma^2_e + r\sigma^2_{lt} + rl\sigma^2_t$ | $\sigma^2_e$ + r [cov.(F.S.) – 2 Cov.(H.S.) + rl cov.(H.S.)] |
| **Lines x testers** | (l-1)(t-1) | $M_3$ | $\sigma^2_e + r\sigma^2_{lt}$ | $\sigma^2_e$ + r [cov.(F.S.) – 2 Cov.(H.S.) |
| **Error** | (r-1)(lt-1) | $M_4$ | $\sigma^2_e$ | |
| **Total** | (rlt-1) | | | |

Where

r, t and l are the number of replications, testers and lines respectively and

$\sigma^2_t$ = variance due to testers

$\sigma^2_l$ = variance due to lines

$\sigma^2_{lt}$ = variance due to line x tester

$\sigma^2$ e = variance due to error

Cov ( F.S.) = covariance of full – sibs and

Cov (H.S.) = covariance of half – sibs

The Cov (H.S.) for lines as well as testers is equal to 1/4 $\sigma^2$ A.

When mean squares for lines, testers and lines x testers are significant Cov (H.S.) for lines and testers is calculated as

$\sigma^2{}_l$ = Cov (H.S.) lines = $M_1 – M_3$ / rt = 1/2 $\sigma^2{}_A$ = $\sigma^2{}_{gca}$

$\sigma^2{}_t$ = Cov (H.S.) testers = $M_2 – M_3$ / rl = 1/2 $\sigma^2{}_A$ = $\sigma^2{}_{gca}$

$\sigma^2{}_{lxt}$ = [cov. (F.S.)–2 Cov. (H.S.)] = $M_3 – M_4$ / r = $\sigma^2{}_D$ = $\sigma^2{}_{sca}$

Average Cov (H.S.) over lines and testers may be computed as

$M_1 + M_2 – M_3$ / r (l+t) = $\sigma^2{}_{gca}$

$$Cov.F.S. = \frac{(M_l - M_e) + (M_t - M_e) + (M_{lxt} - M_e)}{3 \times r} + \frac{6r \operatorname{cov} HS - r(l+t)\operatorname{cov} H.S.}{3r}$$

**Mathematical model for combining ability for pooled analysis:**

$$Y_{ijk} = \mu + g_i + g_j + s_k + (lt)_{ij} + (ls)_{jk} + (ts)_{jk} + (lts)_{ijk} + e_{ijk}$$

Where,

| | | |
|---|---|---|
| $Y_{ijk}$ | = | Mean value of ij[th] cross in k[th] environments |
| μ | = | general mean |
| $g_i$ | = | effect of i[th] line |
| $g_j$ | = | effect of j[th] tester |
| $s_k$ | = | effect of k[th] environment |
| $(lt)_{ij}$ | = | interaction effect due to ij[th] cross combination, |
| $(ls)_{jk}$ | = | effect of i[th] line at k[th] environment |
| $(ts)_{jk}$ | = | effect of j[th]tester at k[th] environment |
| $(lts)_{ijk}$ | = | effect of ij[th] cross at k[th] environment and |

$e_{ijk}$ = random error associated with ij th cross in k th environment

**Table 3.4.4 Analysis of variance for combining ability over the environments**

| Source of variation | d. f. | M.S. | Expectations of M.S. |
|---|---|---|---|
| **Environments (e)** | (s-1) | $M_1$ | $\sigma^2_e + r\sigma^2_{lts} + rl\sigma^2_{ts} + rt\sigma^2_{ls} + rlt\sigma^2_s$ |
| **Rep./ Env.** | s(r-1) | | $\sigma^2_e + lts\sigma^2_r$ |
| **line (l)** | (l-1) | $M_2$ | $\sigma^2_e + r\sigma^2_{lts} + rs\sigma^2_{lt} + rt\sigma^2_{ls} + rts\sigma^2_l$ |
| **tester (t)** | (t-1) | $M_3$ | $\sigma^2_e + r\sigma^2_{lts} + rs\sigma^2_{lt} + rl\sigma^2_{ts} + rls\sigma^2_t$ |
| **l x t** | (l-1)(t-1) | $M_4$ | $\sigma^2_e + r\sigma^2_{lts} + rs\sigma^2_{ls}$ |
| **l x e** | (l-1)(s-1) | $M_5$ | $\sigma^2_e + r\sigma^2_{lts} + rt\sigma^2_{ls}$ |
| **t x e** | (t-1)(s-1) | $M_6$ | $\sigma^2_e + r\sigma^2_{lts} + rl\sigma^2_{ts}$ |
| **l x t x e** | (l-1)(t-1)((s-1) | $M_7$ | $\sigma^2_e + r\sigma^2_{lts}$ |
| **Error** | s(r-1)(lt-1) | $M_8$ | $\sigma^2_e$ |

Where,

s = number of environments

l = number of lines (Female parents)

t = number of testers (Male parents)

r = number of replications

$\sigma^2_e$ = genetic variance among individuals from the same mating

$\sigma^2_l$ = variance of line effects

$\sigma^2_t$ = variance of tester effects

$\sigma^2_{lt}$ = variance due to interaction between lines and testers

$\sigma^2_{ls}$ = variance due to interaction between line effects and environments,

$\sigma^2_{ts}$ = variance due to interaction between tester effects and environments,

$\sigma^2_{lts}$ = variance due to interaction among lines, tester and environments,

**Estimation of combining ability variances and effects**

Various variances were estimated as follows:

For single environment – (Table – 3.4.3)

$$\sigma^2_{gca} = \frac{(M_l - M_{lt}) + (M_t - M_{lt})}{r(l+t)} \quad \text{or} \quad \sigma^2_{gca} = \frac{M_1 + M_2 - 2M_3}{r(l+t)}$$

$$\sigma^2_{sca} = \frac{(M_{lxt} - M_e)}{r} \quad \text{or} \quad \sigma^2_{sca} = \frac{(M_3 - M_4)}{r}$$

For pooled analysis – (Table -3.4.4)

$$\sigma^2_{gca} = \frac{M_2 + M_3 - 2M_4 - M_5 - M_6 + 2M_7}{rs(l+t)}$$

$$\sigma^2_{sca} = \frac{(M_4 - M_7)}{rs}$$

$$\sigma^2_{gca\,\mathrm{X}e} = \frac{M_5 + M_6 - 2M_7}{r(l+t)}$$

$$\sigma^2_{sca}\ xe = \frac{M_7 - M_8}{r}$$

$\sigma^2 A = 2\sigma^2 gca$ , $\sigma^2 D = \sigma^2_{sca}$ and

$$Degree\,of\ do\min ance = \sqrt{\sigma^2 D / \sigma^2 A}$$

Where,

$\sigma^2 gca$ = General combining ability variance

$\sigma^2 sca$ = Specific combining ability variance

$\sigma^2 A$ = Additive variance

$\sigma^2 D$ = Dominance variance

$$Heritability\ (ns)\% = \frac{\sigma^2 A}{\sigma^2 Ph} x100$$

**Genetic Advance: -** Genetic advance (GA) was estimated using the formula suggested by Robinson *et al.* (1949), Johnson *et al* (1955).

$$GA = k\ h^2_{ns}\ x\ \sqrt{\sigma^2 Ph}$$

Where,

$\sigma^2 Ph$ = Phenotypic variance

$h^2_{ns}$ = Heritability narrow sense

K = Selection differential (constant) at 5 % selection intensity (Allard, 1960) *i.e.* 2.06

The gca and sca effects were estimated from two way table of lines vs. testers where each figure was a total over replications for single environment and over replication and environment for pooled data.

$$\mu = \frac{X....}{ltrs}$$

**Estimation of GCA effects**

**a) Lines ($g_i$)** = $\frac{Xi...}{trs} - \frac{X....}{ltrs}$

$\Sigma g_i = 0$

Where,

$X....$ = Sum of all the ($ij^{th}$) hybrid combinations (Grand total)

$Xi...$ = total of $i^{th}$ line over all testers, replications and environments

**b)** **Testers ($g_j$)** = $\frac{X.j..}{lrs} - \frac{X....}{ltrs}$

$\Sigma g_j = 0$

Where,

$X.j..$ = Total of $j^{th}$ tester over all lines, replications and environments

**Estimation of SCA effects**

$$s_{ij} = \frac{Xij..}{rs} - \frac{Xi...}{trs} - \frac{X.j..}{lrs} + \frac{X....}{ltrs}$$

$$\sum_i \sum_j S_{ij} = 0$$

Where,

$Xij..$ = $ij^{th}$ cross combination total over all replications and environments

**Standard errors for combining ability effects:**

The standard errors for gca and sca effects will be calculated as follows.

S.E. (gca for lines) $g_i$ = (Me / rts) ½

S.E. (gca for tester) $g_j$ = (Me / rls) ½

S.E. (sca effects )$s_{ij}$ = (Me / rs) ½

S.E. ($g_i$-$g_j$) line = (2Me / rts) ½

S.E. ($g_i$-$g_j$) tester = (2Me/ rls) ½

S.E. ($S_{ij}$-$S_{kl}$) = (2Me/ rs) ½

Significance of gca effects of lines is tested as:

$$t = \frac{g_i - 0}{S.E.g_i}$$

Significance of gca effects of testers is tested as:

$$t = \frac{g_j - 0}{S.E.g_j}$$

Significance of sca effects of crosses is as:

$$t = \frac{s_{ij} - 0}{S.E.s_{ij}}$$

**Critical difference (CD):**

CD = SE x t value at 5% level of significance for error d. f.

**Test of significance of estimates of variances:**

Significance of gca and sca variances and their interaction with environments was tested by 'F' test as follows:

I. To test $\sigma^2_{gca}$ in single environment, F ($n_1$, n2 d.f.) = $\frac{M^+}{M_3}$

Where, $M^+ = t M_1 + l M_2 / (l+t)$ and

d. f. $n_1 = \frac{(l-1)(t-1)(tM_1 + lM_2)^2}{(l-1)t^2 M_1^2 + (t-1)l^2 M_2^2}$

$n_2 = (l-1)(t-1)$

II. To test $\sigma^2_{sca}$ in single environment, F ($n_1$, $n_2$ d. f.) = $\frac{M_3}{M_4}$

Where, $M^+ = t M_1 + l M_2 / (l+t)$ and

d. f. $n_1 = (l-1)(t-1)$

$n_2 = (r-1)(lt-1)$

III. To test $\sigma^2_{gca \times e}$, F ($n_1$,$n_2$ d.f.) = $\frac{(M_5 + M_6)}{2M_7}$

Where,

d. f. n$_1$ = $\frac{(l-1)(t-1)(s-1)(M_5+M_6)^2}{(t-1)(s-1)M_5{}^2+(l-1)(s-1)M_6{}^2}$

n$_2$ = $(l-1)(t-1)(s-1)$

IV. To test $\sigma^2$ sca x e , F (n$_1$,n$_2$ d.f.) = $\frac{M_7}{M_8}$

Where,

d. f. n$_1$ = $(l-1)(t-1)(s-1)$

n$_2$ = $s(lt-1)(r-1)$

In all the cases, $n_1$ and $n_2$ are reffered to the degrees of freedom for numerator and denominator, respectively.

**Per cent contribution of lines, testers and crosses**

The proportional contribution of lines, testers and their interaction will be determined by following formula.

1) Contribution of testers = $\frac{S.S.(t)}{S.S.(crosses)}\times 100$

2) Contribution of lines = $\frac{S.S.(l)}{S.S.(crosses)}\times 100$

3) Contribution of line x tester interaction = $\frac{S.S.(l\times t)}{S.S.(crosses)}\times 100$

Where,

$S.S.(t)$ = Sum of square due to tester

$S.S.(l)$ = Sum of square due to line

$S.S.(lxt)$ = Sum of square due to line x tester

$S.S.(crosses)$ = Total sum of square of two way table

[$S.S.(lxt)$ $= S.S.(crosses)$ - $S.S.(l)$ - $S.S.(t)$]

### 3.4.3 Phenotypic stability analysis

Stability parameters will be computed using the model proposed by Eberhart and Russel (1966).

$$Y_{ij} = \mu_i + \beta_i I_j + \delta_{ij}$$

Where,

$Y_{ij}$ = mean performance of $i^{th}$ genotype in $j^{th}$ environment

$\mu_i$ = mean performance if $i^{th}$ genotype over all environments

$\beta_i$ = the regression coefficient that measuers the response of the $i^{th}$ genotypes to varying environments

$\delta_{ij}$ = deviation from regression of the $i^{th}$ genotype at the $j^{th}$ environment

$I_j$ = the environmental index obtained as the means of all genotypes at the $j^{th}$ environment minus the grand mean, it can be expresses as

$$Ij = \left( \sum_i Y_{ij} \Big/ g \right) - \sum_i \sum_j Y_{ij} \ \Big/ gs \qquad , \qquad \sum_j I_j = 0$$

The first stability parameter, regression coefficient (bi) for the individual genotype was estimated as

$$bi = \sum_j Y_{ij} I_j \Big/ \sum_j I_j^{\,2}$$

The second stability parameter ($s^2d_i$) was estimated using the following formula:

$$S^2 d_i = \left[ \sum_j \delta_{ij}^{\,2} \Big/ (s-2) \right] - S_e^{\,2} / r$$

Where, $S_e^2/r$ was the estimate of pooled error and

$$\sum_i \delta_{ij}^{\,2} = \left[ \sum_j Y_{ij}^{\,2} - Y_{i.}^{\,2} / s \right] - \left[ \left( \sum_j Y_{ij} I_j \right)^2 \Big/ \sum_j I_j^{\,2} \right]$$

The expectations of the mean square in the joint regression analysis is given in Table – 3.4.5

**Table 3.4.5 Joint regression analysis of variance (Eberhert and Russel, 1966)**

| Source | d. f. | S.S. | M.S. |
|---|---|---|---|
| Genotypes (g) | (g -1) | $\frac{1}{s}\sum_i Y_{i.}^2 - C.F.$ | $MS_1$ |
| Environment (s) | (s-1) | $\frac{1}{g}\sum_j Y_{.j}^2 - C.F.$ | |
| Geno. X Env. | (g-1) (s-1) | $\sum_i\sum_j Y_{ij}^2 - \frac{\sum Y_{i.}^2}{s} - \frac{\sum Y_{.j}^2}{g} + C.F.$ | |
| Env.+ (Geno. X Env.) | (g) (s-1) | $\sum_i\sum_j Y_{ij}^2 - \frac{\sum Y_{i.}^2}{s}$ | |
| Environment (Linear) | 1 | $\frac{1}{g}\left(\sum_j Y_{.j} I_j\right)^2 \Big/ \sum_j I_j^2$ | |
| Geno. X Env. (Linear) | (g-1) | $\sum_i\left[\left(\sum_j Y_{ij} I_j\right)^2 \Big/ \sum_j I_j^2\right] - Env.(Linear\ SS)$ | $MS_2$ |
| Pooled deviation | g(s-2) | $\sum_i\sum_j Y_{ij}^2$ | $MS_3$ |
| Pooled deviation due to genotype | (s-2) | $\left[\sum_j Y_{ij}^2 - \frac{Y_{i.}^2}{s}\right] - \left(\sum_j Y_{ij} I_j\right)^2 \Big/ \sum_j I_j^2 = \sum_j Y_{ij}^2$ | |
| Pooled error | S(r-1)(g-1) | | $MS_4$ |

Where,

g = no. of genotypes, s = no. of environments and r = no. of replications

**Test of significance was done as follows**

I The mean square for pooled deviation is tested against the pooled error mean square as

$$F = \frac{MS_3}{MS_4}$$

II Test of significance of differences among the mean performance of genotypes was done using the ‘F’ test,

$$F = \frac{MS_1}{MS_3}$$

III The genetic difference among genotypes for their regression, on environmental index were tested using, the ‘F’ test,

$$F = \frac{MS_2}{MS_3}$$

IV The deviation of $b_i$ values from unity was tested using the ‘F’ test,

$$t = \frac{b_i - 1}{S.E.b_i} \quad \text{at (g-2) d.f.}$$

$$S.E.(b_i) \pm = \sqrt{\frac{Pooled\ deviation\ M.S.}{\sum_j I_j^2}}$$

V Deviation from linear regression for each genotype was tested using the ‘F’ test

$$F = \frac{\left[\sum_j \delta_{ij}^2 \big/ (s-2)\right]}{Pooled\ error}$$

### 3.4.4 Estimation of Standard /Economic heterosis

Per cent economic heterosis was calculated for all the characters under study over standard check as follows.

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

Where,

$\overline{F_1}$ = Mean over replications of hybrid between $i_{th}$ and $j_{th}$ parent

$\overline{SC}$ = Mean performance of superior check hybrid used in the present investigation was the one with the best mean among the three checks evaluated.

**Test of significance**

The significance of the standard heterosis estimates was done using t – test. The S.E. for testing the significance was calculated by the following formula:

$$\text{S.E.} (\overline{F_1} - \overline{SC}) = \sqrt{\frac{2Ems}{rs}}$$

Where,

Ems = Error mean sum of squares.

r = Number of replications.

s = Number of environments.

The t- value was estimated by the formula:

$$t = \frac{\overline{F_1} - \overline{SC}}{SE\left(\overline{F_1} - \overline{SC}\right)}$$

The calculated t value was compared with the table value at error degrees of freedom.

**Calculation of moisture stress indices**

Following indices related to stress tolerance were used for grain yield per plant:

**i) Stress Tolerance (TOL)**

Rosielle and Hamblin (1981) defined stress tolerance (TOL) as the differences in yield between the stress ($Y_s$) and non-stress ($Y_p$) environments.

$$TOL = Y_p - Y_s$$

Where,

$Y_s$ = Yield of genotype under stress condition ($E_3$)

$Y_p$ = Yield of genotype under normal condition ($E_1$)

**ii) Stress Susceptibility Index (SSI)**

It was calculated for yield over stress environment and normal (non-stress) environment as per formula given by Fischer and Maurer (1978).

$$SSI = [1 (Y_s / Y_p)] / S$$

Where,

$Y_s$ = Yield of the genotype in stress condition ($E_3$)

$Y_p$ = Yield of the genotype in normal condition ($E_1$)

S = Stress intensity

Where, $S = 1 - \frac{\text{Mean Ys of all genotypes}}{\text{Mean Yp of all genotypes}}$

**iii) Stress Tolerance Index (STI)**

Fernandez (1992) defined a new advanced index (STI), which can be used to identify genotypes that produce high yield under both stress and non-stress conditions. It was calculated by following formula:

$$STI = [Y_P \times Y_S / \bar{y}_P^2]$$

Where,

$Y_s$ = Yield of genotype under stress condition ($E_3$)

$Y_p$ = Yield of genotype under normal condition ($E_1$)

$\bar{y}$ = Mean yield of all genotypes under normal condition ($E_1$)

**iv) Mean Productivity**

Rosielle and Hamblin (1981) defined mean productivity (MP) for the genotypes with high value of this index will be more desirable. It was calculated by following formula:

MP = Ys + Yp / 2

Where,

$Y_s$ = Yield of genotype under stress condition ($E_3$)

$Y_p$ = Yield of genotype under normal condition ($E_1$)

**v) Geometric Mean Productivity**

Fernandez (1992) defined the genotypes with high GMP value will be more desirable. It was calculated by following formula:

$$GMP= \sqrt{Y_P} \times \sqrt{Y_S}$$

Where,

$Y_s$ = Yield of genotype under stress condition ($E_3$)

$Y_p$ = Yield of genotype under normal condition ($E_1$)

**vi) Yield Index**

Gavuzzi *et al.,* (1997) defined (YI) the genotypes with high value of this index will be suitable for drought stress condition. It was calculated by following formula:

$$YI = \frac{Y_S}{\overline{Y_S}}$$

Where,

$Y_s$ = Yield of genotype under stress condition ($E_3$)

$\bar{y}_s$ = Mean yield of all genotypes under normal condition ($E_3$)

**vii) Yield Stability Index**

Bouslama and Schapaugh, (1984) the genotypes with high YSI values can be regarded as stable genotypes under stress and non-stress conditions. It was calculated by following formula:

$$YSI= \frac{Y_S}{Y_P}$$

Where,

$Y_s$ = Yield of genotype under stress condition ($E_3$)

$Y_p$ = Yield of genotype under normal condition ($E_1$)

**viii) Harmonic mean**

Jafari *et al.* (2009) define (HM) the genotypes with high value of this index will be more desirable. It was calculated by following formula:

$$HM = \frac{2\,(Y_S)(Y_P)}{(Ys+Y_P)}$$

Where,

$Y_s$ = Yield of genotype under stress condition ($E_3$)

$Y_p$ = Yield of genotype under normal condition ($E_1$)

**ix) Sensitivity drought index**

Farshadfar and Javadinia (2011) defined the genotypes with low value of this index will be more desirable. It was calculated by following formula.

$$SDI = \frac{Y_P - Ys}{Y_P}$$

Where,

$Y_s$ = Yield of genotype under stress condition ($E_3$)

$Y_p$ = Yield of genotype under normal condition ($E_1$)

# 4. RESULTS

The present investigation was undertaken to estimate combining ability, standard heterosis, phenotypic stability and moisture stress indices in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. The experimental material for present study was consisting of 77 hybrids of pearl millet which were developed by crossing eleven male sterile lines (female parents) and seven genetically diverse restorer lines (male parents) in line x tester mating design. These hybrids along with three standard check hybrids were evaluated in randomized block design with three replications under three environments at Agricultural Research Station Bikaner during *Kharif*-2019. The results obtained on various aspects are presented below under the following sub headings:

4.1 Analysis of variance

4.2 Mean value of crosses

4.3 Combining ability analysis

4.4 Estimation of standard heterosis

4.5 Phenotypic stability analysis

4.6 Calculation of moisture stress indices

## 4.1 Analysis of variance

The analysis of variance indicated the presence of significant genetic variability among the crosses for all the characters studied in all the individual environments (Table 4.1.1) as well as over the environments (Table 4.1.2). Significant mean sum of squares due to environments for all characters indicated effect of environment on character expression. Mean sum of squares due to treatments and environments were found significant for all the characters indicating the differential responses of the crosses to the environments for all the traits.

**Table 4.1.1 Analysis of variance for grain yield per plant and its components in individual environments**

| Source of variation | df | Environment | Mean squares | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| Replication | 2 | $E_1$ | 15.72 | 7.81 | 39.34 | 0.58 | 5.66 | 5.25 | 0.141 | 193.85 | 3665.72 | 115.61 | 19.69 | 97.01 |
| | | $E_2$ | 0.129 | 0.12 | 98.06 | 0.05 | 7.01 | 11.97 | 0.02 | 22.51 | 265.41 | 60.57 | 5.98 | 41.12 |
| | | $E_3$ | 0.079 | 0.20 | 67.29 | 0.04 | 4.02 | 11.35 | 0.05 | 112.91 | 369.47 | 13.07 | 35.48 | 81.65 |
| Treatments | 79 | $E_1$ | 42.28** | 44.13** | 766.27** | 2.54** | 26.39** | 38.81** | 9.35** | 4236.72** | 18835.56** | 953.95** | 107.31** | 451.45** |
| | | $E_2$ | 65.07** | 64.87** | 478.88** | 2.11** | 71.14** | 97.67** | 9.46** | 3554.64** | 15602.61** | 582.61** | 382.99** | 4160.32** |
| | | $E_3$ | 64.99** | 64.71** | 474.75** | 1.20** | 66.51** | 100.00** | 9.64** | 3571.11** | 14702.44** | 282.56** | 490.14** | 478.63** |
| Error | 158 | $E_1$ | 5.65 | 5.28 | 13.00 | 0.44 | 2.13 | 1.93 | 0.06 | 342.90 | 1289.99 | 83.67 | 20.75 | 64.08 |
| | | $E_2$ | 2.26 | 2.07 | 119.08 | 0.161 | 2.38 | 4.75 | 0.03 | 93.91 | 337.99 | 22.92 | 23.36 | 177.26 |
| | | $E_3$ | 2.19 | 2.02 | 108.46 | 0.09 | 1.33 | 3.72 | 0.02 | 48.35 | 242.26 | 17.29 | 19.51 | 59.07 |

** represents significant at 1% level of significance

## Table 4.1.2 Analysis of variance for grain yield per plant and its components based on data pooled over the environments

| | | Mean sum of squares | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Source of variation** | **df** | **Days to 50% flowering** | **Days to maturity** | **Plant height (cm)** | **Productive tillers/ plant** | **Ear head length (cm)** | **Ear head diameter (cm)** | **Test weight (g)** | **Ear head weight (g)** | **Dry stover yield/ plant (g)** | **Grain yield/ plant (g)** | **Harvest index (%)** | **Threshing index (%)** |
| **Env.** | 2 | 3598** | 3688.72** | 117891.42** | 326.65** | 4705.82** | 6113.19** | 8.51** | 240871** | 1334271.7** | 63677.74** | 1981.7** | 25888.72** |
| **Treat.** | 79 | 146.22** | 147.03** | 1322.5** | 3.56** | 126.06** | 181.64** | 28.36** | 8513.48** | 33932.88** | 1175.69** | 482.04** | 1768.92** |
| **T x E** | 158 | 13.39** | 13.42** | 198.71** | 1.15** | 19** | 27.42** | 0.05* | 1424.51** | 7603.87** | 321.73** | 249.21** | 1660.75** |
| **Error** | 480 | 3.12 | 3.14 | 80.04 | 0.23 | 2 | 3.55 | 0.04 | 161.08 | 633.54 | 41.58 | 21.2 | 99.81 |
| SEm(g) ± | | 0.58 | 0.59 | 2.982 | 0.16 | 0.471 | 0.628 | 0.066 | 4.23 | 8.39 | 2.15 | 1.53 | 3.33 |
| CD(5%) | | 1.63 | 1.64 | 8.286 | 0.44 | 1.309 | 1.745 | 0.185 | 11.76 | 23.31 | 5.97 | 4.26 | 9.25 |
| SEm(gxe) ± | | 1.01 | 1.02 | 5.165 | 0.28 | 0.816 | 1.087 | 0.115 | 7.33 | 14.53 | 3.72 | 2.66 | 5.77 |
| CD(5%) | | 2.83 | 2.84 | 14.353 | 0.77 | 2.268 | 3.022 | 0.320 | 20.36 | 40.38 | 10.35 | 7.39 | 16.03 |
| CV | | 3.60 | 2.24 | 6.604 | 18.93 | 6.919 | 9.932 | 2.122 | 17.6 | 16.17 | 17.84 | 17.07 | 18.05 |
| GM | | 49.03 | 79.12 | 135.459 | 2.53 | 20.438 | 18.969 | 9.422 | 72.12 | 155.69 | 36.15 | 26.97 | 55.34 |

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

## 4.2 Mean values of crosses

The mean values of all the crosses were described for each character and environment as below:

### 4.2.1 Days to 50% flowering

Early flowering is desirable in pearl millet. For environment $E_1$, $E_2$, $E_3$ and over the environment, early flowering genotypes were shown in appendix-I. Out of 80 genotypes, genotypes ICMA 98222 × BIB 481-500 (41), ICMA 88004 × BIB 501-510 (41), ICMA 97111 × BIB 571-580 (41), ICMA 97444 × BIB 481-500 (42), ICMA 97111 × BIB 501-510 (42), ICMA 98222 × BIB 501-510 (42), ICMA 04999 × BIB 511-520 (42), ICMA 88004 × BIB 511-520 (42), ICMA 97111 × BIB 511-520 (42), ICMA 97444 × BIB 511-520 (42), ICMA 97111 × BIB 531-540 (43), ICMA 98222 × BIB 531-540 (42), ICMA 93333 × BIB 551-560 (42), ICMA 98222 × BIB 561-570 (42), ICMA 93333 × BIB 571-580 (42), ICMA 93333 × BIB 481-500 (43), ICMA 97444 × BIB 501-510 (43), ICMA 93333 × BIB 511-520 (43), ICMA 93333 × BIB 531-540 (43), ICMA 97111 × BIB 531-540 (43), ICMA 30201 × BIB 531-540 (43), ICMA 88004 × BIB 551-560 (43), ICMA 98222 × BIB 551-560 (43), ICMA 88004 × BIB 561-570 (43), ICMA 97444 × BIB 561-570 (43), ICMA 88004 × BIB 571-580 (43), ICMA 97444 × BIB 571-580 (43), ICMA 04999 × BIB 481-500 (44), ICMA 30200 × BIB 481-500 (44), ICMA 93333 × BIB 501-510 (44), ICMA 88004 × BIB 481-500 (45), ICMA 10444 × BIB 501-510 (45) and ICMA 30201 × BIB 511-520 (45) were good for early flowering in environment $E_{1.}$ Genotypes ICMA 98222 × BIB 481-500 (41), ICMA 88004 × BIB 501-510 (41), ICMA 04999 × BIB 511-520 (41), ICMA 93333 × BIB 511-520 (41), ICMA 97444 × BIB 511-520 (41), ICMA 97444 × BIB 531-540 (41), ICMA 88004 × BIB 561-570 (41), ICMA 98222 × BIB 561-570 (41), ICMA 97111 × BIB 481-500 (42), ICMA 93333 × BIB 531-540 (42), ICMA 97111 × BIB 561-570 (42), ICMA 88004 × BIB 481-500 (43), ICMA 93333 × BIB 481-500 (43), ICMA 93333 × BIB 551-560

(43), ICMA 93333 × BIB 561-570 (43), ICMA 88004 × BIB 571-580 (43), ICMA 97111 × BIB 571-580 (43), ICMA 97444 × BIB 571-580 (43), ICMA 98222 × BIB 501-510 (44), ICMA 93333 × BIB 571-580 (44), ICMA 98222 × BIB 571-580 (44), ICMA 04999 × BIB 481-500 (45), ICMA 30201 × BIB 481-500 (45), ICMA 30201 × BIB 511-520 (45), ICMA 98222 × BIB 531-540 (45), ICMA 30200 × BIB 531-540 (45) and ICMA 88004 × BIB 551-560 (45) were good for early flowering in environment $E_{2.}$ Genotypes ICMA 88004 × BIB 511-520 (46), ICMA 98222 × BIB 481-500 (47), ICMA 88004 × BIB 501-510 (47), ICMA 04999 × BIB 511-520 (47), ICMA 93333 × BIB 511-520 (47), ICMA 97444 × BIB 511-520 (47), ICMA 97444 × BIB 531-540 (47), ICMA 88004 × BIB 561-570 (47), ICMA 98222 × BIB 561-570 (47), ICMA 97111 × BIB 481-500 (48), ICMA 93333 × BIB 531-540 (48), ICMA 97111 × BIB 561-570 (48), ICMA 88004 × BIB 481-500 (49), ICMA 93333 × BIB 481-500 (49), ICMA 93333 × BIB 551-560 (49), ICMA 93333 × BIB 561-570 (49), ICMA 88004 × BIB 571-580 (49), ICMA 97111 × BIB 571-580 (49), ICMA 97444 × BIB 571-580 (49), ICMA 98222 × BIB 501-510 (50), ICMA 93333 × BIB 571-580 (50) and ICMA 98222 × BIB 571-580 (50) were good for early flowering in environment $E_{3.}$ Genotypes ICMA 98222 × BIB 481-500 (43), ICMA 88004 × BIB 501-510 (43), ICMA 04999 × BIB 511-520 (43), ICMA 88004 × BIB 511-520 (43), ICMA 97444 × BIB 511-520 (43), ICMA 97444 × BIB 531-540 (43), ICMA 98222 × BIB 561-570 (43), ICMA 93333 × BIB 511-520 (44), ICMA 93333 × BIB 531-540 (44), ICMA 88004 × BIB 561-570 (44), ICMA 97111 × BIB 571-580 (44), ICMA 93333 × BIB 481-500 (45), ICMA 98222 × BIB 501-510 (45), ICMA 93333 × BIB 551-560 (45), ICMA 93333 × BIB 561-570 (45), ICMA 97111 × BIB 561-570 (45), ICMA 88004 × BIB 571-580 (45), ICMA 93333 × BIB 571-580 (45), ICMA 97444 × BIB 571-580 (45), ICMA 88004 × BIB 481-500 (46), ICMA 98222 × BIB 531-540 (46), ICMA 97444 × BIB 561-570 (46), ICMA 98222 × BIB 571-580 (46), ICMA 04999 × BIB 481-500 (47), ICMA 97111 × BIB 481-500 (47), ICMA 30200 × BIB

481-500 (47), ICMA 97111 × BIB 501-510 (47), ICMA 10444 × BIB 501-510 (47), ICMA 30201 × BIB 511-520 (47), ICMA 30200 × BIB 531-540 (47), ICMA 30201 × BIB 531-540 (47), ICMA 98222 × BIB 551-560 (47) and ICMA 04999 × BIB 571-580 (47) were good for early flowering in over the environment. However, genotypes ICMA 88004 × BIB 481-500, ICMA 93333 × BIB 481-500, ICMA 98222 × BIB 481-500, ICMA 88004 × BIB 501-510, ICMA 98222 × BIB 501-510, ICMA 04999 × BIB 511-520, ICMA 93333 × BIB 511-510, ICMA 97444 × BIB 511-520, ICMA 93333 × BIB 531-540, ICMA 97444 × BIB 531-540, ICMA 93333 × BIB 551-560, ICMA 88004 × BIB 561-570, ICMA 93333 × BIB 561-570, ICMA 97111 × BIB 561-570, ICMA 98222 × BIB 561-570, ICMA 88004 × BIB 571-580, ICMA 93333 × BIB 571-580, ICMA 97111 × BIB 571-580, ICMA 97444 × BIB 571-580 and ICMA 98222 × BIB 571-580 were good for early flowering in all the three environment as well as over the environment.

**4.2.2 Days to maturity**

Similar to early flowering, early maturity is also desirable in pearl millet. For environment $E_1$, $E_2$, $E_3$ and over the environment, early maturity genotypes were shown in appendix-I. Out of 80 genotypes, genotypes ICMA 98222 × BIB 481-500 (71), ICMA 88004 × BIB 501-510 (71), ICMA 97111 × BIB 571-580 (71), ICMA 97444 × BIB 481-500 (72), ICMA 97111 × BIB 501-510 (72), ICMA 98222 × BIB 501-510 (72), ICMA 04999 × BIB 511-510 (72), ICMA 88004 × BIB 511-520 (72), ICMA 97111 × BIB 511-520 (72), ICMA 97444 × BIB 511-520 (72), ICMA 97444 × BIB 531-540 (72), ICMA 98222 × BIB 531-540 (72), ICMA 93333 × BIB 551-560 (72), ICMA 98222 × BIB 561-570 (72), ICMA 93333 × BIB 571-580 (72), ICMA 93333 × BIB 481-500 (73), ICMA 97444 × BIB 501-510 (73), ICMA 93333 × BIB 511-520 (73), ICMA 93333 × BIB 531-540 (73), ICMA 97111 × BIB 531-540 (73), ICMA 30201 × BIB 531-540 (73), ICMA 88004 × BIB 551-560 (73), ICMA 98222 × BIB 551-560 (73), ICMA 88004 × BIB 561-570 (73), ICMA 97444 × BIB 561-570 (73), ICMA 88004 × BIB 571-580

(73), ICMA 97444 × BIB 571-580 (73), ICMA 04999 × BIB 481-500 (74), ICMA 30200 × BIB 481-500 (74), ICMA 93333 × BIB 501-510 (74), ICMA 93333 × BIB 561-570 (74), ICMA 97111 × BIB 561-570 (74), ICMA 04999 × BIB 571-580 (74), ICMA 98222 × BIB 571-580 (74), ICMA 88004 × BIB 481-500 (75), ICMA 10444 × BIB 501-510 (75) and ICMA 30201 × BIB 511-520 (75) were desirable for early maturity in environment $E_{1.}$ Genotypes ICMA 88004 × BIB 511-520 (70), ICMA 98222 × BIB 481-500 (71), ICMA 88004 × BIB 501-510 (71), ICMA 04999 × BIB 511-520 (71), ICMA 93333 × BIB 511-520 (71), ICMA 97444 × BIB 511-520 (71), ICMA 97444 × BIB 531-540 (71), ICMA 88004 × BIB 561-570 (71), ICMA 98222 × BIB 561-570 (71), ICMA 97111 × BIB 481-500 (72), ICMA 93333 × BIB 531-540 (72), ICMA 97111 × BIB 561-570 (72), ICMA 88004 × BIB 481-500 (73), ICMA 93333 × BIB 481-500 (73), ICMA 93333 × BIB 561-570 (73), ICMA 88004 × BIB 571-580 (73), ICMA 97111 × BIB 571-580 (73), ICMA 97444 × BIB 571-580 (73), ICMA 98222 × BIB 501-510 (74), ICMA 93333 × BIB 571-580 (74) and ICMA 98222 × BIB 571-580 (74) were desirable for early maturity in environment $E_{2.}$ Genotypes ICMA 88004 × BIB 511-520 (76), ICMA 98222 × BIB 481-500 (77), ICMA 88004 × BIB 501-510 (77), ICMA 04999 × BIB 511-520 (77), ICMA 93333 × BIB 511-520 (77), ICMA 97444 × BIB 511-520 (77), ICMA 97444 × BIB 531-540 (77), ICMA 88004 × BIB 561-570 (77), ICMA 98222 × BIB 561-570 (77), ICMA 97111 × BIB 481-500 (78), ICMA 93333 × BIB 531-540 (78), ICMA 97111 × BIB 561-570 (78), ICMA 88004 × BIB 481-500 (79), ICMA 93333 × BIB 481-500 (79), ICMA 93333 × BIB 561-570 (79), ICMA 93333 × BIB 561-570 (79), ICMA 88004 × BIB 571-580 (79), ICMA 97111 × BIB 571-580 (79), ICMA 97444 × BIB 571-580 (79), ICMA 98222 × BIB 501-510 (80), ICMA 93333 × BIB 571-580 (80) and ICMA 98222 × BIB 571-580 (80) were desirable for early maturity in environment $E_{3.}$ Genotypes ICMA 98222 × BIB 481-500 (73), ICMA 88004 × BIB 501-510 (73), ICMA 04999 × BIB 511-520 (73), ICMA 88004 × BIB 511-520 (73), ICMA 97444 × BIB 511-520

(73), ICMA 97444 × BIB 531-540 (73), ICMA 98222 × BIB 561-570 (73), ICMA 93333 × BIB 511-520 (74), ICMA 93333 × BIB 531-540 (74), ICMA 88004 × BIB 561-570 (74), ICMA 97111 × BIB 571-580 (74), ICMA 93333 × BIB 551-560 (75), ICMA 93333 × BIB 561-570 (75), ICMA 97111 × BIB 561-570 (75), ICMA 88004 × BIB 571-580 (75), ICMA 93333 × BIB 571-580 (75), ICMA 97444 × BIB 571-580 (75), ICMA 98222 × BIB 531-540 (76), ICMA 88004 × BIB 551-560 (76), ICMA 97444 × BIB 561-570 (76), ICMA 98222 × BIB 571-580 (76), ICMA 30200 × BIB 531-540 (77), ICMA 30201 × BIB 531-540 (77) and ICMA 98222 × BIB 551-560 (77) were desirable for early maturity in over the environment. However, the genotypes ICMA 98222 × BIB 481-500, ICMA 88004 × BIB 501-510, ICMA 04999 × BIB 511-520, ICMA 88004 × BIB 511-520, ICMA 93333 × BIB 511-520, ICMA 97444 × BIB 511-520, ICMA 93333 × BIB 531-540, ICMA 97444 × BIB 531-540, ICMA 88004 × BIB 561-570, ICMA 93333 × BIB 561-570, ICMA 97111 × BIB 561-570, ICMA 98222 × BIB 561-570, ICMA 88004 × BIB 571-580, ICMA 93333 × BIB 571-580, ICMA 97111 × BIB 571-580, ICMA 97444 × BIB 571-580 and ICMA 98222 × BIB 571-580 were good for early maturity  in all the three environment as well as over the environment.

**4.2.3 Plant height**

The tall plant height is desirable in pearl millet. For environment $E_1$, $E_2$, $E_3$ and over the environment, desirable genotypes for plant height were shown in appendix-I. Genotypes ICMA 93333 × BIB 501-510 (180), ICMA 93333 × BIB 531-540 (177), ICMA 97444 × BIB 481-500 (176), ICMA 97111 × BIB 481-500 (174), ICMA 88004 × BIB 551-560 (174) and RHB- 177 (173) were good for plant height for environment $E_{1.}$ Genotypes ICMA 93333 × BIB 481-500 (168), ICMA 88004 × BIB 481-500 (165), ICMA 93333 × BIB 531-540 (163), ICMA 93333 × BIB 551-560 (163), ICMA 04999 × BIB 481-500 (161) and ICMA 30209 × BIB 551-560 (159) were good for plant height for environment $E_{2.}$ Genotypes ICMA 93333 × BIB 481-500 (141.32),

ICMA 88004 × BIB 481-500 (134.51), ICMA 93333 × BIB 551-560 (133.36), ICMA 93333 × BIB 531-540 (132.76) and ICMA 04999 × BIB 481-500 (130.55) were good for plant height for environment $E_{3.}$ Genotypes ICMA 93333 × BIB 531-540 (158), ICMA 93333 × BIB 481-500 (157), ICMA 88004 × BIB 481-500 (155), ICMA 04999 × BIB 481-500 (153), ICMA 30209 × BIB 551-560 (153) and ICMA 97111 × BIB 481-500 (152) were good for over the environment. The genotypes ICMA 93333 × BIB 531-540 and ICMA 30209 × BIB 551-560 were good for plant height in the entire three environment as well as over the environment.

**4.2.4 Productive tillers per plants**

High number of productive tillers per plant is desirable in this crop. Environment wise *i.e.* $E_1$, $E_2$, $E_3$ and over the environment, mean productive tillers per plant were shown in appendix-I. Out of 80 genotypes, some genotypes had showed higher numbers of productive tillers. These genotypes were ICMA 04999 × BIB 531-540 (6.3), ICMA 30201 × BIB 511-520 (6), ICMA 30209 × BIB 531-540 (5.5), ICMA 93333 × BIB 531-540 (5.3), ICMA 04999 × BIB 561-570 (5.3), ICMA 88004 × BIB 571-580 (5.2) and ICMA 97111 × BIB 571-580 (5.2) for environment $E_{1.}$ Genotypes ICMA 98222 × BIB 481-500 (4.4), ICMA 30201 × BIB 551-560 (4.2), ICMA 30201 × BIB 481-500 (4), ICMA 30200 × BIB 561-570 (4), ICMA 30199 × BIB 481-500 (3.7) and ICMA 30200 × BIB 481-500 (3.6) had higher productive tillers per plant in environment $E_{2.}$ Genotypes ICMA 98222 × BIB 481-500 (3.7), ICMA 30201 × BIB 551-560 (3.3), ICMA 97444 × BIB 511-520 (3.1), ICMA 30199 × BIB 481-500 (2.7), ICMA 30200 × BIB 481-500 (2.6) and ICMA 30201 × BIB 481-500 (2.6) had higher productive tillers per plant in environment $E_{3.}$ Genotypes ICMA 30201 × BIB 511-520 (4), ICMA 30201 × BIB 551-560 (4), ICMA 98222 × BIB 481-500 (3.8), ICMA 30200 × BIB 561-570 (3.8), ICMA 30199 × BIB 481-500 (3.6), ICMA 97444 × BIB 511-520 (3.5) and ICMA 88004 × BIB 571-580 (3.5) were found to have higher productive tillers per plant in environment for over the environment. Genotypes ICMA 30201 × BIB 551-560 found good as well as three environment and over the environment for higher number of productive tillers per plant.

### 4.2.5 Ear head length

Long ear heads are desirable in pearl millet for environment $E_1$, $E_2$, $E_3$ and over the environment. Mean ear head length of genotypes was shown in appendix-II. The genotypes ICMA 93333 × BIB 551-560 (29.8), ICMA 98222 × BIB 481-500 (29.5), ICMA 98222 × BIB 551-560 (29.1), ICMA 98222 × BIB 531-540 (28.7), ICMA 30201 × BIB 481-500 (28.1) and ICMA 88004 × BIB 511-520 (28.1) had long ear head length in environment $E_1$ and genotypes ICMA 10444 × BIB 551-560 (31.5), ICMA 93333 × BIB 551-560 (30.8), ICMA 98222 × BIB 481-500 (30.4), ICMA 30209 × BIB 551-560 (27.6), and ICMA 04999 × BIB 511-520 (27.4) for environment $E_{2;}$ while the genotypes ICMA 93333 × BIB 551-560 (25.32), ICMA 98222 × BIB 481-500 (24.97), ICMA 30201 × BIB 551-560 (23.57), ICMA 10444 × BIB 551-560 (23.33) and ICMA 30209 × BIB 551-560 (22.2) for environment $E_{3.}$ The genotypes ICMA 93333 × BIB 551-560 (28.6), ICMA 98222 × BIB 481-500 (28.3), ICMA 10444 × BIB 551-560 (26.4), ICMA 88004 × BIB 501-510 (26.3) and ICMA 30201 × BIB 551-560 (25.6) had long ear head length for over the environment. The genotypes ICMA 98222 × BIB 481-500 and ICMA 93333 × BIB 551-560 good ear head length for all the three environment as well as over the environment.

### 4.2.6 Ear head diameter

As higher magnitude of ear head diameter is desirable in pearl millet, environment wise i.e. $E_1$, $E_2$, $E_3$ and over the environment, mean ear head diameter were shown for all the genotypes under study in appendix-II. The genotypes ICMA 98222 × BIB 511-520 (31.7), ICMA 98222 × BIB 501-510 (30.3), ICMA 30209 × BIB 501-510 (30.3), HHB-67 Improved (30), ICMA 98222 × BIB 481-500 (29.3), ICMA 30201 × BIB 561-570 (28.7), ICMA 98222 × BIB 571-580 (28.7), ICMA 10444 ×

BIB 571-580 (28.7) and BHB-1602 (28.7) were good for ear head diameter in environment $E_{1.}$ The genotypes ICMA 98222 × BIB 481-500 (28.2), ICMA 10444 × BIB 571-580 (27.7), HHB-67 Improved (27.6), ICMA 93333 × BIB 551-560 (27.2) and ICMA 98222 × BIB 561-570 (26.5) were good for ear head diameter in environment $E_{2.}$ The genotypes ICMA 98222 × BIB 481-500 (25.44), ICMA 10444 × BIB 571-580 (24.94), HHB-67 Improved (24.83), ICMA 93333 × BIB 551-560 (24.43) and ICMA 98222 × BIB 561-570 (23.72) were good for ear head diameter in environment $E_{3.}$ The genotypes ICMA 98222 × BIB 481-500 (27.6), HHB-67 Improved (27.5), ICMA 10444 × BIB 571-580 (27.1), ICMA 98222 × BIB 571-580 (25.6) and ICMA 98222 × BIB 501-510 (25.5) were good for ear head diameter in over the environment. The genotypes ICMA 98222 × BIB 481-500, ICMA 10444 × BIB 571-580 and HHB-67 Improved good ear head diameter for all the three environment as well as over the environment.

**4.2.7 Test weight**

The higher magnitude of test weight is desirable in pearl millet. Perusal of appendix-II is given for mean test weight environment wise i.e. $E_1$, $E_2$, $E_3$ and over the environment. The genotypes ICMA 88004 × BIB 501-510 (13.01), ICMA 98222 × BIB 561-570 (13.01), ICMA 98222 × BIB 481-500 (12.27), ICMA 97111 × BIB 561-570 (12.02), ICMA 30201 × BIB 531-540 (12.01) and ICMA 98222 × BIB 531-540 (11.77) were good for highest test weight in environment $E_{1.}$ The genotypes ICMA 98222 × BIB 481-500 (12.91), ICMA 88004 × BIB 501-510 (12.91), ICMA 98222 × BIB 561-570 (12.34), ICMA 98222 × BIB 531-540 (11.91), ICMA 30201 × BIB 531-540 (11.91), ICMA 88004 × BIB 511-520 (11.90) and ICMA 97111 × BIB 501-510 (11.07) were good for highest test weight in environment $E_{2.}$ The genotypes ICMA 98222 × BIB 481-500 (12.61), ICMA 88004 × BIB 501-510 (12.61), ICMA 98222 × BIB 561-570 (12.61), ICMA 93333 × BIB 551-560 (12.60), ICMA 97111 × BIB 561-570 (11.62), ICMA 30201 × BIB 531-540 (11.61), and ICMA 98222 × BIB 531-540 (11.28) were good for highest test weight in environment $E_3$. The genotypes ICMA 88004 × BIB 501-510 (12.84), ICMA 93333 × BIB 551-560 (12.83), ICMA 98222 × BIB 561-570 (12.65), ICMA 98222 × BIB 481-500 (12.60) and ICMA 30201 × BIB 531-540 (11.84) were good for highest test weight in over the environment. The genotypes ICMA 98222 × BIB 481-500, ICMA 88004 × BIB 501-510, ICMA 98222 × BIB 531-540, ICMA 30201 × BIB 531-540, ICMA 97111 × BIB 561-570 and ICMA 98222 × BIB 561-570 having mean values higher in all the three environment as well as over the environment.

**4.2.8 Ear head weight**

The higher magnitude of ear head weight is desirable in pearl millet. Perusal of appendix-II shows mean values of ear head weight for environment wise i.e. $E_1$, $E_2$, $E_3$ and over the environment. The genotypes ICMA 30199 × BIB 511-520 (210), ICMA 30201 × BIB 511-520 (210), ICMA 30201 × BIB 561-570 (196.67), ICMA 93333 × BIB 551-560 (176.67), ICMA 04999 × BIB 531-540 (153.33), ICMA 30199 × BIB 551-560 (153.33), ICMA 04999 × BIB 561-570 (143.33), ICMA 30199 × BIB 561-570 (143.33) and ICMA 98222 × BIB 481-500 (140) had higher mean value of ear head weight in environment $E_1$. The genotypes ICMA 30201 × BIB 561-570 (160), ICMA 98222 × BIB 481-500 (146.67), ICMA 93333 × BIB 551-560 (143.33), ICMA 88004 × BIB 501-510 (136.67), ICMA 88004 × BIB 511-520 (133.33) and ICMA 10444 × BIB 511-520 (133.33) had higher mean value of ear head weight in environment $E_2$. The genotypes ICMA 93333 × BIB 551-560 (143.33), ICMA 98222 × BIB 481-500 (141.67), ICMA 10444 × BIB 511-520 (140), ICMA 88004 × BIB 511-520 (133.33) and ICMA 98222 × BIB 561-570 (123.33) had higher mean value of ear head weight in environment $E_3$. The genotypes ICMA 30201 × BIB 561-570 (170.56), ICMA 93333 × BIB 551-560 (154.44), ICMA 98222 × BIB 481-500 (142.78), ICMA 88004 × BIB 501-510 (133.89) and ICMA 10444 × BIB 511-520 (131.11) had higher mean value of ear head weight in over the environment. The genotypes ICMA 98222 × BIB 481-500 and ICMA

93333 × BIB 551-560 had higher mean values of ear head weight for all the three environment as well as over the environment.

**4.2.9 Dry stover yield per plant**

As pearl millet is dual crop, the dry stover yield is of graet importance in all the environments. Mean values of dry stover yield per plant for the genotypes were shown in appendix-III. The genotypes ICMA 30199 × BIB 511-520 (510), ICMA 93333 × BIB 551-560 (423.33), ICMA 93333 × BIB 531-540 (416.67), ICMA 04999 × BIB 531-540 (373.33) and ICMA 97444 × BIB 561-570 (343.33) had higher mean values of dry stover yield per plant in environment $E_1$. The genotypes ICMA 98222 × BIB 481-500 (336.67), ICMA 30199 × BIB 501-510 (300), ICMA 30201 × BIB 531-540 (240), ICMA 98222 × BIB 561-570 (240), ICMA 30200 × BIB 481-500 (196.67) and ICMA 04999 × BIB 511-520 (183.33) had higher mean value of dry stover yield per plant in environment $E_2$. The genotypes ICMA 30201 × BIB 481-500 (333.33), ICMA 98222 × BIB 481-500 (306.67), ICMA 30201 × BIB 561-570 (290), ICMA 30199 × BIB 501-510 (276.67) and ICMA 98222 × BIB 561-570 (240) had higher mean value of mean values of dry stover yield per plant in environment $E_3$. The genotypes ICMA 30201 × BIB 481-500 (337.78), ICMA 30201 × BIB 561-570 (312.22), ICMA 98222 × BIB 481-500 (297.78), ICMA 30199 × BIB 501-510 (275.56) and ICMA 30199 × BIB 511-520 (251.11) had higher mean value of mean values of dry stover yield per plant in over the environment.

**4.2.10 Grain yield per plant**

The higher magnitude of grain yield per plant is desirable in pearl millet in all the environments. The mean values of genotypes for grain yield per plant were shown in appendix-III. The genotypes ICMA 98222 × BIB 481-500 (95), ICMA 93333 × BIB 551-560 (94.33), ICMA 04999 × BIB 561-570 (90), ICMA 30199 × BIB 561-570 (86.67) and ICMA 88004 × BIB 501-510 (83.67) had higher mean values of grain yield per plant in environment $E_1$. The genotypes ICMA 98222 × BIB 481-500 (82.33), ICMA 88004 × BIB 501-510 (77.67), ICMA 30201× BIB 561-570 (66.67), ICMA 30201 × BIB 481-500 (61.67), ICMA 30199 × BIB 571-580 (61.67) and ICMA 97444 × BIB 571-580 (51.67) had higher mean values of grain yield per plant in environment $E_2$. The genotypes ICMA 98222 × BIB 481-500 (61.67), ICMA 97444 × BIB 571-580 (45.33), ICMA 88004 × BIB 501-510 (42.33), ICMA 30201 × BIB 561-570 (42.33), ICMA 10444 × BIB 511-520 (41.67) and ICMA 30201 × BIB 511-520 (41.33) had higher mean values of grain yield per plant in environment $E_3$. The genotypes ICMA 98222 × BIB 481-500 (79.67), ICMA 88004 × BIB 501-510 (67.89), ICMA 93333 × BIB 551-560 (54.66), ICMA 10444 × BIB 511-520 (50.56) and ICMA 30201 × BIB 511-520 (50.44) had higher mean value of grain yield per plant in over the environment. The genotypes ICMA 98222 × BIB 481-500 and ICMA 88004 × BIB 501-510 had higher mean values in all the three as well as over the environment.

**4.2.11 Harvest index**

The higher harvest index is desirable in pearl millet. Perusal of appendix-III depicts the mean values of genotypes for environment $E_1$, $E_2$, $E_3$ and over the environment. The genotypes ICMA 98222 × BIB 501-510 (40.21), ICMA 98222 × BIB 481-500 (38.13), ICMA 04999 × BIB 561-570 (36.89), ICMA 97111 × BIB 571-580 (33.46) and ICMA 88004 × BIB 501-510 (31.79) had higher mean value of harvest index in environment $E_{1.}$ The genotypes ICMA 93333 × BIB 571-580 (73.89), ICMA 04999 × BIB 551-560 (66.67), ICMA 30200 × BIB 501-510 (42.50), ICMA 30201 × BIB 501-510 (41.67), ICMA 30209 × BIB 501-510 (41.67), ICMA 30200 × BIB 511-520 (41.67), ICMA 30200 × BIB 551-560 (41.67), ICMA 10444 × BIB 481-500 (40.83) and ICMA 04999 × BIB 531-540 (40.83) had higher mean value of harvest index in environment $E_{2.}$ The genotypes ICMA 98222 × BIB 481-500 (62.33), ICMA 97111 × BIB 551-560 (58.33), ICMA 30199 × BIB 511-520 (56.67), ICMA 88004 × BIB 501-510 (56.48) and ICMA 04999 ×

BIB 531-540 (55.67) had higher mean value of harvest index in environment $E_3$. The genotypes ICMA 98222 × BIB 481-500 (41.95), ICMA 97444 × BIB 551-560 (40.92), ICMA 88004 × BIB 501-510 (39.80), ICMA 30209 × BIB 501-510 (38.90) and ICMA 97111 × BIB 551-560 (38.80) had higher mean value of harvest index in over the environment.

### 4.2.12 Threshing index

The higher magnitude of threshing index is desirable in pearl millet. Perusal of appendix-III depicts the mean values of threshing index of genotypes for environment $E_1$, $E_2$, $E_3$ and over the environment. The genotypes ICMA 10444 × BIB 481-500 (106.67), ICMA 97444 × BIB 551-560 (83.33), ICMA 30209 × BIB 481-500 (74.45), ICMA 98222 × BIB 561-570 (71.17) and ICMA 04999 × BIB 501-510 (69.45) had higher mean value of threshing index in environment $E_1$. The genotypes ICMA 30201 × BIB 481-500 (319.44), ICMA 04999 × BIB 551-560 (146.30), ICMA 88004 × BIB 551-560 (123.61), ICMA 30201 × BIB 531-540 (118.33) and BHB-1602 (97.22) had higher mean value of threshing index in environment $E_2$. The genotypes ICMA 98222 × BIB 481-500 (81.47), ICMA 98222 × BIB 561-570 (74.33), ICMA 93333 × BIB 571-580 (73.87), ICMA 88004 × BIB 501-510 (71.84), and ICMA 93333 × BIB 551-560 (69) had higher mean value of threshing index in environment $E_3$. The genotypes ICMA 30201 × BIB 481-500 (134.48), ICMA 97444 × BIB 551-560 (79.55), ICMA 97111 × BIB 551-560 (73.18), BHB-1602 (70.40) and ICMA 30201 × BIB 531-540 (70.20) had higher mean value of threshing index in over the environment.

## 4.3 Combining ability analysis

The analysis of variance for combining ability and estimation of various components for all the characters were carried out for each environment separately as well as pooled over the environments as per line x tester analysis following the procedure suggested by Kempthorne (1957). The salient features of results obtained are presented below:

The analysis of variance for combining ability in each environment is presented separately. Combining ability analysis for environment $E_1$ for different characters in pearl millet is given in Table 4.3.1. Mean squares due to replications were found non-significant for all the characters in the $E_1$ environment. Likewise, mean squares due to crosses and line x tester were found to be highly significant for all the characters. In case of testers mean square values were found highly significant for productive tillers per plant. Mean sum of square due to lines were found highly significant for days to flowering, days to maturity and harvest index. Mean sum of square due to tester were found highly significant for productive tillers per plant in $E_1$ environment.

Combining ability analysis for environment $E_2$ for the characters under study in pearl millet were shown in Table 4.3.2. Mean sum of squares due to replications were found non-significant for all the characters except ear head length and grain yield per plant. Likewise, mean squares due to crosses and line x tester were found to be highly significant for all the characters. In case of lines, mean square values were found significant for days to flowering, days to maturity, plant height and dry stover yield per plant. Mean sum of square due to tester were found highly significant for productive tillers per plant in $E_2$ environment.

Combining ability analysis for environment $E_3$ for different characters in pearl millet is shown in Table 4.3.3. Mean squares due to replications were found non-significant for all the characters except ear head length and ear head diameter. Likewise, mean squares due to crosses and line x tester were found to be highly significant for all the characters. In case of lines, mean square values were found significant for days to flowering, days to maturity, plant height and threshing index. Mean sum of square due to tester were found highly significant for productive tillers per plant in $E_3$ environment.

The pooled analysis of variance for combining ability (Table 4.3.4) showed significant mean squares due to environments, crosses, line effect, tester effect, line x tester, crosses x environment, line effect x environment, tester effect x environment and environment x line effect x tester effect for all the characters indicating the presence of significant variations among the material used for the present study. The mean squares due to environment, crosses, line x tester and crosses x environment was found highly significant for all the characters. The mean squares due to lines were found highly significant for days to flowering, days to maturity, and significant for plant height and dry stover yield per plant. The tester mean squares were found significant for productive tillers per plant. The mean squares due to line x environment were significant for productive tillers per plant and threshing index. The mean squares due to tester x environment found highly significant for plant height, productive tillers per plant, ear head diameter and test weight. The interaction of environment x line effect x tester effect was found highly significant for all the character except test weight.

Perusal of table 4.3.5 indicated the magnitude of variance due to GCA was lower as compared to magnitude of SCA for all the characters in all the environments. Significant variance due to GCA and SCA indicated the importance of additive as well as non-additive components in the inheritance of majority of the characters. The ratio of variances due to GCA/SCA was less than unity which indicated the preponderance of non-additive components for all the characters in all the environments.

The genetic components for various traits are presented in table 4.3.6 further showed that the ratio of additive variance to dominance variance was less than unity for all the traits in all the environments as well as on pooled basis which indicated the preponderance of non-additive gene action in the inheritance of majority of the characters.

The proportional contribution of lines, testers and their interaction to total variance (%) is presented in table 4.3.7. The maximum contribution of lines to total variance was for days to maturity (30.34%), days to 50%

flowering (29.36%), followed by dry stover yield per plant (25.16%) and plant height (23.67%) based on data pooled over different environments. The maximum contribution of tester to total variance was for productive tillers per plant (18.26%) followed by threshing index (12.58%) and grain yield per plant (11.09%). The line x tester interaction displayed maximum contribution to total variance for ear head length (79.95%), harvest index (79.86) and threshing index (78.49%).

**Table 4.3.1 Combining ability analysis for environment $E_1$ for different characters in pearl millet**

| Source of variation | df | Mean sum of squares | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| **Replication** | **2** | 11.61 | 4.95 | 35.16 | 0.62 | 5.12 | 5.21 | 0.15 | 273.48 | 3555.3 | 84.28 | 17.15 | 90 |
| **Crosses** | **76** | 43.88** | 45.82** | 771.59** | 2.63** | 26.91** | 38.46** | 9.69** | 4370.43** | 19544.77** | 984.87** | 110.83** | 466.79** |
| **Line effect** | **10** | 105.66** | 114.58** | 963.96 | 3.01 | 29.24 | 55.92 | 11.2 | 6123.4 | 30670.02 | 957.29 | 277.42** | 742.58 |
| **Tester effect** | **6** | 31.48 | 26.84 | 1287.91 | 7.26** | 28.66 | 45.5 | 14.34 | 4403.54 | 12562.81 | 987.5 | 71.32 | 630.35 |
| **L x T effect** | **60** | 34.82** | 36.26** | 687.89** | 2.1** | 26.34** | 34.84** | 8.98** | 4074.96** | 18388.76** | 989.21** | 87.02** | 404.46** |
| **Error** | **152** | 5.76 | 5.37 | 13.42 | 0.46 | 2.21 | 1.98 | 0.06 | 350.13 | 1326.14 | 83.89 | 20.93 | 64.39 |
| **SE** | | 1.39 | 1.33 | 2.12 | 0.39 | 0.86 | 0.81 | 0.141 | 10.8 | 21.02 | 5.29 | 2.64 | 4.63 |
| **CD(5%)** | | 3.87 | 3.7 | 5.91 | 1.09 | 2.4 | 2.27 | 0.395 | 30.18 | 58.74 | 14.78 | 7.38 | 12.94 |
| **CV** | | 5.21 | 3.04 | 2.38 | 17.65 | 6.09 | 5.76 | 2.566 | 17.25 | 15.11 | 16.85 | 19.36 | 15.17 |
| **GM** | | 46.11 | 76.19 | 153.89 | 3.84 | 24.43 | 24.44 | 9.54 | 108.48 | 241.02 | 54.37 | 23.63 | 52.9 |

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

**Table 4.3.2 Combining ability analysis for environment $E_2$ for different characters in pearl millet**

| Source of variation | df | Mean sum of squares | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| **Replication** | **2** | 0.21 | 0.48 | 136.8 | 0.04 | 7.93* | 9.36 | 0.03 | 31.12 | 297.4 | 104.76** | 16.26 | 9.13 |
| **Crosses** | **76** | 66.27** | 66.07** | 484.68** | 2.18** | 72.98** | 96.57** | 9.81** | 3676.11** | 16103.14** | 601.6** | 381.8** | 4265.21** |
| **Line effect** | **10** | 122.56* | 125.44* | 840.74* | 1.96 | 98.49 | 122.28 | 11.45 | 4248.47 | 28763.9* | 771.95 | 283.15 | 4974.8 |
| **Tester effect** | **6** | 76.16 | 72.36 | 843.96 | 5.3* | 51.52 | 133.77 | 12.17 | 3245.4 | 14798.41 | 793.82 | 468.13 | 4489.58 |
| **Line x Tester effect** | **60** | 55.9** | 55.55** | 389.41** | 1.9** | 70.87** | 88.57** | 9.3** | 3623.79** | 14123.49** | 553.99** | 389.61** | 4124.51** |
| **Error** | **152** | 2.32 | 2.11 | 116.96 | 0.17 | 2.34 | 4.57 | 0.04 | 95.2 | 346.09 | 20.84 | 20.95 | 172.95 |
| **S.Em±** | | 0.88 | 0.80 | 6.24 | 0.24 | 0.88 | 1.23 | 0.115 | 5.63 | 10.74 | 2.64 | 2.64 | 7.59 |
| **CD(5%)** | | 2.46 | 2.30 | 17.45 | 0.67 | 2.47 | 3.45 | 0.322 | 15.74 | 30.01 | 7.36 | 7.38 | 21.21 |
| **CV** | | 3.21 | 1.90 | 7.66 | 19.27 | 7.23 | 12.28 | 2.111 | 17.17 | 14.65 | 14.8 | 16.27 | 19.7 |
| **GM** | | 47.45 | 77 | 141.22 | 2.14 | 21.16 | 17.4 | 9.474 | 56.82 | 127.01 | 30.84 | 28.13 | 66.77 |

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

## Table 4.3.3 Combining ability analysis for environment $E_3$ for different characters in pearl millet

| Source of variation | df | Mean sum of squares | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| **Replication** | **2** | 2.04 | 0.83 | 98.24 | 0.03 | 4.65* | 12.53* | 0.05 | 117.21 | 402.71 | 20.86 | 41.67 | 118.59 |
| **Crosses** | **76** | 66.79** | 66.07** | 479.8** | 1.23** | 68.54** | 98.16** | 9.99** | 3672** | 15132.19** | 292.48** | 490.91** | 491.22** |
| **Line effect** | **10** | 116.82* | 126.99* | 862.34* | 0.7 | 82.59 | 118.74 | 10.92 | 4066.28 | 23862.47 | 255.73 | 415.68 | 988.96* |
| **Tester effect** | **6** | 68.8 | 70.38 | 836.47 | 3.19* | 44.09 | 133.47 | 14.02 | 3673.67 | 16350.36 | 527.47 | 71.72 | 357.3 |
| **L x T effect** | **60** | 58.25** | 55.48** | 380.38** | 1.12** | 68.64** | 91.2** | 9.44** | 3606.13** | 13555.32** | 275.11** | 545.37** | 421.65** |
| **Error** | **152** | 1.34 | 2.1 | 106.02 | 0.09 | 1.32 | 3.75 | 0.02 | 49.55 | 246.57 | 15.65 | 19.48 | 59.13 |
| **S.Em±** | | 0.66 | 0.83 | 5.94 | 0.17 | 0.66 | 1.11 | 0.081 | 4.06 | 9.07 | 2.28 | 2.55 | 4.44 |
| **CD(5%)** | | 1.86 | 2.33 | 16.6 | 0.48 | 1.85 | 3.12 | 0.22 | 11.36 | 25.33 | 6.38 | 7.12 | 12.4 |
| **CV** | | 2.17 | 1.73 | 9.23 | 18.24 | 7.36 | 13.23 | 1.538 | 13.53 | 15.43 | 16.97 | 15.21 | 16.57 |
| **GM** | | 53.33 | 83.49 | 111.48 | 1.65 | 15.62 | 14.63 | 9.189 | 52.01 | 101.8 | 23.31 | 29.01 | 46.41 |

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

**Table 4.3.4 Combining ability analysis over the environments for different characters in pearl millet**

| Source of variation | df | Mean sum of squares | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (mm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| Replication | 2 | 4.6 | 1.59 | 216.99 | 0.3 | 17.02** | 20.01** | 0.09 | 311.52 | 2846.57* | 103.81 | 15.9 | 80.09 |
| Rep. x Env. | 4 | 3.72 | 2.34 | 26.6 | 0.2 | 0.34 | 3.55 | 0.07 | 55.15 | 704.42 | 53.04 | 29.59 | 68.81 |
| Rep./Env. | 6 | 4.01 | 2.09 | 90.06 | 0.23 | 5.9** | 9.03* | 0.08 | 140.6 | 1418.47* | 69.97 | 25.03 | 72.57 |
| Env. | 2 | 3527.78** | 35.08.16** | 109477.83** | 306.95** | 4581.76** | 5896.98** | 8.17** | 226426.19** | 1271088.35** | 60640.3** | 1924.54** | 24993.59** |
| Crosses | 76 | 150.32** | 151.03** | 1368.63** | 3.68** | 129.25** | 177.29** | 29.38** | 8799.97** | 35026.87** | 1215.81** | 479.46** | 1794.84** |
| Line effect | 10 | 335.36** | 348.27** | 2461.56* | 2.37 | 160.31 | 264.41 | 33.5 | 10443.03 | 66975.48* | 1300.22 | 593.27 | 1218.06 |
| Tester effect | 6 | 158.45 | 141.98 | 1861.41 | 8.5* | 61.01 | 186.21 | 40.21 | 7200.83 | 22751.3 | 1707.53 | 234.49 | 2860.6 |
| Line x Tester effect | 60 | 118.66** | 119.06** | 1137.19** | 3.41** | 130.9** | 161.87** | 27.61** | 8686.04** | 30929.66** | 1152.57** | 484.98** | 1784.4** |
| Env.x crosses | 152 | 13.05** | 13.47** | 183.72** | 1.18** | 19.58** | 27.95** | 0.06** | 1459.29** | 7876.62** | 331.57** | 252.04** | 1714.19** |
| Env.x Line effect | 20 | 7.72 | 9.37 | 102.73 | 1.65* | 25.01 | 16.26 | 0.034 | 1997.56 | 8160.45 | 342.37 | 191.49 | 2744.14* |
| Env.xTester effect | 12 | 12.67 | 13.8 | 553.46** | 3.62** | 31.63 | 63.27** | 0.1586** | 2060.89 | 10480.14 | 300.63 | 188.34 | 1308.32 |
| Env.x L x T effect | 120 | 13.98** | 14.12** | 160.25** | 0.86** | 17.48** | 26.37** | 0.049 | 1309.42** | 7568.96** | 332.87** | 268.51** | 1583.11** |
| Error | 456 | 3.47 | 3.19 | 78.8 | 0.24 | 1.96 | 3.43 | 0.04 | 164.96 | 639.6 | 40.13 | 20.45 | 98.82 |
| S.Em | | 0.62 | 0.59 | 2.96 | 0.16 | 0.47 | 0.62 | 0.07 | 4.28 | 8.43 | 2.11 | 1.51 | 3.31 |
| CD(5%) | | 1.73 | 1.65 | 8.22 | 0.45 | 1.3 | 1.72 | 0.19 | 11.9 | 23.43 | 5.87 | 4.19 | 9.21 |
| CV | | 3.8 | 2.25 | 6.55 | 19.27 | 6.86 | 9.84 | 2.13 | 17.73 | 16.15 | 17.51 | 16.79 | 17.96 |
| GM | | 49 | 79.05 | 135.53 | 2.54 | 20.4 | 18.83 | 9.4 | 72.44 | 156.61 | 36.17 | 26.93 | 55.36 |

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

**Table 4.3.5 Estimation of combining ability variances for grain yield per plant and its components evaluated in different environments.**

| Environment | Source of variation | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $E_1$ | $\sigma^2$ gca | 2.33 | 2.42 | 41.2 | 0.17 | 0.99 | 1.8 | 0.47 | 181.98 | 751.49 | 32.91 | 5.68 | 23.04 |
| | $\sigma^2$ sca | 9.69 | 10.3 | 224.82 | 0.55 | 8.04 | 10.95 | 2.97 | 1241.61 | 5687.54 | 301.77 | 22.03 | 113.36 |
| | $\sigma^2$gca/$\sigma^2$ sca | 0.24 | 0.23 | 0.18 | 0.30 | 0.12 | 0.16 | 0.15 | 0.14 | 0.13 | 0.10 | 0.25 | 0.20 |
| $E_2$ | $\sigma^2$ gca | 3.59 | 3.58 | 26.87 | 0.13 | 2.69 | 4.57 | 0.44 | 135.25 | 793.89 | 28.22 | 13.14 | 168.86 |
| | $\sigma^2$ sca | 17.86 | 17.81 | 90.82 | 0.58 | 22.84 | 28 | 3.09 | 1176.2 | 4592.47 | 177.72 | 122.89 | 1317.19 |
| | $\sigma^2$gca/$\sigma^2$ sca | 0.20 | 0.201 | 0.29 | 0.22 | 0.11 | 0.16 | 0.14 | 0.11 | 0.17 | 0.15 | 0.10 | 0.12 |
| $E_3$ | $\sigma^2$ gca | 3.39 | 3.58 | 27.53 | 0.07 | 2.30 | 4.53 | 0.46 | 141.5 | 735.55 | 13.92 | 8.3 | 22.74 |
| | $\sigma^2$ sca | 18.97 | 17.79 | 91.45 | 0.34 | 22.44 | 29.15 | 3.14 | 1185.53 | 4436.25 | 86.49 | 175.3 | 120.84 |
| | $\sigma^2$gca/$\sigma^2$ sca | 0.17 | 0.20 | 0.30 | 0.20 | 0.10 | 0.15 | 0.14 | 0.11 | 0.16 | 0.16 | 0.04 | 0.18 |
| Pooled | $\sigma^2$ gca | 3.01 | 2.99 | 25.17 | 0.06 | 1.34 | 2.74 | 0.45 | 106.88 | 545.97 | 18.07 | 4.86 | 23.96 |
| | $\sigma^2$ sca | 12.80 | 12.87 | 117.60 | 0.35 | 14.33 | 17.6 | 3.06 | 946.79 | 3365.56 | 123.6 | 51.61 | 187.29 |
| | $\sigma^2$gca/$\sigma^2$ sca | 0.235 | 0.232 | 0.21 | 0.17 | 0.09 | 0.15 | 0.14 | 0.11 | 0.16 | 0.14 | 0.09 | 0.12 |

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

**Table 4.3.6 Genetic components for various traits evaluated in different environments**

| Environment | Source of variation | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $E_1$ | $\sigma^2$ A | 4.65 | 4.84 | 82.41 | 0.35 | 1.98 | 3.61 | 0.94 | 363.95 | 1502.98 | 65.82 | 11.37 | 46.08 |
| | $\sigma^2$ D | 9.69 | 10.3 | 224.82 | 0.55 | 8.04 | 10.95 | 2.97 | 1241.61 | 5687.54 | 301.77 | 22.03 | 113.36 |
| | $\sigma^2 A/\sigma^2$ D | 0.48 | 0.47 | 0.36 | 0.63 | 0.24 | 0.32 | 0.31 | 0.29 | 0.26 | 0.21 | 0.51 | 0.40 |
| $E_2$ | $\sigma^2$ A | 7.19 | 7.17 | 53.73 | 0.26 | 5.38 | 9.14 | 0.87 | 270.5 | 1587.78 | 56.45 | 26.27 | 337.72 |
| | $\sigma^2$ D | 17.86 | 17.81 | 90.82 | 0.58 | 22.84 | 28 | 3.09 | 1176.2 | 4592.47 | 177.72 | 122.89 | 1317.19 |
| | $\sigma^2 A/\sigma^2$ D | 0.402 | 0.40 | 0.59 | 0.44 | 0.23 | 0.32 | 0.28 | 0.23 | 0.34 | 0.3176 | 0.21 | 0.25 |
| $E_3$ | $\sigma^2$ A | 6.78 | 7.15 | 55.07 | 0.14 | 4.59 | 9.06 | 0.92 | 282.99 | 1471.1 | 27.85 | 16.61 | 45.48 |
| | $\sigma^2$ D | 18.97 | 17.79 | 91.45 | 0.34 | 22.44 | 29.15 | 3.14 | 1185.53 | 4436.25 | 86.49 | 175.3 | 120.84 |
| | $\sigma^2 A/ \sigma^2$ D | 0.35 | 0.40 | 0.60 | 0.40 | 0.20 | 0.31 | 0.29 | 0.23 | 0.33 | 0.32 | 0.09 | 0.37 |
| **Pooled** | $\sigma^2$ A | 6.01 | 5.97 | 51.42 | 0.13 | 2.68 | 5.48 | 0.91 | 213.75 | 1091.95 | 36.14 | 9.71 | 47.91 |
| | $\sigma^2$ D | 12.80 | 12.87 | 117.6 | 0.35 | 14.33 | 17.60 | 3.06 | 946.79 | 3365.56 | 123.6 | 51.61 | 187.29 |
| | $\sigma^2 A/\sigma^2$ D | 0.469 | 0.464 | 0.43 | 0.36 | 0.18 | 0.31 | 0.29 | 0.22 | 0.32 | 0.29 | 0.18 | 0.25 |

**Table 4.3.7 Proportional contribution of lines, testers and hybrids of pearl millet towards total variance (%) in different environments**

| Environment | Component | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $E_1$ | Lines (l) | 31.68 | 32.9 | 16.44 | 15.07 | 14.3 | 19.13 | 15.2 | 18.44 | 20.65 | 12.79 | 32.94 | 20.93 |
| | Testers (t) | 5.66 | 4.62 | 13.18 | 21.79 | 8.41 | 9.34 | 11.68 | 7.95 | 5.07 | 7.92 | 5.08 | 10.66 |
| | l x t | 62.65 | 62.47 | 70.38 | 63.15 | 77.29 | 71.53 | 73.12 | 73.61 | 74.28 | 79.29 | 61.98 | 68.41 |
| $E_2$ | Lines (l) | 24.34 | 24.98 | 22.82 | 11.82 | 17.76 | 16.66 | 15.36 | 15.21 | 23.5 | 16.88 | 9.76 | 15.35 |
| | Testers (t) | 9.07 | 8.65 | 13.75 | 19.21 | 5.57 | 10.94 | 9.8 | 6.97 | 7.26 | 10.42 | 9.68 | 8.31 |
| | l x t | 66.59 | 66.37 | 63.43 | 68.98 | 76.67 | 72.4 | 74.84 | 77.82 | 69.24 | 72.7 | 80.56 | 76.34 |
| $E_3$ | Lines (l) | 23.01 | 25.29 | 23.65 | 7.47 | 15.86 | 15.92 | 14.38 | 14.57 | 20.75 | 11.5 | 11.14 | 26.49 |
| | Testers (t) | 8.13 | 8.41 | 13.76 | 20.54 | 5.08 | 10.74 | 11.07 | 7.9 | 8.53 | 14.24 | 1.15 | 5.74 |
| | l x t | 68.85 | 66.30 | 62.59 | 71.99 | 79.07 | 73.07 | 74.55 | 77.53 | 70.72 | 74.26 | 87.71 | 67.77 |
| Pooled | Lines (l) | 29.36 | 30.34 | 23.67 | 8.47 | 16.32 | 19.62 | 15 | 15.61 | 25.16 | 14.07 | 16.28 | 8.93 |
| | Testers (t) | 8.32 | 7.42 | 10.74 | 18.26 | 3.73 | 8.92 | 10.81 | 6.46 | 5.13 | 11.09 | 3.86 | 12.58 |
| | l x t | 62.32 | 62.24 | 65.60 | 73.27 | 79.95 | 72.08 | 74.19 | 77.93 | 69.71 | 74.84 | 79.86 | 78.49 |

### 4.3.1 General combining ability effects

The estimates of general combining ability (GCA) effects of lines ($g_i$) and testers ($g_j$) were determined for each environment as well as over the environments for all the characters. The results obtained are presented in Table 4.3.8 to 4.3.11 and is described for each environment as below:

#### 4.3.1.1 GCA Effect in $E_1$ environment for different characters in pearl millet

Table 4.3.8 depicts GCA Effect of all character in pearl millet.

##### 4.3.1.1.1 Days to 50% flowering

Early flowering is desirable in pearl millet, which is reflected by the negative combining ability effects. Perusal of Table 4.3.8 indicated that out of eleven lines, four lines in environment $E_1$ possessed highly significantly negative GCA effects and whereas, out of seven tester only one possessed significantly negative GCA effects. Thus, these were considered as good general combiner for early flowering.

##### 4.3.1.1.2 Days to maturity

Similar to early flowering, early maturity is also desirable in pearl millet, which is reflected by the negative combining ability effects. Perusal of Table 4.3.8 indicated that out of eleven lines, five lines in environment $E_1$ possessed highly significantly negative GCA effects. Out of seven testers only one possessed significantly negative GCA effects. Thus, these were considered as good general combiner for early maturity.

##### 4.3.1.1.3 Plant height

The tall plant height is desirable in pearl millet, which is reflected by the positive combining ability effects. Perusal of Table 4.3.8 indicated that out of eleven lines, six lines in environment $E_1$ possessed highly significantly positive GCA effects. Out of seven testers, four testers possessed significantly positive GCA effects. Thus, these were considered as good general combiner for plant height.

#### 4.3.1.1.4 Productive tillers per plants

Pearl millet is a fodder crop, high productive tillers per plant is desirable in this crop, which is reflected by the positive combining ability effects. Perusal of Table 4.3.8 revealed that out of eleven lines, three lines in environment $E_1$ possessed significantly positive GCA effects. Out of seven testers, three testers possessed significantly positive GCA effects. Thus, these were considered as good general combiner for productive tillers per plant.

#### 4.3.1.1.5 Ear head length

Long ear heads are desirable in pearl millet; positive combining ability effects were considered. Perusal of Table 4.3.8 revealed that out of eleven lines, three lines in environment E1 possessed significantly positive GCA effects. Out of seven testers, two testers possessed significantly positive GCA effects. Thus, these were considered as good general combiner for ear head length.

#### 4.3.1.1.6 Ear head diameter

As higher magnitude of ear head diameter is desirable in pearl millet, positive GCA effects were considered for the trait. Perusal of Table 4.3.8 revealed that out of eleven lines, four lines in environment $E_1$ possessed significantly positive GCA effects. Out of seven testers, two testers possessed significantly positive GCA effects. Thus, these were considered as good general combiner for ear head diameter.

#### 4.3.1.1.7 Test weight

The higher magnitude of test weight is desirable in pearl millet. Perusal of Table 4.3.8 revealed that out of eleven lines, five lines in environment $E_1$ possessed significantly positive GCA effects. Out of seven testers, three testers possessed significantly positive GCA effects. Thus, these were considered as good general combiner for test weight.

#### 4.3.1.1.8 Ear head weight

The higher magnitude of ear head weight is desirable in pearl millet. Perusal of Table 4.3.8 revealed that out of eleven lines, three lines in environment $E_1$ possessed significantly positive GCA effects. Out of seven testers, three testers possessed significantly positive GCA effects. Thus, these were considered as good general combiner for ear head weight.

**4.3.1.1.9 Dry stover yield per plant**

As pearl millet is dual crop, the dry stover as well as grain yield is of importance, which is reflected by significant positive general combining ability effects. The perusal of GCA effects (Table 4.3.8) revealed that out of eleven lines, three lines in environment $E_1$ possessed significantly positive GCA effects. Out of seven testers, three testers possessed significantly positive GCA effects. Thus, these were considered as good general combiner for dry stover yield per plant.

**4.3.1.1.10 Grain yield per plant**

The higher magnitude of grain yield per plant is desirable in pearl millet. Perusal of Table 4.3.8 revealed that out of eleven lines, four lines in environment $E_1$ possessed significantly positive GCA effects and whereas, out of seven testers, two tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for grain yield per plant.

**4.3.1.1.11 Harvest index**

The higher magnitude of harvest index is desirable in pearl millet. Perusal of Table 4.3.8 revealed that out of eleven lines, four lines in environment $E_1$ possessed significantly positive GCA effects.

## Table 4.3.8 GCA effects in $E_1$ environment for different characters in pearl millet

| Lines (Females) | GCA Effect | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Days to 50% flowering** | **Days to maturity** | **Plant height (cm)** | **Productive tillers/ plant** | **Ear head length (cm)** | **Ear head diameter (cm)** | **Test weight (g)** | **Ear head weight (g)** | **Dry stover yield/ plant (g)** | **Grain yield/ plant (g)** | **Harvest index (%)** | **Threshing index (%)** |
| ICMA-04999 | 1.32* | 1.23* | -11.38** | 0.61** | -0.13 | -2.25** | 0.17** | -2.53 | -20.06* | 1.35 | 2.66** | 2.91 |
| ICMA-88004 | -1.82** | -1.91** | 2.45** | 0.3* | -1.07** | -0.58 | 0.07 | -6.58 | -20.06* | 5.2* | 2.9** | 5.5** |
| ICMA-93333 | -3.01** | -3.1** | 12.56** | 0.16 | -0.21 | -1.39** | 0.65** | 1.99 | 50.89** | -3.03 | -5.68** | -5.77** |
| ICMA-97111 | -0.92 | -1* | -0.1 | 0.06 | -0.1 | -1.06** | 0.18** | -14.44** | -53.4** | -5.7** | 2.61** | -0.12 |
| ICMA-97444 | -1.82** | -1.91** | 4.16** | -0.2 | -0.64 | -1.25** | -0.92** | -13.01** | 9.46 | -2.23 | -1.23 | 5.39** |
| ICMA-98222 | -3.3** | -3.39** | -4.34** | -0.65** | 1.83** | 3.52** | 1.4** | 15.32** | -25.3** | 10.39** | 6.75** | -0.17 |
| ICMA-10444 | 0.89 | 0.81 | -6.64** | -0.46** | 0.83* | 1.09** | 0.49** | -15.87** | -15.06 | -8.65** | -1.89 | 2.44 |
| ICMA-30199 | 3.13** | 3.04** | 4.75** | 0.01 | -2.58** | 1.04** | -0.08 | 23.9** | 76.6** | 9.2** | -2.55* | -2.43 |
| ICMA-30200 | 1.46** | 1.38** | -6.93** | -0.16 | 0.55 | -0.72* | -1.2** | -19.2** | -29.59** | -8.18** | -1.48 | 0.52 |
| ICMA-30201 | 1.8** | 2.19** | 2.6** | 0.48** | 1.03** | 1.13** | -0.24** | 32.47** | 25.65** | -3.89 | -3.88** | -14.29** |
| ICMA-30209 | 2.27** | 2.66** | 2.87** | -0.16 | 0.49 | 0.47 | -0.52** | -2.06 | 0.89 | 5.54** | 1.78 | 6.01** |
| **Testers (Males)** | **GCA Effect** | | | | | | | | | | | |
| BIB 481- 500 | 0.41 | 0.32 | 3** | -0.61** | -1.33** | -1.1** | -0.53** | -15.3** | -21.02** | -2.16 | 1.06 | 8.04** |
| BIB 501-510 | 0.29 | 0.2 | 3.58** | -0.37** | 1.45** | 1.81** | 0.41** | -11.36** | -18.44** | -5.7** | -0.58 | -1.51 |
| BIB 511-520 | -0.71 | -0.8* | -8.58** | -0.08 | -0.15 | 0.96** | 0.01 | 11.52** | 2.32 | -3 | -0.26 | -5.76** |
| BIB 531-540 | -0.62 | -0.71 | 9.13** | 0.4** | 0.97** | -1.19** | 0.3** | -1.97 | 21.41** | -3.31* | -2.95** | -2.73 |
| BIB 551-560 | 1.89** | 1.81** | -5.89** | -0.34** | -0.35 | -1.1** | -1.09** | -5.91 | -19.81** | -1.34 | 0.66 | 2.05 |
| BIB 561-570 | -0.29 | -0.38 | -3.77** | 0.64** | -0.11 | 0.2 | 0.94** | 12.12** | 20.5** | 8.21** | 1.35 | 1.16 |
| BIB 571-580 | -0.96* | -0.44 | 2.53** | 0.36** | -0.48 | 0.44 | -0.04 | 10.91** | 15.04* | 7.3** | 0.71 | -1.25 |
| **SE** (GCA line) | 0.52 | 0.51 | 0.8 | 0.15 | 0.32 | 0.31 | 0.05 | 4.08 | 7.95 | 2 | 1 | 1.75 |
| (gi-gj lines) | 0.74 | 0.72 | 1.13 | 0.21 | 0.46 | 0.43 | 0.08 | 5.77 | 11.24 | 2.83 | 1.41 | 2.48 |
| (GCA tester) | 0.42 | 0.4 | 0.64 | 0.12 | 0.26 | 0.24 | 0.04 | 3.26 | 6.34 | 1.59 | 0.8 | 1.4 |
| (gi-gj tester) | 0.59 | 0.57 | 0.9 | 0.17 | 0.37 | 0.35 | 0.06 | 4.61 | 8.97 | 2.25 | 1.13 | 1.98 |
| **CD**(GCA line) | 1.03 | 1 | 1.58 | 0.29 | 0.64 | 0.61 | 0.11 | 8.07 | 15.7 | 3.95 | 1.97 | 3.46 |
| (gi-gj lines) | 1.46 | 1.41 | 2.23 | 0.41 | 0.91 | 0.86 | 0.15 | 11.41 | 22.2 | 5.58 | 2.79 | 4.89 |
| (GCA tester) | 0.83 | 0.8 | 1.26 | 0.23 | 0.51 | 0.48 | 0.08 | 6.44 | 12.52 | 3.15 | 1.57 | 2.76 |
| (gi-gj tester) | 1.17 | 1.13 | 1.78 | 0.33 | 0.72 | 0.68 | 0.12 | 9.1 | 17.71 | 4.45 | 2.23 | 3.9 |

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

Thus, these were considered as good general combiner for harvest index.

#### 4.3.1.1.12 Threshing index

The higher magnitude of threshing index is desirable in pearl millet Perusal of Table 4.3.8 revealed that out of eleven lines, three lines in environment $E_1$ possessed significantly positive GCA effects and whereas, out of seven testers, one tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for threshing index.

### 4.3.1.2 GCA Effect in $E_2$ environment for different characters in pearl millet

Table 4.3.9 depicts GCA Effect of all character in pearl millet.

#### 4.3.1.2.1 Days to 50% flowering

Perusal of Table 4.3.9 indicated that, out of eleven lines, three lines in environment $E_2$ possessed highly significantly negative GCA effects and whereas, out of seven tester, three tester possessed significantly negative GCA effects. Thus, these were considered as good general combiner for early flowering.

#### 4.3.1.2.2 Days to maturity

Similar to early flowering, early maturity is also desirable in pearl millet, which is reflected by the negative combining ability effects. Perusal of Table 4.3.9 indicated that out of eleven lines, three lines in environment $E_2$ possessed highly significantly negative GCA effects and whereas, out of seven tester, three tester possessed significantly negative GCA effects. Thus, these were considered as good general combiner for early maturity.

#### 4.3.1.2.3 Plant height

The tall plant height is desirable in pearl millet, which is reflected by the positive combining ability effects. Perusal of Table 4.3.9 indicated that out of eleven lines, two lines in environment $E_2$ possessed highly significantly positive GCA effects and whereas, out of seven tester only one tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for plant height.

**4.3.1.2.4 Productive tillers per plants**

As pearl millet is a fodder crop, productive tillers per plant is desirable in this crop, which is reflected by the positive combining ability effects. Perusal of Table 4.3.9 revealed that out of eleven lines, three lines in environment $E_2$ possessed highly significantly positive GCA effects and whereas, out of seven tester, three tester also possessed significantly positive GCA effects. Thus, these were considered as good general combiner for productive tillers per plant.

**4.3.1.2.5 Ear head length**

As long ear heads are desirable in pearl millet, positive combining ability effects were considered as desirable. Perusal of Table 4.3.9 revealed that out of eleven lines, five lines in environment E2 possessed significantly positive GCA effects and whereas, out of seven testers, three tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for ear head length.

**4.3.1.2.6 Ear head diameter**

As higher magnitude of ear head diameter is desirable in pearl millet, positive GCA effects were considered desirable. Perusal of Table 4.3.9 revealed that out of eleven lines, six lines in environment $E_2$ possessed significantly positive GCA effects and whereas, out of seven tester only one tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for ear head diameter.

**4.3.1.2.7 Test weight**

The higher magnitude of test weight is desirable in pearl millet. Perusal of Table 4.3.9 revealed that out of eleven lines, five lines in environment $E_2$ possessed significantly positive GCA effects and whereas out of seven tester, three tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for test weight.

**4.3.1.2.8 Ear head weight**

The higher magnitude of ear head weight is desirable in pearl millet. Perusal of Table 4.3.9 revealed that out of eleven lines, three lines in environment $E_2$ possessed significantly positive GCA effects and whereas out of seven tester, three tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for ear head weight.

**4.3.1.2.9 Dry stover yield per plant**

As pearl millet is dual purpose crop, the dry stover as well as grain yield is of importance, which is reflected by significant positive general combining ability effects. The perusal of GCA effects (Table 4.3.9) revealed that out of eleven lines, three lines in environment $E_2$ possessed significantly positive GCA effects and whereas, out of seven tester, two tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for dry stover yield per plant.

**4.3.1.2.10 Grain yield per plant**

The higher magnitude of grain yield per plant is desirable in pearl millet. Perusal of Table 4.3.9 revealed that out of eleven lines, four lines in environment $E_2$ possessed significantly positive GCA effects and whereas, out of seven tester, two tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for grain yield per plant.

**4.3.1.2.11 Harvest index**

The higher magnitude of harvest index is desirable in pearl millet. Perusal of Table 4.3.9 revealed that, out of eleven lines, five in environment $E_2$ possessed significantly positive GCA effects and whereas out of seven tester, two tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for harvest index.

**4.3.1.2.12 Threshing index**

The higher magnitude of threshing index is desirable in pearl millet. Perusal of Table 4.3.9 revealed that out of eleven lines, three lines in environment $E_2$ possessed significantly positive GCA effects and whereas out of seven tester, two tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for threshing index.

**4.3.1.3 GCA Effect in $E_3$ environment for different characters in pearl millet**

Table 4.3.10 depicts GCA Effect of all character in pearl millet.

**4.3.1.3.1 Days to 50% flowering**

Early flowering is desirable in pearl millet, which is reflected by the negative combining ability effects. Perusal of Table 4.3.10 indicated that out of eleven lines, three lines in environment $E_3$ possessed highly significantly negative GCA effects and whereas, out of seven tester three possessed significantly negative GCA effects. Thus, these were considered as good general combiner for early flowering.

**4.3.1.3.2 Days to maturity**

Similar to early flowering, early maturity is also desirable in pearl millet, which is reflected by the negative combining ability effects. Perusal of Table 4.3.10 indicated that out of eleven lines, three lines in environment $E_3$ possessed highly significantly negative GCA effects and whereas, out of seven tester three possessed

**Table 4.3.9 GCA effects in $E_2$ environment for different characters in pearl millet**

| Lines (Females) | GCA Effect | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| ICMA-04999 | 2.27** | 2.43** | -7.75** | -0.29** | -2.43** | -1.92** | 0.21** | -14.06** | -22.73** | -1.7 | 5.36** | 10.71** |
| ICMA-88004 | -3.49** | -3.52** | 6.82** | -0.02 | 1.01** | 0.99* | 0.04 | 12.32** | -4.63 | 5.64** | 2.28* | 3.55 |
| ICMA-93333 | -3.97** | -4** | 15.2** | -0.05 | 2.84** | 1.19* | 0.71** | 16.03** | -2.25 | 3.64** | 3.7** | -15.12** |
| ICMA-97111 | 0.17 | 0.14 | -3.14 | -0.66** | -2.68** | -2.75** | 0.09* | -11.77** | -49.87** | -11.74** | -1.5 | -5.95* |
| ICMA-97444 | -0.4 | -0.43 | -1.39 | 0.32** | -1.12** | -3.14** | -0.87** | -8.11** | -27.97** | -3.32** | 1 | -7.27* |
| ICMA-98222 | -2.49** | -2.52** | -1.08 | 0.14 | 1.63** | 4.5** | 1.47** | 29.37** | 26.32** | 1.59 | -3.19** | -21.61** |
| ICMA-10444 | 0.7* | 0.67* | -3.83 | -0.12 | 2.22** | 1.19* | 0.47** | -1.73 | -1.77 | -3.84** | -3.01** | -9.77** |
| ICMA-30199 | 3.65** | 3.62** | 2.27 | 0.19* | -2.26** | 1.82** | -0.08 | 1.75 | 47.27** | 6.97** | -5.06** | -0.72 |
| ICMA-30200 | 1.51** | 1.48** | -4.91* | 0.03 | -1.83** | -1.84** | -1.14** | -12.16** | -13.2** | -2.65** | 2.63** | 8.27** |
| ICMA-30201 | 0.46 | 0.43 | 0.19 | 0.48** | 2.73** | 1.76** | -0.3** | 2.18 | 77.27** | 9.16** | -4.97** | 35.91** |
| ICMA-30209 | 1.6** | 1.71** | -2.38 | -0.02 | -0.11 | -1.79** | -0.6** | -13.82** | -28.44** | -3.74** | 2.76** | 2.01 |
| **Testers (Males)** | **GCA Effect** | | | | | | | | | | | |
| BIB 481- 500 | -0.29 | -0.32 | 8.76** | 0.36** | -0.63* | 0.27 | -0.41** | 5.3** | 43.29** | 7.28** | -2.78** | 13.47** |
| BIB 501-510 | 2.1** | 2.07** | -7.49** | -0.56** | -1.33** | -2.3** | 0.44** | 3.78* | -11.56** | -6.39** | -3.02** | -13.43** |
| BIB 511-520 | -0.75** | -0.78** | -1.08 | 0.4** | -1.61** | -0.64 | 0.01 | 13.66** | -8.23* | -0.42 | -0.36 | -15.66** |
| BIB 531-540 | 0.37 | 0.34 | 3.09 | -0.36** | -0.04 | -1.03** | 0.32** | -17.06** | -10.65** | -4.93** | -1.13 | 3.94 |
| BIB 551-560 | 1.83** | 1.8** | 0.63 | -0.25** | 1.17** | -0.82* | -1.12** | -7.94** | -15.5** | -0.6 | 5.44** | 13.78** |
| BIB 561-570 | -1.54** | -1.57** | -2.92 | 0.41** | 0.88** | 0.44 | 0.7** | 2.57 | 12.68** | -0.02 | -3.3** | -1.92 |
| BIB 571-580 | -1.72** | -1.54** | -0.99 | 0.01 | 1.57** | 4.08** | 0.05 | -0.31 | -10.04** | 5.07** | 5.13** | -0.17 |
| **SE** (GCA line) | 0.33 | 0.32 | 2.36 | 0.09 | 0.33 | 0.47 | 0.04 | 2.13 | 4.06 | 1 | 1 | 2.87 |
| (GCA tester) | 0.27 | 0.25 | 1.88 | 0.07 | 0.27 | 0.37 | 0.03 | 1.7 | 3.24 | 0.79 | 0.8 | 2.29 |
| (gi-gj lines) | 0.47 | 0.45 | 3.34 | 0.13 | 0.47 | 0.66 | 0.06 | 3.01 | 5.74 | 1.41 | 1.41 | 4.06 |
| (gi-gj tester) | 0.37 | 0.36 | 2.66 | 0.1 | 0.38 | 0.53 | 0.05 | 2.4 | 4.58 | 1.12 | 1.13 | 3.24 |
| **CD**(GCA line) | 0.66 | 0.63 | 4.66 | 0.18 | 0.66 | 0.92 | 0.09 | 4.21 | 8.02 | 1.97 | 1.97 | 5.67 |
| (GCA tester) | 0.52 | 0.5 | 3.72 | 0.14 | 0.53 | 0.74 | 0.07 | 3.36 | 6.4 | 1.57 | 1.57 | 4.52 |
| (gi-gj lines) | 0.93 | 0.89 | 6.59 | 0.25 | 0.93 | 1.3 | 0.12 | 5.95 | 11.34 | 2.78 | 2.79 | 8.02 |
| (gi-gj tester) | 0.74 | 0.71 | 5.26 | 0.2 | 0.74 | 1.04 | 0.1 | 4.75 | 9.05 | 2.22 | 2.23 | 6.4 |

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

significantly negative GCA effects. Thus, these were considered as good general combiner for early maturity.

**4.3.1.3.3 Plant height**

The tall plant height is desirable in pearl millet, which is reflected by the positive combining ability effects. Perusal of Table 4.3.10 indicated that out of eleven lines, two lines in environment $E_3$ possessed highly significantly positive GCA effects and whereas, out of seven tester only one tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for plant height.

**4.3.1.3.4 Productive tillers per plants**

As pearl millet is a fodder crop, productive tillers per plant is desirable in this crop, which is reflected by the positive combining ability effects. Perusal of Table 4.3.10 revealed that out of eleven lines, four lines in environment $E_3$ possessed highly significantly positive GCA effects and whereas, out of seven tester, three tester also possessed significantly positive GCA effects. Thus, these were considered as good general combiner for productive tillers per plant.

**4.3.1.3.5 Ear head length**

As long ear heads are desirable in pearl millet, positive combining ability effects were considered. Perusal of Table 4.3.10 revealed that out of eleven lines, five lines in environment E3 possessed significantly positive GCA effects and whereas, out of seven tester, three tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for ear head length.

**4.3.1.3.6 Ear head diameter**

As higher magnitude of ear head diameter is desirable in pearl millet, positive GCA effects were considered. Perusal of Table 4.3.10 revealed that out of eleven lines, five lines in environment $E_3$ possessed significantly positive GCA effects and whereas, out of seven tester, only one tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for ear head diameter.

#### 4.3.1.3.7 Test weight

The higher magnitude of test weight is desirable in pearl millet. Perusal of Table 4.3.10 revealed that out of eleven lines, five lines in environment $E_3$ possessed significantly positive GCA effects and whereas, out of seven tester, four tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for test weight.

#### 4.3.1.3.8 Ear head weight

The higher magnitude of ear head weight is desirable in pearl millet. Perusal of Table 4.3.10 revealed that out of eleven lines, three lines in environment $E_3$ possessed significantly positive GCA effects and whereas, out of seven tester, four tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for ear head weight.

#### 4.3.1.3.9 Dry stover yield per plant

As pearl millet is dual crop, the dry stover as well as grain yield is of importance, which is reflected by significant positive general combining ability effects. The perusal of GCA effects (Table 4.3.10) revealed that out of eleven lines, four lines in environment $E_3$ possessed significantly positive GCA effects and whereas, out of seven tester, two tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for dry stover yield per plant.

#### 4.3.1.3.10 Grain yield per plant

The higher magnitude of grain yield per plant is desirable in pearl millet. Perusal of Table 4.3.10 revealed that out of eleven lines, three lines in environment $E_3$ possessed significantly positive GCA effects and whereas, out of seven tester, two tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for grain yield per plant.

**4.3.1.3.11 Harvest index**

The higher magnitude of harvest index is desirable in pearl millet. Perusal of Table 4.3.10 revealed that out of eleven lines, five lines in environment $E_3$ possessed significantly positive GCA effects. Thus, these were considered as good general combiner for harvest index.

**4.3.1.3.12 Threshing index**

The higher magnitude of threshing index is desirable in pearl millet. Perusal of Table 4.3.10 revealed that out of eleven lines, three lines in environment $E_3$ possessed significantly positive GCA effects and whereas, out of seven tester, two tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for threshing index.

**4.3.1.4 GCA Effect in over the environment for different characters in pearl millet**

Table 4.3.11 depicts GCA Effect of all character in pearl millet.

**4.3.1.4.1 Days to 50% flowering**

Early flowering is desirable in pearl millet, which is reflected by the negative combining ability effects. Perusal of Table 4.3.11 indicated that out of eleven lines, four in over the environment possessed highly significantly negative GCA effects and whereas, out of seven tester three possessed significantly negative GCA effects. Thus, these were considered as good general combiner for early flowering.

**4.3.1.4.2 Days to maturity**

Similar to early flowering, early maturity is also desirable in pearl millet, which is reflected by the negative combining ability effects. Perusal of Table 4.3.11 indicated that out of eleven lines, four

## Table 4.3.10 GCA effects in $E_3$ environment for different characters in pearl millet

| Lines (Females) | GCA Effect | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Days to 50% flowering** | **Days to maturity** | **Plant height (cm)** | **Productive tillers/ plant** | **Ear head length (cm)** | **Ear head diameter (cm)** | **Test weight (g)** | **Ear head weight (g)** | **Dry stover yield/ plant (g)** | **Grain yield/ plant (g)** | **Harvest index (%)** | **Threshing index (%)** |
| ICMA-04999 | 2.47** | 2.46** | -8.01** | -0.17* | -2.1** | -1.91** | 0.2** | -13.92** | -25.37** | -0.78 | 4.56** | 1.44 |
| ICMA-88004 | -3.48** | -3.54** | 6.56** | -0.02 | 1.1** | 0.53 | 0.02 | 16.8** | 5.35 | 1.6 | 6.53** | 7.39** |
| ICMA-93333 | -3.86** | -4.02** | 15.42** | -0.04 | 2.7** | 1.2** | 0.7** | 15.13** | 16.3** | 2.93** | -6.16** | 3.95* |
| ICMA-97111 | -0.00433 | 0.13 | -3.4 | -0.37** | -2.88** | -2.74** | 0.15** | -11.3** | -40.84** | -7.88** | 1.14 | 3.26 |
| ICMA-97444 | -0.29 | -0.45 | -1.65 | 0.2** | -0.41 | -3.12** | -0.89** | -11.54** | -26.32** | 1.07 | 3.56** | -0.54 |
| ICMA-98222 | -2.05** | -2.54** | -1.34 | 0.13* | 1.72** | 4.52** | 1.44** | 26.08** | 28.44** | 0.84 | -1.93* | 13** |
| ICMA-10444 | 0.38 | 0.65* | -2.66 | -0.07 | 1.41** | 1.2** | 0.36** | 1.32 | -11.32** | -1.16 | -3.21** | -9.1** |
| ICMA-30199 | 3.76** | 3.6** | 2.96 | 0.18** | -2.02** | 1.84** | -0.09** | -0.58 | 39.63** | 3.93** | -0.98 | -9.44** |
| ICMA-30200 | 1.61** | 1.46** | -5.17* | -0.08 | -1.64** | -1.54** | -1.16** | -12.97** | -16.56** | -2.69** | 2* | -6.34** |
| ICMA-30201 | 0.38 | 0.41 | -0.07 | 0.25** | 2.48** | 1.78** | -0.22** | 1.8 | 64.39** | 4.22** | -7.67** | -1.82 |
| ICMA-30209 | 1.09** | 1.84** | -2.64 | -0.02 | -0.35 | -1.77** | -0.51** | -10.82** | -33.7** | -2.07* | 2.16* | -1.8 |
| **Testers (Males)** | **GCA Effect** | | | | | | | | | | | |
| BIB 481- 500 | -0.25 | -0.34 | 9.11** | 0.31** | -0.97** | 0.17 | -0.43** | 4.81** | 37.14** | 4.87** | 0.36 | -1.38 |
| BIB 501-510 | 2.12** | 2.05** | -7.14** | -0.41** | -0.88** | -2.28** | 0.35** | 3.9** | -15.43** | -5.58** | 1.1 | 3.32* |
| BIB 511-520 | -0.76** | -0.8** | -1.34 | 0.3** | -1.52** | -0.62 | -0.04 | 15.56** | -14.83** | 0.63 | 1.24 | -2.76* |
| BIB 531-540 | 0.3 | 0.32 | 2.83 | -0.39** | -0.07 | -1.01** | 0.28** | -16.86** | -12.55** | -4.97** | -3.06** | -4.66** |
| BIB 551-560 | 1.63** | 1.78** | 0.37 | -0.1 | 0.93** | -0.81* | -1.15** | -8.98** | -20.58** | 0.87 | 0.11 | 4.69** |
| BIB 561-570 | -1.43** | -1.58** | -2.57 | 0.25** | 1.24** | 0.45 | 0.91** | 4.05** | 23.35** | 0.3 | 0.76 | 0.82 |
| BIB 571-580 | -1.61** | -1.43** | -1.25 | 0.03 | 1.27** | 4.1** | 0.07** | -2.47* | 2.9 | 3.87** | -0.5 | -0.03 |
| **SE** (GCA line) | 0.25 | 0.32 | 2.25 | 0.07 | 0.25 | 0.42 | 0.03 | 1.54 | 3.43 | 0.86 | 0.96 | 1.68 |
| (GCA tester) | 0.2 | 0.25 | 1.79 | 0.05 | 0.2 | 0.34 | 0.02 | 1.23 | 2.73 | 0.69 | 0.77 | 1.34 |
| (gi-gj lines) | 0.36 | 0.45 | 3.18 | 0.09 | 0.35 | 0.6 | 0.04 | 2.17 | 4.85 | 1.22 | 1.36 | 2.37 |
| (gi-gj tester) | 0.28 | 0.36 | 2.53 | 0.07 | 0.28 | 0.48 | 0.03 | 1.73 | 3.87 | 0.97 | 1.09 | 1.89 |
| **CD**(GCA line) | 0.5 | 0.62 | 4.44 | 0.13 | 0.5 | 0.83 | 0.06 | 3.03 | 6.77 | 1.71 | 1.9 | 3.32 |
| (GCA tester) | 0.4 | 0.5 | 3.54 | 0.1 | 0.4 | 0.67 | 0.05 | 2.42 | 5.4 | 1.36 | 1.52 | 2.64 |
| (gi-gj lines) | 0.71 | 0.88 | 6.28 | 0.18 | 0.7 | 1.18 | 0.09 | 4.29 | 9.57 | 2.41 | 2.69 | 4.69 |
| (gi-gj tester) | 0.56 | 0.7 | 5.01 | 0.15 | 0.56 | 0.94 | 0.07 | 3.42 | 7.64 | 1.92 | 2.15 | 3.74 |

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

in over the environment possessed highly significantly negative GCA effects and whereas, out of seven tester three possessed significantly negative GCA effects. Thus, these were considered as good general combiner for early maturity.

#### 4.3.1.4.3 Plant height

The tall plant height is desirable in pearl millet, which is reflected by the positive combining ability effects. Perusal of Table 4.3.11 indicated that out of eleven lines, three in over the environment possessed highly significantly positive GCA effects and whereas, out of seven tester two tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for plant height.

#### 4.3.1.4.4 Productive tillers per plants

As pearl millet is a fodder crop, productive tillers per plant is desirable in this crop, which is reflected by the positive combining ability effects. Perusal of Table 4.3.11 revealed that out of eleven lines, two in over the environment possessed highly significantly positive GCA effects and whereas, out of seven tester two tester also possessed significantly positive GCA effects. Thus, these were considered as good general combiner for productive tillers per plant.

#### 4.3.1.4.5 Ear head length

As long ear heads are desirable in pearl millet, positive combining ability effects were considered. Perusal of Table 4.3.11 revealed that out of eleven lines, four in over the environment possessed significantly positive GCA effects and whereas, out of seven tester four tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for ear head length.

#### 4.3.1.4.6 Ear head diameter

As higher magnitude of ear head diameter is desirable in pearl millet, positive GCA effects were considered. Perusal of Table 4.3.11 revealed that out of eleven lines, four in over the environment possessed significantly positive GCA effects and whereas, out of seven tester, one tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for ear head diameter.

**4.3.1.4.7 Test weight**

The higher magnitude of test weight is desirable in pearl millet. Perusal of Table 4.3.11 revealed that out of eleven lines, four in over the environment possessed significantly positive GCA effects, whereas, out of seven testers, three testers possessed significantly positive GCA effects. Thus, these were considered as good general combiner for test weight.

**4.3.1.4.8 Ear head weight**

The higher magnitude of ear head weight is desirable in pearl millet. Perusal of Table 4.3.11 revealed that out of eleven lines, five in over the environment possessed significantly positive GCA effects, whereas, out of seven testers, three testers possessed significantly positive GCA effects. Thus, these were considered as good general combiner for ear head weight.

**4.3.1.4.9 Dry stover yield per plant**

As pearl millet is dual crop, the dry stover as well as grain yield is of importance, which is reflected by significant positive general combining ability effects. The perusal of GCA effects Table 4.3.11 revealed that out of eleven lines, four in over the environment possessed significantly positive GCA effects and whereas, out of seven testers, three testers possessed significantly positive GCA effects. Thus, these were considered as good general combiner for dry stover yield per plant.

**4.3.1.4.10 Grain yield per plant**

The higher magnitude of grain yield per plant is desirable in pearl millet. Perusal of Table 4.3.11 revealed that out of eleven lines, four in over the environment possessed significantly positive GCA effects, whereas, out of seven testers, three testers possessed significantly positive GCA effects. Thus, these were considered as good general combiner for grain yield per plant.

#### 4.3.1.4.11 Harvest index

The higher magnitude of harvest index is desirable in pearl millet. Perusal of Table 4.3.11 revealed that out of eleven lines, three in over the environment possessed significantly positive GCA effects and whereas, out of seven testers, two testers possessed significantly positive GCA effects. Thus, these were considered as good general combiner for harvest index.

#### 4.3.1.4.12 Threshing index

The higher magnitude of threshing index is desirable in pearl millet. Perusal of Table 4.3.11 revealed that out of eleven lines, three in over the environment possessed significantly positive GCA effects and whereas, out of seven tester, two tester possessed significantly positive GCA effects. Thus, these were considered as good general combiner for threshing index.

### 4.3.2 Specific combining ability effects

The estimates of specific combining ability (SCA) effects of crosses ($S_{ij}$) were determined for each environment as well as over the environments for all the characters. The results obtained are presented in Table 4.3.12 to 4.3.15 and described for each character as below:

## Table 4.3.11 GCA effects in over the environment for different characters in pearl millet

| Lines (Females) | GCA Effect | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| ICMA-04999 | 1.95** | 2.04** | -9.04** | 0.05 | -1.55** | -2.03** | 0.19** | -10.17** | -22.72** | -0.38 | 4.2** | 5.02** |
| ICMA-88004 | -2.94** | -2.99** | 5.28** | 0.09 | 0.35* | 0.31 | 0.04 | 7.51** | -6.45* | 4.15** | 3.9** | 5.48** |
| ICMA-93333 | -3.65** | -3.7** | 14.39** | 0.02 | 1.78** | 0.33 | 0.69** | 11.05** | 21.64** | 1.18 | -2.71** | -5.65** |
| ICMA-97111 | -0.19 | -0.25 | -2.21* | -0.32** | -1.89** | -2.18** | 0.14** | -12.5** | -48.04** | -8.44** | 0.75 | -0.94 |
| ICMA-97444 | -0.87** | -0.93** | 0.37 | 0.11 | -0.72** | -2.5** | -0.89** | -10.89** | -14.94** | -1.49 | 1.11 | -0.81 |
| ICMA-98222 | -2.76** | -2.82** | -2.25* | -0.13* | 1.72** | 4.18** | 1.44** | 23.59** | 9.82** | 4.27** | 0.54 | -2.93* |
| ICMA-10444 | 0.76** | 0.71** | -4.38** | -0.21** | 1.49** | 1.16** | 0.44** | -5.42** | -9.39** | -4.55** | -2.7** | -5.48** |
| ICMA-30199 | 3.48** | 3.42** | 3.32** | 0.13* | -2.29** | 1.57** | -0.08** | 8.35** | 54.5** | 6.7** | -2.86** | -4.2** |
| ICMA-30200 | 1.49** | 1.44** | -5.67** | -0.07 | -0.97** | -1.37** | -1.17** | -14.77** | -19.78** | -4.5** | 1.05 | 0.82 |
| ICMA-30201 | 0.9** | 1.01** | 0.91 | 0.4** | 2.08** | 1.56** | -0.25** | 12.15** | 55.77** | 3.16** | -5.51** | 6.6** |
| ICMA-30209 | 1.83** | 2.07** | -0.72 | -0.07 | 0.01 | -1.03** | -0.54** | -8.9** | -20.42** | -0.09 | 2.23** | 2.07 |
| **Testers (Males)** | **GCA Effect** | | | | | | | | | | | |
| BIB 481- 500 | -0.06 | -0.12 | 6.96** | 0.02 | -0.98** | -0.22 | -0.46** | -1.73 | 19.81** | 3.33** | -0.45 | 6.71** |
| BIB 501-510 | 1.5** | 1.44** | -3.68** | -0.45** | -0.26 | -0.92** | 0.4** | -1.23 | -15.14** | -5.89** | -0.83 | -3.87** |
| BIB 511-520 | -0.74** | -0.79** | -3.67** | 0.21** | -1.09** | -0.1 | 0 | 13.58** | -6.91** | -0.93 | 0.21 | -8.06** |
| BIB 531-540 | 0.04 | -0.01 | 5.02** | -0.12* | 0.29* | -1.08** | 0.3** | -11.96** | -0.6 | -4.4** | -2.38** | -1.15 |
| BIB 551-560 | 1.85** | 1.79** | -1.63 | -0.23** | 0.58** | -0.91** | -1.12** | -7.61** | -18.63** | -0.35 | 2.07** | 6.84** |
| BIB 561-570 | -1.12** | -1.18** | -3.09** | 0.43** | 0.67** | 0.36 | 0.85** | 6.25** | 18.85** | 2.83** | -0.39 | 0.02 |
| BIB 571-580 | -1.46** | -1.14** | 0.1 | 0.13** | 0.79** | 2.87** | 0.03 | 2.71* | 2.63 | 5.41** | 1.78** | -0.49 |
| **SE** (GCA line) | 0.23 | 0.23 | 1.12 | 0.06 | 0.18 | 0.23 | 0.03 | 1.62 | 3.19 | 0.8 | 0.57 | 1.25 |
| (GCA tester) | 0.19 | 0.18 | 0.89 | 0.05 | 0.14 | 0.19 | 0.02 | 1.29 | 2.54 | 0.64 | 0.45 | 1 |
| (gi-gj lines) | 0.33 | 0.32 | 1.58 | 0.09 | 0.25 | 0.33 | 0.04 | 2.29 | 4.51 | 1.13 | 0.81 | 1.77 |
| (gi-gj tester) | 0.26 | 0.25 | 1.26 | 0.07 | 0.2 | 0.26 | 0.03 | 1.83 | 3.59 | 0.9 | 0.64 | 1.41 |
| **CD**(GCA line) | 0.46 | 0.44 | 2.2 | 0.12 | 0.35 | 0.46 | 0.05 | 3.18 | 6.26 | 1.57 | 1.12 | 2.46 |
| (GCA tester) | 0.37 | 0.35 | 1.75 | 0.1 | 0.28 | 0.37 | 0.04 | 2.54 | 5 | 1.25 | 0.89 | 1.96 |
| (gi-gj lines) | 0.65 | 0.63 | 3.11 | 0.17 | 0.49 | 0.65 | 0.07 | 4.5 | 8.86 | 2.22 | 1.58 | 3.48 |
| (gi-gj tester) | 0.52 | 0.5 | 2.48 | 0.14 | 0.39 | 0.52 | 0.06 | 3.59 | 7.06 | 1.77 | 1.26 | 2.78 |

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

### 4.3.2.1 SCA Effects in $E_1$ environment for different characters in pearl millet

#### 4.3.2.1.1 Days to 50% flowering

Early flowering is desirable in pearl millet which is reflected by the negative combining ability effects. Perusal of Table 4.3.12 indicated that the SCA effects in $E_1$ environments ranged from -5.75 (ICMA 97111 x BIB 571-580) to 7.95 (ICMA 04999 x BIB 501-510). Out of total 77 crosses, 23 crosses in $E_1$ showed negative significant SCA effects. Hence, these crosses were considered desirable for lesser number of days to 50% flowering.

#### 4.3.2.1.2 Days to maturity

Days to maturity is a desirable trait in pearl millet, which is reflected by the negative combining ability effects. Perusal of Table 4.3.12 indicated that the SCA effects in $E_1$ environments ranged from -5.57 (ICMA 04999 x BIB 571-580) to 10.09 (ICMA 88004 x BIB 531-540). Out of total 77 crosses, 23 crosses in $E_1$ showed negative significant SCA effects. Hence, these crosses were considered for lesser number of days to maturity.

#### 4.3.2.1.3 Plant height

The tall plant height is desirable in pearl millet, which is reflected by the positive combining ability effects. Perusal of Table 4.3.12 indicated that the SCA effects in $E_1$ environments ranged from -51.96 (ICMA 88004 x BIB 531-540) to 23.68 (ICMA 88004 x BIB 551-560). Out of total 77 crosses, 33 crosses in $E_1$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for plant height.

#### 4.3.2.1.4 Productive tillers per plants

As pearl millet is a fodder crop, productive tillers per plant is desirable in this crop, which is reflected by the positive combining ability effects. Perusal of Table 4.3.12 indicated that the SCA effects in $E_1$ environments ranged from -2.50 (ICMA 97111 x BIB 551-560) to

1.79 (ICMA 30201 x BIB 511-520). Out of total 77 crosses, 23 crosses in $E_1$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for productive tillers per plant.

**4.3.2.1.5 Ear head length**

As long ear heads are desirable in pearl millet, positive combining ability effects were considered. Perusal of Table 4.3.12 indicated that the SCA effects in $E_1$ environments ranged from -8.07 (ICMA 88004 x BIB 481-500) to 5.94 (ICMA 93333 x BIB 551-560). Out of total 77 crosses, 18 crosses in $E_1$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for ear head length.

**4.3.2.1.6 Ear head diameter**

As higher magnitude of ear head diameter is desirable in pearl millet, positive GCA effects were considered. Perusal of Table 4.3.12 indicated that the SCA effects in $E_1$ environments ranged from -9.42 (ICMA 10444 x BIB 481-500) to 4.25 (ICMA 10444 x BIB 571-580). Out of total 77 crosses, 30 crosses in $E_1$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for ear head diameter.

**4.3.2.1.7 Test weight**

The higher magnitude of test weight is desirable in pearl millet. Perusal of Table 4.3.12 indicated that the SCA effects in $E_1$ environments ranged from -3.82 (ICMA 88004 x BIB 531-540) to 3.90 (ICMA 93333 x BIB 551-560). Out of total 77 crosses, 40 crosses in $E_1$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for test weight.

**4.3.2.1.8 Ear head weight**

The higher magnitude of ear head weight is desirable in pearl millet. Perusal of Table 4.3.12 indicated that the SCA effects in $E_1$ environments ranged from -74.13 (ICMA 30200 x BIB 511-520) to 72.10 (ICMA 93333 x BIB 551-560). Out of total 77 crosses, 22 crosses in $E_1$

had showed positive significant SCA effects. Thus, these were considered as good specific combiner for ear head weight.

#### 4.3.2.1.9 Dry stover yield per plant

As pearl millet is dual crop, the dry stover as well as grain yield is of importance, which is reflected by significant positive general combining ability effects. Perusal of Table 4.3.12 indicated that the SCA effects in $E_1$ environments ranged from -162.36 (ICMA 88004 x BIB 431-540) to 190.06 (ICMA 30199 x BIB 511-520). Out of total 77 crosses, 31 crosses in $E_1$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for dry stover yield per plant.

#### 4.3.2.1.10 Grain yield per plant

The higher magnitude of grain yield per plant is desirable in pearl millet. Perusal of Table 4.3.12 indicated that the SCA effects in $E_1$ environments ranged from -38.42 (ICMA 30209 x BIB 481-500) to 44.34 (ICMA 93333 x BIB 551-560). Out of total 77 crosses, 26 crosses in $E_1$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for grain yield per plant.

#### 4.3.2.1.11 Harvest index

The higher magnitude of harvest index is desirable in pearl millet. Perusal of Table 4.3.12 indicated that the SCA effects in $E_1$ environments ranged from -10.04 (ICMA 30199 x BIB 511-520) to 10.4 (ICMA 98222 x BIB 501-510). Out of total 77 crosses, 12 crosses in $E_1$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for harvest index.

#### 4.3.2.1.12 Threshing index

The higher magnitude of threshing index is desirable in pearl millet. Perusal of Table 4.3.12 indicated that the SCA effects in $E_1$ environments ranged from -23.78 (ICMA 30201 x BIB 561-570) to 43.29 (ICMA 10444 x BIB 481-500). Out of total 77 crosses, 8 crosses in $E_1$

## Table 4.3.12 SCA Effects in $E_1$ environment for different characters in pearl millet

| Crosses | SCA Effects | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| ICMA 04999 × BIB 481-500 | -3.5* | -3.42* | 20.02** | -0.45 | -0.36 | 3.91** | 0.56** | 19.35 | 46.73* | 13.11* | -0.24 | -2.63 |
| ICMA 88004 × BIB 481-500 | 0.64 | 0.73 | 6.52** | -0.84* | -8.07** | 2.58** | -2.08** | 20.06 | 13.4 | -7.42 | -4.26 | -19.13** |
| ICMA 93333 × BIB 481-500 | -0.5 | -0.42 | -8.39** | -0.59 | -2.57** | 0.72 | 0.71** | -15.17 | -44.22* | -12.51* | -2.86 | -9.4* |
| ICMA 97111 × BIB 481-500 | 4.07** | 4.16** | 17.2** | 0.33 | 1.5 | 1.39 | 0.81** | -3.74 | 0.06 | -3.18 | -0.94 | -2.88 |
| ICMA 97444 × BIB 481-500 | -2.36 | -2.27 | 15.33** | 0.36 | 3.21** | 3.58** | 1.36** | 19.83 | 33.87 | 10.01 | -0.53 | -6.22 |
| ICMA 98222 × BIB 481-500 | -2.55 | -2.46 | 1.32 | 0.78* | 4.54** | 2.48** | 1.86** | 31.49** | 55.3** | 32.39** | 6.68* | 7.24 |
| ICMA 10444 × BIB 481-500 | -1.07 | -0.99 | -17.18** | 0.75 | -2.09* | -9.42** | -1.5** | -52.32** | -124.94** | -16.89** | 10.33** | 43.29** |
| ICMA 30199 × BIB 481-500 | -1.31 | -1.23 | -0.31 | 1.05** | 0.33 | -1.71* | 2.08** | -7.08 | 30.06 | 11.92* | 0.47 | 7.7 |
| ICMA 30200 × BIB 481-500 | -3.65** | -3.56** | 1.47 | 0.52 | 0.81 | 2.72** | -1.8** | 57.68** | 79.59** | 9.3 | -3.57 | -21.16** |
| ICMA 30201 × BIB 481-500 | 7.69** | 7.3** | 3.58 | -0.18 | 3.95** | 2.2** | -0.76** | -5.65 | 54.35* | 1.68 | -3.84 | -4.31 |
| ICMA 30209 × BIB 481-500 | 2.55 | 2.16 | -39.56** | -1.75** | -1.24 | -8.47** | -1.25** | -64.46** | -144.22** | -38.42** | -1.23 | 7.5 |
| ICMA 04999 × BIB 501-510 | 7.95** | 8.04** | -33.64** | -1.35** | -2.57** | -8.33** | -0.93** | -61.26** | -115.84** | -26.68** | 1.21 | 15.15** |
| ICMA 88004 × BIB 501-510 | -3.57* | -3.48* | 3.5 | 0.8* | 5.29** | -0.33 | 2.99** | 39.46** | 64.16** | 29.8** | 5.84* | 7.89 |
| ICMA 93333 × BIB 501-510 | 0.62 | 0.71 | 10.38** | -0.43 | -4.58** | 1.15 | -0.52** | -9.11 | -20.13 | 4.37 | 2.38 | 10.93* |
| ICMA 97111 × BIB 501-510 | -3.81** | -3.72** | -4.65* | 0.97* | 1.78* | 1.81* | 1.04** | 50.65** | 57.49** | 13.7* | -0.57 | -9.22* |
| ICMA 97444 × BIB 501-510 | -1.57 | -1.48 | 5.15* | 0.26 | 2.75** | 3.34** | -1.02** | -9.11 | 87.97** | -4.77 | -8.61** | -0.91 |
| ICMA 98222 × BIB 501-510 | -1.43 | -1.34 | 8.53** | -0.09 | -0.65 | 0.58 | -0.2 | 10.89 | -37.27 | 4.27 | 10.4** | 1.15 |
| ICMA 10444 × BIB 501-510 | -2.62 | -2.53 | 11.72** | -0.45 | -2.49** | -1.33 | -0.16 | -1.26 | -25.84 | -13.35* | -6.42* | -20.1** |
| ICMA 30199 × BIB 501-510 | 1.81 | 1.9 | 9.09** | 0.32 | -0.84 | -0.95 | 0 | -27.68* | -49.18* | -14.54** | -3.05 | -3.13 |
| ICMA 30200 × BIB 501-510 | 1.81 | 1.9 | -1.4 | -0.31 | 0.88 | 2.15** | 0.33* | 5.41 | -16.32 | -0.49 | 1.42 | -4.22 |
| ICMA 30201 × BIB 501-510 | -0.52 | -0.91 | -8.6** | 0.12 | 0.51 | -1.71* | 0.8** | -2.92 | 5.11 | 1.89 | -0.13 | -0.25 |

| Crosses | SCA Effects | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| ICMA 30209 × BIB 501-510 | 1.33 | 0.94 | -0.07 | 0.15 | -0.09 | 3.62** | -2.34** | 4.94 | 49.87* | 5.8 | -2.47 | 2.71 |
| ICMA 04999 × BIB 511-520 | -4.38** | -4.29** | 9.89** | -0.21 | 1.79* | 1.52 | 1.28** | 2.53 | -3.27 | -2.71 | -2.2 | -8.01 |
| ICMA 88004 × BIB 511-520 | -1.9 | -1.82 | -0.24 | -0.43 | 4.91** | 0.52 | 2.37** | -26.75* | -43.27* | -13.23* | -1.8 | -2.11 |
| ICMA 93333 × BIB 511-520 | 0.95 | 1.04 | -4.8* | 1.01* | -1.62 | -0.34 | -0.18 | -21.99* | -67.55** | -5 | 2.47 | 1.13 |
| ICMA 97111 × BIB 511-520 | -2.48 | -2.39 | 1.88 | 0.24 | 0.56 | 0.66 | -0.74** | -8.9 | -26.6 | 4.34 | 5.45* | 4.83 |
| ICMA 97444 × BIB 511-520 | -1.24 | -1.15 | -2.33 | -0.4 | -0.29 | 0.19 | -0.63** | 3.01 | -26.13 | 10.86* | 4.24 | 2.57 |
| ICMA 98222 × BIB 511-520 | 3.9** | 3.99** | -12.96** | -0.42 | -2.05* | 2.76** | -0.22 | -25.32* | -21.36 | -1.76 | 0.31 | 8.14 |
| ICMA 10444 × BIB 511-520 | 3.05* | 3.13* | -1.37 | -0.34 | 2.87** | -1.15 | 0.95** | 15.87 | 105.06** | 17.29** | -3.52 | 2.09 |
| ICMA 30199 × BIB 511-520 | -2.86* | -2.77* | -1.87 | -0.77 | -1.16 | 0.57 | -1.47** | 66.1** | 190.06** | -5.57 | -10.04** | -16.17** |
| ICMA 30200 × BIB 511-520 | 6.48** | 6.56** | -17.05** | -0.51 | -5.1** | -8** | -2.35** | -74.13** | -137.08** | -26.52** | 0.13 | 13.45** |
| ICMA 30201 × BIB 511-520 | -2.19 | -2.58 | 13.06** | 1.79** | -0.64 | 1.14 | 1.71** | 57.53** | 44.35* | 15.86** | 0.76 | -2.23 |
| ICMA 30209 × BIB 511-520 | 0.67 | 0.28 | 15.78** | 0.03 | 0.72 | 2.14** | -0.73** | 12.06 | -14.22 | 6.43 | 4.2 | -3.68 |
| ICMA 04999 × BIB 531-540 | 0.53 | 0.61 | 19.75** | 1.48** | 1.91* | 3.67** | 1.15** | 49.35** | 130.97** | 14.26** | -5.41* | -9.06 |
| ICMA 88004 × BIB 531-540 | 10** | 10.09** | -51.96** | 0.09 | -5.18** | -8** | -3.82** | -73.27** | -162.36** | -39.6** | -2.49 | 5.45 |
| ICMA 93333 × BIB 531-540 | 0.19 | 0.28 | 1.22 | 0.9* | 1.51 | -1.19 | -0.25 | 31.49** | 103.35** | 0.31 | -3.2 | -9.75* |
| ICMA 97111 × BIB 531-540 | -1.23 | -1.15 | 0.66 | -0.57 | 0.36 | 1.48 | -2** | 11.26 | 67.64** | 7.97 | -3.78 | 1.47 |
| ICMA 97444 × BIB 531-540 | -2 | -1.91 | -0.88 | 0.33 | -0.29 | -0.33 | 1.25** | 26.49* | -51.88* | 11.16* | 8.1** | -5.33 |
| ICMA 98222 × BIB 531-540 | -0.19 | -0.1 | 1.51 | -0.23 | 1.49 | -1.09 | 0.53** | 8.16 | -57.12** | -14.79** | -1.46 | -13.94** |
| ICMA 10444 × BIB 531-540 | -0.38 | -0.29 | 13.89** | -0.88* | -0.77 | 4** | 0.67** | 9.35 | -47.36* | 10.93* | 8.1** | 0.76 |
| ICMA 30199 × BIB 531-540 | 0.05 | 0.14 | 2.36 | -1.28** | -0.45 | 1.39 | -0.67** | -40.41** | -62.36** | -13.6* | -1.27 | 3.74 |
| ICMA 30200 × BIB 531-540 | -1.28 | -1.19 | 10.44** | -0.52 | 1.62 | -0.52 | 1.01** | -23.98* | 47.16* | -2.88 | -5 | 12.37** |
| ICMA 30201 × BIB 531-540 | -3.95** | -4.34** | -0.62 | -0.78* | -1.16 | -1.71* | 2.42** | -22.32* | -44.74* | 12.83* | 8.29** | 15.41** |

| Crosses | SCA Effects | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| ICMA 30209 × BIB 531-540 | -1.76 | -2.15 | 3.64 | 1.45** | 0.96 | 2.29** | -0.28* | 23.87* | 76.69** | 13.4* | -1.88 | -1.11 |
| ICMA 04999 × BIB 551-560 | 3.01* | 3.1* | -23.89** | 0.18 | -4.74** | -3.75** | -2.47** | -61.71** | -114.48** | -31.04** | -0.11 | 3.25 |
| ICMA 88004 × BIB 551-560 | -3.51* | -3.42* | 23.68** | 0.59 | 3.22** | 3.58** | 1.49** | 37.34** | 105.52** | 21.77** | -1.02 | 0.27 |
| ICMA 93333 × BIB 551-560 | -2.65 | -2.57 | 6.27** | 0.94* | 5.94** | 2.72** | 3.9** | 72.1** | 151.23** | 44.34** | 3.79 | 4.93 |
| ICMA 97111 × BIB 551-560 | 7.25** | 7.34** | -32.21** | -2.5** | -6.49** | -4.94** | -1.19** | -51.47** | -61.15** | -26.66** | -7.51** | 2.39 |
| ICMA 97444 × BIB 551-560 | 7.82** | 7.91** | -29.16** | -0.74 | -4.25** | -4.75** | -2.53** | -62.9** | -150.67** | -29.14** | 5.03 | 22.99** |
| ICMA 98222 × BIB 551-560 | -1.37 | -1.28 | 12.93** | 0.11 | 3.23** | -0.52 | 0.17 | 18.77 | 50.76* | -6.76 | -8.1** | -12.87** |
| ICMA 10444 × BIB 551-560 | -3.23* | -3.14* | 4.94* | 0.88* | -0.43 | 3.91** | 1.49** | 16.62 | 20.52 | 5.62 | -0.14 | -9.24* |
| ICMA 30199 × BIB 551-560 | -0.8 | -0.71 | 7.55** | -0.18 | 2.96** | 0.63 | -0.33* | 26.86* | -7.81 | 14.43** | 5.17 | -1.99 |
| ICMA 30200 × BIB 551-560 | -1.13 | -1.04 | 6.5** | 0.35 | 2.8** | 2.06* | 0.29* | 9.96 | 25.04 | -1.52 | -2.83 | -8.84 |
| ICMA 30201 × BIB 551-560 | -3.46* | -3.85** | 3.4 | 0.42 | -1.91* | -0.8 | -3.13** | -28.38** | -26.86 | 0.86 | 2.84 | 6.23 |
| ICMA 30209 × BIB 551-560 | -1.94 | -2.33 | 19.99** | -0.05 | -0.34 | 1.87* | 2.31** | 22.81* | 7.9 | 8.1 | 2.87 | -7.11 |
| ICMA 04999 × BIB 561-570 | -2.99* | -2.9* | 4.17 | 1.15** | 0.98 | 3.25** | 1.32** | 43.29** | 45.52* | 35.62** | 9.93** | 6.25 |
| ICMA 88004 × BIB 561-570 | -3.51* | -3.42* | 9.88** | 0.09 | 0.36 | 3.58** | 1.59** | 10.67 | 8.85 | 8.43 | 4.43 | 1.75 |
| ICMA 93333 × BIB 561-570 | -0.65 | -0.57 | 4.07 | -0.33 | 2.71** | -1.61* | 0.13 | -37.9** | -18.77 | -13.33* | -3.75 | 5.58 |
| ICMA 97111 × BIB 561-570 | -3.08* | -3* | 14.43** | 1.56** | 0.87 | 0.39 | 3.39** | -1.47 | -4.48 | -0.66 | 1.53 | -1.13 |
| ICMA 97444 × BIB 561-570 | -2.84* | -2.76* | 10.16** | 1.36** | -1 | -0.75 | 2.49** | 20.43 | 112.66** | 5.86 | -6.21* | -8.57 |
| ICMA 98222 × BIB 561-570 | -3.03* | -2.95* | 0.03 | 1.21** | -2.53** | -3.18** | 3.15** | 2.1 | 80.76** | 21.58** | 0.46 | 16.93** |
| ICMA 10444 × BIB 561-570 | 0.77 | 0.86 | -8.11** | 1.32** | 2.2* | 2.58** | -0.4** | 26.62* | 97.19** | 8.96 | -4.71 | -10.49* |
| ICMA 30199 × BIB 561-570 | -0.46 | -0.38 | -4.29* | 1.28** | -0.23 | 1.29 | 2.29** | 16.86 | -7.81 | 24.43** | 8.15** | 8.17 |
| ICMA 30200 × BIB 561-570 | -3.46* | -3.38* | 1.46 | 1.55** | 0.2 | 3.39** | 3.08** | 39.96** | 41.71* | 28.48** | 8.44** | 4.53 |
| ICMA 30201 × BIB 561-570 | -1.13 | -1.52 | -6.7** | 0.22 | -1.12 | 4.2** | 2.23** | 61.62** | 69.81** | -15.81** | -9.46** | -23.78** |

| Crosses | SCA Effects | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| ICMA 30209 × BIB 561-570 | -3.61* | -4** | -1.84 | 1.32** | 0.14 | 1.2 | 3.05** | 16.15 | 17.9 | 1.43 | -1.16 | -9.12 |
| ICMA 04999 × BIB 571-580 | -5.65** | -5.57** | 14.24** | 0.85* | 3.1** | 2.58** | 2.18** | 43.29** | 85.52** | 15.62** | -2.44 | -9.15 |
| ICMA 88004 × BIB 571-580 | -3.18* | -3.09* | 19.14** | 1.36** | -0.43 | 0.91 | 0.55** | 27.34* | 88.85** | 18.43** | 0.06 | 1.67 |
| ICMA 93333 × BIB 571-580 | -2.99* | -2.9* | 1.77 | 0.17 | -1.29 | 1.39 | -0.72** | 15.43 | -28.77 | 0 | 1.93 | -7.62 |
| ICMA 97111 × BIB 571-580 | -5.75** | -5.66** | 13.22** | 1.63** | 1.52 | 2.06* | 1.77** | 38.53** | 42.19* | 22.67** | 6.56* | 0.33 |
| ICMA 97444 × BIB 571-580 | -2.84* | -2.76* | 12.27** | 0.49 | -0.03 | 1.58 | 2.15** | 37.1** | 69.33** | 14.19** | -1.28 | -8.73 |
| ICMA 98222 × BIB 571-580 | -0.37 | -0.28 | -0.83 | 0.31 | -3.94** | 1.82* | -2.21** | -11.23 | 4.09 | -16.76** | -7.54** | -10.84* |
| ICMA 10444 × BIB 571-580 | -1.56 | -1.47 | 6.63** | 0.38 | 0.82 | 4.25** | 2.02** | 19.96 | 50.52* | 5.62 | -2.89 | -10.53* |
| ICMA 30199 × BIB 571-580 | -1.46 | -1.38 | -2 | 1.25** | -0.52 | 1.63* | 1.17** | 0.19 | -17.81 | 1.1 | 1.33 | -2.53 |
| ICMA 30200 × BIB 571-580 | -3.8** | -3.71** | 9.11** | 0.58 | -1.1 | 1.06 | 2.52** | 19.96 | 35.04 | 11.81* | 2.16 | -0.32 |
| ICMA 30201 × BIB 571-580 | -1.46 | 1.48 | 6.43** | 0.08 | 0.47 | -0.47 | -0.19 | -25.04* | -26.86 | 0.86 | 2.28 | 4.75 |
| ICMA 30209 × BIB 571-580 | -2.27 | 0.67 | 12.6** | 0.52 | -0.05 | 0.2 | 2.32** | 19.48 | 81.23** | 21.43** | 0.42 | 6.62 |
| **SE (SCA)** | 1.39 | 1.34 | 2.12 | 0.39 | 0.86 | 0.81 | 0.14 | 10.8 | 21.02 | 5.29 | 2.64 | 4.63 |
| **SE (Sij-Skl)** | 1.96 | 1.89 | 2.99 | 0.55 | 1.21 | 1.15 | 0.2 | 15.28 | 29.73 | 7.48 | 3.74 | 6.55 |
| **CD 5%(SCA)** | 2.74 | 2.64 | 4.18 | 0.77 | 1.7 | 1.61 | 0.28 | 21.34 | 41.54 | 10.45 | 5.22 | 9.15 |
| **CD 5%(Sij-Skl)** | 3.87 | 3.74 | 5.91 | 1.09 | 2.4 | 2.27 | 0.4 | 30.18 | 58.74 | 14.78 | 7.38 | 12.94 |

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

had showed positive significant SCA effects. Thus, these were considered as good specific combiner for threshing index.

### 4.3.2.2 SCA Effects in $E_2$ environment for different characters in pearl millet

#### 4.3.2.2.1 Days to 50% flowering

Early flowering is desirable in pearl millet, which is reflected by the negative combining ability effects. Perusal of Table 4.3.13 indicated that the SCA effects in $E_2$ environments ranged from -7.79 (ICMA 04999 x BIB 511-520) to 11.01 (ICMA 88004 x BIB 531-540). Out of total 77 crosses, 42 crosses in $E_2$ had showed negative significant SCA effects. Hence, these crosses were considered for lesser number of days to 50% flowering.

#### 4.3.2.2.2 Days to maturity

Days to maturity is a desirable trait in pearl millet, which is reflected by the negative combining ability effects. Perusal of Table 4.3.13 indicated that the SCA effects in $E_2$ environments ranged from -8.13 (ICMA 04999 x BIB 511-520) to 11.04 (ICMA 88004 x BIB 531-540). Out of total 77 crosses, 42 crosses in $E_2$ had showed negative significant SCA effects. Hence, these crosses were considered for lesser number of days to 50% flowering.

#### 4.3.2.2.3 Plant height

The tall plant height is desirable in pearl millet, which is reflected by the positive combining ability effects. Perusal of Table 4.3.13 indicated that the SCA effects in $E_2$ environments ranged from -26.72 (ICMA 97444 x BIB 551-560) to 19.89 (ICMA 30209 x BIB 551-560). Out of total 77 crosses, 6 crosses in $E_2$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for plant height.

#### 4.3.2.2.4 Productive tillers per plants

As pearl millet is a fodder crop, productive tillers per plant is desirable in this crop, which is reflected by the positive combining ability effects. Perusal of Table 4.3.13 indicated that the SCA effects in $E_2$ environments ranged from -1.17 (ICMA 88004 x BIB 481-500) to 2.11 (ICMA 30200 x BIB 561-570). Out of total 77 crosses, 27 crosses in $E_2$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for productive tillers per plant.

**4.3.2.2.5 Ear head length**

As long ear heads are desirable in pearl millet, positive combining ability effects were considered. Perusal of Table 4.3.13 indicated that the SCA effects in E2 environments ranged from -10.6 (ICMA 04999 x BIB 551-560) to 10.23 (ICMA 04999 x BIB 511-520). Out of total 77 crosses, 26 crosses in E2 had showed positive significant SCA effects. Thus, these were considered as good specific combiner for ear head length.

**4.3.2.2.6 Ear head diameter**

As higher magnitude of ear head diameter is desirable in pearl millet, positive GCA effects were considered. Perusal of Table 4.3.13 indicated that the SCA effects in $E_2$ environments ranged from -9.55 (ICMA 10444 x BIB 481-500) to 10.06 (ICMA 88004 x BIB 501-510). Out of total 77 crosses, 33 crosses in $E_2$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for ear head diameter.

**4.3.2.2.7 Test weight**

The higher magnitude of test weight is desirable in pearl millet. Perusal of Table 4.3.13 indicated that the SCA effects in $E_2$ environments ranged from -3.85 (ICMA 88004 x BIB 531-540) to 3.84 (ICMA 93333 x BIB 551-560). Out of total 77 crosses, 41 crosses in $E_2$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for test weight.

**4.3.2.2.8 Ear head weight**

The higher magnitude of ear head weight is desirable in pearl millet. Perusal of Table 4.3.13 indicated that the SCA effects in $E_2$ environments ranged from -73.19 (ICMA 98222 x BIB 511-520) to 108.94 (ICMA 30201 x BIB 561-570). Out of total 77 crosses, 25 crosses in $E_2$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for ear head weight.

**4.3.2.2.9 Dry stover yield per plant**

As pearl millet is dual crop, the dry stover as well as grain yield is of importance, which is reflected by significant positive general combining ability effects. Perusal of Table 4.3.13 indicated that the SCA effects in $E_2$ environments ranged from -146.06 (ICMA 30201 x BIB 501-510) to 141.21 (ICMA 30201 x BIB 561-570). Out of total 77 crosses, 28 crosses in $E_2$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for dry stover yield per plant.

**4.3.2.2.10 Grain yield per plant**

The higher magnitude of grain yield per plant is desirable in pearl millet. Perusal of Table 4.3.13 indicated that the SCA effects in $E_2$ environments ranged from -15.71 (ICMA 30209 x BIB 481-500) to 47.58 (ICMA 88004 x BIB 501-510). Out of total 77 crosses, 21 crosses in $E_2$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for grain yield per plant.

**4.3.2.2.11 Harvest index**

The higher magnitude of harvest index is desirable in pearl millet. Perusal of Table 4.3.13 indicated that the SCA effects in $E_2$ environments ranged from -21.32 (ICMA 98222 x BIB 561-570) to 36.62 (ICMA 93333 x BIB 571-580). Out of total 77 crosses, 19 crosses in $E_2$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for harvest index.

**4.3.2.2.12 Threshing index**

The higher magnitude of threshing index is desirable in pearl millet. Perusal of Table 4.3.13 indicated that the SCA effects in $E_2$ environments ranged from -74.31 (ICMA 30201 x BIB 561-570) to 203.29 (ICMA 30201 x BIB 481-500). Out of total 77 crosses, 9 crosses in $E_2$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for threshing index.

### 4.3.2.3 SCA Effects in $E_3$ environment for different characters in pearl millet

#### 4.3.2.3.1 Days to 50% flowering

Early flowering is desirable in pearl millet, which is reflected by the negative combining ability effects. Perusal of Table 4.3.14 indicated that the SCA effects in $E_3$ environments ranged from -7.79 (ICMA 04999 x BIB 511-520) to 11.01 (ICMA 88004 x BIB 531-540). Out of total 77 crosses, 42 crosses in $E_3$ had showed negative significant SCA effects. Hence, these crosses were considered for lesser number of days to 50% flowering.

#### 4.3.2.3.2 Days to maturity

Days to maturity is a desirable trait in pearl millet, which is reflected by the negative combining ability effects. Perusal of Table 4.3.14 indicated that the SCA effects in $E_3$ environments ranged from -7.79 (ICMA 04999 x BIB 511-520) to 11.01 (ICMA 88004 x BIB 531-540). Out of total 77 crosses, 42 crosses in $E_3$ had showed negative significant SCA effects. Hence, these crosses were considered for lesser number of days to 50% flowering.

#### 4.3.2.3.3 Plant height

The tall plant height is desirable in pearl millet, which is reflected by the positive combining ability effects. Perusal of Table

**Table 4.3.13 SCA Effects in $E_2$ environment for different characters in pearl millet**

| Crosses | SCA Effects | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| ICMA 04999 × BIB 481-500 | -4.75** | -4.91** | 18.31** | -0.61* | 2.62** | 3.4** | 0.64** | 15.27** | 2.42 | -1.42 | -7.46** | -35.39** |
| ICMA 88004 × BIB 481-500 | -0.99 | -0.96 | 7.7 | -1.17** | 0.35 | -3.4** | -2.19** | 5.56 | -12.34 | -2.09 | -0.6 | -31.94** |
| ICMA 93333 × BIB 481-500 | -0.18 | -0.15 | 2.8 | -0.12 | -6.16** | 1.18 | 1.14** | -1.49 | 21.95* | -1.76 | -7.2** | -13.34 |
| ICMA 97111 × BIB 481-500 | -5.32** | -5.29** | 8.9 | -0.38 | 1.11 | 5.68** | 0.75** | 19.65** | 9.57 | 0.29 | -3.46 | -36.39** |
| ICMA 97444 × BIB 481-500 | 8.25** | 8.28** | -11.05 | -0.57* | 1.73 | -5.5** | 1.16** | -25.68** | -82.34** | -15.47** | 6.27* | -4.52 |
| ICMA 98222 × BIB 481-500 | -3.99** | -3.96** | 0.69 | 1.77** | 8.27** | 6.01** | 2.38** | 55.18** | 140.04** | 42.62** | 3.23 | -2.47 |
| ICMA 10444 × BIB 481-500 | 6.82** | 6.85** | -16.9** | -1.04** | -6.55** | -9.55** | -1.62** | -31.39** | -121.86** | -15.28** | 18.49** | -5.03 |
| ICMA 30199 × BIB 481-500 | -0.47 | -0.44 | -0.25 | 0.96** | 0.14 | 2.8* | 1.93** | 12.8* | -54.24** | -5.09 | 4.56 | -27.73** |
| ICMA 30200 × BIB 481-500 | -2.99** | -2.96** | 10.14 | 1.07** | 2.94** | 4.28** | -2.01** | 16.7** | 39.57** | -0.47 | -9.96** | -35.34** |
| ICMA 30201 × BIB 481-500 | -2.61** | -2.58** | 2.48 | 1.06** | 1.94* | 2.57* | -0.86** | -44.97** | 132.42** | 14.39** | -4 | 203.29** |
| ICMA 30209 × BIB 481-500 | 6.25** | 6.13** | -22.82** | -0.98** | -6.41** | -7.49** | -1.32** | -21.63** | -75.19** | -15.71** | 0.13 | -11.13 |
| ICMA 04999 × BIB 501-510 | 4.19** | 4.03** | 0.15 | 0.12 | -3.75** | -4.23** | -1.04** | -19.88** | -26.06* | -4.42 | -3.09 | 5.4 |
| ICMA 88004 × BIB 501-510 | -5.39** | -5.35** | 13.67* | 0.4 | 6.33** | 10.06** | 2.96** | 63.74** | 139.18** | 47.58** | 3.73 | 2.41 |
| ICMA 93333 × BIB 501-510 | 2.42** | 2.45** | -1.99 | 0.48* | -0.12 | -4.01** | -0.64** | -39.97** | -3.2 | -9.09** | -11.36** | 14.84 |
| ICMA 97111 × BIB 501-510 | -3.39** | -3.35** | 10.71 | 0.12 | 9.16** | 9.83** | 1.07** | 64.5** | 24.42* | 2.29 | -6.99** | -33.84** |
| ICMA 97444 × BIB 501-510 | -0.15 | -0.12 | 6.41 | -0.32 | 2.19* | 7.62** | -1.13** | -23.16** | -20.82 | -10.47** | -9.93** | -9.56 |
| ICMA 98222 × BIB 501-510 | -3.05** | -3.02** | 6.63 | 0.25 | 2.2* | 4.83** | -0.33** | 36.69** | -48.44** | -12.71** | -7.46** | -21.02** |
| ICMA 10444 × BIB 501-510 | -5.58** | -5.55** | 15.75* | 0.96** | -0.41 | 1.15 | -0.19 | 11.12 | 39.65** | 6.05* | -4.76 | -5.67 |
| ICMA 30199 × BIB 501-510 | -0.19 | -0.16 | -2.96 | -0.54* | -0.47 | -8.29** | 0.14 | -5.69 | 137.27** | -1.42 | -10.2** | -0.39 |

| Crosses | SCA Effects | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| ICMA 30200 × BIB 501-510 | 1.95* | 1.98* | -10.14 | -0.09 | -2.52** | -4.54** | 0.21 | -27.45** | -55.58** | -2.14 | 14.75** | 32.59** |
| ICMA 30201 × BIB 501-510 | 5** | 5.03** | -21.51** | -0.84** | -7.15** | -7.97** | 1.29** | -34.12** | -146.06** | -14.28** | 21.52** | -21.73** |
| ICMA 30209 × BIB 501-510 | 4.19** | 4.07** | -16.71** | -0.54* | -5.45** | -4.44** | -2.33** | -25.78** | -40.35** | -1.38 | 13.79** | 36.97** |
| ICMA 04999 × BIB 511-520 | -7.97** | -8.13** | 2.7 | 0.64** | 10.27** | 7.28** | 1.21** | 13.58* | 87.27** | 7.94** | -12.88** | -9.44 |
| ICMA 88004 × BIB 511-520 | -2.87** | -2.84** | -6.3 | -0.57* | -0.41 | 0.15 | 2.38** | 50.53** | -34.16** | -14.39** | -3.47 | -38.08** |
| ICMA 93333 × BIB 511-520 | -1.39 | -1.36 | -2.83 | 0.14 | 0.97 | 1.56 | -0.27* | -29.85** | -3.2 | -5.06 | -5.81* | 15.34* |
| ICMA 97111 × BIB 511-520 | 5.46** | 5.49** | -11.46 | -0.39 | -2.52** | -5.28** | -0.67** | -29.38** | -22.25* | -8.01** | -2.94 | -8.65 |
| ICMA 97444 × BIB 511-520 | -5.3** | -5.27** | 13.89* | 1.22** | 5.12** | 5.19** | -0.7** | 27.62** | 72.51** | 12.89** | -4.38 | 1.81 |
| ICMA 98222 × BIB 511-520 | 9.8** | 9.83** | -5.19 | -1.15** | -9.09** | -12.24** | -0.04 | -73.19** | -95.11** | -13.01** | 14.03** | 43.28** |
| ICMA 10444 × BIB 511-520 | -1.06 | -1.03 | 3.43 | 1.07** | 1.7 | 1.67 | 0.96** | 64.58** | 112.99** | 23.42** | -3.08 | -2.96 |
| ICMA 30199 × BIB 511-520 | 1.65 | 1.68* | -6.35 | -0.92** | -4.32** | 0.68 | -1.49** | -5.57 | -29.39** | -10.73** | -3.31 | -10.71 |
| ICMA 30200 × BIB 511-520 | 5.8** | 5.83** | -8.79 | -1.15** | -5.28** | -5.5** | -2.43** | -39** | -58.92** | -8.44** | 11.26** | 40.61** |
| ICMA 30201 × BIB 511-520 | -1.82* | -1.79* | 5.32 | 0.51* | 0.26 | 5.32** | 1.74** | 4 | -46.06** | 7.08** | 8.24** | -25.71** |
| ICMA 30209 × BIB 511-520 | -2.3** | -2.41** | 15.58* | 0.61* | 3.29** | 1.16 | -0.68** | 16.67** | 16.32 | 8.32** | 2.34 | -5.5 |
| ICMA 04999 × BIB 531-540 | 3.91** | 3.75** | -14.74* | -0.49* | -2.82** | -5.34** | 1.05** | 2.64 | -46.97** | -5.21* | 8.47** | -14.3 |
| ICMA 88004 × BIB 531-540 | 11.01** | 11.04** | -24.85** | 0.64** | -5.99** | -7.58** | -3.85** | -31.41** | -58.4** | -12.21** | 7.38** | 19.68* |
| ICMA 93333 × BIB 531-540 | -1.85* | -1.82* | 3.25 | 0.29 | 1.3 | -1.45 | -0.36** | 27.54** | 12.55 | 20.45** | 8.61** | 4.6 |
| ICMA 97111 × BIB 531-540 | 5.01** | 5.04** | -12 | -0.11 | -6.94** | -3.53** | -1.97** | -1.32 | -9.83 | 4.5 | 7.38** | 6.36 |
| ICMA 97444 × BIB 531-540 | -6.42** | -6.39** | 11.82 | 0.08 | 3.37** | 3.05* | 1.14** | 31.68** | 38.27** | 7.41** | -4.27 | -16.61* |
| ICMA 98222 × BIB 531-540 | -0.66 | -0.63 | 6.52 | -0.32 | 1.33 | -3.01* | 0.65** | -35.79** | -92.68** | -9.16** | 13.96** | 6.45 |

| Crosses | SCA Effects | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| ICMA 10444 × BIB 531-540 | -1.85* | -1.82* | 4.68 | -0.34 | 1.26 | 4.54** | 0.65** | -4.7 | -24.59* | -3.74 | -3.44 | -5.38 |
| ICMA 30199 × BIB 531-540 | -1.13 | -1.1 | 1.07 | -0.28 | 0.98 | 1.82 | -0.73** | -1.51 | -43.64** | -3.88 | 2.33 | 2.51 |
| ICMA 30200 × BIB 531-540 | -4.32** | -4.29** | 6.46 | -0.23 | 4.49** | 5.63** | 1.27** | 5.73 | 66.84** | 1.74 | -15.01** | -1.21 |
| ICMA 30201 × BIB 531-540 | -2.28* | -2.25** | 11.56 | -0.26 | 0.15 | 3.42** | 2.41** | -16.94** | 46.36** | -6.07* | -9.87** | 11.72 |
| ICMA 30209 × BIB 531-540 | -1.42 | -1.53 | 6.23 | 0.99** | 2.87** | 2.43 | -0.26* | 24.06** | 112.08** | 6.17* | -15.54** | -13.82 |
| ICMA 04999 × BIB 551-560 | 2.46** | 2.3** | -2.77 | -0.62* | -10.6** | -5.81** | -2.51** | -15.48** | -45.45** | -0.21 | 27.73** | 55.04** |
| ICMA 88004 × BIB 551-560 | -1.11 | -1.08 | 4.58 | -0.08 | 2.01* | 3.97** | 1.52** | -31.2** | -16.88 | -0.88 | 2.94 | 39.51** |
| ICMA 93333 × BIB 551-560 | -1.97* | -1.94* | 6.31 | -0.39 | 5.6** | 9.41** | 3.84** | 78.42** | 37.4** | 4.45 | -11.16** | -38.14** |
| ICMA 97111 × BIB 551-560 | 4.55** | 4.58** | -15.35* | 0.06 | -7.41** | -4.75** | -1.1** | -17.77** | -11.65 | 0.84 | 6.59* | 25.4** |
| ICMA 97444 × BIB 551-560 | 6.46** | 6.49** | -26.72** | -0.94** | -7.76** | -4.28** | -2.58** | -14.1* | -36.88** | -5.26* | 12.08** | 10.05 |
| ICMA 98222 × BIB 551-560 | -0.78 | -0.75 | -0.24 | -0.46 | 3.2** | 0.79 | 0.1 | -8.25 | 42.16** | 6.5* | -9.05** | -3.39 |
| ICMA 10444 × BIB 551-560 | -2.97** | -2.94** | 7.2 | 0.45 | 6.9** | 1.62 | 1.52** | -7.15 | 70.26** | -5.74* | -19.07** | -16.89* |
| ICMA 30199 × BIB 551-560 | -2.26* | -2.23** | 5.01 | 0.07 | 4.24** | 3.85** | -0.33** | 9.37 | 1.21 | 7.79** | -0.26 | -3.96 |
| ICMA 30200 × BIB 551-560 | 2.22* | 2.25** | -7.05 | -0.69** | -6.56** | -6.25** | 0.23* | -16.06** | -51.65** | -8.26** | 5.46* | 5.11 |
| ICMA 30201 × BIB 551-560 | -2.4** | -2.37** | 9.15 | 1.78** | 4.96** | -1.72 | -3.08** | 2.28 | -18.79 | -7.74** | -9.94** | -56.46** |
| ICMA 30209 × BIB 551-560 | -4.21** | -4.32** | 19.89** | 0.81** | 5.43** | 3.15* | 2.39** | 19.94** | 30.26** | 8.5** | -5.33* | -16.26* |
| ICMA 04999 × BIB 561-570 | 1.13 | 0.97 | -10.8 | 0.74** | 0.7 | 5.3** | 1.28** | 3.52 | 34.55** | 3.12 | -12.85** | -7.93 |
| ICMA 88004 × BIB 561-570 | -4.78** | -4.75** | -1.54 | 0.58* | -1.83* | 2.4 | 1.59** | -24.53** | 6.45 | -7.55** | -10.58** | -6.32 |
| ICMA 93333 × BIB 561-570 | -2.64** | -2.61** | -9.69 | 0.55* | -0.41 | -1.36 | 0.07 | -21.58** | 20.74 | -10.55** | -18.75** | -10.43 |
| ICMA 97111 × BIB 561-570 | -7.11** | -7.08** | 11.47 | 1.27** | 3.45** | 0.77 | 2.58** | -7.1 | 38.35** | 3.17 | -10.09** | 5.96 |
| ICMA 97444 × BIB 561-570 | -3.54** | -3.51** | -5.64 | 0.9** | -4.98** | -3.49** | 2.66** | -4.1 | -0.22 | -7.59** | -11.01** | -19.95** |

| Crosses | SCA Effects | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| ICMA 98222 × BIB 561-570 | -5.78** | -5.75** | -3.68 | 0.53* | -1.87* | 5.39** | 2.51** | 51.75** | 102.16** | -10.16** | -21.32** | -42.31** |
| ICMA 10444 × BIB 561-570 | -0.3 | -0.27 | -13.23* | 0.07 | -1.48 | -3.19* | -0.38** | -17.15** | -39.74** | -1.4 | 5.24* | 16.72* |
| ICMA 30199 × BIB 561-570 | -1.92* | -1.89* | -9.28 | 0.71** | -0.42 | -2.2 | 2.29** | -7.29 | -8.79 | -4.88 | -6.78* | -4 |
| ICMA 30200 × BIB 561-570 | -4.78** | -4.75** | 5.61 | 2.11** | 4.12** | 3.01* | 3.03** | 33.28** | 21.69* | 13.07** | -2.21 | -29.78** |
| ICMA 30201 × BIB 561-570 | -2.73** | -2.7** | -0.79 | -0.74** | -0.49 | 2.29 | 1.61** | 108.94** | 141.21** | 27.26** | -8.36** | -74.31** |
| ICMA 30209 × BIB 561-570 | -4.54** | -4.65** | -1.41 | 0.54* | 0 | 4.94** | 2.77** | -0.06 | -6.41 | 1.84 | 0.56 | -0.42 |
| ICMA 04999 × BIB 571-580 | -5.87** | -4.7** | 1.99 | 1.12** | 3.69** | 5.55** | 2.35** | 18.52** | 27.88* | 6.45* | -8.96** | -23.05** |
| ICMA 88004 × BIB 571-580 | -2.78** | -2.75** | 1.58 | 1.11** | -0.34 | 0.56 | 0.58** | -14.53* | 9.78 | -4.21 | -8.46** | -14.93 |
| ICMA 93333 × BIB 571-580 | -1.3 | -1.27 | -3 | -0.02 | -1.07 | 0.83 | -0.78** | 5.09 | -52.6** | 7.79** | 36.62** | -2.52 |
| ICMA 97111 × BIB 571-580 | -6.11** | -6.08** | 2.58 | 0.35 | 3.26** | 3.44** | 2.32** | -10.44 | 5.02 | 3.17 | 0.46 | 11.51 |
| ICMA 97444 × BIB 571-580 | -6.21** | -6.18** | 6.13 | 0.54* | 0.44 | 3.56** | 2.45** | 25.9** | 63.12** | 24.74** | 2.18 | 9.13 |
| ICMA 98222 × BIB 571-580 | -2.45** | -2.42** | -9.88 | 0.3 | -3.93** | 4.39** | -2.28** | -8.25 | -14.5 | 2.17 | -2.44 | -10.2 |
| ICMA 10444 × BIB 571-580 | -1.97* | -1.94* | -6.1 | -0.26 | -1.31 | 9.92** | 2.05** | 2.85 | -3.07 | 2.93 | -2.43 | -10.45 |
| ICMA 30199 × BIB 571-580 | -2.59** | -2.56** | 7.61 | 0.91** | -0.04 | 7.5** | 1.17** | 16.04** | 31.21** | 24.45** | 4.6 | 14.61 |
| ICMA 30200 × BIB 571-580 | -4.78** | -4.75** | -1.38 | -0.1 | 2.9** | 9.54** | 2.7** | 44.94** | 71.69** | 10.74** | -13.34** | -41.65** |
| ICMA 30201 × BIB 571-580 | -0.06 | -0.03 | -11.36 | -0.61* | 0.43 | 2.25 | -0.14 | -1.06 | -75.45** | -14.4** | -6.64* | -66.46** |
| ICMA 30209 × BIB 571-580 | -4.87** | -3.99** | -5.91 | -0.5* | 0.38 | 6.4** | 2.44** | 4.94 | -3.07 | -1.5 | -5 | -19.5* |
| **SE (SCA)** | 0.88 | 0.84 | 6.24 | 0.24 | 0.88 | 1.23 | 0.12 | 5.63 | 10.74 | 2.64 | 2.64 | 7.59 |
| **SE (Sij-Skl)** | 1.24 | 1.19 | 8.83 | 0.34 | 1.25 | 1.75 | 0.16 | 7.97 | 15.19 | 3.73 | 3.74 | 10.74 |
| **CD 5%(SCA)** | 1.74 | 1.66 | 12.34 | 0.47 | 1.74 | 2.44 | 0.23 | 11.13 | 21.22 | 5.21 | 5.22 | 15 |
| **CD 5%(Sij-Skl)** | 2.46 | 2.34 | 17.45 | 0.67 | 2.47 | 3.45 | 0.32 | 15.74 | 30.01 | 7.36 | 7.38 | 21.21 |

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

4.3.14 indicated that the SCA effects in $E_3$ environments ranged from -26.72 (ICMA 97444 x BIB 551-560) to 19.89 (ICMA 30209 x BIB 551-560). Out of total 77 crosses, 6 crosses in $E_3$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for plant height.

**4.3.2.3.4 Productive tillers per plants**

As pearl millet is a fodder crop, productive tillers per plant is desirable in this crop, which is reflected by the positive combining ability effects. Perusal of Table 4.3.14 indicated that the SCA effects in $E_3$ environments ranged from -1.01 (ICMA 98222 x BIB 511-520) to 1.61 (ICMA 98222 x BIB 481-500). Out of total 77 crosses, 24 crosses in $E_3$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for productive tillers per plant.

**4.3.2.3.5 Ear head length**

As long ear heads are desirable in pearl millet, positive combining ability effects were considered. Perusal of Table 4.3.14 indicated that the SCA effects in E3 environments ranged from -10.6 (ICMA 04999 x BIB 551-560) to 10.23 (ICMA 04999 x BIB 511-520). Out of total 77 crosses, 26 crosses in E3 had showed positive significant SCA effects. Thus, these were considered as good specific combiner for ear head length.

**4.3.2.3.6 Ear head diameter**

As higher magnitude of ear head diameter is desirable in pearl millet, positive GCA effects were considered. Perusal of Table 4.3.14 indicated that the SCA effects in $E_3$ environments ranged from -9.55 (ICMA 10444 x BIB 481-500) to 10.06 (ICMA 98222 x BIB 481-500). Out of total 77 crosses, 33 crosses in $E_3$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for ear head diameter.

#### 4.3.2.3.7 Test weight

The higher magnitude of test weight is desirable in pearl millet. Perusal of Table 4.3.14 indicated that the SCA effects in $E_3$ environments ranged from -3.42 (ICMA 88004 x BIB 531-540) to 3.83 (ICMA 93333 x BIB 551-560). Out of total 77 crosses, 35 crosses in $E_3$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for test weight.

#### 4.3.2.3.8 Ear head weight

The higher magnitude of ear head weight is desirable in pearl millet. Perusal of Table 4.3.14 indicated that the SCA effects in $E_3$ environments ranged from -70.32 (ICMA 98222 x BIB 511-520) to 110.17 (ICMA 30201 x BIB 561-570). Out of total 77 crosses, 24 crosses in $E_3$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for ear head weight.

#### 4.3.2.3.9 Dry stover yield per plant

As pearl millet is dual crop, the dry stover as well as grain yield is of importance, which is reflected by significant positive general combining ability effects. Perusal of Table 4.3.14 indicated that the SCA effects in $E_3$ environments ranged from -110.95 (ICMA 10444 x BIB 481-500) to 150.67 (ICMA 30199 x BIB 501-510). Out of total 77 crosses, 28 crosses in $E_3$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for dry stover yield per plant.

#### 4.3.2.3.10 Grain yield per plant

The higher magnitude of grain yield per plant is desirable in pearl millet. Perusal of Table 4.3.14 indicated that the SCA effects in $E_3$ environments ranged from -13.44 (ICMA 98222 x BIB 511-520) to 32.65 (ICMA 98222 x BIB 481-500). Out of total 77 crosses, 19 crosses in $E_3$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for grain yield per plant.

#### 4.3.2.3.11 Harvest index

The higher magnitude of harvest index is desirable in pearl millet. Perusal of Table 4.3.14 indicated that the SCA effects in $E_3$ environments ranged from -21.69 (ICMA 04999 x BIB 551-560) to 34.89 (ICMA 98222 x BIB 481-500). Out of total 77 crosses, 19 crosses in $E_3$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for harvest index.

#### 4.3.2.3.12 Threshing index

The higher magnitude of threshing index is desirable in pearl millet. Perusal of Table 4.3.14 indicated that the SCA effects in $E_3$ environments ranged from -24.73 (ICMA 93333 x BIB 561-570) to 23.43 (ICMA 98222 x BIB 481-500). Out of total 77 crosses, 9 crosses in $E_3$ had showed positive significant SCA effects. Thus, these were considered as good specific combiner for threshing index.

### 4.3.2.4 SCA Effects in over the environment for different characters in pearl millet

#### 4.3.2.4.1 Days to 50% flowering

Early flowering is desirable in pearl millet, which is reflected by the negative combining ability effects. Perusal of Table 4.3.15 indicated that the SCA effects in over the environments ranged from -6.77 (ICMA 04999 x BIB 511-520) to 10.68 (ICMA 88004 x BIB 531-540). Out of total 77 crosses, 42 crosses in over the environment showed negative significant SCA effects, while nine crosses *viz.,* (ICMA 04999 x BIB 481-500), (ICMA 30209 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 30201 x BIB 531-540), (ICMA 10444 x BIB 551-560), (ICMA 30201 x BIB 551-560), and (ICMA 88004 x BIB 561-570) had negative significant SCA effects in all the environment as well as in pooled analysis. Hence, these crosses were considered for lesser number of days to 50% flowering.

## Table 4.3.14 SCA Effects in $E_3$ environment for different characters in pearl millet

| Crosses | SCA Effects | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| ICMA 04999 × BIB 481-500 | -5.56** | -4.94** | 17.97** | -0.69** | 2.72** | 3.51** | 0.66** | 15.43** | -16.9 | -6.06** | 7.73** | 4.6 |
| ICMA 88004 × BIB 481-500 | -0.94 | -0.94 | 7.36 | -0.88** | 0.69 | -6.15** | -2.18** | -3.61 | -14.29 | -1.11 | -12.9** | -8.4 |
| ICMA 93333 × BIB 481-500 | -0.23 | -0.13 | 5.31 | -0.39* | -7.25** | 1.29 | 1.15** | -0.28 | 11.43 | -1.45 | -1.24 | -5.01 |
| ICMA 97111 × BIB 481-500 | -5.09** | -5.28** | 8.55 | 0.03 | -0.27 | 5.78** | 0.69** | 19.48** | 5.24 | 1.03 | -15.24** | -16.75** |
| ICMA 97444 × BIB 481-500 | 8.2** | 8.29** | -11.4 | 0.27 | 1.45* | -5.4** | 1.18** | -21.95** | -74.29** | -11.92** | -6.27* | 4.17 |
| ICMA 98222 × BIB 481-500 | -4.37** | -3.94** | 0.34 | 1.61** | 8.6** | 6.12** | 2.41** | 58.77** | 139.29** | 32.65** | 34.89** | 23.43** |
| ICMA 10444 × BIB 481-500 | 7.2** | 6.87** | -15.34* | -0.89** | -6.31** | -9.44** | -1.51** | -31.47** | -110.95** | -4.68* | 14.51** | 0.5 |
| ICMA 30199 × BIB 481-500 | -0.52 | -0.42 | -1.55 | 0.55** | 1.33* | 2.91* | 1.95** | 15.43** | -45.24** | 2.55 | -3.63 | 8.58 |
| ICMA 30200 × BIB 481-500 | -3.04** | -2.94** | 9.79 | 0.72** | 3.18** | 6.1** | -2** | 17.81** | 44.29** | -0.83 | -16.32** | -2.8 |
| ICMA 30201 × BIB 481-500 | -2.47** | -2.56** | 2.13 | 0.44* | 2.61** | 2.67* | -0.94** | -46.95** | 130** | -0.73 | -5.01 | -1.55 |
| ICMA 30209 × BIB 481-500 | 6.82** | 6.01** | -23.17** | -0.77** | -6.74** | -7.39** | -1.41** | -22.66** | -68.57** | -9.45** | 3.47 | -6.79 |
| ICMA 04999 × BIB 501-510 | 4.07** | 4** | -0.2 | -0.07 | -1.11 | -4.25** | -0.95** | -18.66** | -24.33** | -2.28 | -3.67 | -2.5 |
| ICMA 88004 × BIB 501-510 | -5.31** | -5.34** | 13.33* | 0.4* | 5.87** | 10.51** | 3.04** | 62.29** | 128.29** | 23.01** | 19.84** | 14.71** |
| ICMA 93333 × BIB 501-510 | 2.41** | 2.47** | -2.82 | -0.03 | -0.34 | -4.03** | -0.56** | -39.37** | -22.66* | -9.32** | -8.51** | -5.75 |
| ICMA 97111 × BIB 501-510 | -4.12** | -3.34** | 10.36 | 0.13 | 8.99** | 9.81** | 0.73** | 57.06** | 14.48 | 4.82* | -15.55** | 11.35* |
| ICMA 97444 × BIB 501-510 | -0.16 | -0.1 | 6.06 | -0.31 | 1.12 | 7.6** | -1.05** | -21.04** | -20.04* | -8.13** | 4.33 | -14.19** |
| ICMA 98222 × BIB 501-510 | -3.4** | -3** | 6.28 | -0.17 | 1.75** | 4.81** | -0.54** | 39.68** | -51.47** | -7.9** | -13.4** | -1.07 |
| ICMA 10444 × BIB 501-510 | -5.16** | -5.53** | 13.98* | 1.1** | 0.04 | 1.13 | -0.13 | 7.77 | 48.29** | 2.1 | -11.9** | -12.3** |
| ICMA 30199 × BIB 501-510 | -0.21 | -0.15 | 2.41 | -0.38* | -1.07 | -8.31** | 0.23** | -3.66 | 150.67** | 12.34** | -14.32** | -15.01** |
| ICMA 30200 × BIB 501-510 | 1.93** | 2* | -10.48 | 0.01 | -2.4** | -4.85** | 0.3** | -24.61** | -53.14** | -3.71 | 10.56** | 4.28 |
| ICMA 30201 × BIB 501-510 | 5.17** | 5.04** | -21.86** | -0.46** | -7.27** | -7.99** | 1.28** | -34.37** | -134.09** | -10.61** | 12.23** | 0.75 |

| Crosses | SCA Effects | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| ICMA 30209 × BIB 501-510 | 4.79** | 3.95** | -17.06** | -0.22 | -5.57** | -4.46** | -2.35** | -25.09** | -36** | -0.32 | 20.4** | 19.74** |
| ICMA 04999 × BIB 511-520 | -8.05** | -8.16** | 2.96 | 0.56** | 9.94** | 7.27** | 1.26** | 11.34** | 101.73** | 8.18** | -15.58** | -7.18 |
| ICMA 88004 × BIB 511-520 | -2.76** | -2.82** | -6.04 | -0.28 | -0.5 | 0.61 | 2.43** | 48.96** | -42.32** | -9.2** | -6.41* | 16.62** |
| ICMA 93333 × BIB 511-520 | -1.38* | -1.35 | -3.04 | 0.52** | 1.11 | 1.54 | -0.22** | -31.04** | -19.94* | -5.54* | -0.18 | -7.41 |
| ICMA 97111 × BIB 511-520 | 5.76** | 5.51** | -11.2 | -0.38* | -2.32** | -5.3** | -0.7** | -32.94** | -29.46** | 1.27 | -20.72** | -5.9 |
| ICMA 97444 × BIB 511-520 | -5.29** | -5.25** | 14.15* | 0.98** | 4.41** | 5.18** | -0.66** | 28.96** | 69.35** | 9.65** | -5.3* | 0.25 |
| ICMA 98222 × BIB 511-520 | 9.48** | 9.84** | -4.93 | -1.01** | -9.18** | -12.26** | 0.01 | -70.32** | -95.41** | -13.44** | 12.68** | -7.99 |
| ICMA 10444 × BIB 511-520 | -1.62* | -1.01 | 2.26 | 0.39* | 2.51** | 1.65 | 0.75** | 71.1** | 97.68** | 18.89** | -6.11* | 5.3 |
| ICMA 30199 × BIB 511-520 | 1.67* | 1.7* | -7.04 | -0.72** | -4.55** | 0.66 | -1.44** | -5.32 | -19.94* | -9.2** | 27.39** | -4.37 |
| ICMA 30200 × BIB 511-520 | 5.81** | 5.84** | -8.53 | -0.86** | -5.46** | -5.8** | -2.39** | -37.94** | -53.74** | -9.92** | 9.42** | 7.02 |
| ICMA 30201 × BIB 511-520 | -1.62* | -1.77* | 5.58 | 0.27 | 0.51 | 5.31** | 1.69** | 5.63 | -31.36** | 13.18** | 9.56** | 13.84** |
| ICMA 30209 × BIB 511-520 | -2** | -2.54** | 15.84** | 0.54** | 3.53** | 1.14 | -0.74** | 11.58** | 23.4* | -3.87 | -4.75 | -10.19* |
| ICMA 04999 × BIB 531-540 | 3.89** | 3.72** | -14.48* | -0.08 | -3.03** | -5.36** | 1.1** | 0.43 | -47.21** | -6.22** | 25.15** | 5.48 |
| ICMA 88004 × BIB 531-540 | 11.18** | 11.06** | -24.59** | 0.13 | -5.96** | -7.12** | -3.8** | -35.28** | -71.26** | -8.6** | 9.43** | 1.2 |
| ICMA 93333 × BIB 531-540 | -1.77** | -1.8* | 3.03 | 0.05 | 1.57* | -1.47 | -0.32** | 29.72** | -2.21 | 18.74** | 13.43** | 1.53 |
| ICMA 97111 × BIB 531-540 | 4.37** | 5.06** | -11.74 | 0.11 | -6.62** | -3.54** | -2** | -0.52 | -21.73* | 0.88 | 0.57 | -8.56 |
| ICMA 97444 × BIB 531-540 | -6.35** | -6.37** | 12.08* | -0.06 | 2.78** | 3.04** | 1.18** | 23.05** | 33.74** | 5.26* | -6.35* | -1.22 |
| ICMA 98222 × BIB 531-540 | 1.42* | -0.61 | 6.78 | -0.26 | 1.36* | -3.02** | 0.37** | -32.9** | -49.35** | -7.84** | -5.08* | 12.59** |
| ICMA 10444 × BIB 531-540 | -3.35** | -1.8* | 3.52 | -0.19 | 2.19** | 4.52** | 0.79** | -8.14* | -11.26 | -5.84* | 0.15 | -0.65 |
| ICMA 30199 × BIB 531-540 | -1.06 | -1.09 | 0.37 | -0.2 | 0.87 | 1.8 | -0.68** | 0.43 | -38.87** | -0.93 | -4.04 | 2.46 |
| ICMA 30200 × BIB 531-540 | -4.25** | -4.28** | 6.72 | 0 | 4.43** | 5.33** | 1.32** | 6.15 | 67.32** | 0.69 | -10.41** | -3.18 |
| ICMA 30201 × BIB 531-540 | -2.01** | -2.23** | 11.82* | -0.18 | 0.52 | 3.41** | 2.36** | -18.61** | 26.36** | -1.22 | -7.52** | 1.07 |

| Crosses | SCA Effects | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| ICMA 30209 × BIB 531-540 | -2.06** | -1.66* | 6.49 | 0.68** | 1.9** | 2.42* | -0.32** | 35.67** | 114.46** | 5.07* | -15.33** | -10.72* |
| ICMA 04999 × BIB 551-560 | 2.56** | 2.27** | -2.51 | -0.37* | -10.6** | -5.82** | -2.48** | -12.45** | -42.51** | -2.06 | -21.69** | -13.54** |
| ICMA 88004 × BIB 551-560 | -1.49* | -1.06 | 4.84 | -0.27 | 2.25** | 4.43** | 1.55** | -14.83** | -26.56** | 3.22 | -1.02 | -6.59 |
| ICMA 93333 × BIB 551-560 | -1.77** | -1.92* | 6.09 | -0.21 | 6.08** | 9.4** | 3.87** | 85.17** | 19.16* | 4.22 | 3.3 | 13.95** |
| ICMA 97111 × BIB 551-560 | 5.03** | 4.6** | -15.09* | -0.14 | -6.88** | -4.76** | -1.14** | -15.06** | -20.37* | -3.3 | 28.07** | 7.98 |
| ICMA 97444 × BIB 551-560 | 6.65** | 6.51** | -26.46** | -0.71** | -8.14** | -4.29** | -2.55** | -8.16* | -38.23** | -3.92 | 15.31** | 21.44** |
| ICMA 98222 × BIB 551-560 | -0.92 | -0.73 | 0.02 | -0.21 | 3.44** | 0.77 | 0.14 | -24.11** | 40.35** | 3.65 | -9.35** | -23.26** |
| ICMA 10444 × BIB 551-560 | -2.35** | -2.92** | 6.03 | 0.25 | 5.38** | 1.6 | 1.46** | -9.35* | 80.11** | -2.35 | -8.98** | 3.84 |
| ICMA 30199 × BIB 551-560 | -2.06** | -2.21** | 4.31 | -0.06 | 4.34** | 3.84** | -0.29** | 4.22 | 9.16 | -0.11 | -4.71 | 16.5** |
| ICMA 30200 × BIB 551-560 | 2.42** | 2.27** | -6.79 | -0.46** | -6.41** | -6.56** | 0.26** | -16.73** | -47.99** | -0.83 | 6.54* | -17.09** |
| ICMA 30201 × BIB 551-560 | -3.35** | -2.35** | 9.41 | 1.53** | 4.54** | -1.74 | -3.14** | 3.51 | -5.61 | -4.4 | -4.34 | -2.99 |
| ICMA 30209 × BIB 551-560 | -4.73** | -4.45** | 20.15** | 0.66** | 6** | 3.14** | 2.32** | 7.79 | 32.49** | 5.89* | -3.12 | -0.26 |
| ICMA 04999 × BIB 561-570 | 1.23 | 0.94 | -10.54 | 0.14 | 0.7 | 5.28** | 1.31** | 2.55 | 57.49** | 1.94 | 4.64 | 7.7 |
| ICMA 88004 × BIB 561-570 | -4.49** | -4.73** | -1.28 | 0.49** | -1.59* | 2.86* | 1.62** | -26.49** | 93.44** | -4.45 | -3.07 | -16.83** |
| ICMA 93333 × BIB 561-570 | -2.44** | -2.59** | -9.91 | 0.38* | 0.07 | -1.38 | 0.1 | -24.83** | 19.16* | -8.45** | -4.18 | -24.73** |
| ICMA 97111 × BIB 561-570 | -6.63** | -7.06** | 11.73 | 0.82** | 3.97** | 0.75 | 3.43** | -0.06 | 69.63** | 2.7 | 11.49** | 10.31* |
| ICMA 97444 × BIB 561-570 | -3.35** | -3.49** | -5.38 | 0.6** | -1.03 | -3.51** | 2.7** | 0.17 | 5.11 | -8.59** | -10.64** | -17.62** |
| ICMA 98222 × BIB 561-570 | -5.92** | -5.73** | -3.42 | 0.38* | -1.63* | 5.37** | 3.13** | 54.22** | 100.35** | -4.35 | -21.36** | 10.23* |
| ICMA 10444 × BIB 561-570 | 0.32 | -0.26 | -7.74 | 0.14 | -1.67* | -3.2** | -0.25** | -11.02** | -29.89** | -1.35 | 16.42** | -4.34 |
| ICMA 30199 × BIB 561-570 | -1.73* | -1.87* | -9.98 | 0.57** | -0.33 | -2.22* | 2.33** | -4.11 | -0.84 | -6.78** | -2.96 | 1.07 |
| ICMA 30200 × BIB 561-570 | -4.58** | -4.73** | 5.87 | 0.97** | 4.27** | 2.71* | 3.06** | 34.94** | 25.35** | 9.84** | 10.54** | 2.87 |
| ICMA 30201 × BIB 561-570 | -2.35** | -2.68** | -0.53 | -0.73** | 0.09 | 2.27* | 2.22** | 110.17** | 144.39** | 13.94** | -1.83 | -11.19* |

| Crosses | SCA Effects | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| ICMA 30209 × BIB 561-570 | -3.73** | -4.78** | -1.15 | 0.09 | 0.58 | 4.93** | 3.05** | 7.79 | -0.84 | -0.78 | 8.05** | -0.05 |
| ICMA 04999 × BIB 571-580 | -4.44** | -4.4** | 2.25 | 1** | 2.03** | 5.54** | 2.38** | 20.89** | 39.16** | 8.94** | 3.45 | -3.16 |
| ICMA 88004 × BIB 571-580 | -2.49** | -2.73** | 1.84 | 0.89** | -0.1 | 1.02 | 0.61** | -11.49** | 0.11 | -0.45 | -5.83* | -9.31* |
| ICMA 93333 × BIB 571-580 | -1.11 | -1.26 | -3.22 | 0.16 | -0.59 | 0.81 | -0.74** | 0.17 | 62.49** | 4.22 | -2.6 | 18.82** |
| ICMA 97111 × BIB 571-580 | -5.63** | -6.06** | 2.84 | -0.08 | 3.79** | 3.42** | 2.27** | -8.4* | 49.63** | -4.97* | 11.4** | -7.02 |
| ICMA 97444 × BIB 571-580 | -6.01** | -6.16** | 6.39 | -0.29 | 0.07 | 3.55** | 2.48** | 18.51** | 91.77** | 20.08** | 8.95** | -1.42 |
| ICMA 98222 × BIB 571-580 | -2.58** | -2.4** | -9.62 | 0.15 | -3.69** | 4.37** | -2.23** | -5.78 | -16.32 | -0.35 | 1.65 | -22.52** |
| ICMA 10444 × BIB 571-580 | -1.35* | -1.92* | -7.27 | -0.31 | -1.5* | 9.9** | 2.18** | 0.65 | -6.56 | -4.35 | -4.05 | -0.94 |
| ICMA 30199 × BIB 571-580 | -2.39** | -2.54** | 6.92 | 0.75** | 0.06 | 7.48** | 1.2** | 12.55** | 12.49 | 4.55* | 2.29 | -17.83** |
| ICMA 30200 × BIB 571-580 | -4.58** | -4.73** | -1.12 | 0.11 | 3.04** | 9.23** | 2.73** | 39.94** | 85.35** | 7.17** | -10.3** | 0.31 |
| ICMA 30201 × BIB 571-580 | 0.32 | -0.02 | -11.1 | -0.39* | -0.33 | 2.24* | -0.2* | 0.17 | -62.27** | -7.73** | -3.04 | -8.52 |
| ICMA 30209 × BIB 571-580 | -5.39** | -3.11** | -5.66 | -0.49** | 0.95 | 6.38** | 2.73** | 4.46 | 2.49 | 5.89* | -8.7** | -0.33 |
| **SE (SCA)** | 0.67 | 0.84 | 5.94 | 0.17 | 0.66 | 1.12 | 0.08 | 4.06 | 9.07 | 2.28 | 2.55 | 4.44 |
| **SE (Sij-Skl)** | 0.95 | 1.18 | 8.41 | 0.24 | 0.94 | 1.58 | 0.12 | 5.75 | 12.82 | 3.23 | 3.6 | 6.28 |
| **CD 5%(SCA)** | 1.32 | 1.65 | 11.74 | 0.34 | 1.31 | 2.21 | 0.16 | 8.03 | 17.91 | 4.51 | 5.03 | 8.77 |
| **CD 5%(Sij-Skl)** | 1.87 | 2.34 | 16.61 | 0.48 | 1.85 | 3.12 | 0.23 | 11.36 | 25.33 | 6.38 | 7.12 | 12.4 |

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

#### 4.3.2.4.2 Days to maturity

Early maturity is desirable in pearl millet, which is reflected by the negative combining ability effects. Perusal of Table 4.3.15 indicated that the SCA effects in over the environments ranged from -6.77 (ICMA 04999 x BIB 511-520) to 10.68 (ICMA 88004 x BIB 531-540). Out of total 77 crosses, 42 crosses in over the environment showed negative significant SCA effects, while nine crosses *viz.,* (ICMA 04999 x BIB 481-500), (ICMA 30209 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 30201 x BIB 531-540), (ICMA 10444 x BIB 551-560), (ICMA 30201 x BIB 551-560), and (ICMA 88004 x BIB 561-570) had negative significant SCA effects in all the environment as well as in pooled analysis. Hence, these crosses were considered for lesser number of days to 50% flowering.

#### 4.3.2.4.3 Plant height

The tall plant height is desirable in pearl millet, which is reflected by the positive combining ability effects. Perusal of Table 4.3.15 indicated that the SCA effects in over the environments ranged from -28.4 (ICMA 30209 x BIB 481-500) to 19.93 (ICMA 30209 x BIB 551-560). Out of total 77 crosses, 25 crosses in over the environment showed positive significant SCA effects. However, four crosses *viz.,* (ICMA 04999 x BIB 481-500), (ICMA 30200 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 30201 x BIB 531-540), (ICMA 10444 x BIB 551-560), (ICMA 30201 x BIB 551-560), and (ICMA 88004 x BIB 561-570) 57 had positive significant SCA effects in individual environment as well as in pooled analysis. Thus, these were considered as good specific combiner for plant height.

#### 4.3.2.4.4 Productive tillers per plants

As pearl millet is a fodder crop, high number of productive tillers per plant is desirable in this crop, which is reflected by the positive combining ability effects. Perusal of Table 4.3.15 indicated that the SCA effects in over the environments ranged from -1.17 (ICMA 30209 x BIB 481-500) to 1.55 (ICMA 30200 x BIB 561-570). Out of total 77 crosses, 31 crosses in over the environment showed positive significant SCA effects, while three crosses *viz.,* (ICMA 04999 x BIB 481-500), (ICMA 30209 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 30201 x BIB 531-540), (ICMA 10333 x BIB 551-560), (ICMA 30201 x BIB 551-560), and (ICMA 88004 x BIB 561-570) had positive significant SCA effects in all the environment as well as in pooled analysis. Thus, these were considered as good specific combiner for productive tillers per plant.

#### 4.3.2.4.5 Ear head length

As long ear heads are desirable in pearl millet, positive combining ability effects were considered. Perusal of Table 4.3.15 indicated that the SCA effects in over the environments ranged from -8.65 (ICMA 04999 x BIB 551-560) to 7.45 (ICMA 04999 x BIB 511-520). Out of total 77 crosses, 32 crosses in over the environment showed positive significant SCA effects, while ten crosses *viz.,* (ICMA 04999 x BIB 481-500), (ICMA 30209 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 30201 x BIB 531-540), (ICMA 10333 x BIB 551-560), (ICMA 30201 x BIB 551-560), and (ICMA 88004 x BIB 561-570) had positive significant SCA effects in all the environment as well as in pooled analysis. Thus, these were considered as good specific combiner for ear head length.

#### 4.3.2.4.6 Ear head diameter

As higher magnitude of ear head diameter is desirable in pearl millet, positive GCA effects were considered. Perusal of Table 4.3.15 indicated that the SCA effects in over the environments ranged from -9.51 (ICMA 10444 x BIB 481-500) to 8.03 (ICMA 10444 x BIB 571-

580). Out of total 77 crosses, 40 crosses in over the environment showed positive significant SCA effects, while eleven crosses *viz.,* (ICMA 04999 x BIB 481-500), (ICMA 30209 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 30201 x BIB 531-540), (ICMA 10333 x BIB 551-560), (ICMA 30201 x BIB 551-560), and (ICMA 88004 x BIB 561-570) had positive significant SCA effects in all the environment as well as in pooled analysis. Thus, these were considered as good specific combiner for ear head diameter.

**4.3.2.4.7 Test weight**

The higher magnitude of test weight is desirable in pearl millet. Perusal of Table 4.3.15 indicated that the SCA effects in over the environments ranged from -2.58 (ICMA 97444 x BIB 551-560) to 3.83 (ICMA 93333 x BIB 551-560). Out of total 77 crosses, 48 crosses in over the environment showed positive significant SCA effects, while twenty crosses *viz.,* (ICMA 04999 x BIB 481-500), (ICMA 30209 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 30201 x BIB 531-540), (ICMA 10333 x BIB 551-560), (ICMA 30201 x BIB 551-560), and (ICMA 88004 x BIB 561-570) had positive significant SCA effects in all the environment as well as in pooled analysis. Thus, these were considered as good specific combiner for test weight.

**4.3.2.4.8 Ear head weight**

The higher magnitude of ear head weight is desirable in pearl millet. Perusal of Table 4.3.15 indicated that the SCA effects in over the environments ranged from -50.36 (ICMA 30200 x BIB 511-520) to 93.58 (ICMA 30201 x BIB 561-570). Out of total 77 crosses, 30 crosses in over the environment showed positive significant SCA effects. While eight crosses *viz.,* (ICMA 04999 x BIB 481-500), (ICMA 30209 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 30201 x BIB 531-540), (ICMA

10333 x BIB 551-560), (ICMA 30201 x BIB 551-560), and (ICMA 88004 x BIB 561-570) had positive significant SCA effects in all the environment as well as in pooled analysis. Thus, these were considered as good general combiner for ear head weight.

**4.3.2.4.9 Dry stover yield per plant**

As pearl millet is dual crop, the dry stover as well as grain yield is of importance, which is reflected by significant positive specific combining ability effects. Perusal of Table 4.3.15 indicated that the SCA effects in over the environments ranged from -119.25 (ICMA 10444 x BIB 481-500) to 111.54 (ICMA 98222 x BIB 481-500). Out of total 77 crosses, 32 crosses in over the environment showed positive significant SCA effects, while five crosses *viz.,* (ICMA 04999 x BIB 481-500), (ICMA 30209 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 30201 x BIB 531-540), (ICMA 10333 x BIB 551-560), (ICMA 30201 x BIB 551-560), and (ICMA 88004 x BIB 561-570) had positive significant SCA effects in all the environment as well as in pooled analysis. Thus, these were considered as good specific combiner for dry stover yield per plant

**4.3.2.4.10 Grain yield per plant**

The higher magnitude of grain yield per plant is desirable in pearl millet. Perusal of Table 4.3.15 indicated that the SCA effects in over the environments ranged from -21.19 (ICMA 30209 x BIB 481-500) to 35.89 (ICMA 98222 x BIB 481-500). Out of total 77 crosses, 27 crosses in over the environment showed positive significant SCA effects, while nine crosses *viz.,* (ICMA 04999 x BIB 481-500), (ICMA 30209 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 30201 x BIB 531-540), (ICMA 10333 x BIB 551-560), (ICMA 30201 x BIB 551-560), and (ICMA 88004 x BIB 561-570) had positive significant SCA effects in all the environment as well as in pooled analysis. Thus, these were considered as good specific combiner for grain yield per plant.

#### 4.3.2.4.11 Harvest index

The higher magnitude of harvest index is desirable in pearl millet. Perusal of Table 4.3.15 indicated that the SCA effects in over the environments ranged from -14.07 (ICMA 98222 x BIB 561-570) to 14.93 (ICMA 98222 x BIB 481-500). Out of total 77 crosses, 21 crosses in over the environment showed positive significant SCA effects, while nine crosses *viz.,* (ICMA 04999 x BIB 481-500), (ICMA 30200 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 30201 x BIB 531-540), (ICMA 10333 x BIB 551-560), (ICMA 30201 x BIB 551-560), and (ICMA 88004 x BIB 561-570) had positive significant SCA effects in all the environment as well as in pooled analysis. Thus, these were considered as good specific combiner for harvest index.

#### 4.3.2.4.12 Threshing index

The higher magnitude of threshing index is desirable in pearl millet. Perusal of Table 4.3.15 indicated that the SCA effects in over the environments ranged from -23.41 (ICMA 30201 x BIB 571-580) to 65.81 (ICMA 30201 x BIB 481-500). Out of total 77 crosses, 15 crosses showed positive significant SCA effects, while nine crosses *viz.,* (ICMA 04999 x BIB 481-500), (ICMA 30209 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 30201 x BIB 531-540), (ICMA 10333 x BIB 551-560), (ICMA 30201 x BIB 551-560), and (ICMA 88004 x BIB 561-570) had positive significant SCA effects in all the environment as well as in pooled analysis. Thus, these were considered as good specific combiner for threshing index.

**Table 4.3.15 SCA Effects in over the environment for different characters in pearl millet**

| Crosses | SCA Effects | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| ICMA 04999 × BIB 481-500 | -4.34** | -4.43** | 18.88** | -0.58** | 1.62** | 3.57** | 0.64** | 16.69** | 10.75 | 1.87 | 0.01 | -11.14** |
| ICMA 88004 × BIB 481-500 | -0.45 | -0.39 | 7.31* | -0.96** | -2.46** | -1.4* | -1.77** | 7.34 | -4.41 | -3.54 | -5.92** | -19.82** |
| ICMA 93333 × BIB 481-500 | -0.29 | -0.23 | -0.93 | -0.37* | -4.96** | 1.03 | 1.13** | -5.65 | -3.61 | -5.24* | -3.77* | -9.25** |
| ICMA 97111 × BIB 481-500 | -2.2** | -2.14** | 11.66** | 0 | 1.24* | 4.25** | 0.62** | 11.8** | 4.96 | -0.62 | -6.55** | -18.67** |
| ICMA 97444 × BIB 481-500 | 4.71** | 4.77** | -2.26 | 0.02 | 2.23** | -2.47** | 1.16** | -9.26* | -40.92** | -5.79** | -0.17 | -2.19 |
| ICMA 98222 × BIB 481-500 | -3.51** | -3.46** | 0.9 | 1.39** | 7.03** | 4.84** | 2.3** | 48.48** | 111.54** | 35.89** | 14.93** | 9.4** |
| ICMA 10444 × BIB 481-500 | 4.19** | 4.24** | -16.99** | -0.39* | -5.06** | -9.51** | -1.62** | -38.4** | -119.25** | -12.28** | 14.44** | 12.92** |
| ICMA 30199 × BIB 481-500 | -0.75 | -0.69 | -0.27 | 0.85** | 0.2 | 1.3* | 1.93** | 7.05 | -23.14** | 3.13 | 0.47 | -3.82 |
| ICMA 30200 × BIB 481-500 | -3.21** | -3.15** | 7.25* | 0.77** | 2.23** | 3.76** | -2.01** | 30.73** | 54.48** | 2.67 | -9.95** | -19.77** |
| ICMA 30201 × BIB 481-500 | 0.82 | 0.72 | 2.84 | 0.44** | 2.61** | 2.45** | -0.95** | -32.52** | 105.59** | 5.11* | -4.28** | 65.81** |
| ICMA 30209 × BIB 481-500 | 5.01** | 4.77** | -28.4** | -1.17** | -4.68** | -7.81** | -1.43** | -36.25** | -96** | -21.19** | 0.79 | -3.47 |
| ICMA 04999 × BIB 501-510 | 5.44** | 5.35** | -11.12** | -0.43** | -3.36** | -5.59** | -1.04** | -33.27** | -55.41** | -11.13** | -1.85 | 6.02 |
| ICMA 88004 × BIB 501-510 | -4.78** | -4.73** | 10.28** | 0.53** | 5.98** | 6.59** | 3.38** | 55.16** | 110.54** | 33.46** | 9.8** | 8.34* |
| ICMA 93333 × BIB 501-510 | 1.82** | 1.88** | 2.13 | 0 | -1.61** | -2.29** | -0.65** | -29.49** | -15.33 | -4.68* | -5.83** | 6.67* |
| ICMA 97111 × BIB 501-510 | -3.52** | -3.47** | 5.59 | 0.41* | 6.7** | 7.16** | 0.94** | 57.4** | 32.13** | 6.94** | -7.7** | -10.57** |
| ICMA 97444 × BIB 501-510 | -0.62 | -0.57 | 5.99* | -0.12 | 2.38** | 6.19** | -1.14** | -17.77** | 15.7 | -7.79** | -4.74** | -8.22* |
| ICMA 98222 × BIB 501-510 | -2.51** | -2.46** | 7.26* | -0.01 | 1.25* | 3.41** | -0.41* | 29.09** | -45.73** | -5.45* | -3.49* | -6.98* |
| ICMA 10444 × BIB 501-510 | -4.59** | -4.54** | 14.41** | 0.54** | -1.11* | 0.33 | -0.19 | 5.88 | 20.7* | -1.73 | -7.69** | -12.69** |
| ICMA 30199 × BIB 501-510 | 0.47 | 0.53 | 1.06 | -0.2 | -0.59 | -5.85** | 0.14 | -12.34** | 79.59** | -1.2 | -9.19** | -6.18 |
| ICMA 30200 × BIB 501-510 | 1.9** | 1.96** | -7.23* | -0.13 | -1.38** | -2.31** | 0.21 | -15.55** | -41.68** | -2.11 | 8.91** | 10.88** |
| ICMA 30201 × BIB 501-510 | 3.15** | 3.05** | -17.21** | -0.39* | -4.6** | -5.88** | 1.19** | -23.8** | -91.68** | -7.67** | 11.2** | -7.08* |

| Crosses | SCA Effects | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| ICMA 30209 × BIB 501-510 | 3.24** | 2.99** | -11.16** | -0.2 | -3.66** | -1.75** | -2.44** | -15.31** | -8.82 | 1.36 | 10.57** | 19.8** |
| ICMA 04999 × BIB 511-520 | -6.77** | -6.86** | 5.1 | 0.33* | 7.45** | 5.36** | 1.21** | 9.15* | 61.91** | 4.47* | -10.22** | -8.21* |
| ICMA 88004 × BIB 511-520 | -2.55** | -2.49** | -4.28 | -0.43** | 1.36** | 0.27 | 2.81** | 24.24** | -39.91** | -12.28** | -3.89* | -7.85* |
| ICMA 93333 × BIB 511-520 | -0.61 | -0.56 | -3.48 | 0.56** | 0.11 | 0.93 | -0.27 | -27.63** | -30.23** | -5.2* | -1.17 | 3.02 |
| ICMA 97111 × BIB 511-520 | 2.82** | 2.87** | -7.01* | -0.17 | -1.49** | -3.3** | -0.8** | -23.74** | -26.1** | -0.8 | -6.07** | -3.24 |
| ICMA 97444 × BIB 511-520 | -3.95** | -3.89** | 8.48** | 0.6** | 3.32** | 3.52** | -0.7** | 19.87** | 38.58** | 11.14** | -1.81 | 1.54 |
| ICMA 98222 × BIB 511-520 | 7.83** | 7.89** | -7.78* | -0.86** | -6.75** | -7.24** | -0.13 | -56.28** | -70.63** | -9.41** | 9.01** | 14.47** |
| ICMA 10444 × BIB 511-520 | 0.31 | 0.36 | 1.83 | 0.37* | 2.09** | 0.73 | 0.95** | 50.51** | 105.24** | 19.86** | -4.24** | 1.48 |
| ICMA 30199 × BIB 511-520 | 0.15 | 0.21 | -4.86 | -0.81** | -3.26** | 0.64 | -1.49** | 18.4** | 46.91** | -8.5** | 4.68** | -10.42** |
| ICMA 30200 × BIB 511-520 | 6.03** | 6.08** | -11.55** | -0.84** | -5.22** | -6.34** | -2.44** | -50.36** | -83.25** | -14.96** | 6.94** | 20.37** |
| ICMA 30201 × BIB 511-520 | -1.94** | -2.05** | 7.9** | 0.86** | -0.04 | 3.93** | 1.64** | 22.39** | -11.02 | 12.04** | 6.18** | -4.7 |
| ICMA 30209 × BIB 511-520 | -1.31* | -1.56** | 15.65** | 0.39* | 2.43** | 1.49* | -0.79** | 13.44** | 8.5 | 3.63 | 0.6 | -6.46 |
| ICMA 04999 × BIB 531-540 | 2.78** | 2.7** | -3.24 | 0.3 | -1.24* | -2.34** | 1.05** | 17.47** | 12.26 | 0.95 | 9.4** | -5.96 |
| ICMA 88004 × BIB 531-540 | 10.68** | 10.73** | -33.88** | 0.29 | -5.72** | -7.72** | -3.42** | -46.65** | -97.34** | -20.14** | 4.77** | 8.77** |
| ICMA 93333 × BIB 531-540 | -1.17 | -1.11 | 2.57 | 0.41* | 1.37** | -1.36* | -0.37 | 29.58** | 37.9** | 13.17** | 6.28** | -1.21 |
| ICMA 97111 × BIB 531-540 | 2.93** | 2.98** | -7.78* | -0.19 | -4.51** | -1.86** | -2.1** | 3.14 | 12.03 | 4.45* | 1.39 | -0.24 |
| ICMA 97444 × BIB 531-540 | -4.94** | -4.89** | 7.59* | 0.12 | 2.15** | 1.93** | 1.14** | 27.07** | 6.71 | 7.94** | -0.84 | -7.72* |
| ICMA 98222 × BIB 531-540 | -0.5 | -0.45 | 4.85 | -0.26 | 1.39** | -2.37** | 0.56** | -20.18** | -66.39** | -10.6** | 2.48 | 1.7 |
| ICMA 10444 × BIB 531-540 | -1.36* | -1.3* | 7.75* | -0.47** | 0.58 | 4.36** | 0.65** | -1.16 | -27.73** | 0.45 | 1.6 | -1.75 |
| ICMA 30199 × BIB 531-540 | -0.74 | -0.69 | 1.5 | -0.59** | 0.5 | 1.68** | -0.73** | -13.83** | -48.29** | -6.13** | -1 | 2.91 |
| ICMA 30200 × BIB 531-540 | -3.31** | -3.25** | 7.79* | -0.25 | 3.53** | 3.58** | 1.27** | -4.04 | 60.44** | -0.15 | -10.14** | 2.66 |
| ICMA 30201 × BIB 531-540 | -2.84** | -2.94** | 7.5* | -0.41* | -0.29 | 1.71** | 2.32** | -19.29** | 9.33 | 1.85 | -3.03* | 9.4** |

| Crosses | SCA Effects | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| ICMA 30209 × BIB 531-540 | -1.53* | -1.78** | 5.36 | 1.04** | 2.23** | 2.38** | -0.37 | 27.87** | 101.07** | 8.21** | -10.92** | -8.55* |
| ICMA 04999 × BIB 551-560 | 2.65** | 2.56** | -9.81** | -0.27 | -8.65** | -5.12** | -2.51** | -29.88** | -67.48** | -11.11** | 1.98 | 14.92** |
| ICMA 88004 × BIB 551-560 | -1.91** | -1.86** | 10.94** | 0.08 | 2.41** | 3.84** | 1.95** | -2.9 | 20.69* | 8.03** | 0.3 | 11.07** |
| ICMA 93333 × BIB 551-560 | -2.2** | -2.14** | 6.29* | 0.12 | 5.71** | 7.18** | 3.83** | 78.57** | 69.26** | 17.67** | -1.36 | -6.42 |
| ICMA 97111 × BIB 551-560 | 5.45** | 5.51** | -20.97** | -0.86** | -7.1** | -4.81** | -1.23** | -28.1** | -31.05** | -9.71** | 9.05** | 11.92** |
| ICMA 97444 × BIB 551-560 | 6.91** | 6.97** | -27.53** | -0.8** | -6.59** | -4.44** | -2.58** | -28.39** | -75.26** | -12.77** | 10.81** | 18.16** |
| ICMA 98222 × BIB 551-560 | -0.98 | -0.92 | 4.15 | -0.19 | 3.21** | 0.36 | 0.01 | -4.53 | 44.42** | 1.13 | -8.84** | -13.17** |
| ICMA 10444 × BIB 551-560 | -3.05** | -3** | 6.45* | 0.53** | 4.45** | 2.38** | 1.52** | 0.04 | 56.96** | -0.82 | -9.4** | -7.43* |
| ICMA 30199 × BIB 551-560 | -1.77** | -1.71** | 5.86 | -0.06 | 3.81** | 2.78** | -0.33 | 13.48** | 0.85 | 7.37** | 0.07 | 3.52 |
| ICMA 30200 × BIB 551-560 | 1.1 | 1.16 | -2.54 | -0.27 | -3.43** | -3.49** | 0.23 | -7.61 | -24.86** | -3.53 | 3.05* | -6.94* |
| ICMA 30201 × BIB 551-560 | -2.75** | -2.86** | 7.23* | 1.25** | 2.68** | -1.41* | -3.17** | -7.53 | -17.09* | -3.76 | -3.81* | -17.74** |
| ICMA 30209 × BIB 551-560 | -3.45** | -3.7** | 19.93** | 0.47** | 3.5** | 2.73** | 2.28** | 16.85** | 23.55** | 7.5** | -1.86 | -7.88* |
| ICMA 04999 × BIB 561-570 | -0.24 | -0.33 | -5.81 | 0.68** | 0.79 | 4.62** | 1.28** | 16.45** | 45.85** | 13.56** | 0.57 | 2.01 |
| ICMA 88004 × BIB 561-570 | -4.36** | -4.3** | 2.26 | 0.39* | -1.1* | 2.79** | -0.98** | -13.45** | 36.25** | -1.18 | -3.07* | -7.13* |
| ICMA 93333 × BIB 561-570 | -1.98** | -1.92** | -5.1 | 0.2 | 0.63 | -1.44* | 0.07 | -28.1** | 7.04 | -10.77** | -8.89** | -9.86** |
| ICMA 97111 × BIB 561-570 | -5.77** | -5.71** | 12.46** | 1.22** | 2.59** | 0.64 | 3.35** | -2.88 | 34.5** | 1.73 | 0.98 | 5.05 |
| ICMA 97444 × BIB 561-570 | -3.31** | -3.25** | -0.37 | 0.95** | -3.66** | -2.58** | 2.66** | 5.5 | 39.18** | -3.44 | -9.29** | -15.38** |
| ICMA 98222 × BIB 561-570 | -4.86** | -4.81** | -2.44 | 0.71** | -2.09** | 2.53** | 3** | 36.02** | 94.42** | 2.36 | -14.07** | -5.05 |
| ICMA 10444 × BIB 561-570 | 0.06 | 0.11 | -11.52** | 0.51** | -0.26 | -1.27* | -0.38 | -0.51 | 9.18 | 2.07 | 5.65** | 0.63 |
| ICMA 30199 × BIB 561-570 | -1.44* | -1.38* | -7.62* | 0.85** | -0.36 | -1.04 | 2.29** | 1.82 | -5.82 | 4.26* | -0.53 | 1.75 |
| ICMA 30200 × BIB 561-570 | -4.34** | -4.29** | 4.22 | 1.55** | 2.81** | 3.14** | 3.02** | 36.05** | 29.58** | 17.13** | 5.59** | -7.46* |
| ICMA 30201 × BIB 561-570 | -2.2** | -2.3** | -2.76 | -0.42* | -0.7 | 2.92** | 2.19** | 93.58** | 118.47** | 8.46** | -6.55** | -36.43** |

| Crosses | SCA Effects | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| ICMA 30209 × BIB 561-570 | -4.23** | -4.48** | -1.55 | 0.65** | 0.05 | 3.7** | 3.02** | 7.96 | 3.55 | 0.83 | 2.48 | -3.19 |
| ICMA 04999 × BIB 571-580 | -5.8** | -4.89** | 6.08* | 0.99** | 3.49** | 4.56** | 2.35** | 27.56** | 50.85** | 10.34** | -2.65 | -11.79** |
| ICMA 88004 × BIB 571-580 | -2.91** | -2.86** | 7.43* | 1.12** | -0.37 | 0.68 | 1.01** | 0.43 | 32.91** | 4.59* | -4.75** | -7.52* |
| ICMA 93333 × BIB 571-580 | -1.86** | -1.81** | -1.41 | 0.11 | -1.15* | 1.01 | -0.78** | 6.9 | -6.29 | 4.01 | 11.98** | 2.89 |
| ICMA 97111 × BIB 571-580 | -5.99** | -5.94** | 6.13* | 0.63** | 2.68** | 2.98** | 2.19** | 6.56 | 32.28** | 6.96** | 6.14** | 1.6 |
| ICMA 97444 × BIB 571-580 | -5.09** | -5.03** | 8.18** | 0.25 | 0.29 | 2.91** | 2.44** | 27.17** | 74.74** | 19.67** | 3.29* | -0.34 |
| ICMA 98222 × BIB 571-580 | -1.75** | -1.7** | -6.86* | 0.25 | -3.93** | 3.53** | -2.36** | -8.42* | -8.91 | -4.98* | -2.78 | -14.52** |
| ICMA 10444 × BIB 571-580 | -1.83** | -1.78** | -1.86 | -0.06 | -0.6 | 8.03** | 2.05** | 7.82 | 13.63 | 1.4 | -3.13* | -7.31* |
| ICMA 30199 × BIB 571-580 | -2.22** | -2.16** | 4.41 | 0.97** | -0.2 | 5.54** | 1.17** | 9.6* | 8.63 | 10.04** | 2.74 | -1.91 |
| ICMA 30200 × BIB 571-580 | -4.45** | -4.4** | 2.12 | 0.2 | 1.56** | 6.71** | 2.7** | 34.94** | 64.03** | 9.91** | -7.16** | -13.89** |
| ICMA 30201 × BIB 571-580 | -0.53 | 0.48 | -5.43 | -0.3 | 0.44 | 1.35* | -0.23 | -8.64* | -54.87** | -7.09** | -2.47 | -23.41** |
| ICMA 30209 × BIB 571-580 | -4.01** | -2.14** | 0.26 | -0.16 | 0.24 | 4.33** | 2.69** | 9.63* | 26.88** | 8.61** | -4.43** | -4.41 |
| **SE (SCA)** | 0.62 | 0.6 | 3.03 | 0.16 | 0.51 | 0.64 | 0.2 | 4.28 | 8.43 | 2.11 | 1.51 | 3.31 |
| **SE (Sij-Skl)** | 0.88 | 0.84 | 4.28 | 0.23 | 0.71 | 0.91 | 0.28 | 6.05 | 11.92 | 2.99 | 2.13 | 4.69 |
| **CD 5%(SCA)** | 1.22 | 1.17 | 5.95 | 0.32 | 0.99 | 1.26 | 0.39 | 8.41 | 16.57 | 4.15 | 2.96 | 6.51 |
| **CD 5%(Sij-Skl)** | 1.73 | 1.65 | 8.41 | 0.45 | 1.4 | 1.78 | 0.56 | 11.9 | 23.43 | 5.87 | 4.19 | 9.21 |

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

## 4.4 Estimation of standard heterosis

The standard heterosis was estimated as percent increase or decrease of mean performance over the best check in the experiment. In the present experiment, there were three standard checks used for comparison of the hybrids. Among these three standard checks, the HHB67-imp gave the highest grain yield per plant in over the environments as compared to the other checks. Therefore, HHB67-imp was considered as best check for estimation of standard heterosis in individual environment as well as over the environments. The results obtained are presented in Table 4.4.1 to 4.4.4 and described as under:

**4.4.1 Days to 50% flowering**

The significant negative standard heterosis (%) for days to 50% flowering (Table 4.4.1) was observed in 15 cross in $E_{1,}$ 50 cross in $E_2$ and 49 crosses in $E_3$ and 38 crosses in pooled analysis. Hence, these crosses were considered as desirable for this trait. The standard heterosis ranged from -8.7 (ICMA 97444 x BIB 481-500) to 21.74 (ICMA 04999 x BIB 501-510) in $E_1$, -19.61 (ICMA 98222 x BIB 481-500) to 9.80 (ICMA 04999 x BIB 501-510) in $E_2$, -19.30 (ICMA 88004 x BIB 511-520) to 8.77 (ICMA 04999 x BIB 501-510) in $E_3$ and -15.69 (ICMA 04999 x BIB 511-520) to 13.73 (ICMA 04999 x BIB 501-510) in pooled analysis. The cross ICMA 98222 x BIB 481-500, ICMA 88004 x BIB 501-510, ICMA 97111 x BIB 501-510, ICMA 98222 x BIB 501-510, ICMA 04999 x BIB 511-520, ICMA 88004 x BIB 511-520, ICMA 97444 x BIB 511-520, ICMA 97444 x BIB 531-540, ICMA 98222 x BIB 531-540, ICMA 10444 x BIB 531-540, ICMA 93333 x BIB 551-560, ICMA 98222 x BIB 561-570, ICMA 93333 x BIB 571-580 and ICMA 97111 x BIB 571-580 exhibited significant negative heterosis in all the three environments as well as over the environments. Hence, these crosses were considered as desirable for this trait.

### 4.4.2 Days to maturity

The significant negative standard heterosis (%) for days to 50% flowering was observed in 15 cross in $E_{1,}$ 50 cross in $E_2$ and 49 crosses in $E_3$ and 38 crosses in pooled analysis (Table 4.4.1). The standard heterosis ranged from -6.58 (ICMA 88004 x BIB 501-510) to 13.16 (ICMA 04999 x BIB 501-510) in $E_1$, -13.58 (ICMA 88004 x BIB 511-520) to 9.226.17 (ICMA 04999 x BIB 501-510) in $E_2$, -12.64 (ICMA 88004 x BIB 511-520) to 5.75 (ICMA 04999 x BIB 501-510) in $E_3$ and -9.88 (ICMA 04999 x BIB 511-520) to 8.64 (ICMA 04999 x BIB 501-510) in pooled analysis. The cross ICMA 98222 x BIB 481-500, ICMA 88004 x BIB 501-510, ICMA 97111 x BIB 501-510, ICMA 98222 x BIB 501-510, ICMA 04999 x BIB 511-520, ICMA 88004 x BIB 511-520, ICMA 97444 x BIB 511-520, ICMA 97444 x BIB 531-540, ICMA 98222 x BIB 531-540, ICMA 10444 x BIB 531-540, ICMA 93333 x BIB 551-560, ICMA 98222 x BIB 561-570, ICMA 93333 x BIB 571-580 and ICMA 97111 x BIB 571-580 exhibited significant negative heterosis in all the three environments as well as over the environments. Hence, these crosses were considered as desirable for this trait.

### 4.4.3 Plant height

The significant positive standard heterosis (%) for plant height was observed in 6 cross in $E_{1,}$ 36 cross in $E_2$ and 36 crosses in $E_3$ and 19 crosses in pooled analysis (Table 4.4.1). The standard heterosis ranged from -32.53 (ICMA 04999 x BIB 501-510) to 8.43 (ICMA 93333 x BIB 501-510) in $E_1$, -11.81 (ICMA 30201 x BIB 501-510) to 32.28 (ICMA 93333 x BIB 481-500) in $E_2$, -15.16 (ICMA 30201 x BIB 501-510) to 45.47 (ICMA 93333 x BIB 481-500) in $E_3$ and -17.69 (ICMA 97444 x BIB 551-560) to 21.54 (ICMA 93333 x BIB 531-540) in pooled analysis. The cross ICMA 97111 x BIB 481-500, ICMA 93333 x BIB 501-510, ICMA 93333 x BIB 531-540 and ICMA 88004 x BIB 551-560 exhibited significant positive heterosis in all the three environments as well as over the environments. Hence, these crosses were considered as desirable for plant height trait.

### 4.4.4 Productive tillers per plant

The significant positive standard heterosis (%) for productive tillers per plant (Table 4.4.2) was observed in 13 cross in $E_1$, 34 in $E_2$, 34 in $E_3$ and 23 in pooled analysis. The standard heterosis ranged from -70.27 (ICMA 97111 x BIB 551-560) to 70.27 (ICMA 04999 x BIB 531-540) in $E_1$, -33.33 (ICMA 04999 x BIB 531-540) to 193.33 (ICMA 98222 x BIB 481-500) in $E_2$, -9.09 (ICMA 10444 x BIB 481-500) to 236.36 (ICMA 98222 x BIB 481-500) in $E_3$ and -38.10 (ICMA 30209 x BIB 481-500) to 90.48 (ICMA 30201 x BIB 511-520) in pooled analysis. The cross ICMA 93333 x BIB 511-520, ICMA 30201 x BIB 511-520, ICMA 30209 x BIB 531-540, ICMA 97111 x BIB 461-570, ICMA 30199 x BIB 561-570, ICMA 04999 x BIB 571-580, ICMA 88004 x BIB 571-580 and ICMA 30199 x BIB 571-580 exhibited significant positive standard heterosis in all the environments as well as in pooled analysis. Hence these crosses were considered as desirable for this trait.

### 4.4.5 Ear head length

Significant positive standard heterosis (%) for ear head length (Table 4.4.3) was observed in 4 crosses in $E_1$, 11 crosses in $E_2$, 10 crosses in $E_3$ and 8 crosses in pooled analysis. It ranged from -45.74 (ICMA 88004 x BIB 481-550) to 16.67 (ICMA 88004 x BIB 501-510) in $E_1$, -46.09 (ICMA 30200 x BIB 511-520) to 36.96 (ICMA 10444 x BIB 551-560) in $E_2$, -65.53 (ICMA 97111 x BIB 531-540) to 44.52 (ICMA 93333 x BIB 551-560) in $E_3$ and -51.13 (ICMA 04999 x BIB 551-560) to 29.41 (ICMA 93333 x BIB 551-560) in pooled analysis. Crosses ICMA 98222 x BIB 481-500, ICMA 88004 x BIB 501-510 and ICMA 93333 x BIB 551-560 exhibited significant positive standard heterosis in each environment as well as over the environments and considered as desirable for ear head length.

### 4.4.6 Ear head diameter

None of the crosses observed significant positive standard heterosis (%) for ear head diameter (Table 4.4.3) in any of the three environment and pooled analysis. The standard heterosis ranged from -49.00 (ICMA 30209 x BIB 481-500) to 5.67 (ICMA 98222 x BIB 511-520) in $E_1$, -69.57 (ICMA 30209 x BIB 481-500) to 2.17 (ICMA 98222 x BIB 481-500) in $E_2$, -76.88 (ICMA 30200 x BIB 551-560) to 2.42 (ICMA 98222 x BIB 481-500) in $E_3$ and -64.36 (ICMA 30209 x BIB 481-500) to 0.36 (ICMA 98222 x BIB 481-500) in pooled analysis.

### 4.4.7 Test weight

The significant positive standard heterosis (%) for test weight (Table 4.4.3) was observed in 21 crosses in $E_1$, 26 crosses in $E_2$, 21 crosses in $E_3$ and 25 crosses in pooled analysis. The standard heterosis ranged from -50.05 (ICMA 97444 x BIB 551-560) to 29.97 (ICMA 88004 x BIB 501-510 and ICMA 98222 x BIB 561-570) in $E_1$, -50.55 (ICMA 97444 x BIB 551-560) to 30.27 (ICMA 98222 x BIB 481-500) in $E_2$, -52.13 (ICMA 97444 x BIB 551-560) to 31.22 (ICMA 98222 x BIB 561-570) in $E_3$ and -50.91 (ICMA ICMA 97444 x BIB 551-560) to 30.49 (ICMA 88004 x BIB 501-510) in pooled analysis. The cross ICMA 98222 x BIB 481-500, ICMA 30199 x BIB 481-500, ICMA 88004 x BIB 501-510, ICMA 98222 x BIB 501-510, ICMA 30201 x BIB 501-510, ICMA 04999 x BIB 511-520, ICMA 88004 x BIB 511-520, ICMA 98222 x BIB 511-520, ICMA 10444 x BIB 511-520, ICMA 30201 x BIB 511-520, ICMA 98222 x BIB 531-540, ICMA 10444 x BIB 531-540, ICMA 30201 x BIB 531-540, ICMA 93333 x BIB 551-560, ICMA 98222 x BIB 561-570, ICMA 30902 x BIB 561-570 and ICMA 04999 x BIB 571-580 exhibited positive standard heterosis for test weight in all the environments as well as in pooled analysis. Hence, these crosses were considered as desirable for test weight.

#### 4.4.8 Ear head weight

Significant positive standard heterosis (%) for ear head weight (Table 4.4.3) was observed in 4 crosses in $E_1$, 21 crosses in $E_2$, 41 crosses in $E_3$ and 13 crosses in pooled analysis. It ranged from -81.25 (ICMA 10444 x BIB 481-550) to 57.50 (ICMA 30199 x BIB 511-520) in $E_1$, -63.75 (ICMA 30201 x BIB 481-500) to 200.02 (ICMA 30201 x BIB 561-570) in $E_2$, -63.15 (ICMA 30201 x BIB 481-500) to 389.42 (ICMA 30201 x BIB 561-570) in $E_3$ and -70.68 (ICMA 88004 x BIB 531-540) to 134.35 (ICMA 30201 x BIB 561-570) in pooled analysis. Crosses ICMA 30201 x BIB 511-520, ICMA 93333 x BIB 551-560 and ICMA 30201 x BIB 551-570 exhibited significant positive standard heterosis in each environment as well as over the environments and considered as desirable for ear head weight.

#### 4.4.9 Dry stover yield per plant

Significant positive standard heterosis (%) for dry stover yield per plant (Table 4.3.4) was observed 16 crosses in $E_1$, 20 crosses in $E_2$, 35 crosses in $E_3$ and 22 crosses in pooled analysis. The standard heterosis ranged from – 68.05 (ICMA 30209 x BIB 481-500) to 73.61 (ICMA 93333 x BIB 531-540) in $E_1$, -63.89 (ICMA 04999 x BIB 551-560) to 180.56 (ICMA 98222 x BIB 481-500) in $E_2$, -82.61 (ICMA 04999 x BIB ICMA 04999 x BIB 551-560) to 334.76 (ICMA 30201 x BIB 481-500) in $E_3$ and -67.18 (ICMA 10444 x BIB 481-500) to 132.06 (ICMA 30201 x BIB 481-500) in pooled analysis. The crosses ICMA 30199 x BIB 481-500, ICMA 30201 x BIB 481-500, ICMA 10444 x BIB 511-520, ICMA 30209 x BIB 531-540 and ICMA 30201 x BIB 561-570 had exhibited significant positive and highest standard heterosis in each environment as well as over the environments and considered as desirable for dry stover yield per plant.

### 4.4.10 Grain yield per plant

Significant positive standard heterosis (%) for grain yield per plant (Table 4.4.4) was observed for 6 crosses in $E_1$, 18 crosses in $E_2$, 22 crosses in $E_3$ and 7 crosses in pooled analysis. It ranged from -75.00 (ICMA 88004 x BIB 531-540) to 42.49 (ICMA 98222 x BIB 481-500) in $E_1$, -64.43 (ICMA 97444 x BIB 501-510) to 174.43 (ICMA 98222 x BIB 481-500) in $E_2$, -51.50 (ICMA 97444 x BIB 501-510) to 180.32 (ICMA 98222 x BIB 481-500) in $E_3$ and -60.11 (ICMA 30200 x BIB 511-520 and ICMA 88004 x BIB 531-540) to 101.39 (ICMA 98222 x BIB 481-500) in pooled analysis. Cross ICMA 98222 x BIB 481-500 (101.39%), ICMA 88004 x BIB 501-510 (71.61%), ICMA 10444 x BIB 511-520 (27.81%), ICMA 30201 x BIB 511-520 (27.5%), ICMA 93333 x BIB 551-560 (38.17%), ICMA 97444 x BIB 571-580 (36.5%) and ICMA 30199 x BIB 571-580 (32.86%) exhibited significant positive standard heterosis over the environments. Hence, these crosses were considered as desirable for grain yield per plant.

### 4.4.11 Harvest index

The significant positive standard heterosis (%) for harvest index (Table 4.4.4) was observed 3 crosses in $E_1$, 26 crosses in $E_2$, 36 crosses in $E_3$ and 22 crosses in pooled analysis. The standard heterosis ranged from -61.31 (ICMA 30199 x BIB 511-520) to 36.72 (ICMA 98222 x BIB 481-500) in $E_1$, -63.52 (ICMA 98222x BIB 561-570) to 197.22 (ICMA 93333 x BIB 571-580) in $E_2$, -71.99 (ICMA 98222 x BIB 561-570) to 198.94 (ICMA 98222 x BIB 481-500) in $E_3$ and -42.76 (ICMA 30199 x BIB 501-510) to 71.02 (ICMA 98222 x BIB 481-500) in pooled analysis.

### 4.4.12 Threshing index

The significant positive standard heterosis (%) for threshing index (Table 4.4.4) was observed 9 crosses in $E_1$, 21 crosses in $E_2$, 17 crosses in $E_3$ and 15 crosses in pooled analysis. The standard heterosis ranged from -66.35 (ICMA 30201 x BIB 561-570) to 112.62

**Table 4.4.1 Estimates of standard heterosis for days to 50% flowering, days to maturity and plant height**

| Crosses/hybrids | Days to 50% flowering | | | | Days to maturity | | | | Plant height | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled |
| ICMA 04999 × BIB 481-500 | -4.35 | -11.76** | -10.53** | -7.84** | -2.63 | -7.41** | -6.9** | -4.94** | 0 | 26.77** | 34.38** | 17.69** |
| ICMA 88004 × BIB 481-500 | -2.17 | -15.69** | -14.04** | -9.8** | -1.32 | -9.88** | -9.2** | -6.17** | 0 | 29.92** | 38.46** | 19.23** |
| ICMA 93333 × BIB 481-500 | -6.52 | -15.69** | -14.04** | -11.76** | -3.95 | -9.88** | -9.2** | -7.41** | -3.01 | 32.28** | 45.47** | 20.77** |
| ICMA 97111 × BIB 481-500 | 8.7* | -17.65** | -15.79** | -7.84** | 5.26* | -11.11** | -10.34** | -4.94** | 4.82** | 22.83** | 29.43** | 16.92** |
| ICMA 97444 × BIB 481-500 | -8.7* | 7.84** | 7.02** | 3.92 | -5.26* | 4.94** | 4.6** | 2.47 | 6.02** | 8.66 | 10.69 | 8.46 |
| ICMA 98222 × BIB 481-500 | -10.87* | -19.61** | -17.54** | -15.69** | -6.58* | -12.35** | -11.49** | -9.88** | -7.23** | 18.11* | 23.1** | 8.46 |
| ICMA 10444 × BIB 481-500 | 0 | 7.84** | 7.02** | 5.88* | 0 | 4.94** | 4.6** | 3.7* | -19.88** | 1.57 | 5.6 | -6.15 |
| ICMA 30199 × BIB 481-500 | 4.35 | -1.96 | -1.75 | 0 | 2.63 | -1.23 | -1.15 | 0 | -3.01 | 19.69** | 25.58** | 11.54* |
| ICMA 30200 × BIB 481-500 | -4.35 | -9.8** | -8.77** | -7.84** | -2.63 | -6.17** | -5.75** | -4.94** | -9.04** | 22.05** | 28.88** | 10.77 |
| ICMA 30201 × BIB 481-500 | 21.74** | -11.76** | -10.53** | 0 | 13.16** | -7.41** | -6.9** | 0 | -1.81 | 20.47** | 26.26** | 12.31* |
| ICMA 30209 × BIB 481-500 | 10.87* | 7.84** | 7.02** | 9.8** | 6.58* | 4.94** | 4.6** | 6.17** | -27.71** | -1.57 | -2.44 | -13.08* |
| ICMA 04999 × BIB 501-510 | 21.74** | 9.8** | 8.77** | 13.73** | 13.16** | 6.17** | 5.75** | 8.64** | -32.53** | -0.79 | -1.05 | -14.62** |
| ICMA 88004 × BIB 501-510 | -10.87* | -19.61** | -17.54** | -15.69** | -6.58* | -12.35** | -11.49** | -9.88** | -1.81 | 21.26** | 27.87** | 13.08* |
| ICMA 93333 × BIB 501-510 | -4.35 | -5.88* | -5.26* | -3.92 | -2.63 | -3.7* | -3.45* | -2.47 | 8.43** | 15.75* | 20.37* | 13.85* |
| ICMA 97111 × BIB 501-510 | -8.7* | -9.8** | -8.77** | -7.84** | -5.26* | -6.17** | -5.75** | -4.94** | -7.83** | 11.02 | 14.57 | 3.85 |
| ICMA 97444 × BIB 501-510 | -6.52 | -3.92 | -3.51 | -3.92 | -3.95 | -2.47 | -2.3 | -2.47 | 0.6 | 9.45 | 11.94 | 6.15 |
| ICMA 98222 × BIB 501-510 | -8.7* | -13.73** | -12.28** | -11.76** | -5.26* | -8.64** | -8.05** | -7.41** | -2.41 | 9.45 | 12.49 | 5.38 |
| ICMA 10444 × BIB 501-510 | -2.17 | -11.76** | -10.53** | -7.84** | -1.32 | -7.41** | -6.9** | -4.94** | -1.81 | 14.96* | 19.05* | 9.23 |
| ICMA 30199 × BIB 501-510 | 10.87* | 3.92 | 3.51 | 5.88* | 6.58* | 2.47 | 2.3 | 3.7* | 3.01 | 4.72 | 12.92 | 6.15 |
| ICMA 30200 × BIB 501-510 | 8.7* | 3.92 | 3.51 | 5.88* | 5.26* | 2.47 | 2.3 | 3.7* | -10.24** | -6.3 | -8.72 | -8.46 |
| ICMA 30201 × BIB 501-510 | 4.35 | 7.84** | 7.02** | 7.84** | 2.63 | 4.94** | 4.6** | 4.94** | -9.04** | -11.81 | -15.16 | -11.54* |

| Crosses/hybrids | Days to 50% flowering | | | | Days to maturity | | | | Plant height | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled |
| ICMA 30209 × BIB 501-510 | 8.7* | 7.84** | 7.02** | 7.84** | 5.26* | 4.94** | 4.6** | 4.94** | -3.61* | -9.45 | -12.88 | -7.69 |
| ICMA 04999 × BIB 511-520 | -8.7* | -19.61** | -17.54** | -15.69** | -5.26* | -12.35** | -11.49** | -9.88** | -13.25** | 6.3 | 8.17 | -1.54 |
| ICMA 88004 × BIB 511-520 | -8.7* | -21.57** | -19.3** | -15.69** | -5.26* | -13.58** | -12.64** | -9.88** | -10.84** | 11.02 | 13.91 | 2.31 |
| ICMA 93333 × BIB 511-520 | -6.52 | -19.61** | -17.54** | -13.73** | -3.95 | -12.35** | -11.49** | -8.64** | -7.83** | 20.47** | 26.1** | 10 |
| ICMA 97111 × BIB 511-520 | -8.7* | 1.96 | 1.75 | 0 | -5.26* | 1.23 | 1.15 | 0 | -11.45** | -0.79 | -1.67 | -5.38 |
| ICMA 97444 × BIB 511-520 | -8.7* | -19.61** | -17.54** | -15.69** | -5.26* | -12.35** | -11.49** | -9.88** | -11.45** | 20.47** | 26.23** | 8.46 |
| ICMA 98222 × BIB 511-520 | 0 | 5.88* | 5.26* | 3.92 | 0 | 3.7* | 3.45* | 2.47 | -22.89** | 5.51 | 6.92 | -6.15 |
| ICMA 10444 × BIB 511-520 | 6.52 | -9.8** | -8.77** | -3.92 | 3.95 | -6.17** | -5.75** | -2.47 | -17.47** | 10.24 | 12.96 | -0.77 |
| ICMA 30199 × BIB 511-520 | 0 | 1.96 | 1.75 | 1.96 | 0 | 1.23 | 1.15 | 1.23 | -10.84** | 7.09 | 9.17 | 0 |
| ICMA 30200 × BIB 511-520 | 15.22** | 5.88* | 5.26* | 9.8** | 9.21** | 3.7* | 3.45* | 6.17** | -27.11** | -0.79 | -0.74 | -12.31* |
| ICMA 30201 × BIB 511-520 | -2.17 | -11.76** | -10.53** | -7.84** | -1.32 | -7.41** | -6.9** | -4.94** | -3.01 | 14.96* | 19.04* | 8.46 |
| ICMA 30209 × BIB 511-520 | 4.35 | -9.8** | -8.77** | -3.92 | 2.63 | -6.17** | -5.75** | -2.47 | -1.2 | 20.47** | 26.96** | 13.08* |
| ICMA 04999 × BIB 531-540 | 2.17 | 5.88* | 5.26* | 5.88* | 1.32 | 3.7* | 3.45* | 3.7* | 3.01 | -3.94 | -5.49 | -1.54 |
| ICMA 88004 × BIB 531-540 | 17.39** | 7.84** | 7.02** | 11.76** | 10.53** | 4.94** | 4.6** | 7.41** | -31.33** | -0.79 | -0.9 | -13.85* |
| ICMA 93333 × BIB 531-540 | -6.52 | -17.65** | -15.79** | -13.73** | -3.95 | -11.11** | -10.34** | -8.64** | 6.63** | 28.35** | 36.65** | 21.54** |
| ICMA 97111 × BIB 531-540 | -6.52 | 3.92 | 3.51 | 1.96 | -3.95 | 2.47 | 2.3 | 1.23 | -1.2 | 1.57 | 2.07 | 0.77 |
| ICMA 97444 × BIB 531-540 | -8.7* | -19.61** | -17.54** | -15.69** | -5.26* | -12.35** | -11.49** | -9.88** | 0 | 22.05** | 28.4** | 14.62** |
| ICMA 98222 × BIB 531-540 | -8.7* | -11.76** | -10.53** | -9.8** | -5.26* | -7.41** | -6.9** | -6.17** | -3.61* | 18.11* | 23.25** | 10 |
| ICMA 10444 × BIB 531-540 | 0 | -7.84** | -7.02** | -3.92 | 0 | -4.94** | -4.6** | -2.47 | 2.41 | 14.17* | 18.54* | 10 |
| ICMA 30199 × BIB 531-540 | 6.52 | -1.96 | -1.75 | 1.96 | 3.95 | -1.23 | -1.15 | 1.23 | 2.41 | 16.54* | 21.09* | 11.54* |
| ICMA 30200 × BIB 531-540 | 0 | -11.76** | -10.53** | -7.84** | 0 | -7.41** | -6.9** | -4.94** | 0.6 | 14.96* | 19.25* | 10 |
| ICMA 30201 × BIB 531-540 | -6.52 | -9.8** | -8.77** | -7.84** | -3.95 | -6.17** | -5.75** | -4.94** | -0.6 | 22.83** | 29.76** | 14.62** |

| Crosses/hybrids | Days to 50% flowering | | | | Days to maturity | | | | Plant height | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled |
| ICMA 30209 × BIB 531-540 | 0 | -5.88* | -5.26* | -3.92 | 0 | -3.7* | -3.45* | -2.47 | 2.41 | 16.54* | 21.62* | 11.54* |
| ICMA 04999 × BIB 551-560 | 13.04** | 5.88* | 5.26* | 7.84** | 7.89** | 3.7* | 3.45* | 4.94** | -31.93** | 3.15 | 4.3 | -11.54* |
| ICMA 88004 × BIB 551-560 | -6.52 | -11.76** | -10.53** | -9.8** | -3.95 | -7.41** | -6.9** | -6.17** | 4.82** | 20.47** | 26.87** | 15.38** |
| ICMA 93333 × BIB 551-560 | -8.7* | -15.69** | -14.04** | -11.76** | -5.26* | -9.88** | -9.2** | -7.41** | 0.6 | 28.35** | 37.27** | 18.46** |
| ICMA 97111 × BIB 551-560 | 17.39** | 5.88* | 5.26* | 9.8** | 10.53** | 3.7* | 3.45* | 6.17** | -30.12** | -3.15 | -3.9 | -14.62** |
| ICMA 97444 × BIB 551-560 | 17.39** | 7.84** | 7.02** | 11.76** | 10.53** | 4.94** | 4.6** | 7.41** | -25.9** | -10.24 | -13.8 | -17.69** |
| ICMA 98222 × BIB 551-560 | -6.52 | -9.8** | -8.77** | -7.84** | -3.95 | -6.17** | -5.75** | -4.94** | -5.42** | 11.02 | 13.77 | 4.62 |
| ICMA 10444 × BIB 551-560 | 0 | -7.84** | -7.02** | -3.92 | 0 | -4.94** | -4.6** | -2.47 | -12.05** | 14.17* | 18.6* | 3.85 |
| ICMA 30199 × BIB 551-560 | 8.7* | 0 | 0 | 3.92 | 5.26* | 0 | 0 | 2.47 | -3.61* | 17.32* | 22.61* | 10 |
| ICMA 30200 × BIB 551-560 | 4.35 | 3.92 | 3.51 | 3.92 | 2.63 | 2.47 | 2.3 | 2.47 | -10.84** | 2.36 | 2.81 | -3.08 |
| ICMA 30201 × BIB 551-560 | 0 | -7.84** | -7.02** | -3.92 | 0 | -4.94** | -4.6** | -2.47 | -7.23** | 18.9** | 24.75** | 9.23 |
| ICMA 30209 × BIB 551-560 | 4.35 | -7.84** | -7.02** | -3.92 | 2.63 | -4.94** | -4.6** | -2.47 | 3.01 | 25.2** | 33.15** | 17.69** |
| ICMA 04999 × BIB 561-570 | 0 | 3.92 | 3.51 | 3.92 | 0 | 2.47 | 2.3 | 2.47 | -15.06** | -3.15 | -3.96 | -8.46 |
| ICMA 88004 × BIB 561-570 | -6.52 | -19.61** | -17.54** | -13.73** | -3.95 | -12.35** | -11.49** | -8.64** | -3.61* | 15.75* | 20.57* | 8.46 |
| ICMA 93333 × BIB 561-570 | -4.35 | -15.69** | -14.04** | -11.76** | -2.63 | -9.88** | -9.2** | -7.41** | -0.6 | 15.75* | 20.8* | 10 |
| ICMA 97111 × BIB 561-570 | -4.35 | -17.65** | -15.79** | -11.76** | -2.63 | -11.11** | -10.34** | -7.41** | -2.41 | 18.11* | 23.7** | 10.77 |
| ICMA 97444 × BIB 561-570 | -6.52 | -11.76** | -10.53** | -9.8** | -3.95 | -7.41** | -6.9** | -6.17** | -2.41 | 6.3 | 7.9 | 3.08 |
| ICMA 98222 × BIB 561-570 | -8.7* | -19.61** | -17.54** | -15.69** | -5.26* | -12.35** | -11.49** | -9.88** | -13.25** | 7.87 | 10.23 | -0.77 |
| ICMA 10444 × BIB 561-570 | 8.7* | -1.96 | -1.75 | 1.96 | 5.26* | -1.23 | -1.15 | 1.23 | -19.88** | -1.57 | 4.43 | -7.69 |
| ICMA 30199 × BIB 561-570 | 10.87* | 0 | 0 | 3.92 | 6.58* | 0 | 0 | 2.47 | -10.84** | 6.3 | 7.91 | -0.77 |
| ICMA 30200 × BIB 561-570 | 0 | -9.8** | -8.77** | -5.88* | 0 | -6.17** | -5.75** | -3.7* | -13.86** | 12.6 | 15.84 | 2.31 |
| ICMA 30201 × BIB 561-570 | 6.52 | -7.84** | -7.02** | -1.96 | 3.95 | -4.94** | -4.6** | -1.23 | -13.25** | 11.02 | 14.51 | 1.54 |

| Crosses/hybrids | Days to 50% flowering | | | | Days to maturity | | | | Plant height | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled |
| ICMA 30209 × BIB 561-570 | 2.17 | -9.8** | -8.77** | -5.88* | 1.32 | -6.17** | -5.75** | -3.7* | -10.24** | 8.66 | 11.23 | 1.54 |
| ICMA 04999 × BIB 571-580 | -4.35 | -9.8** | -8.77** | -7.84** | -2.63 | -6.17** | -5.75** | -4.94** | -9.04** | 7.09 | 9.2 | 0.77 |
| ICMA 88004 × BIB 571-580 | -6.52 | -15.69** | -14.04** | -11.76** | -3.95 | -9.88** | -9.2** | -7.41** | 2.41 | 18.11* | 23.78** | 13.08* |
| ICMA 93333 × BIB 571-580 | -8.7* | -13.73** | -12.28** | -11.76** | -5.26* | -8.64** | -8.05** | -7.41** | -2.41 | 21.26** | 27.69** | 13.08* |
| ICMA 97111 × BIB 571-580 | -10.87* | -15.69** | -14.04** | -13.73** | -6.58* | -9.88** | -9.2** | -8.64** | -3.01 | 11.02 | 14.55 | 6.15 |
| ICMA 97444 × BIB 571-580 | -6.52 | -15.69** | -14.04** | -11.76** | -3.95 | -9.88** | -9.2** | -7.41** | -1.2 | 15.75* | 20.01* | 10 |
| ICMA 98222 × BIB 571-580 | -4.35 | -13.73** | -12.28** | -9.8** | -2.63 | -8.64** | -8.05** | -6.17** | -13.86** | 3.15 | 3.85 | -3.85 |
| ICMA 10444 × BIB 571-580 | 2.17 | -5.88* | -5.26* | -1.96 | 1.32 | -3.7* | -3.45* | -1.23 | -10.84** | 3.94 | 4.91 | -2.31 |
| ICMA 30199 × BIB 571-580 | 8.7* | -1.96 | -1.75 | 1.96 | 5.26* | -1.23 | -1.15 | 1.23 | -9.04** | 19.69** | 25.3** | 9.23 |
| ICMA 30200 × BIB 571-580 | 0 | -9.8** | -8.77** | -5.88* | 0 | -6.17** | -5.75** | -3.7* | -9.64** | 7.09 | 8.65 | 0.77 |
| ICMA 30201 × BIB 571-580 | 4.35 | -1.96 | -1.75 | 0 | 2.63 | -1.23 | -1.15 | 0 | -5.42** | 3.15 | 3.63 | 0 |
| ICMA 30209 × BIB 571-580 | 4.35 | -9.8** | -8.77** | -3.92 | 2.63 | -6.17** | -5.75** | -2.47 | -1.81 | 5.51 | 6.59 | 3.08 |
| RHB - 177 | 2.17 | -9.8** | -8.77** | -5.88* | 1.32 | -6.17** | -5.75** | -3.7* | 4.22* | 7.87 | 9.64 | 6.92 |
| BHB - 1602 | 2.17 | 1.96 | 1.75 | 1.96 | 1.32 | 1.23 | 1.15 | 1.23 | 0 | 2.36 | 3.07 | 1.54 |

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

**Table 4.4.2 Estimates of standard heterosis for productive tillers per plant, ear head length and ear head diameter**

| Crosses/hybrids | productive tillers per plant | | | | Ear head length | | | | Ear head diameter | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled |
| ICMA 04999 × BIB 481-500 | -8.11 | 6.67 | 0 | -4.76 | -12.4** | -10 | -12.84* | -11.76* | -16.67** | -30.43** | -33.91** | -26.55** |
| ICMA 88004 × BIB 481-500 | -27.03 | -13.33 | 0 | -19.05 | -45.74** | -4.78 | -6.16 | -21.27** | -15.67** | -44.57** | -63.03** | -39.64** |
| ICMA 93333 × BIB 481-500 | -24.32 | 53.33* | 36.36 | 4.76 | -21.32** | -25.22** | -42.35** | -28.05** | -24.33** | -27.54** | -30.33** | -27.27** |
| ICMA 97111 × BIB 481-500 | -2.7 | 0 | 45.45* | 4.76 | -5.04 | -17.39** | -34.36** | -17.19** | -21** | -25.36** | -28.11** | -24.73** |
| ICMA 97444 × BIB 481-500 | -8.11 | 53.33* | 118.18** | 28.57 | -0.39 | -8.26 | -10.45 | -5.88 | -14.33** | -67.39** | -74.67** | -50.18** |
| ICMA 98222 × BIB 481-500 | -8.11 | 193.33** | 236.36** | 80.95** | 14.34** | 32.17** | 42.52** | 28.05** | -2.33 | 2.17 | 2.46 | 0.36 |
| ICMA 10444 × BIB 481-500 | -5.41 | -13.33 | -9.09 | -9.52 | -15.5** | -29.57** | -44.35** | -28.05** | -50** | -66.3** | -73.54** | -62.55** |
| ICMA 30199 × BIB 481-500 | 16.22 | 146.67** | 145.45** | 71.43** | -19.38** | -20** | -20.32** | -19.91** | -24.33** | -19.2** | -21.26** | -21.82** |
| ICMA 30200 × BIB 481-500 | -2.7 | 140** | 136.36** | 57.14** | -5.04 | -6.09 | -7.59 | -5.88 | -15.67** | -27.17** | -21.99** | -21.45** |
| ICMA 30201 × BIB 481-500 | -5.41 | 166.67** | 136.36** | 61.9** | 8.91 | 9.57 | 12.67* | 9.95 | -11** | -20.29** | -22.43** | -17.45** |
| ICMA 30209 × BIB 481-500 | -64.86** | 0 | 9.09 | -38.1* | -13.57** | -39.13** | -56.85** | -33.94** | -49** | -69.57** | -77.25** | -64.36** |
| ICMA 04999 × BIB 501-510 | -27.03 | -6.67 | -9.09 | -19.05 | -10.08* | -40.87** | -34.19** | -27.15** | -47.67** | -67.39** | -74.99** | -62.55** |
| ICMA 88004 × BIB 501-510 | 24.32 | 33.33 | 45.45* | 28.57 | 16.67** | 18.26** | 23.92** | 19** | -15.67** | -5.07 | -5.76 | -9.09 |
| ICMA 93333 × BIB 501-510 | -13.51 | 33.33 | 9.09 | 0 | -18.22** | -2.17 | -2.45 | -8.6 | -13.33** | -55.43** | -61.62** | -42.18** |
| ICMA 97111 × BIB 501-510 | 21.62 | -33.33 | -9.09 | 4.76 | 6.98 | 14.35** | 19.01** | 12.67* | -10** | -19.57** | -21.75** | -16.73** |
| ICMA 97444 × BIB 501-510 | -5.41 | 6.67 | 0 | 0 | 8.53 | -9.13 | -11.87* | -3.17 | -5.67 | -28.99** | -32.18** | -21.45** |
| ICMA 98222 × BIB 501-510 | -27.03 | 33.33 | 9.09 | -4.76 | 5.04 | 3.04 | 3.88 | 4.07 | 1 | -11.59 | -12.65* | -7.27 |
| ICMA 10444 × BIB 501-510 | -29.73* | 60** | 109.09** | 14.29 | -6.2 | -6.09 | -7.65 | -6.33 | -13.33** | -36.96** | -40.8** | -29.45** |
| ICMA 30199 × BIB 501-510 | 2.7 | -20 | -9.09 | -4.76 | -12.79** | -25.65** | -33.5** | -22.62** | -12.33** | -68.84** | -76.28** | -50.55** |
| ICMA 30200 × BIB 501-510 | -18.92 | 0 | 9.09 | -9.52 | 5.81 | -32.61** | -38.93** | -19.46** | -7.67* | -68.48** | -75.92** | -48.73** |
| ICMA 30201 × BIB 501-510 | 10.81 | -20 | -9.09 | 0 | 6.2 | -33.04** | -43.21** | -20.36** | -14.33** | -67.75** | -75.23** | -50.55** |

| Crosses/hybrids | productive tillers per plant | | | | Ear head length | | | | Ear head diameter | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled |
| ICMA 30209 × BIB 501-510 | -5.41 | -33.33 | -9.09 | -14.29 | 1.94 | -37.83** | -49.71** | -25.34** | 1 | -67.75** | -75.31** | -45.09** |
| ICMA 04999 × BIB 511-520 | 13.51 | 93.33** | 109.09** | 47.62* | 0.39 | 19.13** | 25.23** | 13.57** | -17.67** | -19.93** | -21.99** | -19.64** |
| ICMA 88004 × BIB 511-520 | -2.7 | 26.67 | 45.45* | 14.29 | 8.91 | -12.61* | -16.15** | -4.98 | -15.67** | -35.14** | -38.99** | -29.09** |
| ICMA 93333 × BIB 511-520 | 32.43* | 73.33** | 118.18** | 57.14** | -13.18** | 1.74 | 2.23 | -4.07 | -21** | -29.35** | -32.5** | -27.27** |
| ICMA 97111 × BIB 511-520 | 10.81 | 0 | 9.09 | 9.52 | -4.26 | -37.39** | -49.2** | -27.6** | -16.67** | -68.48** | -75.92** | -52** |
| ICMA 97444 × BIB 511-520 | -13.51 | 173.33** | 181.82** | 66.67** | -9.3* | 2.17 | 3.31 | -1.81 | -19** | -31.88** | -35.28** | -28.36** |
| ICMA 98222 × BIB 511-520 | -27.03 | 0 | 0 | -14.29 | -6.59 | -47.39** | -62.16** | -35.29** | 5.67 | -67.39** | -74.71** | -42.91** |
| ICMA 10444 × BIB 511-520 | -18.92 | 133.33** | 109.09** | 38.1* | 8.53 | 2.17 | 2.85 | 4.98 | -15.67** | -28.99** | -32.06** | -25.09** |
| ICMA 30199 × BIB 511-520 | -18.92 | 20 | 27.27 | 0 | -20.54** | -43.48** | -57.02** | -38.01** | -10** | -30.07** | -33.47** | -24** |
| ICMA 30200 × BIB 511-520 | -16.22 | -6.67 | -9.09 | -14.29 | -23.64** | -46.09** | -60.05** | -41.18** | -44.33** | -65.94** | -73.14** | -60.36** |
| ICMA 30201 × BIB 511-520 | 62.16** | 133.33** | 127.27** | 90.48** | -4.26 | -2.17 | -2.45 | -3.17 | -7.67* | -13.77* | -15.02* | -12* |
| ICMA 30209 × BIB 511-520 | -2.7 | 106.67** | 127.27** | 47.62* | -1.16 | -1.3 | -1.37 | -1.36 | -6.67 | -41.67** | -46.11** | -30.18** |
| ICMA 04999 × BIB 531-540 | 70.27** | -33.33 | -9.09 | 33.33 | 5.43 | -30.87** | -40.53** | -19.46** | -17.67** | -67.03** | -74.39** | -51.27** |
| ICMA 88004 × BIB 531-540 | 24.32 | 60** | 27.27 | 33.33 | -25.97** | -30** | -39.04** | -30.77** | -51** | -64.49** | -71.65** | -61.82** |
| ICMA 93333 × BIB 531-540 | 43.24** | 33.33 | 18.18 | 38.1* | 3.49 | 10 | 13.07* | 8.14 | -31** | -41.67** | -46.19** | -39.27** |
| ICMA 97111 × BIB 531-540 | 0 | -33.33 | -9.09 | -9.52 | -0.39 | -50** | -65.53** | -34.84** | -21** | -63.41** | -70.4** | -50.18** |
| ICMA 97444 × BIB 531-540 | 18.92 | 46.67* | 27.27 | 28.57 | -5.04 | 1.74 | 2.23 | -0.9 | -27.67** | -40.94** | -45.47** | -37.45** |
| ICMA 98222 × BIB 531-540 | -8.11 | 6.67 | 0 | -4.76 | 11.24* | 4.78 | 6.28 | 7.69 | -14.33** | -35.14** | -39.07** | -28.73** |
| ICMA 10444 × BIB 531-540 | -21.62 | -13.33 | -9.09 | -19.05 | -1.16 | 6.96 | 9.3 | 4.52 | -5.67 | -19.93** | -22.03** | -15.27** |
| ICMA 30199 × BIB 531-540 | -18.92 | 13.33 | 9.09 | -4.76 | -13.18** | -13.91* | -17.87** | -14.48** | -14.33** | -27.54** | -30.45** | -23.64** |
| ICMA 30200 × BIB 531-540 | -2.7 | 6.67 | 9.09 | 0 | 6.98 | 3.48 | 4.62 | 4.98 | -26.67** | -26.81** | -29.84** | -27.64** |
| ICMA 30201 × BIB 531-540 | 5.41 | 33.33 | 18.18 | 14.29 | -1.94 | 4.35 | 5.82 | 2.26 | -24.33** | -21.74** | -24.24** | -23.64** |

| Crosses/hybrids | productive tillers per plant | | | | Ear head length | | | | Ear head diameter | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled |
| ICMA 30209 × BIB 531-540 | 48.65** | 86.67** | 72.73** | 61.9** | 4.26 | 3.91 | -2.45 | 2.26 | -13.33** | -38.41** | -42.53** | -30.55** |
| ICMA 04999 × BIB 551-560 | 16.22 | -33.33 | -9.09 | 0 | -25.58** | -59.57** | -78.03** | -51.13** | -42.33** | -67.75** | -75.43** | -60.73** |
| ICMA 88004 × BIB 551-560 | 18.92 | 20 | 18.18 | 19.05 | 1.55 | 10 | 13.53* | 7.69 | -12.33** | -22.1** | -24.33** | -19.27** |
| ICMA 93333 × BIB 551-560 | 24.32 | 0 | 18.18 | 19.05 | 15.5** | 33.91** | 44.52** | 29.41** | -17.67** | -1.45 | -1.61 | -7.64 |
| ICMA 97111 × BIB 551-560 | -70.27** | -13.33 | -9.09 | -47.62* | -32.17** | -46.96** | -61.3** | -44.8** | -42.33** | -67.03** | -74.51** | -60.36** |
| ICMA 97444 × BIB 551-560 | -29.73* | -13.33 | -9.09 | -23.81 | -25.58** | -41.74** | -54.39** | -38.91** | -42.33** | -66.67** | -74.14** | -60** |
| ICMA 98222 × BIB 551-560 | -18.92 | 6.67 | 36.36 | -4.76 | 12.79** | 18.26** | 23.86** | 17.65** | -12.33** | -20.65** | -22.96** | -18.55** |
| ICMA 10444 × BIB 551-560 | 5.41 | 46.67* | 54.55* | 23.81 | -5.04 | 36.96** | 33.16** | 19.46** | -5.67 | -29.71** | -32.98** | -22.18** |
| ICMA 30199 × BIB 551-560 | -10.81 | 46.67* | 54.55* | 14.29 | -5.04 | 5.65 | 7.65 | 2.26 | -16.67** | -19.2** | -21.43** | -18.91** |
| ICMA 30200 × BIB 551-560 | 0 | -20 | -9.09 | -4.76 | 6.2 | -39.57** | -51.54** | -24.89** | -17.67** | -69.2** | -76.88** | -52.73** |
| ICMA 30201 × BIB 551-560 | 18.92 | 180** | 200** | 90.48** | -10.08* | 30.43** | 34.53** | 15.84** | -21** | -39.86** | -44.14** | -34.18** |
| ICMA 30209 × BIB 551-560 | -10.81 | 80** | 100** | 28.57 | -6.2 | 20** | 26.71** | 11.76* | -14.33** | -35.14** | -38.82** | -28.73** |
| ICMA 04999 × BIB 561-570 | 43.24** | 53.33* | 36.36 | 42.86* | -3.49 | -10.43 | -13.53* | -8.6 | -19** | -27.54** | -30.69** | -25.45** |
| ICMA 88004 × BIB 561-570 | 5.41 | 66.67** | 81.82** | 33.33 | -9.3* | -6.52 | -8.33 | -8.14 | -12.33** | -27.54** | -30.65** | -22.91** |
| ICMA 93333 × BIB 561-570 | -10.81 | 60** | 72.73** | 19.05 | 3.1 | 7.83 | 10.22 | 6.79 | -32.33** | -40.58** | -44.99** | -38.91** |
| ICMA 97111 × BIB 561-570 | 37.84* | 66.67** | 81.82** | 52.38** | -3.88 | 0.43 | 0.68 | -1.36 | -24.33** | -47.1** | -52.28** | -40.36** |
| ICMA 97444 × BIB 561-570 | 27.03 | 106.67** | 109.09** | 61.9** | -13.18** | -29.57** | -13.81* | -19** | -29** | -63.77** | -71** | -53.45** |
| ICMA 98222 × BIB 561-570 | 10.81 | 73.33** | 90.91** | 38.1* | -9.3* | -3.91 | -5.08 | -6.33 | -21** | -3.99 | -4.47 | -10.55 |
| ICMA 10444 × BIB 561-570 | 18.92 | 20 | 45.45* | 23.81 | 5.04 | 0.43 | -7.02 | 0.45 | -10** | -47.1** | -52.36** | -35.27** |
| ICMA 30199 × BIB 561-570 | 29.73* | 86.67** | 109.09** | 57.14** | -17.44** | -14.78** | -18.95** | -16.74** | -14.33** | -41.3** | -45.83** | -32.73** |
| ICMA 30200 × BIB 561-570 | 32.43* | 166.67** | 118.18** | 80.95** | -3.88 | 6.96 | 9.42 | 3.62 | -13.33** | -35.51** | -39.59** | -28.73** |
| ICMA 30201 × BIB 561-570 | 13.51 | 6.67 | 0 | 9.52 | -6.98 | 6.96 | 9.08 | 2.26 | -4.33 | -25.36** | -27.99** | -18.55** |

| Crosses/hybrids | productive tillers per plant | | | | Ear head length | | | | Ear head diameter | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled |
| ICMA 30209 × BIB 561-570 | 27.03 | 60** | 45.45* | 38.1* | -4.26 | -3.48 | -4.28 | -4.07 | -16.67** | -28.62** | -31.61** | -25.09** |
| ICMA 04999 × BIB 571-580 | 35.14* | 80** | 118.18** | 61.9** | 5.04 | 2.61 | -5.94 | 1.36 | -21** | -26.81** | -29.68** | -25.45** |
| ICMA 88004 × BIB 571-580 | 40.54** | 100** | 118.18** | 66.67** | -12.4** | 0 | 0.11 | -4.98 | -21** | -34.42** | -38.06** | -30.55** |
| ICMA 93333 × BIB 571-580 | 2.7 | 20 | 54.55* | 14.29 | -12.4** | 4.78 | 6.45 | -1.36 | -22.33** | -32.61** | -36.21** | -30.18** |
| ICMA 97111 × BIB 571-580 | 40.54** | 6.67 | 0 | 23.81 | -1.16 | -0.43 | -0.4 | -0.45 | -19** | -37.32** | -41.56** | -32** |
| ICMA 97444 × BIB 571-580 | 2.7 | 86.67** | 36.36 | 28.57 | -9.3* | -6.09 | -7.53 | -7.69 | -21** | -38.41** | -42.57** | -33.45** |
| ICMA 98222 × BIB 571-580 | -13.51 | 53.33* | 63.64** | 14.29 | -14.73** | -13.04* | -16.84** | -14.48** | -4.33 | -7.61 | -8.5 | -6.91 |
| ICMA 10444 × BIB 571-580 | -8.11 | 0 | 9.09 | -4.76 | -0.39 | 0.87 | -6.05 | -1.36 | -4.33 | 0.36 | 0.44 | -1.45 |
| ICMA 30199 × BIB 571-580 | 29.73* | 100** | 127.27** | 61.9** | -18.6** | -13.04* | -16.78** | -16.29** | -13.33** | -6.16 | -6.77 | -9.09 |
| ICMA 30200 × BIB 571-580 | 5.41 | 20 | 45.45* | 14.29 | -8.91 | 1.74 | 2.45 | -2.26 | -21** | -11.96 | -13.29* | -15.64** |
| ICMA 30201 × BIB 571-580 | 10.81 | 20 | 27.27 | 14.29 | -0.78 | 10.87* | 6.74 | 5.43 | -20** | -25.36** | -28.15** | -24.36** |
| ICMA 30209 × BIB 571-580 | 5.41 | -6.67 | -9.09 | 0 | -5.04 | -1.74 | -2.17 | -3.17 | -20** | -23.19** | -25.73** | -22.91** |
| RHB - 177 | 10.81 | 20 | 18.18 | 14.29 | -0.39 | 11.74* | 8.05 | 5.88 | -16.67** | -41.67** | -59.69** | -38.18** |
| BHB - 1602 | 16.22 | 20 | 9.09 | 14.29 | -17.44** | -12.61* | -16.38** | -15.38** | -4.33 | -19.57** | -21.83** | -14.91** |

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

**Table 4.4.3 Estimates of standard heterosis for test weight, ear head weight and dry stover yield per plant**

| Crosses/hybrids | Test weight | | | | Ear head weight | | | | Dry stover yield per plant | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled |
| ICMA 04999 × BIB 481-500 | -2.7 | 0.1 | 0.1 | -0.81 | -17.5 | 18.75 | 84.18** | 6.1 | 2.78 | 25 | 26.09 | 12.98 |
| ICMA 88004 × BIB 481-500 | -29.97** | -30.27** | -31.22** | -30.49** | -20 | 50.01** | 121.03** | 17.56 | -11.11 | 27.78* | 69.56** | 13.73 |
| ICMA 93333 × BIB 481-500 | 3.7 | 10.09** | 10.41* | 8.03** | -40** | 43.77** | 126.3** | 4.58 | -5.55 | 58.33** | 117.39** | 33.59* |
| ICMA 97111 × BIB 481-500 | -0.1 | -0.1 | -0.1 | -0.1 | -43.75** | 31.26* | 105.24** | -3.82 | -30.55* | 8.33 | 34.77* | -8.4 |
| ICMA 97444 × BIB 481-500 | -5.59** | -5.65** | -5.83 | -5.69** | -25* | -46.88** | -26.33 | -30.54* | 9.72 | -50** | -50.01** | -17.18 |
| ICMA 98222 × BIB 481-500 | 22.58** | 30.27** | 31.22** | 28.05** | 5 | 175.02** | 347.33** | 96.18** | 4.17 | 180.56** | 299.99** | 104.58** |
| ICMA 10444 × BIB 481-500 | -19.98** | -20.18** | -20.81** | -20.33** | -81.25** | -45.62** | -15.79 | -63.05** | -66.67** | -61.11** | -78.26** | -67.18** |
| ICMA 30199 × BIB 481-500 | 10.09** | 10.19** | 10.51* | 10.26** | -17.5 | 43.77** | 126.3** | 18.32 | 36.11** | 36.11** | 73.9** | 42.75** |
| ICMA 30200 × BIB 481-500 | -39.96** | -40.36** | -41.62** | -40.65** | -1.25 | 25.01 | 94.73** | 19.08 | 12.5 | 63.89** | 117.39** | 45.03** |
| ICMA 30201 × BIB 481-500 | -19.98** | -20.18** | -20.81** | -20.33** | -10 | -63.75** | -63.15** | -30.85* | 25* | 216.67** | 334.76** | 132.06** |
| ICMA 30209 × BIB 481-500 | -27.67** | -27.95** | -28.82** | -28.15** | -80** | -49.99** | -26.33 | -64.88** | -68.05** | -44.44** | -52.17** | -58.78** |
| ICMA 04999 × BIB 501-510 | -8.19** | -8.27** | -8.53 | -8.33** | -75** | -49.99** | -26.33 | -61.83** | -63.89** | -44.44** | -52.17** | -56.49** |
| ICMA 88004 × BIB 501-510 | 29.97** | 30.27** | 31.22** | 30.49** | -2.5 | 156.27** | 326.27** | 83.97** | 11.11 | 108.33** | 186.94** | 68.7** |
| ICMA 93333 × BIB 501-510 | 0.7 | 0.71 | 0.73 | 0.71 | -32.5** | -31.24* | 0 | -27.48 | 5.55 | -8.33 | 4.34 | 1.53 |
| ICMA 97111 × BIB 501-510 | 11.59** | 11.71** | 12.07* | 10.67** | 0 | 112.51** | 221.03** | 59.54** | -5.55 | -25 | -21.74 | -13.74 |
| ICMA 97444 × BIB 501-510 | -19.98** | -20.18** | -20.81** | -20.33** | -43.75** | -45** | -26.33 | -41.54** | 33.33** | -44.44** | -47.83** | -2.29 |
| ICMA 98222 × BIB 501-510 | 11.49** | 11.6** | 11.97* | 10.67** | -7.5 | 137.52** | 284.18** | 70.23** | -33.33** | -22.23 | -17.4 | -27.49 |
| ICMA 10444 × BIB 501-510 | 2.8 | 2.83 | 2.91 | 2.44 | -40** | 31.26* | 105.24** | -1.53 | -24.3 | 27.78* | 60.86** | 4.96 |
| ICMA 30199 × BIB 501-510 | -1.4 | 0.71 | 0.73 | 0 | -30** | 6.26 | 63.15** | -7.64 | 4.17 | 150** | 260.86** | 89.31** |
| ICMA 30200 × BIB 501-510 | -9.29** | -9.38** | -9.68 | -9.45** | -37.5** | -60.62** | -42.12* | -43.82** | -26.39* | -61.11** | -78.26** | -45.04** |
| ICMA 30201 × BIB 501-510 | 4.9* | 10.09** | 10.41* | 8.43** | -5 | -46.24** | -26.33 | -18.16 | 5.55 | -61.11** | -78.26** | -27.48 |

| Crosses/hybrids | Test weight | | | | Ear head weight | | | | Dry stover yield per plant | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled |
| ICMA 30209 × BIB 501-510 | -29.27** | -29.57** | -30.49** | -29.78** | -25* | -60.62** | -36.85* | -35.42* | 13.89 | -61.11** | -78.26** | -22.9 |
| ICMA 04999 × BIB 511-520 | 9.99** | 10.09** | 10.41* | 10.16** | -10 | 31.26* | 105.24** | 16.79 | -8.33 | 52.78** | 113.03** | 29.77* |
| ICMA 88004 × BIB 511-520 | 19.88** | 20.08** | 20.71** | 20.22** | -35** | 150.01** | 321** | 61.83** | -25* | -33.33** | -34.79* | -29.01* |
| ICMA 93333 × BIB 511-520 | 0.2 | 0.2 | 0.21 | 0.2 | -25* | 6.26 | 63.15** | -4.58 | -5.55 | -5.56 | 8.69 | -3.06 |
| ICMA 97111 × BIB 511-520 | -10.09** | -10.19** | -10.51* | -10.26** | -27.5* | -45** | -26.33 | -31.6* | -31.95* | -61.11** | -78.26** | -48.09** |
| ICMA 97444 × BIB 511-520 | -19.98** | -20.18** | -20.81** | -20.33** | -17.5 | 68.76** | 168.39** | 30.53* | -5.55 | 36.11** | 69.56** | 19.08 |
| ICMA 98222 × BIB 511-520 | 7.29** | 10.09** | 10.41* | 9.25** | -17.5 | -49.99** | -26.33 | -26.72 | -18.05 | -58.33** | -73.91** | -38.93** |
| ICMA 10444 × BIB 511-520 | 9.99** | 10.09** | 10.41* | 9.04** | -10 | 150.01** | 342.06** | 80.15** | 38.89** | 91.67** | 126.07** | 68.69** |
| ICMA 30199 × BIB 511-520 | -19.88** | -20.08** | -20.71** | -20.22** | 57.5** | 25.01 | 94.73** | 54.96** | 112.5** | 13.89 | 39.13* | 72.51** |
| ICMA 30200 × BIB 511-520 | -39.96** | -40.36** | -41.62** | -40.65** | -80** | -63.75** | -47.36** | -71.3** | -68.05** | -61.11** | -78.26** | -67.94** |
| ICMA 30201 × BIB 511-520 | 10.19** | 10.29** | 10.61* | 10.37** | 57.5** | 43.77** | 136.82** | 65.65** | 30.55* | 25 | 56.51** | 33.58* |
| ICMA 30209 × BIB 511-520 | -17.08** | -17.26** | -17.79** | -17.38** | -2.5 | 37.5* | 115.76** | 24.42 | -4.17 | -11.11 | 0 | -5.34 |
| ICMA 04999 × BIB 531-540 | 11.49** | 11.6** | 11.97* | 11.69** | 15 | -46.88** | -31.58 | -6.87 | 55.55** | -61.11** | -78.26** | 0 |
| ICMA 88004 × BIB 531-540 | -39.16** | -39.56** | -40.79** | -39.84** | -80** | -61.24** | -47.36** | -70.68** | -66.67** | -55.56** | -69.57** | -64.12** |
| ICMA 93333 × BIB 531-540 | 2.3 | 2.32 | 2.39 | 2.34 | 5 | 56.25** | 152.6** | 38.93** | 73.61** | 5.56 | 34.77* | 48.09** |
| ICMA 97111 × BIB 531-540 | -19.88** | -20.08** | -20.71** | -20.22** | -22.5 | -49.99** | -26.33 | -29.77* | 15.28 | -52.78** | -65.21** | -17.56 |
| ICMA 97444 × BIB 531-540 | 1.5 | 1.51 | 1.56 | 1.52 | -10 | 18.75 | 47.36** | 5.34 | -8.33 | 5.56 | 26.09 | 1.53 |
| ICMA 98222 × BIB 531-540 | 17.58** | 20.18** | 20.81** | 18.39** | -2.5 | -37.5* | -10.55 | -12.21 | -25* | -58.33** | -10.88 | -31.68* |
| ICMA 10444 × BIB 531-540 | 9.99** | 10.09** | 10.41* | 10.16** | -25* | -37.5* | -10.55 | -25.95 | -16.67 | -25 | -13.04 | -18.32 |
| ICMA 30199 × BIB 531-540 | -9.19** | -9.28** | -9.57 | -9.35** | -32.5** | -25 | 10.51 | -24.43 | 15.28 | 0 | 17.39 | 11.45 |
| ICMA 30200 × BIB 531-540 | -3.6 | 0.2 | 0.21 | -1.02 | -52.5** | -37.5* | -10.55 | -42.76** | 16.67 | 41.67** | 82.6** | 35.11* |
| ICMA 30201 × BIB 531-540 | 19.98** | 20.18** | 20.81** | 20.33** | -12.5 | -53.12** | -42.12* | -26.72 | 1.39 | 100** | 134.77** | 51.9** |

| Crosses/hybrids | Test weight | | | | Ear head weight | | | | Dry stover yield per plant | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled |
| ICMA 30209 × BIB 531-540 | -9.69** | -9.79** | -10.09* | -9.86** | -3.75 | -6.24 | 89.45** | 9.15 | 41.67** | 66.67** | 121.73** | 62.59** |
| ICMA 04999 × BIB 551-560 | -38.46** | -38.85** | -40.06** | -39.13** | -71.25** | -63.75** | -47.36** | -65.95** | -63.89** | -63.89** | -82.61** | -67.18** |
| ICMA 88004 × BIB 551-560 | 0.1 | 0.1 | 0.1 | 0.1 | 0 | -43.75** | 42.09* | -4.59 | 27.78* | -25 | -21.74 | 4.58 |
| ICMA 93333 × BIB 551-560 | 29.87** | 30.17** | 31.11** | 30.39** | 32.51** | 168.76** | 352.57** | 112.2** | 76.39** | 22.23 | 52.17** | 57.25** |
| ICMA 97111 × BIB 551-560 | -25.57** | -25.83** | -26.64** | -26.02** | -72.5** | -63.75** | -47.36** | -66.72** | -55.55** | -58.33** | -73.91** | -59.54** |
| ICMA 97444 × BIB 551-560 | -50.05** | -50.55** | -52.13** | -50.91** | -80** | -49.99** | -26.33 | -64.88** | -66.67** | -61.11** | -78.26** | -67.18** |
| ICMA 98222 × BIB 551-560 | 0.1 | 0.1 | 0.1 | 0.1 | 2.51 | 31.26* | 42.09* | 15.27 | 2.78 | 50** | 95.64** | 32.06* |
| ICMA 10444 × BIB 551-560 | 4.3* | 4.34** | 4.47 | 3.76* | -22.5 | -25 | 10.51 | -18.33 | -5.55 | 50** | 95.64** | 27.48 |
| ICMA 30199 × BIB 551-560 | -19.58** | -19.78** | -20.4** | -19.92** | 15 | 12.51 | 47.36** | 19.08 | 20.83 | 33.33** | 69.56** | 32.82* |
| ICMA 30200 × BIB 551-560 | -24.68** | -24.92** | -25.7** | -25.1** | -30** | -61.24** | -57.91** | -41.69** | -9.72 | -61.11** | -78.26** | -35.88* |
| ICMA 30201 × BIB 551-560 | -49.25** | -49.75** | -51.3** | -50.1** | -20 | 0 | 52.6** | -4.59 | -8.33 | 41.67** | 82.6** | 21.37 |
| ICMA 30209 × BIB 551-560 | 2.3 | 2.32 | 2.39 | 2.34 | -7.5 | 3.13 | 26.3 | 0 | -4.17 | -5.56 | 4.34 | -3.06 |
| ICMA 04999 × BIB 561-570 | -0.6 | -0.61 | -0.62 | -0.61 | 7.5 | -28.13 | 0 | -2.29 | 2.78 | 2.78 | 47.82** | 10.68 |
| ICMA 88004 × BIB 561-570 | 1.1 | 0.71 | -30.49** | 0.91 | -20 | -31.24* | 5.24 | -19.08 | -12.5 | -5.56 | 134.77** | 15.27 |
| ICMA 93333 × BIB 561-570 | -7.69** | -7.77** | -8.01 | -7.83** | -50** | -18.75 | 5.24 | -34.35* | 5.55 | 8.33 | 52.17** | 14.5 |
| ICMA 97111 × BIB 561-570 | 20.08** | 11.2** | 20.92** | 17.38** | -35** | -43.75** | 0 | -32.06* | -31.95* | -16.67 | 43.47* | -14.51 |
| ICMA 97444 × BIB 561-570 | 0.2 | 2.42 | 2.5 | 1.73 | -17.5 | -31.24* | 0 | -18.32 | 43.05** | -30.56* | -21.74 | 11.45 |
| ICMA 98222 × BIB 561-570 | 29.97** | 24.52** | 31.22** | 28.56** | -10 | 143.77** | 289.42** | 70.98** | 15.28 | 100** | 173.9** | 66.41** |
| ICMA 10444 × BIB 561-570 | -14.59** | -14.73** | -15.19** | -14.84** | -15 | -43.75** | 5.24 | -19.08 | 26.39* | -41.67** | -47.83** | -5.34 |
| ICMA 30199 × BIB 561-570 | 6.59** | 6.66** | 6.87 | 6.71** | 7.5 | -18.75 | 21.03 | 3.05 | 20.83 | 25 | 56.51** | 28.24* |
| ICMA 30200 × BIB 561-570 | 3.3 | 3.33* | 3.43 | 3.35* | -7.5 | 31.26* | 105.24** | 18.32 | -2.78 | 0 | 17.39 | 1.53 |
| ICMA 30201 × BIB 561-570 | 4.3* | -2.42 | 4.47 | 2.13 | 47.51** | 200.02** | 389.42** | 134.35** | 31.95* | 175** | 278.24** | 114.5** |

| Crosses/hybrids | Test weight | | | | Ear head weight | | | | Dry stover yield per plant | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled |
| ICMA 30209 × BIB 561-570 | 9.69** | 6.16** | 10.09* | 8.64** | -12.5 | -34.37* | 26.3 | -12.21 | 0 | -36.11** | -39.13* | -16.8 |
| ICMA 04999 × BIB 571-580 | 7.99** | 10.19** | 10.51* | 9.55** | 7.5 | 0 | 57.88** | 12.97 | 19.45 | -2.78 | 23.91 | 14.12 |
| ICMA 88004 × BIB 571-580 | -9.29** | -9.38** | -9.68 | -9.45** | -7.5 | -12.49 | 52.6** | 0 | 20.83 | -2.78 | 13.04 | 12.98 |
| ICMA 93333 × BIB 571-580 | -16.18** | -16.35** | -16.86** | -16.46** | -10 | 31.26* | 84.18** | 13.74 | 1.39 | -52.78** | 108.69** | 5.34 |
| ICMA 97111 × BIB 571-580 | 3.9 | 8.58** | 8.84 | 7.11** | -5 | -49.99** | -26.33 | -19.08 | -12.5 | -44.44** | 17.39 | -16.03 |
| ICMA 97444 × BIB 571-580 | -3.2 | 0.2 | 0.21 | -0.91 | -5 | 25.01 | 57.88** | 11.45 | 25* | 22.23 | 91.3** | 35.88* |
| ICMA 98222 × BIB 571-580 | -23.58** | -23.81** | -24.56** | -23.98** | -20 | 31.26* | 99.97** | 9.92 | -16.67 | 2.78 | 21.73 | -4.58 |
| ICMA 10444 × BIB 571-580 | 9.59** | 9.69** | 9.99 | 9.76** | -20 | -6.24 | 42.09* | -7.64 | 6.95 | -11.11 | -17.4 | -2.29 |
| ICMA 30199 × BIB 571-580 | -4.6* | -4.64** | -4.79 | -4.67** | -5 | 25.01 | 73.67** | 13.74 | 16.67 | 58.33** | 73.9** | 38.16** |
| ICMA 30200 × BIB 571-580 | -2.3 | 0 | 0 | -0.71 | -22.5 | 53.14** | 121.03** | 16.79 | -5.55 | 41.67** | 95.64** | 25.19 |
| ICMA 30201 × BIB 571-580 | -19.88** | -20.08** | -20.71** | -20.22** | -17.5 | -6.24 | 42.09* | -6.11 | -8.33 | -5.56 | 8.69 | -4.58 |
| ICMA 30209 × BIB 571-580 | 2.4 | 2.93 | 6.66 | 3.96* | -10 | -25 | 15.79 | -9.92 | 26.39* | -33.33** | -34.79* | -0.77 |
| RHB - 177 | 2.3 | 2.32 | 2.39 | 2.34 | -20 | -9.38 | 36.82* | -9.16 | -11.11 | -11.11 | 0 | -9.16 |
| BHB - 1602 | -0.3 | 0.61 | 0.62 | 0.3 | -30** | -31.24* | -10.55 | -27.48 | -4.17 | -36.11** | -34.79* | -18.32 |

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

**Table 4.4.4 Estimates of standard heterosis for grain yield per plant, harvest index and threshing index**

| Crosses/hybrids | Grain yield per plant | | | | Harvest index | | | | Threshing index | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled |
| ICMA 04999 × BIB 481-500 | 0 | 16.67 | -3.05 | 3.64 | -2.76 | -6.48 | 99.86** | 25.07 | 22.01 | 0 | 28.47 | 15.36 |
| ICMA 88004 × BIB 481-500 | -25* | 38.9** | 30.32* | 1.39 | -16.35 | 8.73 | 10.36 | -0.29 | -5.7 | -6.68 | 10.74 | -1.59 |
| ICMA 93333 × BIB 481-500 | -45** | 33.33** | 34.86* | -10.39 | -42.06** | -12.11 | 5.42 | -18.47 | -8.77 | -6.79 | 10.59 | -2.72 |
| ICMA 97111 × BIB 481-500 | -35.01** | -11.1 | -3.05 | -23.05 | -5.49 | -17.98 | -26.76 | -15.74 | 15.49 | -31.79 | -20.67 | -12.45 |
| ICMA 97444 × BIB 481-500 | -10 | -35.57** | -21.23 | -18.55 | -17.78 | 31.26* | 27.91 | 11.74 | 19.79 | 23.2 | 22.41 | 21.79 |
| ICMA 98222 × BIB 481-500 | 42.49** | 174.43** | 180.32** | 101.39** | 36.72** | 2.13 | 198.94** | 71.02** | 35.54** | 1.08 | 104.9** | 41.32* |
| ICMA 10444 × BIB 481-500 | -60** | -36.67** | 1.5 | -42.69** | 18.79 | 64.24** | 95.06** | 55.77** | 112.62** | 17.76 | -8.35 | 43.32* |
| ICMA 30199 × BIB 481-500 | 9.99 | 33.33** | 57.59** | 24.7 | -18.9 | 0 | 18.75 | -1.83 | 31.97* | -6.79 | 11.09 | 11.46 |
| ICMA 30200 × BIB 481-500 | -20.01 | 16.67 | 12.14 | -4.78 | -29.58* | -27.51 | -27.82 | -28.37 | -19.67 | -4.28 | -9.71 | -11.07 |
| ICMA 30201 × BIB 481-500 | -25* | 105.57** | 43.95** | 20.78 | -39.15** | -34.07* | -19.95 | -32* | -15.63 | 474.95** | 4.8 | 177.28** |
| ICMA 30209 × BIB 481-500 | -71.01** | -37.77** | -24.23 | -53.94** | -9.5 | 13.64 | 67.87** | 20.26 | 48.4** | 27.99 | -8.35 | 25.09 |
| ICMA 04999 × BIB 501-510 | -65.01** | -38.9** | -33.32* | -52.53** | -3.44 | 10.14 | 48.68** | 15.94 | 38.43** | 25 | 22.41 | 28.91 |
| ICMA 88004 × BIB 501-510 | 25.5* | 158.9** | 92.41** | 71.61** | 13.98 | 25.18 | 170.89** | 62.25** | 29.12* | 6.73 | 80.68** | 34.66* |
| ICMA 93333 × BIB 501-510 | -25* | -36.67** | -48.5** | -32.31* | -29.15* | -29.81* | -25.9 | -28.45 | 12.72 | -4.5 | 20.55 | 8.27 |
| ICMA 97111 × BIB 501-510 | -15 | -50** | -33.32* | -27.25* | -10 | -33.15* | -24.7 | -21.97 | -16.18 | -75.63** | 61.8** | -17.59 |
| ICMA 97444 × BIB 501-510 | -37.5** | -64.43** | -51.5** | -46.92** | -52.6** | -34.88* | 82.25** | -8.4 | 11.36 | -34.29 | -11.97 | -12.45 |
| ICMA 98222 × BIB 501-510 | -5.01 | -55.57** | -51.5** | -26.42* | 44.17** | -41.83** | -29.11 | -5.63 | 4.39 | -80.72** | 55.11** | -14.27 |
| ICMA 10444 × BIB 501-510 | -60** | -11.1 | -15.14 | -39.33** | -47.11** | -30.21* | -28.06 | -36* | -32.77* | -31.79 | -28.75 | -31.3 |
| ICMA 30199 × BIB 501-510 | -35.01** | 0 | 54.55** | -9.56 | -37.4** | -60.34** | -28.97 | -42.76** | -8.65 | -6.01 | -36.44* | -15.24 |
| ICMA 30200 × BIB 501-510 | -40** | -34.43** | -48.5** | -40.17** | -17.57 | 70.96** | 104.65** | 46.96** | -4.94 | 69.55** | 19.89 | 30.29 |
| ICMA 30201 × BIB 501-510 | -30** | -35.57** | -48.5** | -34.83** | -31.7* | 67.62** | 66.28** | 29.64 | -26.57* | 21.53 | 22.41 | 5.18 |

| Crosses/hybrids | Grain yield per plant | | | | Harvest index | | | | Threshing index | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled |
| ICMA 30209 × BIB 501-510 | -10 | -35.57** | -30.32* | -20.25 | -19.83 | 67.62** | 152.61** | 58.58** | 19.79 | 66.16** | 70.2** | 51.26** |
| ICMA 04999 × BIB 511-520 | -25* | 22.23 | 42.41** | -0.58 | -14.52 | -18.54 | -7.77 | -13.94 | -16.2 | -5.72 | -4.65 | -9.05 |
| ICMA 88004 × BIB 511-520 | -35.01** | -27.77* | -25.77 | -31.47* | -12.23 | 6.96 | 45.66** | 10.68 | 0.72 | -70.16** | 70.2** | -7.36 |
| ICMA 93333 × BIB 511-520 | -35.01** | -3.33 | -3.05 | -21.08 | -27.68* | 3.26 | 14.68 | -5.22 | -15.29 | -7.61 | 1.06 | -7.9 |
| ICMA 97111 × BIB 511-520 | -25* | -64.43** | -21.23 | -34.28* | 12.69 | -6.15 | -48.82** | -11.09 | 3.35 | -34.29 | 3.12 | -11.09 |
| ICMA 97444 × BIB 511-520 | -10 | 33.33** | 57.59** | 13.47 | -5.38 | -1.85 | 36.74* | 7.75 | 9.83 | -17.84 | 9.05 | -0.95 |
| ICMA 98222 × BIB 511-520 | -10 | -36.67** | -48.5** | -23.89 | 9.14 | 55.31** | 96.64** | 49.53** | 9.83 | 30.99 | 22.41 | 21.34 |
| ICMA 10444 × BIB 511-520 | -10 | 66.67** | 89.41** | 27.81* | -35.57** | -12.75 | 0.38 | -17.65 | 2.99 | -30.92 | 0.23 | -10.72 |
| ICMA 30199 × BIB 511-520 | -17.5 | -11.1 | -15.14 | -15.44 | -61.31** | -21.92 | 171.8** | 18.06 | -43.11** | -28.58 | -24.95 | -32.6 |
| ICMA 30200 × BIB 511-520 | -75** | -35.57** | -48.5** | -60.11** | -21.05 | 67.62** | 99.86** | 43.17** | 21.81 | 79.99** | 11.49 | 41.2* |
| ICMA 30201 × BIB 511-520 | -5.01 | 55.57** | 87.86** | 27.5* | -27.36* | 24.9 | 54.1** | 13.37 | -38.99** | 10.35 | 40.02* | 1.44 |
| ICMA 30209 × BIB 511-520 | -5.01 | 16.67 | -18.18 | -1.97 | 5.27 | 32.26* | 32.66 | 22.18 | -1.4 | -14.29 | -20.37 | -11.51 |
| ICMA 04999 × BIB 531-540 | 0 | -36.67** | -48.5** | -18.28 | -35.68** | 64.24** | 167** | 55.52** | -12.26 | 20.79 | 22.41 | 9.84 |
| ICMA 88004 × BIB 531-540 | -75** | -35.57** | -48.5** | -60.11** | -24.35 | 47.51** | 101.06** | 35.47* | 21.81 | 69.08** | 26.58 | 41.15* |
| ICMA 93333 × BIB 531-540 | -27.51* | 66.67** | 81.82** | 16.56 | -57.66** | 58.13** | 59.38** | 14.64 | -30.95* | 8.33 | 18.79 | -2.37 |
| ICMA 97111 × BIB 531-540 | -20.01 | -37.77** | -48.5** | -29.78* | -30.01* | 32.3* | 32.71 | 8.81 | 2.69 | 27.99 | -8.35 | 9.32 |
| ICMA 97444 × BIB 531-540 | -10 | 0 | 12.14 | -3.39 | -1.18 | -4.51 | 11.13 | 1.18 | 0.12 | -15.73 | 0.55 | -5.81 |
| ICMA 98222 × BIB 531-540 | -30** | -38.9** | -48.5** | -35.69** | -6.85 | 51.97** | -9.11 | 12.39 | -28.14* | 0 | 69.34** | 9.24 |
| ICMA 10444 × BIB 531-540 | -20.01 | -38.9** | -48.5** | -30.08* | -3.55 | -17.3 | 9.83 | -4.4 | 6.38 | 0 | -19.52 | -3.13 |
| ICMA 30199 × BIB 531-540 | -30** | -3.33 | -3.05 | -18.28 | -39.51** | -2.33 | 0.43 | -15.61 | 2.61 | 30.49 | -12.58 | 9.09 |
| ICMA 30200 × BIB 531-540 | -40** | -16.67 | -25.77 | -31.47* | -49.09** | -41.15** | -15.88 | -36.98* | 25.69 | 39.99* | -18.96 | 18.95 |
| ICMA 30201 × BIB 531-540 | -10 | -3.33 | -3.05 | -7.03 | -10 | -51.05** | -48.39** | -34.73* | 2.21 | 112.98** | 3.12 | 44.74** |

| Crosses/hybrids | Grain yield per plant | | | | Harvest index | | | | Threshing index | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled |
| ICMA 30209 × BIB 531-540 | 4.99 | -5.57 | -3.05 | 0.83 | -26.21 | -42.76** | -38.66* | -35.3* | 9.75 | 5.99 | -26.51 | -1.61 |
| ICMA 04999 × BIB 551-560 | -65.01** | -5.57 | -3.05 | -38.5** | -3.73 | 168.18** | -42.45* | 43.38** | 21.81 | 163.32** | -1.91 | 69.36** |
| ICMA 88004 × BIB 551-560 | 19.99 | 16.67 | 31.82* | 21.33 | -6.17 | 56.07** | 66.14** | 35.34* | 21.05 | 122.48** | 30.53 | 62.37** |
| ICMA 93333 × BIB 551-560 | 41.49** | 27.77* | 42.41** | 38.17** | -19.65 | 5.03 | 26 | 1.63 | 7.85 | -50.88** | 73.54** | 3.36 |
| ICMA 97111 × BIB 551-560 | -69** | -35.57** | -40.91** | -55.33** | -30.48* | 55.55** | 179.76** | 58.17** | 14.05 | 79.99** | 56.77** | 50.89** |
| ICMA 97444 × BIB 551-560 | -67.5** | -27.77* | -3.05 | -45.5** | 0.72 | 87.73** | 130.22** | 66.82** | 66.1** | 49.98* | 81.09** | 64.02** |
| ICMA 98222 × BIB 551-560 | -15 | 27.77* | 30.32* | 4.2 | -17.75 | -14.16 | -14.44 | -15.57 | -16.48 | 0 | 2.72 | -4.95 |
| ICMA 10444 × BIB 551-560 | -25* | -31.1* | -6.05 | -23.03 | -20.19 | -53.74** | -18.8 | -31.1* | -4.03 | -3.01 | 15.29 | 1.63 |
| ICMA 30199 × BIB 551-560 | 15 | 50** | 27.27 | 26.11 | -3.51 | 13.72 | 12.42 | 6.85 | 0.74 | 36.56 | 46.28** | 26.85 |
| ICMA 30200 × BIB 551-560 | -35.01** | -35.57** | -6.05 | -29.78* | -28.4* | 67.62** | 80.67** | 34.94* | -7.06 | 69.08** | -30.41 | 15.63 |
| ICMA 30201 × BIB 551-560 | -25* | 5.57 | 9.09 | -10.97 | -16.64 | -24.9 | -17.94 | -19.77 | -6.54 | 7.99 | 16.45 | 5.28 |
| ICMA 30209 × BIB 551-560 | 0 | 16.67 | 27.27 | 9.25 | 3.76 | 24.74 | 35.11* | 19.73 | 7.34 | 19.33 | 23.34 | 16.29 |
| ICMA 04999 × BIB 561-570 | 34.99** | 5.57 | 15.14 | 23.86 | 32.27* | 4.91 | 83.84** | 37.67* | 27.79* | 49.98* | 51.51** | 42.74* |
| ICMA 88004 × BIB 561-570 | 0 | -5.57 | -3.05 | -1.97 | 13.37 | 1.69 | 56.31** | 21.61 | 24 | 39.99* | 4.8 | 24.85 |
| ICMA 93333 × BIB 561-570 | -45** | -22.23 | -15.14 | -33.72* | -46.72** | -25.46 | -9.88 | -29.11 | 9.15 | -1.01 | -23.74 | -3.73 |
| ICMA 97111 × BIB 561-570 | -30** | -27.77* | -13.64 | -26.42* | 1.94 | -11.54 | 100.24** | 25.23 | 7.04 | 45* | 62.65** | 36.72* |
| ICMA 97444 × BIB 561-570 | -15 | -35.57** | -24.23 | -21.92 | -39.58** | -5.19 | 5.76 | -15.12 | 3.19 | -4.01 | -17.15 | -5.13 |
| ICMA 98222 × BIB 561-570 | 27.49* | -27.77* | -6.05 | 7.31 | 12.94 | -63.52** | -71.99** | -36.93* | 42.93** | -70.05** | 86.95** | 11.81 |
| ICMA 10444 × BIB 561-570 | -20.01 | -16.67 | -1.5 | -15.75 | -36.57** | 44.05** | 103.02** | 30.21* | -6.52 | 57.49** | -5.26 | 18.27 |
| ICMA 30199 × BIB 561-570 | 30** | 7.77 | -3.05 | 18.25 | 7.21 | -12.55 | 20.82 | 4.4 | 20.97 | 36.48 | 7.47 | 23.2 |
| ICMA 30200 × BIB 561-570 | 9.99 | 35.57** | 42.41** | 22.45 | 12.05 | 36.77* | 99.86** | 45.29** | 19.59 | 6.28 | 19.79 | 14.56 |

| Crosses/hybrids | Grain yield per plant | | | | Harvest index | | | | Threshing index | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled |
| ICMA 30201 × BIB 561-570 | -50.01** | 122.23** | 92.41** | 19.92 | -60.7** | -18.5 | -5.9 | -30.9* | -66.35** | -24.12 | -4.2 | -33.24* |
| ICMA 30209 × BIB 561-570 | -10 | -5.57 | -3.05 | -7.61 | -10.68 | 48.43** | 88.63** | 37.42* | 3.33 | 47.84* | 23.87 | 25.94 |
| ICMA 04999 × BIB 571-580 | 4.99 | 16.67 | 46.95** | 15.72 | -12.08 | 20.6 | 78.13** | 24.54 | -2.89 | 22.77 | 24.17 | 14.29 |
| ICMA 88004 × BIB 571-580 | 15 | 5.57 | 15.14 | 12.64 | -2.29 | 10.18 | 43.07* | 14.8 | 23.82 | 24.5 | 23.72 | 24.04 |
| ICMA 93333 × BIB 571-580 | -25* | 38.9** | 42.41** | 3.64 | -26.35 | 197.22** | -2.3 | 56.01** | -17.16 | 13.23 | 85.79** | 22.58 |
| ICMA 97111 × BIB 571-580 | 4.99 | -27.77* | -48.5** | -13.22 | 19.97 | 30.89* | 99.86** | 46.31** | 9.95 | 54.99** | 19.04 | 29.63 |
| ICMA 97444 × BIB 571-580 | -2.5 | 72.23** | 106.05** | 36.5** | -21.91 | 47.91** | 99.71** | 36.16* | 2.87 | 48.33* | 23.59 | 25.88 |
| ICMA 98222 × BIB 571-580 | -30** | 13.33 | 12.14 | -11.25 | -15.74 | 12.43 | 38.37* | 9.13 | -12.42 | -12.26 | 4.58 | -7.71 |
| ICMA 10444 × BIB 571-580 | -25* | -2.23 | -15.14 | -17.42 | -30.05* | 13.19 | 4.84 | -5.54 | -6.6 | 8.59 | 3.27 | 1.9 |
| ICMA 30199 × BIB 571-580 | -5.01 | 105.57** | 48.5** | 32.86* | -17.28 | 33.27* | 46** | 17.73 | -0.34 | 70** | -40.07* | 15.65 |
| ICMA 30200 × BIB 571-580 | -15 | 27.77* | 30.32* | 4.2 | -10.47 | -8 | -0.1 | -6.69 | 9.93 | -15.1 | 13.36 | 1.3 |
| ICMA 30201 × BIB 571-580 | -25* | -16.67 | -6.05 | -19.39 | -18.64 | -11.63 | -11.7 | -14.31 | -9.49 | -10.01 | 2.52 | -6.41 |
| ICMA 30209 × BIB 571-580 | 19.99 | -16.67 | 27.27 | 12.06 | -5.02 | 26.11 | 8.35 | 9.29 | 34.7** | 13.5 | 23.14 | 23.44 |
| RHB - 177 | -25* | -27.77* | -18.18 | -24.44 | -16.17 | -17.1 | -11.61 | -15.17 | -6.98 | -18 | 11.32 | -6.19 |
| BHB - 1602 | -20.01 | 16.67 | 12.14 | -4.78 | -16.31 | 88.09** | 121.15** | 57.93** | 13.69 | 74.98** | 43.23** | 45.15** |

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

(ICMA 10444 x BIB 481-500) in $E_1$, -80.72 (ICMA 98222 x BIB 501-510) to 474.95 (ICMA 30201 x BIB 481-500) in $E_2$, -40.07 (ICMA 30199 x BIB 571-580) to 104.90 (ICMA 98222 x BIB 481-500) in $E_3$ and -33.24 (ICMA 30201 x BIB 561-570) to 177.28 (ICMA 30201 x BIB 481-500) were found in pooled analysis. The cross ICMA 97444 x BIB 551-560 and ICMA 04999 x BIB 561-570 exhibited significant positive standard heterosis over the environments. Hence, this cross was considered as desirable for threshing index.

## 4.5 Phenotypic stability analysis

The nature and extent of genotype (G) x environment (E) interactions were studied as per model proposed by Eberhart and Russell (1966). The pooled analysis of variance for phenotypic stability for different traits is presented in Table 4.5.1. The mean sum of squares due to genotypes and environments were found to be significant for all the characters except mean sum of squares due to genotypes for threshing index. The variance due to E + (G x E) and environment (linear) was found significant for all the characters except harvest index. The mean squares due to G x E (linear) were found significant for all the characters except days to 50% flowering, days to maturity, plant height, ear head length, test weight, and grain yield indicating that genotypes were predictable based on such characters. The mean squares due to pooled deviation (non-linear) were found non-significant for all characters indicating role of unpredictable causes not affecting stability.

### Mean performance and stability parameters

In present investigation, the model proposed by Eberhart and Russell (1966) was used for analysis of G x E interactions. It considered both linear ($b_i$) and non-linear ($S^2d_i$) components of G x E interaction for the prediction of performance of individual genotypes. The stability parameters such as regression coefficient ($b_i$) and deviation from regression ($S^2d_i$) along with mean performance of genotypes for various characters were computed to assess the stability and suitability of performance over the different environments. The mean performance and stability parameters are presented in Table 4.5.2 to 4.5.4. The linear regression coefficient ($b_i$) was considered as a measure of responsiveness and deviation from regression ($S^2d_i$) as measure of stability. The high mean performances of crosses were decided on the basis of general mean.

According to model proposed by Eberhart and Russell (1966), a stable genotype is one whose regression coefficient ($b_i$) equals to unity and deviation from regression ($S^2d_i$) is zero. A high value of $b_i$ indicated more responsive genotypes and may be recommended for highly favorable environments. The value $b_i$ around unity indicates its wider adaptability. If $b_i$ is less than unity, the genotype may be recommended for growing only in poor environmental conditions. If $S^2d_i$ is significantly deviated from zero, it will invalidate the linear prediction. While insignificant $S^2d_i$ indicates that the performance of a genotype for a given environment may be predicted. The character wise results are presented as under:

### 4.5.1 Days to 50% flowering

The means of genotypes for days to 50% flowering ranged from 42.78 (ICMA 88004 x BIB 511-520) to 58.00 (ICMA 04999 x BIB 501-510) and regression coefficient ranged from -0.19 (ICMA 30201 x BIB 481-500) to 2.13 (ICMA 97444 x BIB 481-500). The population mean of genotypes for days to 50% flowering was 49.02 days. The estimate of $S^2d_i$ significantly differed from zero for 24 genotype exhibiting instability of these genotypes (Table 4.5.2). Out of 80 genotypes, 27 genotypes *viz.,* (ICMA 04999 x BIB 481-500), (ICMA 93333 x BIB 481-500), (ICMA 98222 x BIB 481-500), (ICMA 30200 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 98222 x BIB 501-510), (ICMA 10444 x BIB 501-510), (ICMA 04999 x BIB 511-520),

**Table 4.5.1 Analysis of variance for phenotypic stability for grain yield per plant and its components**

| Source | Mean squares | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | df | Days to 50% flowering | Days to maturity | Plant height (cm) | Productive tillers/ plant | Ear head length (cm) | Ear head diameter (cm) | Test weight (g) | Ear head weight (g) | Dry stover yield/ plant (g) | Grain yield/ plant (g) | Harvest index (%) | Threshing index (%) |
| Genotypes | 79 | 48.41** | 48.32** | 441.77** | 1.19** | 42.11** | 60.55** | 9.45** | 2837.84** | 11310.88** | 391.9** | 160.68** | 589.63 |
| Environment | 2 | 1206.57** | 1242.15** | 39292.39** | 108.88** | 1569.91** | 2039.17** | 2.84** | 80290.89** | 444756.84** | 21226.56** | 660.66** | 8629.69** |
| Env. + ( G x E) | 160 | 19.58** | 19.9** | 556.01** | 1.74** | 25.87** | 34.52** | 0.05** | 1472.53** | 8062.34** | 371.24** | 90.29 | 654.53** |
| Env. (linear) | 1 | 2413.15** | 2484.3** | 78584.78** | 217.75** | 3139.83** | 4078.34** | 5.68** | 160581.78** | 889513.68** | 42453.12** | 1321.32** | 17259.38** |
| G x E ( linear) | 79 | 3.99 | 3.72 | 72.44 | 0.65** | 7.3 | 16.86** | 0.013 | 929.68** | 4694.11** | 175.83** | 86.88 | 925.55** |
| Pooled deviations | 80 | 5.04 | 5.07 | 58.17 | 0.11 | 5.29 | 1.42 | 0.022 | 19.72 | 370.32 | 38.19 | 78.27 | 179.33 |
| Pooled error | 480 | 1.04 | 1.14 | 26.67 | 0.08 | 0.67 | 1.18 | 0.013 | 53.69 | 211.18 | 13.86 | 7.07 | 33.27 |

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

(ICMA 97444 x BIB 511-520), (ICMA 30201 x BIB 511-520), (ICMA 93333 x BIB 531-540), (ICMA 97444 x BIB 531-540), (ICMA 10444 x BIB 531-540), (ICMA 30200 x BIB 531-540), (ICMA 30209 x BIB 531-540), (ICMA 88004 x BIB 551-560), (ICMA 93333 x BIB 551-560), (ICMA 10444 x BIB 551-560), (ICMA 30201 x BIB 551-560), (ICMA 98222 x BIB 561-570), (ICMA 30200 x BIB 561-570), (ICMA 30209 x BIB 561-570), (ICMA 88004 x BIB 571-580), (ICMA 93333 x BIB 571-580), (ICMA 97444 x BIB 571-580), (ICMA 98222 x BIB 571-580), (ICMA 30200 x BIB 571-580) and RHB-177 had mean Significantly lower than general mean, regression coefficient equivalent to unity and $S^2d_i$ equivalent to zero, exhibiting average stability and wider adaptability, hence, considered most stable and desirable for earliness over variable environments. The genotypes *viz.,* (ICMA 93333 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 98222 x BIB 531-540), (ICMA 30201 x BIB 531-540), (ICMA 98222 x BIB 551-560), (ICMA 97444 x BIB 561-570), (ICMA 04999 x BIB 571-580) and (ICMA 97111 x BIB 571-580) had mean significantly lower than general mean, regression coefficient more than to unity and $S^2d_i$ equivalent to zero, exhibiting below average stability and considered stable for better environment. The genotypes *viz.,* (ICMA 10444 x BIB 531-540), (ICMA 30209 x BIB 551-560) and (ICMA 93333 x BIB 561-570) had mean significantly less than general mean, regression coefficient less than to unity and $S^2d_i$ equivalent to zero, exhibiting above average stability, hence, these genotypes were considered for poor environmental conditions.

**4.5.2 Days to maturity**

The means of genotypes for days to maturity ranged from 72.67 (ICMA 88004 x BIB 511-520) to 88.00 days (ICMA 04999 x BIB 501-510) and regression coefficient ranged from -0.17 to 2.1. The population mean of genotypes for days to maturity was 79.05 days. The estimate of $S^2d_i$ significantly differed from zero for 26 genotype exhibiting instability of these genotypes (Table 4.5.2). Out of 80 genotypes, 30 genotypes *viz.,* (ICMA 04999 x BIB 481-500), (ICMA 93333 x BIB 481-500), (ICMA 98222 x BIB 481-500), (ICMA 30200 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 98222 x BIB 501-510), (ICMA 10444 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 97444 x BIB 511-520), (ICMA 30201 x BIB 511-520), (ICMA 93333 x BIB 531-540), (ICMA 97444 x BIB 531-540), (ICMA 10444 x BIB 531-540), (ICMA 30200 x BIB 531-540), (ICMA 88004 x BIB 551-560), (ICMA 93333 x BIB 551-560), (ICMA 10444 x BIB 551-560), (ICMA 30201 x BIB 551-560), (ICMA 93333 x BIB 561-570), (ICMA 97444 x BIB 561-570), (ICMA 98222 x BIB 561-570), (ICMA 30200 x BIB 561-570), (ICMA 30209 x BIB 561-570), (ICMA 88004 x BIB 571-580), (ICMA 93333 x BIB 571-580), (ICMA 97111 x BIB 571-580), (ICMA 97444 x BIB 571-580), (ICMA 98222 x BIB 571-580), (ICMA 30200 x BIB 571-580), RHB-177 had mean significantly lower than general mean, regression coefficient equivalent to unity and $S^2d_i$ equivalent to zero, exhibiting average stability and wider adaptability, hence, considered most stable and desirable for earliness over variable environments. The genotypes *viz.,* (ICMA 93333 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 97444 x BIB 501-510), (ICMA 98222 x BIB 531-540), (ICMA 30201 x BIB 531-540) and (ICMA 98222 x BIB 561-560) had mean significantly lower than general mean, regression coefficient more than to unity and $S^2d_i$ equivalent to zero, exhibiting below average stability and considered for better environment.

**4.5.3 Plant height**

The means of genotypes for plant height ranged from 106.91 cm (ICMA 97444 x BIB 551-560) to 157.59 cm (ICMA 93333 x BIB 531-540) and regression coefficient ranged from 0.39 (ICMA 04999 x BIB 551-560) to 1.69 (ICMA 04999 x BIB 531-540). The population mean of genotypes for plant height was 135.47. The estimate of $S^2d_i$ significantly differed from zero for 18 genotype exhibiting instability of this genotype (Table 4.5.2). Out of 80 genotypes, 24 genotypes *viz.,* (ICMA 04999 x BIB 481-500), (ICMA 88004 x BIB 481-500), (ICMA 97111 x BIB 481-500), (ICMA 98222 x BIB 481-500), (ICMA 30201 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 10444 x BIB 501-510), (ICMA 93333 x BIB 511-520), (ICMA 30201 x BIB 511-520), (ICMA 30209 x BIB 511-520), (ICMA 93333 x BIB 531-540), (ICMA 97444 x BIB 531-540), (ICMA 98222 x BIB 531-540), (ICMA 30201 x BIB 531-540), (ICMA 93333 x BIB 551-560), (ICMA 98222 x BIB 551-560), (ICMA 30199 x BIB 551-560), (ICMA 30201 x BIB 551-560), (ICMA 30209 x BIB 551-560), (ICMA 88004 x BIB 561-570), (ICMA 93333 x BIB 561-570), (ICMA 93333 x BIB 571-580), (ICMA 97111 x BIB 571-580), (ICMA 97444 x BIB 571-580) had mean significantly higher than general mean, regression coefficient equivalent to unity and $S^2d_i$ equivalent to zero, exhibiting average stability, hence, considered most desirable over variable environments. The genotype (ICMA 97444 x BIB 481-500), (ICMA 93333 x BIB 501-510), (ICMA 97444 x BIB 501-510), (ICMA 98222 x BIB 501-510), (ICMA 30199 x BIB 501-510), (ICMA 10444 x BIB 531-540), (ICMA 30199 x BIB 531-540), (ICMA 30200 x BIB 531-540), (ICMA 30209 x BIB 531-540), (ICMA 88004 x BIB 551-560), (ICMA 88004 x BIB 571-580) and (ICMA 97111 x BIB 571-580) had mean significantly more than general mean, regression coefficient more than unity and $S^2d_i$ equivalent to zero, exhibiting below average stability and considered for better environment. The genotype (ICMA 30200 x BIB 481-500) and (ICMA 30199 x BIB 571-580) had mean significantly more than general mean, regression coefficient less than to unity and $S^2d_i$ equivalent to zero, exhibiting above average stability, hence, these genotypes were considered for poor environmental conditions.

**Table 4.5.2 Estimates of stability parameters for days to 50% flowering, days to maturity, plant height and productive tillers per plant**

| Genotypes | Days to 50% flowering | | | Days to maturity | | | Plant height | | | productive tillers/plant | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ |
| ICMA 04999 × BIB 481-500 | 46.33 | 0.83** | -1.02 | 76.67 | 0.96** | -1.09 | 152.52 | 0.85** | -3.28 | 2.03 | 1.04** | -0.08 |
| ICMA 88004 × BIB 481-500 | 45.56 | 0.64 | 3.33* | 75.67 | 0.68 | 3.28* | 155.17 | 0.78** | 22.88 | 1.7 | 0.74** | -0.07 |
| ICMA 93333 × BIB 481-500 | 45 | 0.88** | -0.23 | 75 | 0.87** | -0.42 | 156.77 | 0.53 | 83.23* | 2.2 | 0.51* | 0.08 |
| ICMA 97111 × BIB 481-500 | 46.67 | 0.1 | 33.3** | 76.67 | 0.11 | 33.13** | 151.91 | 1.1** | -21.16 | 2.23 | 0.98** | 0.1 |
| ICMA 97444 × BIB 481-500 | 52.67 | 2.13 | 50.28** | 82.67 | 2.1 | 51.87** | 140.51 | 1.49** | 149.72* | 2.7 | 0.5** | -0.02 |
| ICMA 98222 × BIB 481-500 | 42.89 | 0.83** | -0.32 | 73 | 0.87** | -0.42 | 141.2 | 0.83** | 2.24 | 3.83 | -0.25 | 0.28* |
| ICMA 10444 × BIB 481-500 | 53.89 | 1.7 | 21.36** | 84 | 1.72* | 21.7** | 121.53 | 0.73** | -7.5 | 1.93 | 1.16** | -0.04 |
| ICMA 30199 × BIB 481-500 | 51.44 | 1.12** | -0.96 | 81.33 | 1.06** | -0.98 | 145 | 0.92** | -20.3 | 3.57 | 0.62* | 0.17 |
| ICMA 30200 × BIB 481-500 | 47.22 | 1.02** | -0.89 | 77.33 | 1.06** | -0.98 | 143.74 | 0.66* | 65.7 | 3.27 | 0.33 | 0.28* |
| ICMA 30201 × BIB 481-500 | 50.67 | -0.19 | 58.57** | 80.67 | -0.17 | 58.63** | 146.22 | 0.95** | -22.41 | 3.37 | 0.22 | 0.79** |
| ICMA 30209 × BIB 481-500 | 55.67 | 1.26** | 1.46 | 85.67 | 1.25** | 1.59 | 113.26 | 0.65* | 78.73* | 1.33 | 0 | -0.03 |
| ICMA 04999 × BIB 501-510 | 58 | 0.88** | -0.23 | 88 | 0.87** | -0.42 | 111.38 | 0.47 | 201.99** | 1.7 | 0.76** | -0.08 |
| ICMA 88004 × BIB 501-510 | 42.89 | 0.83** | -0.32 | 73 | 0.87** | -0.42 | 147.08 | 0.91** | -20.59 | 2.73 | 1.39** | -0.04 |
| ICMA 93333 × BIB 501-510 | 48.67 | 1.26** | 1.46 | 78.67 | 1.25** | 1.59 | 147.98 | 1.38** | 86.4* | 2.13 | 0.85** | 0 |
| ICMA 97111 × BIB 501-510 | 46.44 | 1.17** | 1.79 | 76.67 | 1.25** | 1.59 | 135.1 | 0.97** | -26.03 | 2.17 | 1.69** | 0.29* |
| ICMA 97444 × BIB 501-510 | 49 | 1.46** | 6.93** | 79 | 1.44** | 7.29** | 138.25 | 1.29** | 34.8 | 2.07 | 1.09** | -0.08 |
| ICMA 98222 × BIB 501-510 | 45.33 | 1.07** | -0.92 | 75.33 | 1.06** | -0.98 | 136.76 | 1.18** | 0.69 | 1.97 | 0.6** | 0.05 |
| ICMA 10444 × BIB 501-510 | 46.89 | 0.83** | -0.32 | 77 | 0.87** | -0.42 | 141.55 | 1.08** | -23.51 | 2.43 | 0.13** | -0.08 |
| ICMA 30199 × BIB 501-510 | 54.33 | 1.07** | -0.92 | 84.33 | 1.06** | -0.98 | 137.9 | 1.31** | 200.16** | 2 | 1.32** | 0.03 |
| ICMA 30200 × BIB 501-510 | 54 | 1.17** | -0.11 | 84 | 1.15** | -0.09 | 118.89 | 1.33** | 52.92 | 1.9 | 0.83** | -0.07 |
| ICMA 30201 × BIB 501-510 | 54.67 | 1.55* | 10.81** | 84.67 | 1.53* | 11.31** | 115.14 | 1.49** | 170.63** | 2.1 | 1.47** | 0.07 |
| ICMA 30209 × BIB 501-510 | 55.44 | 1.41** | 3.6* | 85.33 | 1.34** | 4.04* | 119.88 | 1.62** | 267.41** | 1.83 | 1.21** | 0.11 |
| ICMA 04999 × BIB 511-520 | 43.33 | 0.78** | 1.27 | 73.33 | 0.77** | 1.04 | 128.03 | 0.92** | -20.44 | 3.13 | 0.83** | -0.06 |
| ICMA 88004 × BIB 511-520 | 42.78 | 0.73 | 3.75* | 72.67 | 0.68 | 3.28* | 133.22 | 0.89** | -12.95 | 2.37 | 0.92** | -0.07 |
| ICMA 93333 × BIB 511-520 | 43.78 | 0.73 | 3.75* | 73.67 | 0.68 | 3.28* | 142.84 | 0.76** | 30.93 | 3.3 | 1.18** | 0 |
| ICMA 97111 × BIB 511-520 | 50.78 | 1.89 | 26.56** | 80.67 | 1.82 | 28.07** | 122.84 | 1.16** | -11.17 | 2.27 | 1.36** | -0.01 |
| ICMA 97444 × BIB 511-520 | 43.33 | 0.78** | 1.27 | 73.33 | 0.77** | 1.04 | 140.88 | 0.64 | 91.14* | 3.47 | -0.1 | 0.5** |
| ICMA 98222 × BIB 511-520 | 53.33 | 1.65* | 15.47** | 83.33 | 1.63* | 16.11** | 121.96 | 0.63 | 89.81* | 1.77 | 0.71** | -0.08 |

| Genotypes | Days to 50% flowering | | | Days to maturity | | | Plant height | | | productive tillers/plant | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ |
| ICMA 10444 × BIB 511-520 | 48.78 | 0.49 | 6.03** | 79 | 0.59 | 6.3* | 128.91 | 0.69* | 57.61 | 2.93 | 0.16 | 0.58** |
| ICMA 30199 × BIB 511-520 | 52 | 1.46** | 6.93** | 82 | 1.44** | 7.29** | 130.02 | 0.97** | -25.97 | 2.07 | 0.71** | -0.08 |
| ICMA 30200 × BIB 511-520 | 55.67 | 0.97** | -0.96 | 85.67 | 0.96** | -1.09 | 114.48 | 0.64 | 75.42 | 1.83 | 0.96** | -0.08 |
| ICMA 30201 × BIB 511-520 | 47.11 | 0.93** | -0.14 | 77 | 0.87** | -0.42 | 140.88 | 1.04** | -26.23 | 4 | 1.54** | -0.05 |
| ICMA 30209 × BIB 511-520 | 48.56 | 0.64 | 3.33* | 78.67 | 0.68 | 3.28* | 146.78 | 0.95** | -24.84 | 3.07 | 0.44** | 0 |
| ICMA 04999 × BIB 531-540 | 53.67 | 1.55* | 10.81** | 83.67 | 1.53* | 11.31** | 128.27 | 1.69** | 349.23** | 2.77 | 2.56** | 0.77** |
| ICMA 88004 × BIB 531-540 | 56.78 | 1.02** | -0.93 | 86.67 | 0.96** | -1.09 | 112.09 | 0.51 | 168.92** | 2.8 | 1.4** | -0.03 |
| ICMA 93333 × BIB 531-540 | 44.33 | 0.78** | 1.27 | 74.33 | 0.77** | 1.04 | 157.59 | 1.02** | -26.68 | 2.87 | 1.83** | -0.06 |
| ICMA 97111 × BIB 531-540 | 51.33 | 1.7 | 28.7** | 81.67 | 1.82 | 28.07** | 130.72 | 1.42** | 112.25* | 1.9 | 1.31** | 0.14 |
| ICMA 97444 × BIB 531-540 | 43.33 | 0.78** | 1.27 | 73.33 | 0.77** | 1.04 | 148.58 | 0.96** | -24.43 | 2.67 | 1.33** | -0.07 |
| ICMA 98222 × BIB 531-540 | 46.67 | 1.46** | -0.6 | 76 | 1.15** | -0.09 | 143.25 | 0.94** | -22.48 | 2.03 | 1.04** | -0.08 |
| ICMA 10444 × BIB 531-540 | 47.89 | 0.63** | -1.03 | 78.67 | 0.96** | -1.09 | 143.39 | 1.22** | 12.93 | 1.73 | 0.87** | -0.07 |
| ICMA 30199 × BIB 531-540 | 51.78 | 1.02** | -0.93 | 81.67 | 0.96** | -1.09 | 145.21 | 1.18** | -6.22 | 1.97 | 0.8** | -0.07 |
| ICMA 30200 × BIB 531-540 | 47.33 | 0.78** | 1.27 | 77.33 | 0.77** | 1.04 | 142.95 | 1.15** | -10.46 | 2.13 | 1.1** | -0.07 |
| ICMA 30201 × BIB 531-540 | 47 | 1.17** | -0.11 | 77 | 1.15** | -0.09 | 149.02 | 0.92** | -20.36 | 2.4 | 1.15** | -0.07 |
| ICMA 30209 × BIB 531-540 | 48.89 | 0.88** | -0.75 | 79.33 | 1.06** | -0.98 | 145.38 | 1.16** | -5.12 | 3.4 | 1.61** | -0.07 |
| ICMA 04999 × BIB 551-560 | 55.33 | 1.07** | -0.92 | 85.33 | 1.06** | -0.98 | 115.11 | 0.39 | 271.5** | 2.1 | 1.6** | 0.25* |
| ICMA 88004 × BIB 551-560 | 46 | 0.92** | -0.8 | 76.33 | 1.06** | -0.98 | 150.08 | 1.14** | -9.68 | 2.5 | 1.42** | -0.06 |
| ICMA 93333 × BIB 551-560 | 44.78 | 1.02** | -0.93 | 74.67 | 0.96** | -1.09 | 154.45 | 0.81** | 0.21 | 2.47 | 1.57** | 0.09 |
| ICMA 97111 × BIB 551-560 | 56 | 0.88** | -0.23 | 86 | 0.87** | -0.42 | 110.79 | 0.6 | 99.25* | 1.13 | 0 | -0.03 |
| ICMA 97444 × BIB 551-560 | 56.78 | 1.02** | -0.93 | 86.67 | 0.96** | -1.09 | 106.91 | 0.92** | -19.92 | 1.63 | 0.73** | -0.08 |
| ICMA 98222 × BIB 551-560 | 47 | 1.17** | -0.11 | 77 | 1.15** | -0.09 | 136.18 | 1.06** | -25.19 | 2.03 | 0.71** | -0.05 |
| ICMA 10444 × BIB 551-560 | 48.67 | 0.97** | -0.96 | 78.67 | 0.96** | -1.09 | 135.41 | 0.76** | 20.41 | 2.6 | 0.96** | -0.08 |
| ICMA 30199 × BIB 551-560 | 52.56 | 0.93** | -0.99 | 82.67 | 0.96** | -1.09 | 142.71 | 0.95** | -24.73 | 2.4 | 0.7** | -0.07 |
| ICMA 30200 × BIB 551-560 | 53.33 | 1.36** | 3.81* | 83.33 | 1.34** | 4.04* | 125.96 | 1.09** | -20.96 | 1.97 | 1.28** | 0.02 |
| ICMA 30201 × BIB 551-560 | 48.33 | 0.83** | -1.02 | 78.67 | 0.96** | -1.09 | 142.06 | 0.8** | 6.64 | 3.97 | 0.4 | 0.18 |
| ICMA 30209 × BIB 551-560 | 48.78 | 0.54* | 0.57 | 79.33 | 0.77** | 1.04 | 153.12 | 0.97** | -26.04 | 2.73 | 0.46** | -0.04 |
| ICMA 04999 × BIB 561-570 | 52.56 | 1.51* | 11.15** | 82.67 | 1.53* | 11.31** | 119.1 | 1.08** | -20.48 | 3.03 | 1.72** | -0.08 |

| Genotypes | Days to 50% flowering | | | Days to maturity | | | Plant height | | | productive tillers/plant | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ |
| ICMA 88004 × BIB 561-570 | 43.67 | 0.68 | 3.54* | 73.67 | 0.68 | 3.28* | 141.38 | 0.99** | -26.58 | 2.8 | 0.84** | -0.08 |
| ICMA 93333 × BIB 561-570 | 45.22 | 0.73** | 1.12 | 75.33 | 0.77** | 1.04 | 143.12 | 1.08** | -20.39 | 2.53 | 0.6** | -0.06 |
| ICMA 97111 × BIB 561-570 | 44.78 | 0.73 | 3.75* | 74.67 | 0.68 | 3.28* | 144.06 | 0.97** | -25.95 | 3.2 | 1.42** | -0.06 |
| ICMA 97444 × BIB 561-570 | 46.44 | 1.12** | -0.96 | 76.33 | 1.06** | -0.98 | 133.94 | 1.27** | 26.72 | 3.37 | 1.04** | -0.04 |
| ICMA 98222 × BIB 561-570 | 43.33 | 0.78** | 1.27 | 73.33 | 0.77** | 1.04 | 129.36 | 0.88** | -13.7 | 2.93 | 0.89** | -0.08 |
| ICMA 10444 × BIB 561-570 | 51.89 | 0.83** | -0.32 | 82 | 0.87** | -0.42 | 119.82 | 0.74**# | -24.53 | 2.6 | 1.32** | 0.03 |
| ICMA 30199 × BIB 561-570 | 53 | 0.88** | -0.23 | 83 | 0.87** | -0.42 | 129.28 | 1** | -26.49 | 3.3 | 1.13** | -0.08 |
| ICMA 30200 × BIB 561-570 | 48 | 0.88** | -0.23 | 78 | 0.87** | -0.42 | 132.85 | 0.76** | 30.78 | 3.77 | 0.97 | 0.58** |
| ICMA 30201 × BIB 561-570 | 49.67 | 0.68 | 3.54* | 79.67 | 0.68 | 3.28* | 132.08 | 0.8** | 6.48 | 2.3 | 1.42** | -0.06 |
| ICMA 30209 × BIB 561-570 | 48.44 | 0.83** | 1.42 | 78.33 | 0.77** | 1.04 | 131.69 | 0.96** | -24.7 | 2.9 | 1.38** | -0.07 |
| ICMA 04999 × BIB 571-580 | 47.67 | 1.22** | -1 | 77.33 | 1.15** | -0.09 | 131.03 | 1.03** | -26.09 | 3.37 | 1.21** | -0.03 |
| ICMA 88004 × BIB 571-580 | 45 | 0.88** | -0.23 | 75 | 0.87** | -0.42 | 146.75 | 1.12** | -13.89 | 3.53 | 1.26** | -0.08 |
| ICMA 93333 × BIB 571-580 | 45.33 | 1.07** | -0.92 | 75.33 | 1.06** | -0.98 | 146.68 | 0.9** | -17.32 | 2.43 | 1** | 0 |
| ICMA 97111 × BIB 571-580 | 44.44 | 1.12** | -0.96 | 74.33 | 1.06** | -0.98 | 137.76 | 1.12** | -13.81 | 2.63 | 1.91** | 0.02 |
| ICMA 97444 × BIB 571-580 | 44.89 | 0.83** | -0.32 | 75 | 0.87** | -0.42 | 142.53 | 1.08** | -23.53 | 2.7 | 0.92* | 0.29* |
| ICMA 98222 × BIB 571-580 | 46.11 | 0.93** | -0.14 | 76 | 0.87** | -0.42 | 124.96 | 0.98** | -25.88 | 2.43 | 0.6** | -0.06 |
| ICMA 10444 × BIB 571-580 | 49.67 | 0.97** | -0.96 | 79.67 | 0.96** | -1.09 | 127.31 | 1.05** | -25.03 | 2.03 | 1.02** | -0.06 |
| ICMA 30199 × BIB 571-580 | 52.11 | 0.93** | -0.14 | 82 | 0.87** | -0.42 | 141.58 | 0.73** | 38.64 | 3.43 | 1.04** | -0.08 |
| ICMA 30200 × BIB 571-580 | 48 | 0.88** | -0.23 | 78 | 0.87** | -0.42 | 130.52 | 1.01** | -26.69 | 2.43 | 1.08** | -0.02 |
| ICMA 30201 × BIB 571-580 | 51.22 | 1.02** | -0.89 | 81.33 | 0.68 | 3.28* | 129.56 | 1.25** | 18.64 | 2.43 | 1.25** | -0.06 |
| ICMA 30209 × BIB 571-580 | 48.22 | 0.49 | 2.72 | 78.67 | 0.64 | 11.07** | 133.52 | 1.31** | 42.94 | 2.1 | 1.34** | -0.04 |
| RHB - 177 (Check-1) | 48.33 | 0.78** | 1.27 | 78.33 | 0.77** | 1.04 | 138.84 | 1.45** | 121.54* | 2.4 | 1.28** | -0.07 |
| HHB 67 improved (Check-2) | 51.33 | 1.36** | 3.81* | 81.33 | 1.34** | 4.04* | 130.05 | 1.49** | 168.75** | 2.1 | 1.2** | -0.06 |
| BHB - 1602 ( Check-3) | 52.33 | 1.36** | 3.81* | 82.33 | 1.34** | 4.04* | 132.04 | 1.44** | 125.35* | 2.43 | 1.41** | -0.07 |
| **Population mean** | 49.02 | | | 79.05 | | | 135.47 | | | 2.53 | | |
| **SE (mean)** | 0.72 | | | 0.75 | | | 3.65 | | | 0.2 | | |
| **CD (5%)** | 2 | | | 2.1 | | | 10.14 | | | 0.56 | | |

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

#### 4.5.4 Total number of productive tillers per plant

The means of genotypes for total number of productive tillers per plant ranged from 1.13 (ICMA 97111 x BIB 551-560) to 4.00 (ICMA 30201 x BIB 511-520) and regression coefficient ranged from -0.10 (ICMA 97444 x BIB 511-520) to 2.56 (ICMA 04999 x BIB 531-540). The population mean of genotypes for total number of productive tillers per plant was 2.53. The estimate of $S^2d_i$ significantly differed from zero for 10 genotype exhibiting instability of this genotype (Table 4.5.2). Out of 80 genotypes, 7 genotypes, (ICMA 04999 x BIB 511-520), (ICMA 10444 x BIB 551-560), (ICMA 88004 x BIB 561-570), (ICMA 97444 x BIB 561-570), (ICMA 98222 x BIB 561-570), (ICMA 97444 x BIB 571-580) and (ICMA 30199 x BIB 571-580) had mean significantly higher than general mean, regression coefficient equivalent to unity and $S^2d_i$ equivalent to zero, exhibiting average stability and wider adaptability, hence, considered most stable and desirable for total number of productive tillers per plant over variable environments. The genotypes (ICMA 88004 x BIB 501-510), (ICMA 93333 x BIB 511-520), (ICMA 30201 x BIB 511-520), (ICMA 04999 x BIB 531-540), (ICMA 88004 x BIB 531-540), (ICMA 93333 x BIB 531-540), (ICMA 97444 x BIB 531-540), (ICMA 30209 x BIB 531-540), (ICMA 04999 x BIB 561-570), (ICMA 97111 x BIB 561-570), (ICMA 10444 x BIB 561-570), (ICMA 30199 x BIB 561-570), (ICMA 30209 x BIB 561-570), (ICMA 04999 x BIB 571-580), (ICMA 88004 x BIB 571-580) and (ICMA 97111 x BIB 571-580) had mean significantly more than general mean, regression coefficient more than unity and $S^2d_i$ equivalent to zero, exhibiting below average stability and considered for suitable for better environment. The genotypes (ICMA 97444 x BIB 481-500), (ICMA 30199 x BIB 481-500), (ICMA 30209 x BIB 511-520), (ICMA 30209 x BIB 551-560) and (ICMA 93333 x BIB 561-570) had mean significantly more than general mean, regression coefficient less than to unity and $S^2d_i$ equivalent to zero, exhibiting above average stability, hence, these genotypes were considered stable for poor environmental conditions.

**4.5.5 Ear head length**

The means of genotypes ranged from 10.78 cm (ICMA 04999 x BIB 551-560) to 28.64 cm (ICMA 93333 x BIB 551-560) and regression coefficient ranged from -0.14 (ICMA 88004 x BIB 481-500) to 2.11 (ICMA 97111 x BIB 551-560). The population mean of genotypes for ear head length was 20.44. The estimate of $S^2d_i$ significantly differed from zero for 31 genotypes exhibiting instability of these genotypes (Table 4.5.3). Out of 80 genotypes, 25 genotypes i.e., (ICMA 30200 x BIB 481-500), (ICMA 30201 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 97111 x BIB 501-510), (ICMA 98222 x BIB 501-510), (ICMA 10444 x BIB 501-510), (ICMA 30201 x BIB 511-520), (ICMA 30209 x BIB 511-520), (ICMA 93333 x BIB 531-540), (ICMA 97444 x BIB 531-540), (ICMA 10444 x BIB 531-540), (ICMA 30200 x BIB 531-540), (ICMA 30201 x BIB 531-540), (ICMA 88004 x BIB 551-560), (ICMA 98222 x BIB 551-560), (ICMA 93333 x BIB 561-570), (ICMA 97111 x BIB 561-570), (ICMA 98222 x BIB 561-570), (ICMA 30209 x BIB 561-570), (ICMA 97111 x BIB 571-580), (ICMA 10444 x BIB 571-580), (ICMA 30201 x BIB 571-580), (ICMA 30209 x BIB 571-580), RHB-177 and HHB 67 improve had mean significantly higher than general mean, regression coefficient equivalent to unity and $S^2d_i$ equivalent to zero, exhibiting average stability and wider adaptability, hence, considered most stable and desirable for ear head length over variable environments. The genotypes (ICMA 97444 x BIB 481-500), (ICMA 97444 x BIB 501-510), (ICMA 88004 x BIB 511-520), (ICMA 10444 x BIB 511-520), (ICMA 98222 x BIB 531-540), (ICMA 10444 x BIB 561-570), (ICMA 30209 x BIB 531-540) and (ICMA 04999 x BIB 571-580) had mean significantly more than general mean, regression coefficient more than unity and $S^2d_i$ equivalent to zero, exhibiting below average stability and considered for better environment. The genotypes (ICMA 97444 x BIB 511-520), (ICMA 30199 x BIB 551-560), (ICMA

30200 x BIB 561-570), (ICMA 88004 x BIB 571-580) and (ICMA 30200 x BIB 571-580) had mean significantly more than general mean, regression coefficient less than to unity and $S^2d_i$ equivalent to zero, exhibiting above average stability, hence, these genotypes were considered for poor environmental conditions.

**4.5.6 Ear head diameter**

The means of genotypes ranged from 9.78 cm (ICMA 30209 BIB 481-500) to 27.65 cm (ICMA 98222 BIB 481-500) and regression coefficient ranged from -0.05 (ICMA 93333 x BIB 551-560) to 2.72 (ICMA 98222 x BIB 511-520). The population mean of genotypes for ear head diameter was 18.97mm. The estimate of $S^2d_i$ significantly differed from zero for nine genotype exhibiting instability of these genotypes (Table 4.5.3). Out of 80 genotypes, 16 genotypes, (ICMA 04999 x BIB 481-500), (ICMA 97111 x BIB 501-510), (ICMA 98222 x BIB 501-510), (ICMA 88004 x BIB 511-520), (ICMA 97444 x BIB 511-520), (ICMA 10444 x BIB 511-520), (ICMA 30199 x BIB 511-520), (ICMA 98222 x BIB 531-540), (ICMA 10444 x BIB 531-540), (ICMA 30199 x BIB 531-540), (ICMA 88004 x BIB 551-560), (ICMA 30209 x BIB 551-560), (ICMA 88004 x BIB 561-570), (ICMA 30209 x BIB 561-570), (ICMA 88004 x BIB 571-580), and BHB-1602 had mean significantly higher than general mean, regression coefficient equivalent to unity and $S^2d_i$ equivalent to zero, exhibiting average stability and wider adaptability, hence, considered most stable and desirable for ear head diameter over variable environments. The genotypes (ICMA 97444 x BIB 501-510), (ICMA 10444 x BIB 501-510), (ICMA 30209 x BIB 511-520), (ICMA 30209 x BIB 531-540), (ICMA 10444 x BIB 551-560), (ICMA 30200 x BIB 561-570) and (ICMA 30201 x BIB 561-570) had mean significantly more than general mean, regression coefficient more than unity and $S^2d_i$ equivalent to zero, exhibiting below average stability and considered for better environment. The genotypes (ICMA 93333 x BIB 481-550), (ICMA 97111 x BIB 481-500), (ICMA 30200 x BIB 481-500), (ICMA

30201 x BIB 481-500), (ICMA 04999 x BIB 511-520), (ICMA 93333 x BIB 511-520), (ICMA 30201 x BIB 511-520), (ICMA 30200 x BIB 531-540), (ICMA 98222 x BIB 551-560), (ICMA 30199 x BIB 551-560), (ICMA 04999 x BIB 561-570), (ICMA 04999 x BIB 571-580), (ICMA 93333 x BIB 571-580), (ICMA 98222 x BIB 571-580), (ICMA 30201 x BIB 571-580), (ICMA 30209 x BIB 571-580) and HHB 67 improve had mean significantly more than general mean, regression coefficient less than to unity and $S^2d_i$ equivalent to zero, exhibiting above average stability, hence, these genotypes were considered for poor environmental conditions.

**4.5.7 Test weight**

The means of genotypes for test weight ranged from 4.83 g (ICMA 97444 x BIB 551-560) to 12.84 g (ICMA 88004 x BIB 501-510) and regression coefficient ranged from -0.05 (ICMA 30209 x BIB 571-580) to 2.16 (ICMA 97111 x BIB 501-510). The estimate of $S^2d_i$ significantly differed from zero for 8 genotype exhibiting instability of this genotype. The population mean of genotypes for test weight was 9.42 g(Table 4.5.3). Out of 80 genotypes, 25 genotypes, (ICMA 97111 x BIB 481-500), (ICMA 97444 x BIB 481-500), (ICMA 30199 x BIB 481-500), (ICMA 88004 x BIB 501-510), (ICMA 93333 x BIB 501-510), (ICMA 04999 x BIB 511-520), (ICMA 88004 x BIB 511-520), (ICMA 93333 x BIB 511-520), (ICMA 30201 x BIB 511-520), (ICMA 04999 x BIB 531-540), (ICMA 93333 x BIB 531-540), (ICMA 97444 x BIB 531-540), (ICMA 10444 x BIB 531-540), (ICMA 30201 x BIB 531-540), (ICMA 88004 x BIB 551-560), (ICMA 93333 x BIB 551-560), (ICMA 98222 x BIB 551-560), (ICMA 30209 x BIB 551-560), (ICMA 04999 x BIB 561-570), (ICMA 30199 x BIB 561-570), (ICMA 30200 x BIB 561-570), (ICMA 10444 x BIB 571-580), RHB-177, BHB 67 improve and

**Table 4.5.3 Estimates of stability parameters for ear head length, ear head diameter, test weight and ear head weight**

| Genotypes | Ear head length | | | Ear head diameter | | | Test weight | | | Ear head weight | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ |
| ICMA 04999 × BIB 481-500 | 19.52 | 0.85** | -0.27 | 20.2 | 0.87** | -1.11 | 9.76 | 0.54 | 0.01175 | 77.22 | 0.9** | -53.54 |
| ICMA 88004 × BIB 481-500 | 17.45 | -0.14 | 31.3** | 16.59 | 1.6** | 0.23 | 6.84 | 1.1** | -0.01276 | 85.56 | 0.59** | -28.84 |
| ICMA 93333 × BIB 481-500 | 15.87 | 1.18** | -0.41 | 20 | 0.52** | -0.35 | 10.63 | -0.16 | 0.12645** | 76.11 | 0.11 | -43.8 |
| ICMA 97111 × BIB 481-500 | 18.33 | 1.47** | -0.31 | 20.72 | 0.57** | -0.46 | 9.83 | 1.1** | -0.01276 | 70 | 0.14* | -44.49 |
| ICMA 97444 × BIB 481-500 | 20.83 | 1.12** | -0.1 | 13.66 | 2.06** | 3.94* | 9.28 | 1.1** | -0.01276 | 50.55 | 1.35** | -52.01 |
| ICMA 98222 × BIB 481-500 | 28.29 | 0.57 | 3.59* | 27.65 | 0.35 | 0.54 | 12.6 | -0.38 | 0.1818** | 142.78 | -0.07 | -39.27 |
| ICMA 10444 × BIB 481-500 | 15.92 | 1.35** | 0.26 | 10.29 | 0.85** | -1.12 | 7.84 | 1.1** | -0.01276 | 26.89 | -0.05 | -50.35 |
| ICMA 30199 × BIB 481-500 | 17.72 | 0.78** | -0.66 | 21.52 | 0.27 | 0.96 | 10.85 | 1.1** | -0.01276 | 86.11 | 0.66** | -52.29 |
| ICMA 30200 × BIB 481-500 | 20.76 | 0.95** | -0.66 | 21.59 | 0.63** | -0.59 | 5.84 | 1.1** | -0.01276 | 86.67 | 1.23** | -52.88 |
| ICMA 30201 × BIB 481-500 | 24.35 | 0.96** | -0.65 | 22.65 | 0.74** | -0.95 | 7.84 | 1.1** | -0.01276 | 50.33 | 1.91** | -51.62 |
| ICMA 30209 × BIB 481-500 | 14.62 | 1.63** | 4.84** | 9.78 | 0.98** | -1.18 | 7.07 | 1.1** | -0.01276 | 25.56 | 0.03 | -48.65 |
| ICMA 04999 × BIB 501-510 | 16.11 | 1.23 | 17.83** | 10.3 | 0.97** | -1.18 | 9.02 | 1.1** | -0.01276 | 27.78 | 0.16** | -50.4 |
| ICMA 88004 × BIB 501-510 | 26.34 | 0.96** | -0.65 | 24.97 | 0.13 | 2.02 | 12.84 | 1.1** | -0.01276 | 133.89 | -0.1 | -51.26 |
| ICMA 93333 × BIB 501-510 | 20.23 | 0.52 | 4.68** | 15.94 | 1.73** | 1.22 | 9.91 | 1.1** | -0.01276 | 52.78 | 1.02** | -53.64 |
| ICMA 97111 × BIB 501-510 | 24.92 | 0.79** | 0.22 | 22.88 | 0.76** | -0.95 | 10.89 | 2.16** | -0.01154 | 116.11 | 0.48** | -10.98 |
| ICMA 97444 × BIB 501-510 | 21.45 | 1.38** | 3.42* | 21.58 | 1.18** | -1 | 7.84 | 1.1** | -0.01276 | 42.55 | 0.89** | -52.57 |
| ICMA 98222 × BIB 501-510 | 23 | 1.01** | -0.65 | 25.46 | 0.87** | -1.14 | 10.89 | 2.07** | -0.01186 | 123.89 | -0.01 | -40.88 |
| ICMA 10444 × BIB 501-510 | 20.66 | 0.92** | -0.6 | 19.37 | 1.17** | -1 | 10.08 | 1.46** | -0.01299 | 71.67 | 0.23** | -46.36 |
| ICMA 30199 × BIB 501-510 | 17.08 | 1.21** | 0.66 | 13.6 | 2.17** | 5.02* | 9.84 | 0.68 | 0.00002 | 67.22 | 0.72** | -52.77 |
| ICMA 30200 × BIB 501-510 | 17.83 | 1.78* | 20.69** | 14.13 | 2.31** | 6.55* | 8.91 | 1.1** | -0.01276 | 40.89 | 1.16** | -48.5 |
| ICMA 30201 × BIB 501-510 | 17.58 | 1.88* | 19.87** | 13.58 | 2.07** | 3.94* | 10.67 | 0.08 | 0.0766** | 59.56 | 1.84** | -45.78 |
| ICMA 30209 × BIB 501-510 | 16.47 | 1.89* | 19.77** | 15.11 | 2.58** | 9.69** | 6.91 | 1.1** | -0.01276 | 47 | 1.45** | -33.69 |
| ICMA 04999 × BIB 511-520 | 25.08 | 0.51 | 4.99** | 22.06 | 0.51** | -0.27 | 10.84 | 1.1** | -0.01276 | 85 | 0.96** | -53.64 |
| ICMA 88004 × BIB 511-520 | 20.96 | 1.47** | 5.56** | 19.45 | 1.04** | -1.16 | 11.83 | 1.1** | -0.01276 | 117.78 | -0.85 | -44.37 |
| ICMA 93333 × BIB 511-520 | 21.24 | 0.57 | 3.88** | 19.99 | 0.69** | -0.83 | 9.86 | 1.1** | -0.01276 | 69.45 | 0.84** | -53.48 |
| ICMA 97111 × BIB 511-520 | 16 | 1.71** | 12.63** | 13.23 | 2.01** | 3.51* | 8.83 | 1.1** | -0.01276 | 49.78 | 1.29** | -53.65 |
| ICMA 97444 × BIB 511-520 | 21.67 | 0.65* | 2.04* | 19.72 | 0.83** | -1.09 | 7.84 | 1.1** | -0.01276 | 95 | 0.42** | -49.43 |
| ICMA 98222 × BIB 511-520 | 14.28 | 1.88* | 19.82** | 15.66 | 2.72** | 11.94** | 10.75 | 0.56 | 0.00984 | 53.33 | 1.55** | -43.41 |

| Genotypes | Ear head length | | | Ear head diameter | | | Test weight | | | Ear head weight | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ |
| ICMA 10444 × BIB 511-520 | 23.17 | 1.12** | -0.2 | 20.59 | 0.85** | -1.12 | 10.73 | 2.13** | -0.01164 | 131.11 | -0.31 | -40.66 |
| ICMA 30199 × BIB 511-520 | 13.68 | 1.43** | 4.27** | 20.94 | 1.08** | -1.15 | 7.85 | 1.1** | -0.01276 | 112.78 | 2.66** | -17.98 |
| ICMA 30200 × BIB 511-520 | 13.03 | 1.4** | 3.92** | 10.92 | 1.03** | -1.17 | 5.84 | 1.1** | -0.01276 | 20.89 | 0.16** | -51.99 |
| ICMA 30201 × BIB 511-520 | 21.43 | 0.88** | -0.45 | 24.2 | 0.65** | -0.77 | 10.86 | 1.1** | -0.01276 | 120.56 | 2.44** | 4.02 |
| ICMA 30209 × BIB 511-520 | 21.83 | 0.94** | -0.64 | 19.16 | 1.53** | 0.18 | 8.13 | 1.1** | -0.01276 | 90.55 | 1.08** | -53.6 |
| ICMA 04999 × BIB 531-540 | 17.84 | 1.81** | 16.68** | 13.39 | 1.94** | 2.8 | 10.99 | 1.1** | -0.01276 | 67.78 | 2.34** | -39.91 |
| ICMA 88004 × BIB 531-540 | 15.29 | 0.96** | -0.67 | 10.51 | 0.77** | -0.98 | 5.92 | 1.1** | -0.01276 | 21.34 | 0.15** | -48.42 |
| ICMA 93333 × BIB 531-540 | 23.94 | 0.81** | 0.15 | 16.72 | 0.73** | -0.93 | 10.07 | 1.1** | -0.01276 | 101.11 | 1.06** | -51.52 |
| ICMA 97111 × BIB 531-540 | 14.41 | 2.11* | 31.31** | 13.72 | 1.72** | 1.18 | 7.85 | 1.1** | -0.01 | 51.11 | 1.43** | -46.2 |
| ICMA 97444 × BIB 531-540 | 21.94 | 0.78** | 0.45 | 17.18 | 0.82** | -1.07 | 9.99 | 1.1** | -0.01 | 76.67 | 1.2** | 2.57 |
| ICMA 98222 × BIB 531-540 | 23.81 | 1.13** | -0.13 | 19.58 | 1.09** | -1.14 | 11.65 | 1.62* | 0.02 | 63.89 | 1.81** | -44.88 |
| ICMA 10444 × BIB 531-540 | 23.08 | 0.75** | 0.65 | 23.25 | 0.91** | -1.16 | 10.84 | 1.1** | -0.01 | 53.89 | 1.26** | -52.58 |
| ICMA 30199 × BIB 531-540 | 18.86 | 0.92** | -0.6 | 20.99 | 0.85** | -1.12 | 8.92 | 1.1** | -0.01 | 55 | 0.96** | -53.64 |
| ICMA 30200 × BIB 531-540 | 23.24 | 1.05** | -0.56 | 19.87 | 0.43* | 0.17 | 9.74 | 0.34 | 0.03 | 41.66 | 0.6** | -51.72 |
| ICMA 30201 × BIB 531-540 | 22.61 | 0.8** | 0.23 | 21.04 | 0.35 | 0.58 | 11.84 | 1.1** | -0.01 | 53.33 | 1.73** | -51.52 |
| ICMA 30209 × BIB 531-540 | 22.63 | 1.13** | -0.44 | 19.09 | 1.21** | -0.93 | 8.87 | 1.1** | -0.01 | 79.44 | 1.32** | 86.38 |
| ICMA 04999 × BIB 551-560 | 10.78 | 1.67** | 11.28** | 10.77 | 1.15** | -1.08 | 5.99 | 1.1** | -0.01 | 24.78 | 0.37** | -53.41 |
| ICMA 88004 × BIB 551-560 | 23.8 | 0.75** | 0.62 | 22.2 | 0.75** | -0.98 | 9.85 | 1.1** | -0.01 | 69.44 | 1.72** | 229.59* |
| ICMA 93333 × BIB 551-560 | 28.64 | 0.56 | 3.86** | 25.44 | -0.05 | 3.38* | 12.83 | 1.1** | -0.01 | 154.44 | 0.61** | -49.01 |
| ICMA 97111 × BIB 551-560 | 12.16 | 1.2** | 0.57 | 10.91 | 1.13** | -1.09 | 7.28 | 1.1** | -0.01 | 24.22 | 0.34** | -53.25 |
| ICMA 97444 × BIB 551-560 | 13.53 | 1.25** | 1.21 | 10.97 | 1.12** | -1.11 | 4.83 | 1.1** | -0.01 | 25.56 | 0.03 | -48.65 |
| ICMA 98222 × BIB 551-560 | 26 | 0.86** | -0.25 | 22.44 | 0.71** | -0.86 | 9.85 | 1.1** | -0.01 | 83.89 | 1.47** | 101.21 |
| ICMA 10444 × BIB 551-560 | 26.44 | 0.28 | 35.25** | 21.45 | 1.21** | -0.97 | 10.21 | 1.65** | -0.01 | 59.44 | 1.2** | -53.15 |
| ICMA 30199 × BIB 551-560 | 22.55 | 0.68** | 1.59 | 22.27 | 0.53** | -0.25 | 7.88 | 1.1** | -0.01 | 86.67 | 1.83** | -45.37 |
| ICMA 30200 × BIB 551-560 | 16.6 | 2.03* | 27.55** | 12.98 | 2.01** | 3.32 | 7.37 | 1.1** | -0.01 | 42.44 | 1.39** | -53.74 |
| ICMA 30201 × BIB 551-560 | 25.59 | 0.09 | 28.25** | 18.06 | 1.01** | -1.17 | 4.91 | 1.1** | -0.01 | 69.44 | 1.02** | -53.68 |
| ICMA 30209 × BIB 551-560 | 24.67 | 0.31 | 10.44** | 19.6 | 1.08** | -1.12 | 10.07 | 1.1** | -0.01 | 72.78 | 1.4** | -22.21 |
| ICMA 04999 × BIB 561-570 | 20.22 | 1.1** | -0.32 | 20.5 | 0.7** | -0.82 | 9.78 | 1.1** | -0.01 | 71.11 | 1.98** | -47.94 |

| Genotypes | Ear head length | | | Ear head diameter | | | Test weight | | | Ear head weight | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ |
| ICMA 88004 × BIB 561-570 | 20.32 | 0.85** | -0.27 | 21.17 | 0.92** | -1.16 | 9.93 | 1.18** | -0.01 | 58.89 | 1.31** | -48.36 |
| ICMA 93333 × BIB 561-570 | 23.57 | 0.85** | -0.18 | 16.79 | 0.65** | -0.74 | 9.07 | 1.1** | -0.01 | 47.78 | 0.53** | -26.62 |
| ICMA 97111 × BIB 561-570 | 21.85 | 0.84** | -0.12 | 16.38 | 1.12** | -1.1 | 11.55 | 0.2 | 0.49** | 49.45 | 1.01** | -30.45 |
| ICMA 97444 × BIB 561-570 | 17.9 | 0.76 | 7.44** | 12.83 | 1.47** | -0.21 | 10.01 | 0.66 | 0 | 59.45 | 1.38** | -51.56 |
| ICMA 98222 × BIB 561-570 | 20.71 | 0.8** | 0.23 | 24.64 | -0.08 | 3.7* | 12.65 | 0.53 | 0.19** | 124.44 | -0.11 | -27.32 |
| ICMA 10444 × BIB 561-570 | 22.16 | 1.15** | -0.67 | 17.81 | 1.59** | 0.38 | 8.38 | 1.1** | -0.01 | 58.89 | 1.48** | 5.34 |
| ICMA 30199 × BIB 561-570 | 18.37 | 0.83** | -0.14 | 18.45 | 1.27** | -0.82 | 10.5 | 1.1** | -0.01 | 75 | 1.87** | -43.57 |
| ICMA 30200 × BIB 561-570 | 22.86 | 0.68** | 1.58 | 19.6 | 1.13** | -1.1 | 10.17 | 1.1** | -0.01 | 86.11 | 1.02** | -53.64 |
| ICMA 30201 × BIB 561-570 | 22.57 | 0.61 | 3.04* | 22.39 | 1.11** | -1.09 | 10.05 | 0.43 | 0.27** | 170.56 | 0.72** | -52.8 |
| ICMA 30209 × BIB 561-570 | 21.22 | 0.91** | -0.56 | 20.56 | 0.81** | -1.07 | 10.69 | 0.74 | 0.07* | 63.89 | 1.43** | 21.85 |
| ICMA 04999 × BIB 571-580 | 22.39 | 1.22** | -0.58 | 20.45 | 0.61** | -0.61 | 10.78 | 0.68 | 0 | 82.22 | 1.67** | -40.51 |
| ICMA 88004 × BIB 571-580 | 21.05 | 0.62* | 2.63* | 19.06 | 0.84** | -1.11 | 8.91 | 1.1** | -0.01 | 72.78 | 1.38** | -16.14 |
| ICMA 93333 × BIB 571-580 | 21.78 | 0.51 | 4.98** | 19.25 | 0.74** | -0.94 | 8.22 | 1.1** | -0.01 | 82.78 | 1.03** | -32.66 |
| ICMA 97111 × BIB 571-580 | 21.95 | 0.93** | -0.59 | 18.7 | 1.96** | -1.18 | 10.54 | 0.18 | 0.06* | 58.89 | 1.85** | -35.16 |
| ICMA 97444 × BIB 571-580 | 20.4 | 0.84** | -0.22 | 18.32 | 0.96** | -1.18 | 9.75 | 0.42 | 0.02 | 81.11 | 1.26** | -0.55 |
| ICMA 98222 × BIB 571-580 | 18.86 | 0.86** | -0.34 | 25.64 | 0.58** | -0.47 | 7.48 | 1.1** | -0.01 | 80 | 0.74** | -49.26 |
| ICMA 10444 × BIB 571-580 | 21.79 | 1.07** | -0.16 | 27.11 | 0.34 | 0.6 | 10.8 | 1.1** | -0.01 | 67.22 | 1.08** | -53.6 |
| ICMA 30199 × BIB 571-580 | 18.53 | 0.76** | 0.51 | 25.02 | 0.24 | 1.17 | 9.38 | 1.1** | -0.01 | 82.78 | 1.21** | -38.31 |
| ICMA 30200 × BIB 571-580 | 21.62 | 0.67** | 1.76 | 23.18 | 0.16 | 1.72 | 9.77 | 0.64 | 0 | 85 | 0.51** | -12.34 |
| ICMA 30201 × BIB 571-580 | 23.27 | 0.84** | 3.15* | 20.81 | 0.6** | -0.56 | 7.85 | 1.1** | -0.01 | 68.33 | 1.14** | -53.42 |
| ICMA 30209 × BIB 571-580 | 21.41 | 0.86** | -0.26 | 21.21 | 0.54** | -0.33 | 10.23 | -0.05 | -0.01 | 65.56 | 1.49** | -44.7 |
| RHB - 177 (Check-1) | 23.44 | 0.82* | 3.32* | 17.04 | 1.48** | 0.84 | 10.07 | 1.1** | -0.01 | 66.11 | 1.11** | -53.43 |
| HHB 67 improved (Check-2) | 22.11 | 0.95** | -0.64 | 27.48 | 0.49** | -0.14 | 9.84 | 1.1** | -0.01 | 72.78 | 1.68** | 33.31 |
| BHB - 1602 ( Check-3) | 18.68 | 0.78** | 0.32 | 23.44 | 0.94** | -1.17 | 9.87 | 0.92** | -0.01 | 52.78 | 1.12** | -50.14 |
| **Population mean** | 20.44 | | | 18.97 | | | 9.42 | | | 72.12 | | |
| **SE (mean)** | 0.58 | | | 0.77 | | | 0.08 | | | 5.18 | | |
| **CD (5%)** | 1.61 | | | 2.13 | | | 0.22 | | | 14.38 | | |

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

BHB-1602 had mean significantly higher than general mean, regression coefficient equivalent to unity and $S^2d_i$ equivalent to zero, exhibiting average stability and wider adaptability, hence, considered most stable and desirable for test weight over variable environments. The genotypes (ICMA 97111 x BIB 501-510), (ICMA 98222 x BIB 501-510), (ICMA 10444 x BIB 501-510), (ICMA 10444 x BIB 511-520), (ICMA 98222 x BIB 531-540), (ICMA 10444 x BIB 551-560), and (ICMA 88004 x BIB 561-570) had mean significantly more than general mean, regression coefficient more than unity and $S^2d_i$ equivalent to zero, exhibiting below average stability and considered for better environment.

**4.5.8 Ear head weight**

The means of genotypes ranged from 20.89 (ICMA 30200 x BIB 511-520) to 170.56 (ICMA 30201 x BIB 561-570) and regression coefficient ranged from -0.01 (ICMA 98222 x BIB 501-510) to 2.66 (ICMA 30199 x BIB 511-520). The population mean of genotypes for ear head length was 72.12. The estimate of $S^2d_i$ significantly differed from zero for one genotypes exhibiting instability of these genotypes (Table 4.5.3). Out of 80 genotypes, 7 genotypes, (ICMA 04999 x BIB 481-500), (ICMA 04999 x BIB 511-520), (ICMA 30209 x BIB 511-520), (ICMA 93333 x BIB 531-540), (ICMA 30200 x BIB 561-570), (ICMA 30201 x BIB 561-570) and (ICMA 93333 x BIB 571-580) had mean significantly higher than general mean, regression coefficient equivalent to unity and $S^2d_i$ equivalent to zero, exhibiting average stability and wider adaptability, hence, considered most stable and desirable for ear head weight over variable environments. The genotypes (ICMA 30200 x BIB 481-500), (ICMA 30199 x BIB 511-520), (ICMA 30201 x BIB 511-520), (ICMA 97444 x BIB 531-540), (ICMA 30209 x BIB 531-540), (ICMA 98222 x BIB 551-560), (ICMA 30199 x BIB 551-560), (ICMA 30209 x BIB 551-560), (ICMA 30199 x BIB 561-570), (ICMA 04999 x BIB 571-580), (ICMA 88004 x BIB 571-580), (ICMA 97444 x BIB 571-580), (ICMA 30199 x BIB 571-580) and HHB

67 improved had mean significantly more than general mean, regression coefficient more than unity and $S^2d_i$ equivalent to zero, exhibiting below average stability and considered for better environment. The genotypes (ICMA 88004 x BIB 481-500), (ICMA 30199 x BIB 481-500), (ICMA 97111 x BIB 501-510), (ICMA 97444 x BIB 511-520), (ICMA 93333 x BIB 551-560), (ICMA 98222 x BIB 571-580), (ICMA 30200 x BIB 571-580) had mean significantly more than general mean, regression coefficient less than to unity and $S^2d_i$ equivalent to zero, exhibiting above average stability, hence, these genotypes were considered for poor environmental conditions.

**4.5.9 Dry stover yield per plant**

The means of genotypes for dry stover yield per plant ranged 47.78 g (ICMA 10444 x BIB 481-500, ICMA 04999 x BIB 551-560 and ICMA 97444 x BIB 551-560) to 337.78 g (ICMA 30201 x BIB 481-500) and regression coefficient ranged from -0.27 (ICMA 30199 x BIB 501-510) to 3 (ICMA 30199 x BIB 511-520). The population mean of genotypes for dry stover yield per plant was 155.69 g. The estimate of $S^2d_i$ significantly differed from zero for eight genotypes exhibiting instability of these genotypes (Table 4.5.4). Out of 80 genotypes, 6 genotypes, (ICMA 04999 x BIB 481-500), (ICMA 10444 x BIB 511-520), (ICMA 30200 x BIB 531-540), (ICMA 04999 x BIB 561-570), (ICMA 93333 x BIB 561-570) and (ICMA 30199 x BIB 571-580) had mean significantly higher than general mean, regression coefficient equivalent to unity and $S^2d_i$ equivalent to zero, exhibiting average stability and wider adaptability, hence, considered most stable and desirable for dry stover yield per plant over variable environments. The genotypes (ICMA 30199 x BIB 481-500), (ICMA 30199 x BIB 511-520), (ICMA 30201 x BIB 511-520), (ICMA 93333 x BIB 531-540), (ICMA 30199 x BIB 531-540), (ICMA 30209 x BIB 531-540), (ICMA 93333 x BIB 551-560), (ICMA 30199 x BIB 551-560), (ICMA 97444 x BIB 551-560), (ICMA 30199 x BIB 561-570), (ICMA 04999 x BIB 571-580), (ICMA 88004 x BIB 571-580) and (ICMA 97444 x BIB 571-580) had mean significantly more than general mean, regression coefficient more than unity and $S^2d_i$ equivalent to zero, exhibiting below average stability and considered for better environment. The genotypes (ICMA 88004 x BIB 481-500), (ICMA 93333 x BIB 481-500), (ICMA 30200 x BIB 481-500), (ICMA 04999 x BIB 511-520), (ICMA 97444 x BIB 511-520), (ICMA 98222 x BIB 551-560), (ICMA 10444 x BIB 551-560), (ICMA 30201 x BIB 551-560), (ICMA 98222 x BIB 561-570) and (ICMA 30200 x BIB 571-580) had mean significantly more than general mean, regression coefficient less than to unity and $S^2d_i$ equivalent to zero, exhibiting above average stability, hence, these genotypes were considered for poor environmental conditions.

**4.5.10 Grain yield per plant**

Perusal of Table 4.5.4 revealed that the means of genotypes for grain yield per plant ranged from 15.78 g (ICMA 30200 x BIB 511-520 and ICMA 88004 x BIB 531-540) to 79.67 g (ICMA 98222 x BIB 481-500) and regression coefficient ranged from -0.56 (ICMA 30201 x BIB 561-570) to 2.21 (ICMA 98222 x BIB 561-570). The population mean of genotypes for grain yield per plant was 36.15 g. The estimate of $S^2d_i$ significantly differed from zero for ten genotype exhibiting instability of these genotypes. Out of 80 genotypes, 6 genotypes, (ICMA 98222 x BIB 481-500), (ICMA 30200 x BIB 481-500), (ICMA 97444 x BIB 511-520), (ICMA 98222 x BIB 551-560), (ICMA 30200 x BIB 571-580) and BHB-1602 had mean significantly higher than general mean, regression coefficient equivalent to unity and $S^2d_i$ equivalent to zero, exhibiting average stability and wider adaptability, hence, considered most stable and desirable for grain yield per plant over variable environments. The genotypes (ICMA 04999 x BIB 481-500), (ICMA 30199 x BIB 481-500), (ICMA 30209 x BIB 511-520), (ICMA 97444 x BIB 531-540), (ICMA 30201 x BIB 531-540), (ICMA 30209 x BIB 531-540), (ICMA 88004 x BIB 551-560), (ICMA 93333 x BIB 551-560), (ICMA 30199 x BIB 551-560), (ICMA 30209 x BIB 551-560), (ICMA 04999 x BIB 561-570), (ICMA 88004 x BIB 561-570), (ICMA 98222 x

BIB 561-570), (ICMA 30199 x BIB 561-570), (ICMA 30200 x BIB 561-570), (ICMA 30209 x BIB 561-570), (ICMA 04999 x BIB 571-580), (ICMA 88004 x BIB 571-580), (ICMA 30209 x BIB 571-580), and HHB 67 improved had mean significantly more than general mean, regression coefficient more than unity and $S^2d_i$ equivalent to zero, exhibiting below average stability and considered for better environment. The genotypes (ICMA 88004 x BIB 481-500), (ICMA 04999 x BIB 511-520), (ICMA 10444 x BIB 511-520), (ICMA 30201 x BIB 511-520), (ICMA 93333 x BIB 571-580) and (ICMA 97444 x BIB 571-580) had mean significantly more than general mean, regression coefficient less than to unity and $S^2d_i$ equivalent to zero, exhibiting above average stability, hence, these genotypes were considered for poor environmental conditions.

**4.5.11 Harvest index**

The means of genotypes for harvest index ranged from 14.04% (ICMA 30199 x BIB 501-510) to 41.95% (ICMA 98222 x BIB 481-500) and regression coefficient ranged from 0.08 (ICMA 30201 x BIB 481-500) to 5.19 (ICMA 30209 x BIB 501-510). The population mean of genotypes for harvest index was 26.97%. The estimate of $S^2d_i$ significantly differed from zero for 18 genotypes exhibiting instability of these genotypes (Table 4.5.4). Out of 80 genotypes, 19 genotypes, (ICMA 10444 x BIB 481-500), (ICMA 30200 x BIB 501-510), (ICMA 30201 x BIB 501-510) (ICMA 30209 x BIB 501-510), (ICMA 98222 x BIB 511-520), (ICMA 30200 x BIB 511-520), (ICMA 30201 x BIB 511-520), (ICMA 04999 x BIB 531-540), (ICMA 88004 x BIB 531-540), (ICMA 93333 x BIB 531-540), (ICMA 88004 x BIB 551-560), (ICMA 97111 x BIB 551-560), (ICMA 97444 x BIB 551-560), (ICMA 30200 x BIB 551-560), (ICMA 10444 x BIB 561-570), (ICMA 30209 x BIB 561-570), (ICMA 97444 x BIB 571-580), (ICMA 30199 x BIB 571-580) and HHB 67 improved had mean significantly more than general mean, regression coefficient more than unity and $S^2d_i$ equivalent to zero, exhibiting below average stability and considered suitable for better environment.

**4.5.12 Threshing index**

The means of genotypes for threshing index ranged from 32.38% (ICMA 30201 x BIB 561-570) to 134.48% (ICMA 30201 x BIB 481-500) and regression coefficient ranged from -0.01 (ICMA 30200 x BIB 571-580) to 14.68 (ICMA 30201 x BIB 481-500). The population mean of genotypes for threshing index was 55.34%. The estimate of $S^2d_i$ significantly differed from zero for 21 genotypes exhibiting instability of these genotypes (Table 4.5.4). Out of 80 genotypes, 4 genotypes, (ICMA 97444 x BIB 481-500), (ICMA 30209 x BIB 551-560), (ICMA 04999 x BIB 571-580) and (ICMA 88004 x BIB 571-580) had mean significantly higher than general mean, regression coefficient equivalent to unity and $S^2d_i$ equivalent to zero, exhibiting average stability and wider adaptability, hence, considered most stable and desirable for threshing index over variable environments. The genotypes (ICMA 30201 x BIB 481-500), (ICMA 30200 x BIB 501-510), (ICMA 98222 x BIB 511-520), (ICMA 30200 x BIB 511-520), (ICMA 88004 x BIB 531-540), (ICMA 30200 x BIB 531-540), (ICMA 30201 x BIB 531-540), (ICMA 04999 x BIB 551-560), (ICMA 88004 x BIB 551-560), (ICMA 97111 x BIB 551-560), (ICMA 30200 x BIB 551-560), (ICMA 04999 x BIB 561-570), (ICMA 88004 x BIB 561-570), (ICMA 10444 x BIB 561-570), (ICMA 30199 x BIB 561-570), (ICMA 30209 x BIB 561-570), (ICMA 97111 x BIB 571-580), (ICMA 97444 x BIB 571-580), (ICMA 30199 x BIB 571-580) and BHB-1602 had mean significantly more than general mean, regression coefficient more than unity and $S^2d_i$ equivalent to zero, exhibiting below average stability and considered stable for better environment.

**Table 4.5.4 Estimates of stability parameters for dry stover yield per plant, grain yield per plant, harvest index and threshing index**

| Genotypes | Dry stover yield per plant | | | Grain yield per plant | | | Harvest index | | | Threshing index | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ |
| ICMA 04999 × BIB 481-500 | 164.45 | 1** | 185.91 | 41 | 1.42** | -9.28 | 30.68 | 1.49 | 145.02** | 55.95 | 0.12 | 15.19 |
| ICMA 88004 × BIB 481-500 | 165.55 | 0.57** | -172.21 | 40.11 | 0.6* | 23.92 | 24.46 | 0.24 | 1.93 | 47.73 | 0.38** | -32.85 |
| ICMA 93333 × BIB 481-500 | 194.45 | 0.4** | -120.84 | 35.45 | 0.14 | 31.85 | 20 | 1.15** | -6.79 | 47.18 | 0.39** | -32.98 |
| ICMA 97111 × BIB 481-500 | 133.33 | 0.41** | -76.8 | 30.44 | 0.69** | -13.87 | 20.67 | -1.82 | 0.04 | 42.46 | 0.03 | 346.2** |
| ICMA 97444 × BIB 481-500 | 120.55 | 1.66** | 9.39 | 32.22 | 1.45** | 28.17 | 27.41 | 1.2 | 16.98 | 59.07 | 0.91** | -16.06 |
| ICMA 98222 × BIB 481-500 | 297.78 | -0.51 | 744.8* | 79.67 | 0.94* | 83.65** | 41.95 | 1.99 | 631.53** | 68.54 | -1.18 | -14.05 |
| ICMA 10444 × BIB 481-500 | 47.78 | 0.4** | -10.87 | 22.67 | 0.18 | -2.14 | 38.21 | 1.51** | -6.19 | 69.51 | 0.72 | 2346.46** |
| ICMA 30199 × BIB 481-500 | 207.78 | 1.4** | -195.23 | 49.33 | 1.28** | -4.11 | 24.08 | 0.43** | -6.98 | 54.06 | 0.15 | 212.63** |
| ICMA 30200 × BIB 481-500 | 211.11 | 0.71** | -137.96 | 37.67 | 0.88** | -6.71 | 17.57 | -0.69 | -4.02 | 43.13 | 0.86** | -32.56 |
| ICMA 30201 × BIB 481-500 | 337.78 | -0.38 | 1423.72** | 47.78 | 0.33 | 386.59** | 16.68 | -0.08 | -7 | 134.48 | 14.68** | 4784.1** |
| ICMA 30209 × BIB 481-500 | 60 | 0.23 | 91.7 | 18.22 | 0.07 | -12.73 | 29.5 | 1.43 | 9.25 | 60.67 | 1.39 | 434.31** |
| ICMA 04999 × BIB 501-510 | 63.34 | 0.3 | 45.27 | 18.78 | 0.26** | -12.35 | 28.44 | 0.53 | -1.81 | 62.52 | 0.86 | 95.82* |
| ICMA 88004 × BIB 501-510 | 245.56 | 0.28 | 60.36 | 67.89 | 1.07 | 380.09** | 39.8 | 2.98 | 264.36** | 65.31 | -0.58 | -27.12 |
| ICMA 93333 × BIB 501-510 | 147.78 | 1.24** | -209.27 | 26.78 | 1.26** | -12.19 | 17.55 | -0.71 | -5.98 | 52.51 | 0.17 | -2 |
| ICMA 97111 × BIB 501-510 | 125.56 | 1.19** | -210.82 | 28.78 | 1.45** | 44.9* | 19.14 | -1.8 | -6.97 | 39.97 | -2.43 | -8.21 |
| ICMA 97444 × BIB 501-510 | 142.22 | 2.07** | 137.77 | 21 | 1.07** | 20.3 | 22.47 | 3.27 | 182.97** | 42.46 | -0.16 | 231.94** |
| ICMA 98222 × BIB 501-510 | 105.55 | 0.66** | -121.23 | 29.11 | 1.79** | 47.79* | 23.15 | -5.09 | 1.88 | 41.58 | -2.59 | -4.05 |
| ICMA 10444 × BIB 501-510 | 152.78 | 0.37* | 9.05 | 24 | 0.19 | 8.69 | 15.7 | 0.23 | -3.83 | 33.32 | 0.44** | -29.65 |
| ICMA 30199 × BIB 501-510 | 275.56 | -0.27 | 255.77 | 35.78 | 0.36 | 10.03 | 14.04 | -0.91 | 9.12 | 41.11 | 1.19 | 59.52 |
| ICMA 30200 × BIB 501-510 | 80 | 1.14** | -210.32 | 23.67 | 0.9** | -12.6 | 36.05 | 3.91** | -3.07 | 63.19 | 2.46** | 103.58* |
| ICMA 30201 × BIB 501-510 | 105.56 | 1.73** | -110.19 | 25.78 | 1.14** | -13.69 | 31.8 | 3.65* | 41.57** | 51.01 | 1.13 | 168.15* |
| ICMA 30209 × BIB 501-510 | 112.22 | 1.88** | -46.53 | 31.55 | 1.5** | 14.16 | 38.9 | 5.19** | 18.19 | 73.36 | 1.39 | 116.81* |
| ICMA 04999 × BIB 511-520 | 188.89 | 0.38** | -156.25 | 39.33 | 0.59** | -13.42 | 21.11 | -0.84 | -7 | 44.11 | 0.72** | -33.15 |
| ICMA 88004 × BIB 511-520 | 103.33 | 0.91** | -188.2 | 27.11 | 0.88** | -13.02 | 27.15 | 0.88 | -2.16 | 44.93 | -2.5 | -32.59 |
| ICMA 93333 × BIB 511-520 | 141.11 | 1.01** | -201.97 | 31.22 | 0.68** | -10.43 | 23.25 | 0.88* | -4.07 | 44.67 | 0.56** | -32.36 |
| ICMA 97111 × BIB 511-520 | 75.56 | 1.04** | -205.33 | 26 | 1.19* | 115.43** | 21.81 | -3.17 | 46.4** | 43.12 | -0.36 | 62.67 |
| ICMA 97444 × BIB 511-520 | 173.33 | 0.65** | -66.13 | 44.89 | 0.82** | -13.49 | 26.43 | 0.11 | 1.19 | 48.04 | -0.02 | 44.14 |
| ICMA 98222 × BIB 511-520 | 88.89 | 1.27** | -208.17 | 30.11 | 1.6** | -3.71 | 36.68 | 1.92** | -6.63 | 58.85 | 1.2** | -32.4 |

| Genotypes | Dry stover per plant | | | Grain yield per plant | | | Harvest index | | | Threshing index | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Mean** | **$b_i$** | **$S^2d_i$** | **Mean** | **$b_i$** | **$S^2d_i$** | **Mean** | **$b_i$** | **$S^2d_i$** | **Mean** | **$b_i$** | **$S^2d_i$** |
| ICMA 10444 × BIB 511-520 | 245.55 | 1.07** | 233.4 | 50.56 | 0.55** | -4.52 | 20.2 | 0.65** | -6.27 | 43.3 | -0.21 | 62.94 |
| ICMA 30199 × BIB 511-520 | 251.11 | 3** | 901.97* | 33.45 | 1.17** | -13.48 | 28.96 | 6.29 | 529.64** | 32.69 | 0.54* | -20.91 |
| ICMA 30200 × BIB 511-520 | 46.67 | 0.38** | 2.48 | 15.78 | 0.1 | 13.72 | 35.12 | 3.91** | -2.55 | 68.48 | 2.75** | -32.92 |
| ICMA 30201 × BIB 511-520 | 194.44 | 1.39** | -194.87 | 50.44 | 0.69** | -13.87 | 27.81 | 2.28** | -6.85 | 49.2 | 0.59 | 426.03** |
| ICMA 30209 × BIB 511-520 | 137.78 | 1.09** | -208.11 | 38.78 | 1.39** | 8.73 | 29.97 | 0.06 | 7.05 | 42.92 | 0.64 | 70.85 |
| ICMA 04999 × BIB 531-540 | 145.56 | 2.64** | 508 | 32.33 | 1.83** | 5.8 | 38.15 | 6.38** | 43.66** | 53.27 | 1.03 | 36.56 |
| ICMA 88004 × BIB 531-540 | 52.22 | 0.35* | 16.27 | 15.78 | 0.1 | 13.72 | 33.23 | 3.74** | -4.14 | 68.46 | 2.18** | -27.65 |
| ICMA 93333 × BIB 531-540 | 215.56 | 2.33** | 460.04 | 46.11 | 0.19 | 25.23 | 28.12 | 4.73** | 40.64** | 47.35 | 0.83 | 144.06* |
| ICMA 97111 × BIB 531-540 | 120 | 1.83** | -67.74 | 27.78 | 1.37** | -9.13 | 26.69 | 2.02 | 16.19 | 53.02 | 1.66** | -22.3 |
| ICMA 97444 × BIB 531-540 | 147.78 | 0.86** | -178.17 | 38.22 | 1.16** | -7.66 | 24.82 | -0.83 | -7.07 | 45.68 | 0.24 | 8.5 |
| ICMA 98222 × BIB 531-540 | 99.44 | 0.9** | 668.39* | 25.44 | 1.15** | -12.47 | 27.57 | 0.04 | 173.98** | 52.98 | -0.26 | 451.38** |
| ICMA 10444 × BIB 531-540 | 118.89 | 0.96** | -211.07 | 27.66 | 1.38** | -7.86 | 23.45 | -0.98 | -2.23 | 46.98 | 1 | 90.67 |
| ICMA 30199 × BIB 531-540 | 162.22 | 1.34** | -201.63 | 32.33 | 0.8** | -12.37 | 20.7 | 1.07 | 1.7 | 52.91 | 1.8** | -18.44 |
| ICMA 30200 × BIB 531-540 | 196.67 | 0.99** | -199.89 | 27.11 | 0.73** | -8.5 | 15.46 | 0.44 | -3.7 | 57.69 | 2.05* | 139.82* |
| ICMA 30201 × BIB 531-540 | 221.11 | 0.32 | 1168.55* | 36.78 | 1.26** | -12.19 | 16.01 | -2.75 | -6.83 | 70.2 | 3.97** | 93.53 |
| ICMA 30209 × BIB 531-540 | 236.67 | 1.22** | -210.26 | 39.89 | 1.61** | -0.1 | 15.87 | -1.44 | -7.01 | 47.72 | 1.27 | 140.03* |
| ICMA 04999 × BIB 551-560 | 47.78 | 0.48** | -48.64 | 24.33 | 0 | 12.14 | 35.17 | 1.23 | 1566.42** | 82.14 | 5.42** | 54.26 |
| ICMA 88004 × BIB 551-560 | 152.22 | 1.8** | -78.74 | 48 | 1.7** | 10.44 | 33.2 | 2.01* | 9.39 | 78.75 | 3.69** | 87.83 |
| ICMA 93333 × BIB 551-560 | 228.89 | 2.26** | 183.18 | 54.66 | 2.1** | 27.21 | 24.93 | 0.76** | -6.98 | 50.13 | -2.03 | -31.35 |
| ICMA 97111 × BIB 551-560 | 58.89 | 0.58** | -92.69 | 17.67 | 0.2 | -1.57 | 38.8 | 6.25* | 105.94** | 73.18 | 2.05* | 150.75* |
| ICMA 97444 × BIB 551-560 | 47.78 | 0.4** | -10.87 | 21.56 | 0.01 | -13.82 | 40.92 | 3.86** | -5.75 | 79.55 | 0.47 | 5.1 |
| ICMA 98222 × BIB 551-560 | 192.22 | 0.66** | -121.23 | 41.22 | 0.87** | -8.67 | 20.71 | -0.75 | -2.7 | 46.1 | 0.77** | -25.09 |
| ICMA 10444 × BIB 551-560 | 185.56 | 0.5** | -60.26 | 30.45 | 1.01** | 16.72 | 16.9 | -1.48 | 14.79 | 49.29 | 0.4** | -33.24 |
| ICMA 30199 × BIB 551-560 | 193.33 | 1.14** | -210.32 | 49.89 | 1.51** | 3.13 | 26.21 | -0.32 | 3.63 | 61.52 | 1.02 | 77.89 |
| ICMA 30200 × BIB 551-560 | 93.34 | 1.45** | -186.74 | 27.78 | 0.8** | 14.49 | 33.1 | 3.83** | 17.28 | 56.08 | 3.28** | -30.88 |
| ICMA 30201 × BIB 551-560 | 176.67 | 0.53** | -71.44 | 35.22 | 0.82** | -12.68 | 19.68 | -1.1 | -6.81 | 51.06 | 0.72** | -24.4 |
| ICMA 30209 × BIB 551-560 | 141.11 | 1.06** | -190.54 | 43.22 | 1.26** | -10.56 | 29.37 | 0.06 | -2.82 | 56.4 | 0.86** | -33.01 |
| ICMA 04999 × BIB 561-570 | 161.11 | 0.99** | -91.09 | 49 | 2.17** | 38.54 | 33.77 | -0.65 | 75.6** | 69.23 | 1.18** | -25.85 |

| Genotypes | Dry stover per plant | | | Grain yield per plant | | | Harvest index | | | Threshing index | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ | Mean | $b_i$ | $S^2d_i$ |
| ICMA 88004 × BIB 561-570 | 167.78 | 0.41 | 2846.49** | 38.78 | 1.49** | -4.39 | 29.83 | -0.37 | 22.24* | 60.55 | 1.67** | 20.18 |
| ICMA 93333 × BIB 561-570 | 166.67 | 1.01** | -132.01 | 26.22 | 0.57** | -13.79 | 17.39 | 0.76** | -7.02 | 46.69 | 1.02 | 143.68* |
| ICMA 97111 × BIB 561-570 | 124.44 | 0.43** | 17.47 | 29.11 | 0.93** | -4.06 | 30.72 | 1.14 | 174.56** | 66.31 | 0.97 | 129.55* |
| ICMA 97444 × BIB 561-570 | 162.22 | 2.1** | 260.25 | 30.89 | 1.35** | 16 | 20.82 | 1.15** | -4.15 | 46.01 | 0.86 | 64.79 |
| ICMA 98222 × BIB 561-570 | 242.22 | 0.43** | -23.94 | 42.45 | 2.21** | 114.99** | 15.47 | -4.86 | -6.96 | 54.23 | -3.02 | 121.27* |
| ICMA 10444 × BIB 561-570 | 137.78 | 1.93** | -19.86 | 33.33 | 1.06** | -2.52 | 31.94 | 4.41** | -1.97 | 57.36 | 2.53** | -6.5 |
| ICMA 30199 × BIB 561-570 | 186.67 | 1.22** | -210.26 | 46.78 | 2.14** | -0.02 | 25.61 | -1.2 | 2.63 | 59.75 | 1.54** | 2.82 |
| ICMA 30200 × BIB 561-570 | 147.78 | 1.01** | -202.82 | 48.44 | 1.35** | -13.5 | 35.64 | 1.49 | 14.68 | 55.56 | 0.46 | 15.76 |
| ICMA 30201 × BIB 561-570 | 312.22 | 0.1 | 514.3 | 47.44 | -0.56 | 416.21** | 16.95 | 1.77** | -5.05 | 32.38 | 0.46 | 289.35** |
| ICMA 30209 × BIB 561-570 | 121.11 | 1.39** | -194.87 | 36.55 | 1.26** | -10.56 | 33.71 | 2.69** | -6.99 | 61.08 | 1.71** | 5.32 |
| ICMA 04999 × BIB 571-580 | 166.11 | 1.4** | -108.32 | 45.78 | 1.27** | 11.28 | 30.55 | 1.97 | 9.26 | 55.43 | 1** | -5.58 |
| ICMA 88004 × BIB 571-580 | 164.45 | 1.47** | -181.84 | 44.56 | 1.71** | 8.47 | 28.16 | 0.33 | -4.63 | 60.16 | 0.91* | -5.23 |
| ICMA 93333 × BIB 571-580 | 153.33 | 0.91 | 8042.64** | 41 | 0.54** | 6.99 | 38.27 | 4.06 | 1624.03** | 59.45 | -0.2 | 497.63** |
| ICMA 97111 × BIB 571-580 | 122.22 | 0.98** | 989.54* | 34.33 | 1.92** | -5 | 35.89 | 0.94 | 28.99* | 62.87 | 1.96** | -20.95 |
| ICMA 97444 × BIB 571-580 | 197.78 | 1.17** | 247.3 | 54 | 0.61** | -12.31 | 33.4 | 3.58** | -4.73 | 61.05 | 1.73** | 7.73 |
| ICMA 98222 × BIB 571-580 | 138.89 | 0.73** | -145.88 | 35.11 | 0.66** | -3.96 | 26.77 | 1** | -7.06 | 44.76 | 0.35** | -33.26 |
| ICMA 10444 × BIB 571-580 | 142.22 | 1.36** | -172.51 | 32.67 | 0.97** | -7.95 | 23.17 | 0.95 | 17.88 | 49.42 | 0.95** | -33.21 |
| ICMA 30199 × BIB 571-580 | 201.11 | 0.97** | 315.46 | 52.56 | 0.76 | 271.87** | 28.88 | 1.67* | 0.93 | 56.09 | 3.43** | -23.53 |
| ICMA 30200 × BIB 571-580 | 182.22 | 0.53** | -189.99 | 41.22 | 0.87** | -8.67 | 22.89 | -0.67 | -5.88 | 49.13 | -0.01 | 23.29 |
| ICMA 30201 × BIB 571-580 | 138.89 | 0.96** | -196.51 | 31.89 | 0.97** | -9.26 | 21.02 | -0.58 | -2.12 | 45.39 | 0.43** | -31.35 |
| ICMA 30209 × BIB 571-580 | 144.44 | 1.85** | -58.37 | 44.33 | 1.82** | 133.88** | 26.81 | -0.11 | 31.27* | 59.87 | 0.53 | 94.85 |
| RHB - 177 (Check-1) | 132.22 | 0.96** | -196.25 | 29.89 | 1.07** | -3.86 | 20.81 | -0.82 | -5.84 | 45.5 | 0.04 | -30.72 |
| HHB 67 improved (Check-2) | 145.56 | 1.13** | -103.32 | 39.56 | 1.46** | -9.2 | 24.53 | -1.1 | -1.94 | 48.5 | 0.71* | -14.48 |
| BHB - 1602 ( Check-3) | 118.89 | 1.3** | -189.07 | 37.67 | 0.88** | -6.71 | 38.74 | 4.58** | 1.65 | 70.4 | 2.13** | 68.09 |
| **Population mean** | 155.69 | | | 36.15 | | | 26.97 | | | 55.34 | | |
| **SE (mean)** | 10.28 | | | 2.63 | | | 1.88 | | | 4.08 | | |
| **CD (5%)** | 28.53 | | | 7.31 | | | 5.22 | | | 11.32 | | |

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

### 4.6 Calculation of moisture stress indices

Plant breeding programme mainly focus on selecting genotypes that have high yield firstly under yield potential conditions (non-stress) and secondly under stress conditions. To reach this aim, the classical postulate, widely accepted by breeders for selection, is that a genotype with high yield potential will perform well under most environments. The moisture stress tolerance indices and relative grain yield per plant under normal and stress condition are presented in Table 4.6.1, 4.6.2, and 4.6.3. The mean grain yield per plant decreased under moisture stress condition ($E_3$). Significant difference was observed between the mean grain yield per plant under normal ($E_1$) and moisture stress ($E_3$) conditions for all crosses which indicated that the performance under moisture stress and normal was considerably different. To investigate stress indices for screening of crosses under moisture stress condition, grain yield per plant of crosses under both non-stress ($E_1$) and moisture stress conditions ($E_3$) were used.

In non-stress or normal conditions ($E_1$), the cross ICMA 98222 x BIB-481-500 (95 g) had the highest grain yield per plant followed by ICMA 93333 x BIB-551-560 (94.33 g), ICMA 04999 x BIB-561-570 (90.00 g), ICMA 30199 x BIB-561-570 (86.67 g) and ICMA 98222 x BIB-561-570 (85.00 g). In moisture stress condition ($E_3$), the cross ICMA 98222 x BIB-481-500 (61.67 g) had the highest grain yield per plant followed by ICMA 97444 x BIB-571-580 (45.33 g), ICMA 30201 x BIB-561-570 (42.33 g) and ICMA 88004 x BIB-501-510 (42.33 g), ICMA 10444 x BIB-511-520 (41.67 g) and ICMA 30201 x BIB-511-520 (41.33g). To evaluate the moisture stress tolerance ability of these crosses nine moisture stress indices *viz.,* TOL, SSI, MP, GMP, YI, YSI, HM, STI and SDI were calculated using grain yield per plant in stressed and non-stressed conditions. These indices are described below:

### 4.6.1 Stress tolerance (TOL)

The index, stress tolerance (TOL) indicated the high stress tolerance ability of a given genotype under study. TOL is the difference of yield under non-stress and stress condition, therefore the greater the value of TOL, the larger the yield reduction under stress and higher the stress sensitivity. Lower values of TOL indicated the lower differences in yield between non-stress and stress condition, in other words more tolerance to moisture stress. The cross ICMA 30201 x BIB-561-570 showed (Table 4.6.1) lowest value of TOL (-9.00) and ranked first followed by ICMA 97444 x BIB-551-560 (0.33), ICMA 04999 x BIB-551-560 (2.00), ICMA 30209 x BIB-481-500 (2.67) and ICMA 10444 x BIB-481-500 (4.33) with respect to high moisture stress tolerance ability. The cross ICMA 30199 x BIB-561-570 showed highest TOL value (65.33) which indicated that it was highly susceptible to moisture stress.

### 4.6.2 Stress susceptibility index (SSI)

The stress susceptibility index (SSI) indicated the reduction in yield caused by unfavorable (moisture stress) compared to favorable (normal) environments. Lower SSI values indicated the lower differences in yield between normal and moisture stress condition, in other words more tolerance to moisture stress. SSI is a measure of yield stability. Based on SSI (Table 4.6.1), the cross ICMA 30201 x BIB-516-570 (-0.45) ranked first followed by ICMA 97444 x BIB-551-560 (0.03), ICMA 04999 x BIB-551-560 (0.14), ICMA 30209 x BIB-481-500 (0.23) and ICMA 10444 x BIB-481-500 (0.27). The cross ICMA 97111 x BIB-571-580 showed highest SSI value (1.40) which indicated that it was highly susceptible to moisture stress.

### 4.6.3 Stress tolerance index (STI)

The stress tolerance index (STI) was used to identify crosses that produce high yield under both stress and normal condition. The larger the value of STI for a cross, the higher was its tolerance to stress. The cross ICMA 98222 x BIB-481-500 had highest value (Table 4.6.1) of STI (2.02) which indicated its high tolerance to moisture stress. With respect to STI, the crosses ICMA 88004 x BIB-501-510 (1.22), ICMA 93333 x BIB-551-560 (1.02), ICMA 97444 x BIB-571-580 (1.02), ICMA 30210 x BIB-511-520 (0.90) and ICMA 30199 x BIB-481-500 (0.88) were top 5 crosses of pearl millet under moisture stress condition. The cross ICMA 30200 x BIB-511-520 and ICMA 88004 x BIB-531-540 showed lowest STI value (0.07) which showed that it were highly susceptible to moisture stress.

### 4.6.4 Mean Productivity

The mean production under both stress and non-stress conditions, it will be correlated with yield under both stress and non-stress conditions. MP should increase yield in both stress and non-stress conditions unless the correlation between yields in contrasting environments is highly negative. The genotypes with high yielding performance in both stress and non-stress conditions were found as genotypes with high values of MP. The cross ICMA 98222 x BIB-481-500 had highest value (Table 4.6.2) of MP (78.33) which indicated its high tolerance to moisture stress. With respect to MP, the crosses ICMA 88004 x BIB-501-510 (63.00), ICMA 93333 x BIB-551-560 (62.83), ICMA 04999 x BIB-561-570 (57.67), and ICMA 97444 x BIB-571-580 (55.17) were top 5 crosses of pearl millet under moisture stress condition. The cross ICMA 30200 x BIB-511-520 and ICMA 88004 x BIB-531-540 showed lowest MP value (14.00) which showed that it were highly susceptible to moisture stress.

### 4.6.5 Geometric Mean Productivity

The geometric mean productivity (GMP) shows that high value of GMP is more desirable to selection for drought tolerance. The cross ICMA 98222 x BIB-481-500 had highest value of GMP (76.54) which indicated its high tolerance to moisture stress and first rank for drought tolerance. With respect to GMP (Table 4.6.2), the crosses ICMA 88004 x BIB-501-510 (59.51), ICMA 93333 x BIB-551-560 (54.37), ICMA 97444 x BIB-571-580 (54.28) and ICMA 30210 x BIB-511-520 (51.16), were top 5 crosses of pearl millet within performed better under moisture stress condition. The cross ICMA 30200 x BIB-511-520 and ICMA 88004 x BIB-531-540 showed lowest GMP value (13.74) which showed that it were highly susceptible to moisture stress.

**4.6.6 Yield index**

Yield index (YI) was used to identify crosses that produce high yield under both stress and normal condition. The larger the value of YI for a cross, the higher was its tolerance to stress. The cross ICMA 98222 x BIB-481-500 had highest value of YI (2.65) which indicated its high tolerance to moisture stress and first rank for drought tolerance. With respect to YI (Table 4.6.2), the crosses ICMA 97444 x BIB-571-580 (1.95), ICMA 30210 x BIB-561-570 (1.82), ICMA 10444 x BIB-511-520 (1.79), and ICMA 30210 x BIB-511-520 (51.16), were top 5 crosses of pearl millet perform better under moisture stress condition. The cross ICMA 97444 x BIB-501-510 and ICMA 98222 x BIB-501-510 showed lowest YI value (0.46) which showed that it were highly susceptible to moisture stress.

**4.6.7 Yield stability index**

The genotypes with high YSI values can be regarded as stable genotypes under stress and non-stress conditions. The cross ICMA 30210 x BIB-561-570 had highest value of YSI (1.27) which indicated its stable genotypes under stress and non-stress conditions. With respect to YSI (Table 4.6.3), the crosses ICMA 97444 x BIB-551-560 (0.98), ICMA 04999 x BIB-551-560 (0.91), ICMA 30209 x BIB-481-500 (0.86) and ICMA 10444 x BIB-481-500 (0.84) were top 5 stable crosses of pearl millet under moisture stress condition. The cross ICMA 97111 x BIB-571-580 showed lowest YSI value (0.07) which showed that it was not stable to moisture stress.

### 4.6.8 Harmonic mean

Harmonic mean shows that high value of HM is more desirable to selection for drought tolerance. The cross ICMA 98222 x BIB-481-500 had highest value of HM (74.79) which indicated its high tolerance to moisture stress. With respect to HM (Table 4.6.3), the crosses ICMA 88004 x BIB-501-510 (56.22), ICMA 97444 x BIB-571-580 (53.41), ICMA 30201 x BIB-511-520 (50.02) and ICMA 10444 x BIB-511-520 (49.18), were top 5 crosses of pearl millet more desirable under moisture stress condition. The cross ICMA 30200 x BIB-511-520 and ICMA 88004 x BIB-531-540 showed lowest HM value (13.49) which showed that it were highly susceptible to moisture stress.

### 4.6.9 Sensitivity drought index

Sensitivity drought index (SDI) shows that the genotypes with low value of this index will be more desirable to drought tolerance. The cross ICMA 30201 x BIB-561-570 showed lowest value (Table 4.6.3) of SDI (-0.27) and ranked first followed by ICMA 97444 x BIB-551-560 (0.02), ICMA 04999 x BIB-551-560 (0.09), ICMA 30209 x BIB-481-500 (0.14) and ICMA 10444 x BIB-481-500 (0.16) with respect to high moisture stress tolerance ability. The cross ICMA 97111 x BIB-571-580 showed highest SDI value (0.84) which indicated that it was highly susceptible to moisture stress.

**Table 4.6.1 Grain yield per plant and moisture stress indices in response to normal ($E_1$) and moisture stress ($E_3$) condition**

| Crosses | Grain yield per plant (g) | | | | TOL | Rank | SSI | Rank | STI | Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ ($Y_p$) | Rank | $E_3$ ($Y_s$) | Rank | | | | | | |
| ICMA 04999 × 481-500 | 66.67 | 16 | 21.33 | 36 | 45.33 | 66 | 1.13 | 59 | 0.49 | 31 |
| ICMA 88004 × 481-500 | 50.00 | 44 | 28.67 | 20 | 21.33 | 20 | 0.71 | 22 | 0.49 | 30 |
| ICMA 93333 × 481-500 | 36.67 | 69 | 29.67 | 18 | 7.00 | 8 | 0.32 | 7 | 0.37 | 42 |
| ICMA 97111 × 481-500 | 43.33 | 61 | 21.33 | 36 | 22.00 | 23 | 0.85 | 29 | 0.32 | 50 |
| ICMA 97444 × 481-500 | 60.00 | 26 | 17.33 | 58 | 42.67 | 62 | 1.19 | 63 | 0.36 | 43 |
| ICMA 98222 × 481-500 | 95.00 | 1 | 61.67 | 1 | 33.33 | 45 | 0.58 | 15 | 2.02 | 1 |
| ICMA 10444 × 481-500 | 26.67 | 72 | 22.33 | 33 | 4.33 | 5 | 0.27 | 5 | 0.21 | 67 |
| ICMA 30199 × 481-500 | 73.33 | 11 | 34.67 | 8 | 38.67 | 51 | 0.88 | 33 | 0.88 | 6 |
| ICMA 30200 × 481-500 | 53.33 | 39 | 24.67 | 28 | 28.67 | 35 | 0.90 | 34 | 0.45 | 34 |
| ICMA 30201 × 481-500 | 50.00 | 44 | 31.67 | 13 | 18.33 | 15 | 0.61 | 16 | 0.55 | 23 |
| ICMA 30209 × 481-500 | 19.33 | 78 | 16.67 | 60 | 2.67 | 4 | 0.23 | 4 | 0.11 | 77 |
| ICMA 04999 × 501-510 | 23.33 | 74 | 14.67 | 65 | 8.67 | 12 | 0.62 | 18 | 0.12 | 76 |
| ICMA 88004 × 501-510 | 83.67 | 6 | 42.33 | 3 | 41.33 | 57 | 0.82 | 26 | 1.22 | 2 |
| ICMA 93333 × 501-510 | 50.00 | 44 | 11.33 | 68 | 38.67 | 51 | 1.29 | 74 | 0.20 | 68 |
| ICMA 97111 × 501-510 | 56.67 | 34 | 14.67 | 65 | 42.00 | 58 | 1.24 | 67 | 0.29 | 57 |
| ICMA 97444 × 501-510 | 41.67 | 66 | 10.67 | 79 | 31.00 | 40 | 1.24 | 68 | 0.15 | 75 |
| ICMA 98222 × 501-510 | 63.33 | 22 | 10.67 | 79 | 52.67 | 74 | 1.39 | 79 | 0.23 | 63 |
| ICMA 10444 × 501-510 | 26.67 | 72 | 18.67 | 52 | 8.00 | 10 | 0.50 | 9 | 0.17 | 71 |
| ICMA 30199 × 501-510 | 43.33 | 61 | 34.00 | 10 | 9.33 | 13 | 0.36 | 8 | 0.51 | 28 |
| ICMA 30200 × 501-510 | 40.00 | 67 | 11.33 | 68 | 28.67 | 34 | 1.19 | 65 | 0.16 | 74 |
| ICMA 30201 × 501-510 | 46.67 | 56 | 11.33 | 68 | 35.33 | 46 | 1.26 | 72 | 0.18 | 69 |
| ICMA 30209 × 501-510 | 60.00 | 26 | 15.33 | 64 | 44.67 | 63 | 1.24 | 69 | 0.32 | 52 |
| ICMA 04999 × 511-520 | 50.00 | 44 | 31.33 | 14 | 18.67 | 17 | 0.62 | 19 | 0.54 | 24 |
| ICMA 88004 × 511-520 | 43.33 | 61 | 16.33 | 62 | 27.00 | 30 | 1.04 | 46 | 0.24 | 60 |
| ICMA 93333 × 511-520 | 43.33 | 61 | 21.33 | 36 | 22.00 | 23 | 0.85 | 29 | 0.32 | 50 |
| ICMA 97111 × 511-520 | 50.00 | 44 | 17.33 | 58 | 32.67 | 44 | 1.09 | 54 | 0.30 | 56 |

| Crosses | Grain yield per plant (g) | | | | TOL | Rank | SSI | Rank | STI | Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ ($Y_p$) | Rank | $E_3$ ($Y_s$) | Rank | | | | | | |
| ICMA 97444 × 511-520 | 60.00 | 26 | 34.67 | 8 | 25.33 | 28 | 0.70 | 21 | 0.72 | 14 |
| ICMA 98222 × 511-520 | 60.00 | 26 | 11.33 | 68 | 48.67 | 68 | 1.35 | 77 | 0.23 | 62 |
| ICMA 10444 × 511-520 | 60.00 | 26 | 41.67 | 5 | 18.33 | 16 | 0.51 | 11 | 0.86 | 7 |
| ICMA 30199 × 511-520 | 55.00 | 38 | 18.67 | 52 | 36.33 | 49 | 1.10 | 55 | 0.35 | 46 |
| ICMA 30200 × 511-520 | 16.67 | 79 | 11.33 | 68 | 5.33 | 6 | 0.53 | 12 | 0.07 | 79 |
| ICMA 30201 × 511-520 | 63.33 | 22 | 41.33 | 6 | 22.00 | 22 | 0.58 | 14 | 0.90 | 5 |
| ICMA 30209 × 511-520 | 63.33 | 22 | 18.00 | 56 | 45.33 | 65 | 1.19 | 64 | 0.39 | 41 |
| ICMA 04999 × 531-540 | 66.67 | 16 | 11.33 | 68 | 55.33 | 75 | 1.38 | 78 | 0.26 | 59 |
| ICMA 88004 × 531-540 | 16.67 | 79 | 11.33 | 68 | 5.33 | 6 | 0.53 | 12 | 0.07 | 79 |
| ICMA 93333 × 531-540 | 48.33 | 55 | 40.00 | 7 | 8.33 | 11 | 0.29 | 6 | 0.67 | 17 |
| ICMA 97111 × 531-540 | 53.33 | 39 | 11.33 | 68 | 42.00 | 58 | 1.31 | 75 | 0.21 | 65 |
| ICMA 97444 × 531-540 | 60.00 | 26 | 24.67 | 28 | 35.33 | 46 | 0.98 | 42 | 0.51 | 27 |
| ICMA 98222 × 531-540 | 46.67 | 56 | 11.33 | 68 | 35.33 | 46 | 1.26 | 72 | 0.18 | 69 |
| ICMA 10444 × 531-540 | 53.33 | 39 | 11.33 | 68 | 42.00 | 58 | 1.31 | 75 | 0.21 | 65 |
| ICMA 30199 × 531-540 | 46.67 | 56 | 21.33 | 36 | 25.33 | 27 | 0.90 | 37 | 0.34 | 47 |
| ICMA 30200 × 531-540 | 40.00 | 67 | 16.33 | 62 | 23.67 | 26 | 0.99 | 43 | 0.23 | 64 |
| ICMA 30201 × 531-540 | 60.00 | 26 | 21.33 | 36 | 38.67 | 53 | 1.07 | 51 | 0.44 | 36 |
| ICMA 30209 × 531-540 | 70.00 | 13 | 21.33 | 36 | 48.67 | 69 | 1.16 | 61 | 0.51 | 26 |
| ICMA 04999 × 551-560 | 23.33 | 74 | 21.33 | 36 | 2.00 | 3 | 0.14 | 3 | 0.17 | 72 |
| ICMA 88004 × 551-560 | 80.00 | 7 | 29.00 | 19 | 51.00 | 71 | 1.06 | 49 | 0.80 | 8 |
| ICMA 93333 × 551-560 | 94.33 | 2 | 31.33 | 14 | 63.00 | 77 | 1.11 | 56 | 1.02 | 3 |
| ICMA 97111 × 551-560 | 20.67 | 77 | 13.00 | 67 | 7.67 | 9 | 0.62 | 17 | 0.09 | 78 |
| ICMA 97444 × 551-560 | 21.67 | 76 | 21.33 | 36 | 0.33 | 2 | 0.03 | 2 | 0.16 | 73 |
| ICMA 98222 × 551-560 | 56.67 | 34 | 28.67 | 20 | 28.00 | 32 | 0.82 | 27 | 0.56 | 21 |
| ICMA 10444 × 551-560 | 50.00 | 44 | 20.67 | 47 | 29.33 | 37 | 0.98 | 40 | 0.36 | 44 |
| ICMA 30199 × 551-560 | 76.67 | 9 | 28.00 | 23 | 48.67 | 69 | 1.06 | 48 | 0.74 | 13 |
| ICMA 30200 × 551-560 | 43.33 | 61 | 20.67 | 47 | 22.67 | 25 | 0.87 | 32 | 0.31 | 54 |
| ICMA 30201 × 551-560 | 50.00 | 44 | 24.00 | 32 | 26.00 | 29 | 0.87 | 31 | 0.41 | 38 |

| Crosses | Grain yield per plant (g) | | | | TOL | Rank | SSI | Rank | STI | Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ ($Y_p$) | Rank | $E_3$ ($Y_s$) | Rank | | | | | | |
| ICMA 30209 × 551-560 | 66.67 | 16 | 28.00 | 23 | 38.67 | 53 | 0.97 | 39 | 0.64 | 18 |
| ICMA 04999 × 561-570 | 90.00 | 3 | 25.33 | 26 | 64.67 | 79 | 1.20 | 66 | 0.79 | 10 |
| ICMA 88004 × 561-570 | 66.67 | 16 | 21.33 | 36 | 45.33 | 66 | 1.13 | 59 | 0.49 | 31 |
| ICMA 93333 × 561-570 | 36.67 | 69 | 18.67 | 52 | 18.00 | 14 | 0.82 | 25 | 0.24 | 61 |
| ICMA 97111 × 561-570 | 46.67 | 56 | 19.00 | 51 | 27.67 | 31 | 0.99 | 44 | 0.31 | 55 |
| ICMA 97444 × 561-570 | 56.67 | 34 | 16.67 | 60 | 40.00 | 56 | 1.18 | 62 | 0.33 | 48 |
| ICMA 98222 × 561-570 | 85.00 | 5 | 20.67 | 47 | 64.33 | 78 | 1.26 | 71 | 0.61 | 20 |
| ICMA 10444 × 561-570 | 53.33 | 39 | 21.67 | 35 | 31.67 | 42 | 0.99 | 45 | 0.40 | 39 |
| ICMA 30199 × 561-570 | 86.67 | 4 | 21.33 | 36 | 65.33 | 80 | 1.26 | 70 | 0.64 | 19 |
| ICMA 30200 × 561-570 | 73.33 | 11 | 31.33 | 14 | 42.00 | 58 | 0.95 | 38 | 0.79 | 9 |
| ICMA 30201 × 561-570 | 33.33 | 71 | 42.33 | 3 | -9.00 | 1 | -0.45 | 1 | 0.49 | 33 |
| ICMA 30209 × 561-570 | 60.00 | 26 | 21.33 | 36 | 38.67 | 53 | 1.07 | 51 | 0.44 | 36 |
| ICMA 04999 × 571-580 | 70.00 | 13 | 32.33 | 12 | 37.67 | 50 | 0.90 | 36 | 0.78 | 11 |
| ICMA 88004 × 571-580 | 76.67 | 9 | 25.33 | 26 | 51.33 | 72 | 1.12 | 57 | 0.67 | 16 |
| ICMA 93333 × 571-580 | 50.00 | 44 | 31.33 | 14 | 18.67 | 17 | 0.62 | 19 | 0.54 | 24 |
| ICMA 97111 × 571-580 | 70.00 | 13 | 11.33 | 68 | 58.67 | 76 | 1.40 | 80 | 0.27 | 58 |
| ICMA 97444 × 571-580 | 65.00 | 21 | 45.33 | 2 | 19.67 | 19 | 0.50 | 10 | 1.02 | 4 |
| ICMA 98222 × 571-580 | 46.67 | 56 | 24.67 | 28 | 22.00 | 21 | 0.79 | 23 | 0.40 | 40 |
| ICMA 10444 × 571-580 | 50.00 | 44 | 18.67 | 52 | 31.33 | 41 | 1.04 | 47 | 0.32 | 49 |
| ICMA 30199 × 571-580 | 63.33 | 22 | 32.67 | 11 | 30.67 | 39 | 0.81 | 24 | 0.71 | 15 |
| ICMA 30200 × 571-580 | 56.67 | 34 | 28.67 | 20 | 28.00 | 32 | 0.82 | 27 | 0.56 | 21 |
| ICMA 30201 × 571-580 | 50.00 | 44 | 20.67 | 47 | 29.33 | 37 | 0.98 | 40 | 0.36 | 44 |
| ICMA 30209 × 571-580 | 80.00 | 7 | 28.00 | 23 | 52.00 | 73 | 1.08 | 53 | 0.77 | 12 |
| RHB - 177 (Check-1) | 50.00 | 44 | 18.00 | 56 | 32.00 | 43 | 1.07 | 50 | 0.31 | 53 |
| HHB-67 Improved (Check-2) | 66.67 | 16 | 22.00 | 34 | 44.67 | 64 | 1.12 | 58 | 0.51 | 29 |
| BHB - 1602 ( Check-3) | 53.33 | 39 | 24.67 | 28 | 28.67 | 35 | 0.90 | 34 | 0.45 | 34 |
| **Overall mean** | **54.45** | | **23.24** | | | | | | | |

**Table 4.6.2 Grain yield per plant and moisture stress indices in response to normal ($E_1$) and moisture stress ($E_3$) condition**

| Crosses | Grain yield per plant (g) | | | | MP | Rank | GMP | Rank | YI | Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ ($Y_p$) | Rank | $E_3$ ($Y_s$) | Rank | | | | | | |
| ICMA 04999 × 481-500 | 66.67 | 16 | 21.33 | 36 | 44.00 | 23 | 37.71 | 31 | 0.92 | 36 |
| ICMA 88004 × 481-500 | 50.00 | 44 | 28.67 | 20 | 39.33 | 35 | 37.86 | 30 | 1.23 | 20 |
| ICMA 93333 × 481-500 | 36.67 | 69 | 29.67 | 18 | 33.17 | 57 | 32.98 | 42 | 1.28 | 18 |
| ICMA 97111 × 481-500 | 43.33 | 61 | 21.33 | 36 | 32.33 | 59 | 30.40 | 50 | 0.92 | 36 |
| ICMA 97444 × 481-500 | 60.00 | 26 | 17.33 | 58 | 38.67 | 40 | 32.25 | 43 | 0.75 | 58 |
| ICMA 98222 × 481-500 | 95.00 | 1 | 61.67 | 1 | 78.33 | 1 | 76.54 | 1 | 2.65 | 1 |
| ICMA 10444 × 481-500 | 26.67 | 72 | 22.33 | 33 | 24.50 | 72 | 24.40 | 67 | 0.96 | 33 |
| ICMA 30199 × 481-500 | 73.33 | 11 | 34.67 | 8 | 54.00 | 7 | 50.42 | 6 | 1.49 | 8 |
| ICMA 30200 × 481-500 | 53.33 | 39 | 24.67 | 28 | 39.00 | 36 | 36.27 | 34 | 1.06 | 28 |
| ICMA 30201 × 481-500 | 50.00 | 44 | 31.67 | 13 | 40.83 | 28 | 39.79 | 23 | 1.36 | 13 |
| ICMA 30209 × 481-500 | 19.33 | 78 | 16.67 | 60 | 18.00 | 77 | 17.95 | 77 | 0.72 | 60 |
| ICMA 04999 × 501-510 | 23.33 | 74 | 14.67 | 65 | 19.00 | 76 | 18.50 | 76 | 0.63 | 65 |
| ICMA 88004 × 501-510 | 83.67 | 6 | 42.33 | 3 | 63.00 | 2 | 59.51 | 2 | 1.82 | 3 |
| ICMA 93333 × 501-510 | 50.00 | 44 | 11.33 | 68 | 30.67 | 64 | 23.80 | 68 | 0.49 | 68 |
| ICMA 97111 × 501-510 | 56.67 | 34 | 14.67 | 65 | 35.67 | 48 | 28.83 | 57 | 0.63 | 65 |
| ICMA 97444 × 501-510 | 41.67 | 66 | 10.67 | 79 | 26.17 | 70 | 21.08 | 75 | 0.46 | 79 |
| ICMA 98222 × 501-510 | 63.33 | 22 | 10.67 | 79 | 37.00 | 44 | 25.99 | 63 | 0.46 | 79 |
| ICMA 10444 × 501-510 | 26.67 | 72 | 18.67 | 52 | 22.67 | 73 | 22.31 | 71 | 0.80 | 52 |
| ICMA 30199 × 501-510 | 43.33 | 61 | 34.00 | 10 | 38.67 | 39 | 38.38 | 28 | 1.46 | 10 |
| ICMA 30200 × 501-510 | 40.00 | 67 | 11.33 | 68 | 25.67 | 71 | 21.29 | 74 | 0.49 | 68 |
| ICMA 30201 × 501-510 | 46.67 | 56 | 11.33 | 68 | 29.00 | 66 | 23.00 | 69 | 0.49 | 68 |
| ICMA 30209 × 501-510 | 60.00 | 26 | 15.33 | 64 | 37.67 | 42 | 30.33 | 52 | 0.66 | 64 |
| ICMA 04999 × 511-520 | 50.00 | 44 | 31.33 | 14 | 40.67 | 30 | 39.58 | 24 | 1.35 | 14 |
| ICMA 88004 × 511-520 | 43.33 | 61 | 16.33 | 62 | 29.83 | 65 | 26.60 | 60 | 0.70 | 62 |
| ICMA 93333 × 511-520 | 43.33 | 61 | 21.33 | 36 | 32.33 | 59 | 30.40 | 50 | 0.92 | 36 |
| ICMA 97111 × 511-520 | 50.00 | 44 | 17.33 | 58 | 33.67 | 56 | 29.44 | 56 | 0.75 | 58 |

| Crosses | Grain yield per plant (g) | | | | MP | Rank | GMP | Rank | YI | Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ ($Y_p$) | Rank | $E_3$ ($Y_s$) | Rank | | | | | | |
| ICMA 97444 × 511-520 | 60.00 | 26 | 34.67 | 8 | 47.33 | 19 | 45.61 | 14 | 1.49 | 8 |
| ICMA 98222 × 511-520 | 60.00 | 26 | 11.19 | 68 | 35.67 | 48 | 26.08 | 62 | 0.49 | 68 |
| ICMA 10444 × 511-520 | 60.00 | 26 | 5.87 | 5 | 50.83 | 16 | 50.00 | 7 | 1.79 | 5 |
| ICMA 30199 × 511-520 | 55.00 | 38 | 10.11 | 52 | 36.83 | 46 | 32.04 | 46 | 0.80 | 52 |
| ICMA 30200 × 511-520 | 16.67 | 79 | 6.65 | 68 | 14.00 | 79 | 13.74 | 79 | 0.49 | 68 |
| ICMA 30201 × 511-520 | 63.33 | 22 | 8.02 | 6 | 52.33 | 11 | 51.16 | 5 | 1.78 | 6 |
| ICMA 30209 × 511-520 | 63.33 | 22 | 20.27 | 56 | 40.67 | 29 | 33.76 | 41 | 0.77 | 56 |
| ICMA 04999 × 531-540 | 66.67 | 16 | 7.42 | 68 | 39.00 | 36 | 27.49 | 59 | 0.49 | 68 |
| ICMA 88004 × 531-540 | 16.67 | 79 | 7.56 | 68 | 14.00 | 79 | 13.74 | 79 | 0.49 | 68 |
| ICMA 93333 × 531-540 | 48.33 | 55 | 8.03 | 7 | 44.17 | 22 | 43.97 | 17 | 1.72 | 7 |
| ICMA 97111 × 531-540 | 53.33 | 39 | 9.33 | 68 | 32.33 | 59 | 24.59 | 65 | 0.49 | 68 |
| ICMA 97444 × 531-540 | 60.00 | 26 | 22.52 | 28 | 42.33 | 27 | 38.47 | 27 | 1.06 | 28 |
| ICMA 98222 × 531-540 | 46.67 | 56 | 7.66 | 68 | 29.00 | 66 | 23.00 | 69 | 0.49 | 68 |
| ICMA 10444 × 531-540 | 53.33 | 39 | 8.46 | 68 | 32.33 | 59 | 24.59 | 65 | 0.49 | 68 |
| ICMA 30199 × 531-540 | 46.67 | 56 | 8.36 | 36 | 34.00 | 54 | 31.55 | 47 | 0.92 | 36 |
| ICMA 30200 × 531-540 | 40.00 | 67 | 7.42 | 62 | 28.17 | 68 | 25.56 | 64 | 0.70 | 62 |
| ICMA 30201 × 531-540 | 60.00 | 26 | 8.71 | 36 | 40.67 | 30 | 35.78 | 36 | 0.92 | 36 |
| ICMA 30209 × 531-540 | 70.00 | 13 | 7.94 | 36 | 45.67 | 20 | 38.64 | 26 | 0.92 | 36 |
| ICMA 04999 × 551-560 | 23.33 | 74 | 19.65 | 36 | 22.33 | 74 | 22.31 | 72 | 0.92 | 36 |
| ICMA 88004 × 551-560 | 80.00 | 7 | 8.57 | 19 | 54.50 | 6 | 48.17 | 8 | 1.25 | 19 |
| ICMA 93333 × 551-560 | 94.33 | 2 | 20.07 | 14 | 62.83 | 3 | 54.37 | 3 | 1.35 | 14 |
| ICMA 97111 × 551-560 | 20.67 | 77 | 7.51 | 67 | 16.83 | 78 | 16.39 | 78 | 0.56 | 67 |
| ICMA 97444 × 551-560 | 21.67 | 76 | 9.15 | 36 | 21.50 | 75 | 21.50 | 73 | 0.92 | 36 |
| ICMA 98222 × 551-560 | 56.67 | 34 | 5.25 | 20 | 42.67 | 25 | 40.30 | 21 | 1.23 | 20 |
| ICMA 10444 × 551-560 | 50.00 | 44 | 9.49 | 47 | 35.33 | 51 | 32.15 | 44 | 0.89 | 47 |
| ICMA 30199 × 551-560 | 76.67 | 9 | 9.50 | 23 | 52.33 | 11 | 46.33 | 13 | 1.20 | 23 |
| ICMA 30200 × 551-560 | 43.33 | 61 | 6.38 | 47 | 32.00 | 63 | 29.93 | 54 | 0.89 | 47 |
| ICMA 30201 × 551-560 | 50.00 | 44 | 7.59 | 32 | 37.00 | 44 | 34.64 | 38 | 1.03 | 32 |

| Crosses | Grain yield per plant (g) | | | | MP | Rank | GMP | Rank | YI | Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ ($Y_p$) | Rank | $E_3$ ($Y_s$) | Rank | | | | | | |
| ICMA 30209 × 551-560 | 66.67 | 16 | 28.00 | 23 | 47.33 | 18 | 43.20 | 18 | 1.20 | 23 |
| ICMA 04999 × 561-570 | 90.00 | 3 | 25.33 | 26 | 57.67 | 4 | 47.75 | 10 | 1.09 | 26 |
| ICMA 88004 × 561-570 | 66.67 | 16 | 21.33 | 36 | 44.00 | 23 | 37.71 | 31 | 0.92 | 36 |
| ICMA 93333 × 561-570 | 36.67 | 69 | 18.67 | 52 | 27.67 | 69 | 26.16 | 61 | 0.80 | 52 |
| ICMA 97111 × 561-570 | 46.67 | 56 | 19.00 | 51 | 32.83 | 58 | 29.78 | 55 | 0.82 | 51 |
| ICMA 97444 × 561-570 | 56.67 | 34 | 16.67 | 60 | 36.67 | 47 | 30.73 | 48 | 0.72 | 60 |
| ICMA 98222 × 561-570 | 85.00 | 5 | 20.67 | 47 | 52.83 | 10 | 41.91 | 20 | 0.89 | 47 |
| ICMA 10444 × 561-570 | 53.33 | 39 | 21.67 | 35 | 37.50 | 43 | 33.99 | 39 | 0.93 | 35 |
| ICMA 30199 × 561-570 | 86.67 | 4 | 21.33 | 36 | 54.00 | 7 | 43.00 | 19 | 0.92 | 36 |
| ICMA 30200 × 561-570 | 73.33 | 11 | 31.33 | 14 | 52.33 | 13 | 47.94 | 9 | 1.35 | 14 |
| ICMA 30201 × 561-570 | 33.33 | 71 | 42.33 | 3 | 37.83 | 41 | 37.56 | 33 | 1.82 | 3 |
| ICMA 30209 × 561-570 | 60.00 | 26 | 21.33 | 36 | 40.67 | 30 | 35.78 | 36 | 0.92 | 36 |
| ICMA 04999 × 571-580 | 70.00 | 13 | 32.33 | 12 | 51.17 | 14 | 47.57 | 11 | 1.39 | 12 |
| ICMA 88004 × 571-580 | 76.67 | 9 | 25.33 | 26 | 51.00 | 15 | 44.07 | 16 | 1.09 | 26 |
| ICMA 93333 × 571-580 | 50.00 | 44 | 31.33 | 14 | 40.67 | 30 | 39.58 | 24 | 1.35 | 14 |
| ICMA 97111 × 571-580 | 70.00 | 13 | 11.33 | 68 | 40.67 | 30 | 28.17 | 58 | 0.49 | 68 |
| ICMA 97444 × 571-580 | 65.00 | 21 | 45.33 | 2 | 55.17 | 5 | 54.28 | 4 | 1.95 | 2 |
| ICMA 98222 × 571-580 | 46.67 | 56 | 24.67 | 28 | 35.67 | 48 | 33.93 | 40 | 1.06 | 28 |
| ICMA 10444 × 571-580 | 50.00 | 44 | 18.67 | 52 | 34.33 | 53 | 30.55 | 49 | 0.80 | 52 |
| ICMA 30199 × 571-580 | 63.33 | 22 | 32.67 | 11 | 48.00 | 17 | 45.49 | 15 | 1.41 | 11 |
| ICMA 30200 × 571-580 | 56.67 | 34 | 28.67 | 20 | 42.67 | 25 | 40.30 | 21 | 1.23 | 20 |
| ICMA 30201 × 571-580 | 50.00 | 44 | 20.67 | 47 | 35.33 | 51 | 32.15 | 44 | 0.89 | 47 |
| ICMA 30209 × 571-580 | 80.00 | 7 | 28.00 | 23 | 54.00 | 7 | 47.33 | 12 | 1.20 | 23 |
| RHB - 177 (Check-1) | 50.00 | 44 | 18.00 | 56 | 34.00 | 54 | 30.00 | 53 | 0.77 | 56 |
| HHB-67 Improved (Check-2) | 66.67 | 16 | 22.00 | 34 | 44.33 | 21 | 38.30 | 29 | 0.95 | 34 |
| BHB - 1602 ( Check-3) | 53.33 | 39 | 24.67 | 28 | 39.00 | 36 | 36.27 | 34 | 1.06 | 28 |
| **Overall mean** | **54.45** | | **23.24** | | | | | | | |

**Table 4.6.3 Grain yield per plant and moisture stress indices in response to normal ($E_1$) and moisture stress ($E_3$) condition**

| Crosses | Grain yield per plant (g) | | | | YSI | Rank | HM | Rank | SDI | Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ ($Y_p$) | Rank | $E_3$ ($Y_s$) | Rank | | | | | | |
| ICMA 04999 × 481-500 | 66.67 | 16 | 21.33 | 36 | 0.32 | 59 | 32.32 | 36 | 0.68 | 59 |
| ICMA 88004 × 481-500 | 50.00 | 44 | 28.67 | 20 | 0.57 | 22 | 36.44 | 26 | 0.43 | 22 |
| ICMA 93333 × 481-500 | 36.67 | 69 | 29.67 | 18 | 0.81 | 7 | 32.80 | 33 | 0.19 | 7 |
| ICMA 97111 × 481-500 | 43.33 | 61 | 21.33 | 36 | 0.49 | 29 | 28.59 | 45 | 0.51 | 29 |
| ICMA 97444 × 481-500 | 60.00 | 26 | 17.33 | 58 | 0.29 | 63 | 26.90 | 52 | 0.71 | 63 |
| ICMA 98222 × 481-500 | 95.00 | 1 | 61.67 | 1 | 0.65 | 15 | 74.79 | 1 | 0.35 | 15 |
| ICMA 10444 × 481-500 | 26.67 | 72 | 22.33 | 33 | 0.84 | 5 | 24.31 | 58 | 0.16 | 5 |
| ICMA 30199 × 481-500 | 73.33 | 11 | 34.67 | 8 | 0.47 | 33 | 47.08 | 6 | 0.53 | 33 |
| ICMA 30200 × 481-500 | 53.33 | 39 | 24.67 | 28 | 0.46 | 34 | 33.73 | 29 | 0.54 | 34 |
| ICMA 30201 × 481-500 | 50.00 | 44 | 31.67 | 13 | 0.63 | 16 | 38.78 | 18 | 0.37 | 16 |
| ICMA 30209 × 481-500 | 19.33 | 78 | 16.67 | 60 | 0.86 | 4 | 17.90 | 75 | 0.14 | 4 |
| ICMA 04999 × 501-510 | 23.33 | 74 | 14.67 | 65 | 0.63 | 18 | 18.01 | 74 | 0.37 | 18 |
| ICMA 88004 × 501-510 | 83.67 | 6 | 42.33 | 3 | 0.51 | 26 | 56.22 | 2 | 0.49 | 26 |
| ICMA 93333 × 501-510 | 50.00 | 44 | 11.33 | 68 | 0.23 | 74 | 18.48 | 70 | 0.77 | 74 |
| ICMA 97111 × 501-510 | 56.67 | 34 | 14.67 | 65 | 0.26 | 67 | 23.30 | 60 | 0.74 | 67 |
| ICMA 97444 × 501-510 | 41.67 | 66 | 10.67 | 79 | 0.26 | 68 | 16.99 | 77 | 0.74 | 68 |
| ICMA 98222 × 501-510 | 63.33 | 22 | 10.67 | 79 | 0.17 | 79 | 18.26 | 71 | 0.83 | 79 |
| ICMA 10444 × 501-510 | 26.67 | 72 | 18.67 | 52 | 0.70 | 9 | 21.96 | 63 | 0.30 | 9 |
| ICMA 30199 × 501-510 | 43.33 | 61 | 34.00 | 10 | 0.78 | 8 | 38.10 | 21 | 0.22 | 8 |
| ICMA 30200 × 501-510 | 40.00 | 67 | 11.33 | 68 | 0.28 | 65 | 17.66 | 76 | 0.72 | 65 |
| ICMA 30201 × 501-510 | 46.67 | 56 | 11.33 | 68 | 0.24 | 72 | 18.24 | 72 | 0.76 | 72 |
| ICMA 30209 × 501-510 | 60.00 | 26 | 15.33 | 64 | 0.26 | 69 | 24.42 | 57 | 0.74 | 69 |
| ICMA 04999 × 511-520 | 50.00 | 44 | 31.33 | 14 | 0.63 | 19 | 38.52 | 19 | 0.37 | 19 |
| ICMA 88004 × 511-520 | 43.33 | 61 | 16.33 | 62 | 0.38 | 46 | 23.72 | 59 | 0.62 | 46 |
| ICMA 93333 × 511-520 | 43.33 | 61 | 21.33 | 36 | 0.49 | 29 | 28.59 | 45 | 0.51 | 29 |
| ICMA 97111 × 511-520 | 50.00 | 44 | 17.33 | 58 | 0.35 | 54 | 25.74 | 55 | 0.65 | 54 |

| Crosses | Grain yield per plant (g) | | | | YSI | Rank | HM | Rank | SDI | Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ ($Y_p$) | Rank | $E_3$ ($Y_s$) | Rank | | | | | | |
| ICMA 97444 × 511-520 | 60.00 | 26 | 34.67 | 8 | 0.58 | 21 | 43.94 | 9 | 0.42 | 21 |
| ICMA 98222 × 511-520 | 60.00 | 26 | 11.33 | 68 | 0.19 | 77 | 19.07 | 67 | 0.81 | 77 |
| ICMA 10444 × 511-520 | 60.00 | 26 | 41.67 | 5 | 0.69 | 11 | 49.18 | 5 | 0.31 | 11 |
| ICMA 30199 × 511-520 | 55.00 | 38 | 18.67 | 52 | 0.34 | 55 | 27.87 | 49 | 0.66 | 55 |
| ICMA 30200 × 511-520 | 16.67 | 79 | 11.33 | 68 | 0.68 | 12 | 13.49 | 79 | 0.32 | 12 |
| ICMA 30201 × 511-520 | 63.33 | 22 | 41.33 | 6 | 0.65 | 14 | 50.02 | 4 | 0.35 | 14 |
| ICMA 30209 × 511-520 | 63.33 | 22 | 18.00 | 56 | 0.28 | 64 | 28.03 | 47 | 0.72 | 64 |
| ICMA 04999 × 531-540 | 66.67 | 16 | 11.33 | 68 | 0.17 | 78 | 19.37 | 66 | 0.83 | 78 |
| ICMA 88004 × 531-540 | 16.67 | 79 | 11.33 | 68 | 0.68 | 12 | 13.49 | 79 | 0.32 | 12 |
| ICMA 93333 × 531-540 | 48.33 | 55 | 40.00 | 7 | 0.83 | 6 | 43.77 | 11 | 0.17 | 6 |
| ICMA 97111 × 531-540 | 53.33 | 39 | 11.33 | 68 | 0.21 | 75 | 18.69 | 68 | 0.79 | 75 |
| ICMA 97444 × 531-540 | 60.00 | 26 | 24.67 | 28 | 0.41 | 42 | 34.96 | 27 | 0.59 | 42 |
| ICMA 98222 × 531-540 | 46.67 | 56 | 11.33 | 68 | 0.24 | 72 | 18.24 | 72 | 0.76 | 72 |
| ICMA 10444 × 531-540 | 53.33 | 39 | 11.33 | 68 | 0.21 | 75 | 18.69 | 68 | 0.79 | 75 |
| ICMA 30199 × 531-540 | 46.67 | 56 | 21.33 | 36 | 0.46 | 37 | 29.28 | 42 | 0.54 | 37 |
| ICMA 30200 × 531-540 | 40.00 | 67 | 16.33 | 62 | 0.41 | 43 | 23.20 | 61 | 0.59 | 43 |
| ICMA 30201 × 531-540 | 60.00 | 26 | 21.33 | 36 | 0.36 | 51 | 31.48 | 39 | 0.64 | 51 |
| ICMA 30209 × 531-540 | 70.00 | 13 | 21.33 | 36 | 0.30 | 61 | 32.70 | 34 | 0.70 | 61 |
| ICMA 04999 × 551-560 | 23.33 | 74 | 21.33 | 36 | 0.91 | 3 | 22.29 | 62 | 0.09 | 3 |
| ICMA 88004 × 551-560 | 80.00 | 7 | 29.00 | 19 | 0.36 | 49 | 42.57 | 13 | 0.64 | 49 |
| ICMA 93333 × 551-560 | 94.33 | 2 | 31.33 | 14 | 0.33 | 56 | 47.04 | 7 | 0.67 | 56 |
| ICMA 97111 × 551-560 | 20.67 | 77 | 13.00 | 67 | 0.63 | 17 | 15.96 | 78 | 0.37 | 17 |
| ICMA 97444 × 551-560 | 21.67 | 76 | 21.33 | 36 | 0.98 | 2 | 21.50 | 64 | 0.02 | 2 |
| ICMA 98222 × 551-560 | 56.67 | 34 | 28.67 | 20 | 0.51 | 27 | 38.07 | 23 | 0.49 | 27 |
| ICMA 10444 × 551-560 | 50.00 | 44 | 20.67 | 47 | 0.41 | 40 | 29.25 | 43 | 0.59 | 40 |
| ICMA 30199 × 551-560 | 76.67 | 9 | 28.00 | 23 | 0.37 | 48 | 41.02 | 15 | 0.63 | 48 |
| ICMA 30200 × 551-560 | 43.33 | 61 | 20.67 | 47 | 0.48 | 32 | 27.99 | 48 | 0.52 | 32 |
| ICMA 30201 × 551-560 | 50.00 | 44 | 24.00 | 32 | 0.48 | 31 | 32.43 | 35 | 0.52 | 31 |

| Crosses | Grain yield per plant (g) | | | | YSI | Rank | HM | Rank | SDI | Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ ($Y_p$) | Rank | $E_3$ ($Y_s$) | Rank | | | | | | |
| ICMA 30209 × 551-560 | 66.67 | 16 | 28.00 | 23 | 0.42 | 39 | 39.44 | 17 | 0.58 | 39 |
| ICMA 04999 × 561-570 | 90.00 | 3 | 25.33 | 26 | 0.28 | 66 | 39.54 | 16 | 0.72 | 66 |
| ICMA 88004 × 561-570 | 66.67 | 16 | 21.33 | 36 | 0.32 | 59 | 32.32 | 36 | 0.68 | 59 |
| ICMA 93333 × 561-570 | 36.67 | 69 | 18.67 | 52 | 0.51 | 25 | 24.74 | 56 | 0.49 | 25 |
| ICMA 97111 × 561-570 | 46.67 | 56 | 19.00 | 51 | 0.41 | 44 | 27.01 | 51 | 0.59 | 44 |
| ICMA 97444 × 561-570 | 56.67 | 34 | 16.67 | 60 | 0.29 | 62 | 25.76 | 54 | 0.71 | 62 |
| ICMA 98222 × 561-570 | 85.00 | 5 | 20.67 | 47 | 0.24 | 71 | 33.25 | 31 | 0.76 | 71 |
| ICMA 10444 × 561-570 | 53.33 | 39 | 21.67 | 35 | 0.41 | 45 | 30.81 | 41 | 0.59 | 45 |
| ICMA 30199 × 561-570 | 86.67 | 4 | 21.33 | 36 | 0.25 | 70 | 34.24 | 28 | 0.75 | 70 |
| ICMA 30200 × 561-570 | 73.33 | 11 | 31.33 | 14 | 0.43 | 38 | 43.91 | 10 | 0.57 | 38 |
| ICMA 30201 × 561-570 | 33.33 | 71 | 42.33 | 3 | 1.27 | 1 | 37.30 | 25 | -0.27 | 1 |
| ICMA 30209 × 561-570 | 60.00 | 26 | 21.33 | 36 | 0.36 | 51 | 31.48 | 39 | 0.64 | 51 |
| ICMA 04999 × 571-580 | 70.00 | 13 | 32.33 | 12 | 0.46 | 36 | 44.23 | 8 | 0.54 | 36 |
| ICMA 88004 × 571-580 | 76.67 | 9 | 25.33 | 26 | 0.33 | 57 | 38.08 | 22 | 0.67 | 57 |
| ICMA 93333 × 571-580 | 50.00 | 44 | 31.33 | 14 | 0.63 | 19 | 38.52 | 19 | 0.37 | 19 |
| ICMA 97111 × 571-580 | 70.00 | 13 | 11.33 | 68 | 0.16 | 80 | 19.51 | 65 | 0.84 | 80 |
| ICMA 97444 × 571-580 | 65.00 | 21 | 45.33 | 2 | 0.70 | 10 | 53.41 | 3 | 0.30 | 10 |
| ICMA 98222 × 571-580 | 46.67 | 56 | 24.67 | 28 | 0.53 | 23 | 32.27 | 38 | 0.47 | 23 |
| ICMA 10444 × 571-580 | 50.00 | 44 | 18.67 | 52 | 0.37 | 47 | 27.18 | 50 | 0.63 | 47 |
| ICMA 30199 × 571-580 | 63.33 | 22 | 32.67 | 11 | 0.52 | 24 | 43.10 | 12 | 0.48 | 24 |
| ICMA 30200 × 571-580 | 56.67 | 34 | 28.67 | 20 | 0.51 | 27 | 38.07 | 23 | 0.49 | 27 |
| ICMA 30201 × 571-580 | 50.00 | 44 | 20.67 | 47 | 0.41 | 40 | 29.25 | 43 | 0.59 | 40 |
| ICMA 30209 × 571-580 | 80.00 | 7 | 28.00 | 23 | 0.35 | 53 | 41.48 | 14 | 0.65 | 53 |
| RHB - 177 (Check-1) | 50.00 | 44 | 18.00 | 56 | 0.36 | 50 | 26.47 | 53 | 0.64 | 50 |
| HHB-67 Improved (Check-2) | 66.67 | 16 | 22.00 | 34 | 0.33 | 58 | 33.08 | 32 | 0.67 | 58 |
| BHB - 1602 ( Check-3) | 53.33 | 39 | 24.67 | 28 | 0.46 | 34 | 33.73 | 29 | 0.54 | 34 |
| **Overall mean** | **54.45** | | **23.24** | | | | | | | |

# 5. DISCUSSION

Pearl millet a versatile, historic and has considered as most drought tolerant coarse grain crop. It is stable food for millions of people in India, sub-Saharan Africa and Asia. Among the cultivated food grains, pearl millet is widely cultivated across the arid and semi-arid tropics of Africa and Asia. It is highly cross pollinated crop due to female reproductive organs come to maturity before the male which is called protogynous nature. Pearl millet has the advantages of huge genetic variability and availability of efficient cytoplasmic-genetic male sterile lines which serves great opportunities of crop improvement. The Rajasthan covered largest area and production in the country. However, its productivity is very low due to unavailability of the high yielding genotypes for arid condition and characteristically challenged by low and erratic rainfall and high mean temperature and simultaneously has soils with low organic carbon and poor water-holding capacity (Serba *et al*., 2020). Such unfavorable situations required development of such genotypes which can give higher grain as well as fodder yield under moisture stress conditions.

The accomplishment of any plant breeding programme is mainly dependent on to a great extent of genetic variability present in the material under study. The fundamental aim of any plant breeding programme is to develop encouraging and desirable cultivars having high yield potential over the environments. To carry off this goal, basic information on nature and extent of genetic variation, combining ability, standard heterosis, genotypic x environment interaction (phenotypic stability) and some stress indices is required to design effective breeding programme.

An ideotype is determined by genetic components explained by gene action such as additive, dominance, epistatic or over dominance effects, and the environment in which it is grown (Fasoula and Fasoula, 2003). The magnitude and direction of genetic components are estimated through various parameters including combining ability, heritability and heterosis analysis. Knowledge of gene action and associated trait expression is important for effective breeding and selection (Grami *et al*., 1977; Ma-Teresa *et al.*, 1994).

Combining ability analysis helps to identify superior parents to be used in breeding programs or to identify promising cross combinations for cultivar development (Acquaah, 2007). General combining ability (GCA) is directly related to the breeding value of a parent and is associated with additive genetic effects, while specific combining ability (SCA) is the relative performance of a cross that is associated with non-additive gene action, predominantly contributed by dominance and epistasis (Rojas and Sprague, 1952; Falconer and Mackay, 1996). Therefore, both GCA and SCA effects are important in the selection or development of breeding populations (Viana and Matta, 2003).

Genotype × environment interaction (GEI) is problematic for both the agronomist and breeder because phenotype of cultivars and breeding lines are affecting by GEI, especially if the target environments are not similar. This interaction also reduces the association between phenotypes and genotypes, thereby selected genotypes in one environment may exhibit a poor performance in another environment (Romagosa and Fox, 1993). Therefore plant breeders aim to select genotypes with stable and high performing phenotypes via multi-environment trials (METs). The large magnitude of GxE interaction may necessitate the performing of additional multi-environment trials. If genotypes are being selected for many locations, stability and mean yield across all environments are more important than yield for specific environments (Piepho, 1996). Most plant breeders explore for genotypes that show a stable property as well as high mean yield over environments and generally a genotype is known as the most stable when its yield performance across environments does not deviate from the average yield of the studied genotypes.

The present investigation was carried out to evaluate the experimental material in terms of combining ability, standard heterosis, g x e interaction (phenotypic stability) and moisture stress indices using 77 pearl millet crosses generated by 11 male sterile lines (Female lines) crossed with 7 genetically diverse restorer lines (Male lines) in line x tester mating design. These crosses along with three standard checks were evaluated during *Kharif*, 2019 at Agriculture Research Station Bikaner. The material was evaluated in randomized block design with three replications in three environments. The three different environments were created by manipulating different number of irrigations. The environment $E_1$, $E_2$ and $E_3$ were provided three (Normal moisture condition), two (Limited moisture condition) and one irrigation (only life saving moisture condition), respectively with recommended doses of NPK fertilizers. The observations were recorded on various morphological characters *viz.,* days to 50% flowering, days to maturity, plant height (cm), productive tillers per plant, ear head length (cm), ear head diameter (cm), test weight (g), ear head weight (g), dry stover yield per plant (g), grain yield per plant (g), harvest index (%) and threshing index (%). The mean values of data recorded on various characters were subjected to statistical analysis as per the standard procedure. The results thus obtained have been discussed with respect to the pertinent literature under the following sub-headings:

5.1 Analysis of variance

5.2 Combining ability analysis

5.3 Estimation of standard heterosis

5.4 Phenotypic stability analysis

5.5 Moisture stress indices

## 5.1 Analysis of variance

The analysis of variance for all the individual environments indicated the presence of significant genetic variability among the crosses for all the characters studied (Table 4.1.1). In pooled analysis

(Table 4.1.2) the significant mean sum of squares due to environments for all characters indicated effect of environment on character expression. The crosses x environment interaction were found significant for all the characters indicating the differential responses of the crosses to the varying environments for all the traits. These results confirmed that genotype x environment is a common phenomenon present in crop plant species (Allard and Bradshaw, 1964). These findings are in close agreement with the earlier reports of Yahaya *et al.* (2006), Dakheel *et al.* (2009) and Rajpurohit *et al.* (2012) in pearl millet.

## 5.2 Combining ability analysis

The concept of general and specific combining ability as a measure of gene action was firstly proposed by Sprague and Tatum (1942). The appropriate selection of parents is very crucial in any crossing programme i.e. the lines, which produce good progenies on crossing, are of immense value to a plant breeder. The line x tester analysis proposed by Kempthorne (1957) is a powerful tool to find out good as well as poor combiners. The general combining ability may be defined as the average performance of a line in cross combination and may be recognized as a measure of additive gene action. Likewise, specific combining ability is the deviation from expectation on the basis of average performance of lines involved and it can be recognized as a measure of non-additive gene action. Therefore, combining ability analysis was carried out in the present study for selection of better parents and crosses for their further use in breeding programmes and obtaining information on nature and magnitude of gene action. The gene action is useful in deciding breeding methodology aiming at fixable (additive) and non-fixable (non-additive) genetic variances.

In present investigation, the analysis of variance for combining ability in each environment (Table 4.3.1, Table 4.3.2, table 4.3.3.) exhibited significant mean sum of squares due to crosses and line x tester for all the characters which revealed the sufficient genetic variability among the crosses. In case of lines, mean sum squares were found significant for days to 50% flowering, days to maturity and harvest index in $E_{1,}$ days to 50% flowering, days to maturity, plant height and dry stover yield per plant in $E_{2,}$ days to 50% flowering, days to maturity, plant height and threshing index in $E_{3.}$ Mean sum squares due to testers were found to be significant for productive tillers per plant in $E_{1,}$ $E_2$ and $E_3$. These significant and non-significant mean squares due to lines and testers for various traits in different environments indicated the differences among the parental lines used for the present study.

The pooled analysis of variance for combining ability over the environments (Table 4.3.4) showed significant mean sum squares due to environments, crosses, line effect, tester effect, line x tester, environment x crosses, environment x line effect, environment x tester effect, and environment x line x tester effect for all the characters indicating the differential responses of the genotypes to the environments for all the traits. The mean sum of squares due to environment, crosses, line x tester, environment x crosses, and environment x line x tester effect were found significant for all the characters except test weight for environment x line x tester effect. The mean sum of squares due to line were found significant for days to 50% flowering, days to maturity, plant height and dry stover yield per plant. The tester mean sum of squares was found significant for productive tillers per plant. The significant mean sum of squares due to environment x line was found for productive tillers per plant and threshing index. The significant mean sum of squares due to environment x tester for plant height, productive tillers per plant, ear head length and test weight. So these characters indicated their sensitivity to the environment and for this reason, estimates based over the environments might be biased.

Significant variance due to GCA and SCA (Table 4.3.5) indicated the importance of additive as well as non-additive components in the inheritance of majority of the characters. The ratio of variances due to GCA/SCA was less than unity which indicated the preponderance of non-additive components for all the characters in all the environments. The ratio of additive variance to dominance variance (Table 4.3.6) was less than unity for all the traits in all the environments as well as on pooled basis which indicated the preponderance of non-additive gene action in the inheritance of majority of the characters. Similar results were also reported in pearl millet by Jeeterwal *et al.* (2017), Krishnan *et al.* (2017), Kumar *et al.* (2017a), Solanki *et al.* (2017) and Badurkar *et al.* (2018)

The proportional contribution of lines, testers and their interaction to total variance (%) is presented in Table 4.3.7. The Maximum contribution of lines to total variance was for days to 50% flowering and days to maturity based on data pooled over different environments. The maximum contribution of tester to total variance was for productive tillers per plant and the line x tester interaction displayed maximum contribution of harvest index.

From these results, it was found that additive and non- additive gene actions were responsible in governing the traits under study. Therefore, recurrent selection or mass selection with concurrent random mating may be adopted for population improvement to exploit proportion of additive gene action in the present material. The heterosis breeding may be adopted to exploit non-additive gene action for improving different traits in pearl millet.

**General and specific combining ability (GCA and SCA) effects**

Selection of the parents for hybridization is important aspect in the crop improvement programme and the nature and magnitude of combining ability provide an idea about relative role of fixable and non-fixable gene effects in the inheritance of different characters *i.e.* it helps in identifying suitable parents for crossing programme. The choice of the most suitable breeding method mainly depends on the combining ability behavior and nature of gene action involved in the control of the traits of interest to the breeder. The comprehensive analysis of the combining ability involved in the inheritance of quantitative traits and in the phenomenon of heterosis is necessary for the evaluation of various possible breeding procedures (Allard, 1960). In present investigation, the magnitude and direction of GCA and SCA effects in most of the cases for grain yield per plant and its component traits frequently changed from environment to environment, which complicated the problem of identification of promising parents and crosses.

The best performing parents (lines and testers) on the basis of GCA effects has been given in Table 5.2.1. The GCA effects of the parents revealed that none of the parents (lines and testers) was found to be consistently good general combiner for all the characters (Table 4.3.8 to 4.3.10) which suggested breeding for these characters would be effective when material is tested over wide range of environments. However, a number of parents (lines and testers) showed superior GCA effects for various characters over the environments.

In this present investigation, out of eleven lines tested, nine lines depicted good GCA effects for various characters. Thus these lines were considered good general combiner for different characters. The line ICMA 97444 was good general combiner for days to 50% flowering and days to maturity. The line ICMA 98222 was good general combiner for days to 50% flowering, days to maturity, ear head length, ear head diameter, test weight, ear head weight, dry stover yield per plant and grain yield per plant. The line ICMA 88004 was good general combiner for days to 50% flowering, days to maturity, plant height, ear head length, ear head weight, grain yield per plant, harvest index and threshing index. The line ICMA 93333 was good general combiner for days to 50% flowering, days to maturity, plant height, ear head length, test weight, ear head weight and dry stover yield per plant. The line ICMA 30199 was good general combiner for plant height, productive tillers per plant, ear head diameter, ear head weight, dry stover yield per plant and grain yield per plant. The line ICMA 30201 was good general combiner for productive tillers per plant, ear head length, ear head diameter, ear head weight, dry stover yield per plant, grain yield per plant and threshing index. The line ICMA 10444 was good general combiner for ear head length, ear head diameter and test weight. The line ICMA 97111 was good general combiner for test weight and the line ICMA 04999 was found good general combiner for harvest index and threshing index.

On the other hand, out of seven testers tested, the tester BIB 571-580 was found good general combiner for days to 50% flowering, days to maturity, productive tillers per plant, ear head length, ear head diameter, ear head weight, grain yield per plant and harvest index. The tester, BIB 561- 570 was found good general combiner for days to 50% flowering, days to maturity, productive tillers per plant, ear head length, test weight, ear head weight, dry stover yield per plant and grain yield per plant. The tester, BIB 511- 520 was good general combiner for days to 50% flowering, days to maturity, productive tillers per plant, and ear head weight. BIB 481- 500 for was found good general combiner for plant height, dry stover yield per plant, grain yield per plant and threshing index. BIB 531- 540 was found good general combiner for plant height, ear head length and test weight. BIB 551- 560 was found good general combiner for ear head length, harvest index, threshing

**Table 5.2.1: The best performing parents (lines and testers) on the basis of GCA effects**

| Characters | Parents | |
|---|---|---|
| | **Lines** | **Testers** |
| Days to 50% flowering | 1. ICMA-97444(-0.87**)<br>2. ICMA-98222(-2.76**)<br>3. ICMA-88004 (-2.94**)<br>4. ICMA-93333 (-3.65**) | 1.BIB 571-580 (-1.46**)<br>2.BIB 561-570 (-1.12**)<br>3.BIB 511-520 (-0.74**) |
| Days to maturity | 1. ICMA-97444(-0.93**)<br>2. ICMA-98222(-2.82**)<br>3. ICMA-88004 (-2.99**)<br>4. ICMA-93333 (-3.70**) | 1.BIB 571-580 (-1.14**)<br>2.BIB 561-570 (-1.18**)<br>3.BIB 511-520 (-0.79**) |

| | | |
|---|---|---|
| Plant height (cm) | 1. ICMA-93333 (14.39**)<br>2. ICMA-88004 (5.28**)<br>3. ICMA-30199 (3.32**) | 1.BIB 481- 500 (6.96**)<br>2.BIB 531-540 (5.02**) |
| Productive tillers per plant | 1. ICMA-30201 (0.40**)<br>2. ICMA-30199 (0.13**) | 1.BIB 511-520 (0.21**)<br>2.BIB 561-570 (0.43**)<br>3.BIB 571-580 (0.13**) |
| Ear head length (cm) | 1. ICMA-30201 (2.08**)<br>2. ICMA-93333 (1.78**)<br>3. ICMA-98222 (1.72**)<br>4. ICMA-10444 (1.49**)<br>5. ICMA-88004 (0.35**) | 1.BIB 571-580 (0.79**)<br>2.BIB 561-570 (0.67**)<br>3.BIB 551-560 (0.58**)<br>4.BIB 531-540 (0.29**) |
| Ear head diameter (cm) | 1. ICMA-98222 (4.18**)<br>2. ICMA-30199 (1.57**)<br>3. ICMA-30201 (1.56**)<br>4. ICMA-10444 (1.16**) | 1.BIB 571-580 (2.87**) |
| Test weight (g) | 1. ICMA-98222 (1.44**)<br>2. ICMA-93333 (0.69**)<br>3. ICMA-10444 (0.44**)<br>4. ICMA-04999 (0.19**)<br>5. ICMA-97111 (0.14**) | 1.BIB 561-570 (0.85**)<br>2.BIB 501-510 (0.40**)<br>3.BIB 531-540 (0.30**) |
| Ear head weight (g) | 1. ICMA-98222 (23.59**)<br>2. ICMA-30201 (12.15**)<br>3. ICMA-93333 (11.05**)<br>4. ICMA-30199 (8.35**)<br>5. ICMA-88004 (7.51**) | 1.BIB 511-520 (13.58**)<br>2.BIB 561-570 (6.25**)<br>3.BIB 571-580 (2.71**) |
| Dry stover yield per plant (g) | 1. ICMA-30201 (55.77**)<br>2. ICMA-30199 (54.50**)<br>3. ICMA-93333 (21.64**)<br>4. ICMA-98222 (9.82**) | 1.BIB 481- 500 (19.81**)<br>2.BIB 561-570 (18.85**) |
| Grain yield per plant (g) | 1. ICMA-30199 (6.70**)<br>2. ICMA-98222 (4.27**)<br>3. ICMA-88004 (4.15**)<br>4. ICMA-30201 (3.16**) | 1.BIB 571-580 (5.41**)<br>2.BIB 481- 500 (3.33**)<br>3.BIB 561-570 (2.83**) |
| Harvest index (%) | 1. ICMA-04999 (4.20**)<br>2. ICMA-88004 (3.90**)<br>3. ICMA-30209 (2.23**) | 1.BIB 551-560 (2.07**)<br>2.BIB 571-580 (1.78**) |
| Threshing index (%) | 1. ICMA-30201 (6.60**)<br>2. ICMA-88004 (5.48**)<br>3. ICMA-04999 (5.02**) | 1.BIB 551-560 (6.84**)<br>2.BIB 481- 500 (6.71**) |

index and BIB 501-510 was found good general combiner for test weight. Eldie *et al.* (2017), Krishnan *et al.* (2017), Gavali *et al.* (2018), Ladumor *et al.* (2018), Saini *et al.* (2018) and Santosh *et al.* (2018) also reported various lines and testers having good combining ability behavior for yield and its attributing characters in pearl millet.

The top five cross combinations on the basis of high SCA effects for each character are presented in Table 5.2.2. From these top five crosses for each character, common specific cross combinations for more than one character were selected. Thus, out of 80 hybrids, 29 hybrids exhibited best specific cross combinations with significant SCA effects. The cross combination with significant SCA effects for at least five characters was ICMA 97111 x BIB 561- 570. It was found significant for days to 50% flowering, days to maturity, plant height, productive tillers per plant and test weight; hybrid ICMA 98222 x BIB 481- 500 for productive tillers per plant, ear head length, dry stover yield per plant, grain yield per plant, and harvest index; hybrid ICMA 88004 x BIB 501- 510 for ear head length, ear head diameter, test weight, ear head weight, dry stover yield per plant, grain yield and ICMA 93333 x BIB 551-560 for ear head length, ear head diameter, test weight, ear head weight and grain yield per plant. The cross combinations with significant and high SCA effects for at least two or more characters were ICMA 04999 x BIB 511- 520 for days to 50% flowering, days to maturity and ear head length; hybrid ICMA 97111 x BIB 571- 580 for days to 50% flowering and days to maturity; hybrid ICMA 04999 x BIB 571- 580 for days to 50% flowering and days to maturity; hybrid ICMA 97444 x BIB 571- 580 for days to 50% flowering, days to maturity and grain yield per plant; hybrid ICMA 30200 x BIB 561- 570 for productive tillers per plant and test weight; ICMA 97111 x BIB 501-510 for ear head length, ear head diameter, test weight and ear head weight; hybrid ICMA 30201 x BIB 561-570 for ear head

**Table 5.2.2: The best performing cross combination on the basis of SCA effects**

| **Characters** | cross combination |
|---|---|
| Days to 50% flowering | 1. ICMA 04999 × 511-520 (-6.77$^{**}$)<br>2. ICMA 97111 × 571-580 (-5.99$^{**}$)<br>3. ICMA 04999 × 571-580 (-5.80$^{**}$)<br>4. ICMA 97111 × 561-570 (-5.77$^{**}$)<br>5. ICMA 97444 × 571-580 (-5.09$^{**}$) |
| Days to maturity | 1. ICMA 04999 × 511-520 (-6.86$^{**}$)<br>2. ICMA 97111 × 571-580 (-5.94$^{**}$)<br>3. ICMA 97111 × 561-570 (-5.71$^{**}$)<br>4. ICMA 97444 × 571-580 (-5.03$^{**}$)<br>5. ICMA 97444 × 531-540 (-4.89$^{**}$) |
| Plant height (cm) | 1. ICMA 30209 × 551-560 (19.93$^{**}$)<br>2. ICMA 04999 × 481-500 (18.88$^{**}$)<br>3. ICMA 30209 × 511-520 (15.65$^{**}$)<br>4. ICMA 10444 × 501-510 (14.41$^{**}$)<br>5. ICMA 97111 × 561-570 (12.46$^{**}$) |
| Productive tillers per plant | 1. ICMA 30200 × 561-570 (1.55$^{**}$)<br>2. ICMA 98222 × 481-500 (1.39$^{**}$)<br>3. ICMA 30201 × 551-560 (1.25$^{**}$)<br>4. ICMA 97111 × 561-570 (1.22$^{**}$)<br>5. ICMA 88004 × 571-580 (1.12$^{**}$) |
| Ear head length (cm) | 1. ICMA 04999 × 511-520 (7.45$^{**}$)<br>2. ICMA 98222 × 481-500 (7.03$^{**}$)<br>3. ICMA 97111 × 501-510 (6.70$^{**}$)<br>4. ICMA 88004 × 501-510 (5.98$^{**}$)<br>5. ICMA 93333 × 551-560 (5.71$^{**}$) |
| Ear head diameter (cm) | 1. ICMA 10444 × 571-580 (8.03$^{**}$)<br>2. ICMA 93333 × 551-560 (7.18$^{**}$)<br>3. ICMA 97111 × 501-510 (7.16$^{**}$)<br>4. ICMA 30200 × 571-580 (6.71$^{**}$)<br>5. ICMA 88004 × 501-510 (6.59$^{**}$) |
| Test weight (g) | 1. ICMA 93333 × 551-560 (3.83$^{**}$)<br>2. ICMA 88004 × 501-510 (3.38$^{**}$)<br>3. ICMA 97111 × 561-570 (3.35$^{**}$)<br>4. ICMA 30200 × 561-570 (3.02$^{**}$)<br>5. ICMA 30209 × 561-570 (3.02$^{**}$)<br>6. ICMA 98222 × 561-570 (3.00$^{**}$) |
| Ear head weight (g) | 1. ICMA 30201 × 561-570 (93.58$^{**}$)<br>2. ICMA 93333 × 551-560 (78.57$^{**}$)<br>3. ICMA 97111 × 501-510 (57.40$^{**}$)<br>4. ICMA 88004 × 501-510 (55.16$^{**}$)<br>5. ICMA 10444 × 511-520 (50.51$^{**}$) |
| Dry stover yield per plant (g) | 1. ICMA 30201 × 561-570 (118.47$^{**}$)<br>2. ICMA 98222 × 481-500 (111.54$^{**}$)<br>3. ICMA 88004 × 501-510 (110.50$^{**}$)<br>4. ICMA 10444 × 511-520 (105.24$^{**}$)<br>5. ICMA 30209 × 531-540 (101.07$^{**}$) |
| Grain yield per plant (g) | 1. ICMA 98222 × 481-500 (35.89$^{**}$)<br>2. ICMA 88004 × 501-510 (33.46$^{**}$)<br>3. ICMA 10444 × 511-520 (19.86$^{**}$)<br>4. ICMA 97444 × 571-580 (19.67$^{**}$)<br>5. ICMA 93333 × 551-560 (17.67$^{**}$) |
| Harvest index (%) | 1. ICMA 98222 × 481-500 (14.93$^{**}$)<br>2. ICMA 10444 × 481-500 (14.44$^{**}$)<br>3. ICMA 93333 × 571-580 (11.98$^{**}$)<br>4. ICMA 97444 × 551-560 (10.81$^{**}$)<br>5. ICMA 30201 × 501-510 (11.20$^{**}$) |
| Threshing index (%) | 1. ICMA 30201 × 481-500 (65.81$^{**}$)<br>2. ICMA 30200 × 511-520 (20.37$^{**}$)<br>3. ICMA 30209 × 501-510 (19.80$^{**}$)<br>4. ICMA 97444 × 551-560 (18.16$^{**}$)<br>5. ICMA 04999 × 551-560 (14.92$^{**}$) |

weight and dry stover yield per plant, hybrid ICMA 10444 x BIB 511-520 for dry stover yield per plant and grain yield per plant; hybrid ICMA 97444 x BIB 551-560 for harvest index and threshing index. The cross combinations with significant and high SCA effects for at least one character was exhibited in hybrid ICMA 97444 x BIB 531-540 for days to maturity, hybrid ICMA 30209 x BIB 551-560, ICMA 04999 x BIB 481-500, ICMA 30209 x BIB 511-520 and ICMA 10444 x BIB 501-510 for plant height, hybrid ICMA 30201 x BIB 551- 560 for productive tillers per plant, hybrid ICMA 30201 x BIB 551- 560 for ear head diameter, hybrid ICMA 30209 x BIB 561- 570, ICMA 98222 x BIB 561- 570 for test weight, hybrid ICMA 30209 x BIB 531- 540 for dry stover yield per plant, hybrids ICMA 10444 x BIB 481- 500, ICMA 93333 x BIB 571-580 and hybrid ICMA 30201 x BIB 501- 510 for harvest index; and hybrid ICMA 30201 x BIB 481- 500, ICMA 30200 x BIB 511- 520 and ICMA 30209 x BIB 501- 510 was found specific combiner for threshing index. Izge *et al.* (2007), Singh and Sharma (2014), Rafiq *et al.* (2016), Eldie *et al.* (2017), Krishnan *et al.* (2017), Siddique *et al.* (2017), Gavali *et al.* (2018) and Ladumor *et al.* (2018) also reported some specific combiners for various traits in pearl millet.

## 5.3 Estimation of standard heterosis

Heterosis is an important genetic phenomenon, synonymous with hybrid vigour refers to the manifested superiority of the $F_1$ hybrid resulting from the cross of genetically dissimilar homozygous parents. The best way to utilize heterosis in crop is to produce $F_1$ hybrids, which possess maximum heterozygosity (Cheita *et al.,* 2006). The pearl millet is highly cross-pollinated and has protogynous condition. The provision of cytoplasmic-genetic male sterile lines in this crop has made commercial exploitation of heterosis and hybrid seed production on large scale feasible. Plant breeders have extensively explored and utilized heterosis in enhancing the yield in a number of crops including pearl millet. The possibility of commercial exploitation of hybrid vigour depends primarily on the magnitude of heterosis and feasibility of hybrid seed production at commercial scale.

The extent of heterosis mainly depends on the magnitude of non-additive gene action and wide genetic diversity among parents. In any crop improvement programme, superiority of $F_1$ over standard check (standard heterosis) has an economic importance and is now widely used for expression of heterosis. The negative heterosis is important for characters like early flowering and early maturity. In present investigation, standard heterosis was estimated for grain yield per plant and its component characters over best standard check (HHB-67 improved).

The best five crosses for different characters over the environments for standard heterosis have been presented in (Table 5.3.1). The maximum values of standard heterosis were 101.39 (ICMA 98222 x BIB 481-500) for grain yield per plant. While for its components, it was -15.69 (ICMA 98222 x BIB 481-500) for days to 50% flowering, -9.88 (ICMA 98222 x BIB 481-500) for days to maturity, 21.54 (ICMA 93333 x BIB 531-540) for plant height, 90.48 (ICMA 30201 x BIB 511-520) for productive tillers per plant, 29.41 (ICMA 93333 x BIB 551-560) for ear head length, 0.36 (ICMA 98222 x BIB 481-500) for ear head diameter, 30.49 (ICMA 88004 x BIB 501-510) for test weight, 134.35 (ICMA 30201 x BIB 561-570) for ear head weight per plant, 132.06 (ICMA 30201 x BIB 481-500) for dry stover yield per plant 71.02 (ICMA 98222 x BIB 481-500) for harvest index and 177.28 (ICMA 30201 x BIB 481-500) for threshing index. Superior hybrids with standard heterosis were also reported earlier by Vagadiya *et al.* (2010), Jethva *et al.* (2012), Parmar *et al.* (2015), Acharya *et al.* (2017), Bhasker *et al.* (2017), Kumar *et al.* (2017b) and Badhe *et al.* (2018) in pearl millet.

The grain yield per plant in pearl millet is the character of economic importance for which considerable magnitude of standard heterosis was registered in number of crosses in the present study. On the basis of data pooled over all the three environments, the standard heterosis ranged from -60.11 (ICMA 30200 x BIB 511-520 and ICMA 88004 x BIB 531-540) to 101.39 (ICMA 98222 x BIB 481-500). In present investigation, amongst 80 crosses, the seven crosses *viz.,* ICMA 98222 x BIB 481-500, ICMA 88004 x BIB 501-510, ICMA 10444 x BIB 511-520, ICMA 30201 x BIB 511-520, ICMA 93333 x BIB 551-560, ICMA 97444 x BIB 571-580, and ICMA 30199 x BIB 571-580 were found with positive significant standard heterosis for grain yield per plant. The present and earlier studies clearly showed that heterosis does exist in inter-varietal crosses of pearl millet.

The cross combinations with significant heterosis over the environments for almost all characters was ICMA 98222 x BIB 481-500. It exhibited significant heterosis for days to 50% flowering, days to maturity, productive tillers per plant, ear head length, ear head diameter, test weight, ear head weight, dry stover yield per plant, grain yield per plant, harvest index and threshing index. The cross combinations with significant heterosis over the environments for at least six characters was ICMA 88004 x BIB 501-510 (for days to 50% flowering, days to maturity, test weight, ear head weight, grain yield, harvest index), and ICMA 93333 x BIB 551-560 (for days to 50% flowering, days to maturity, plant height, ear head length, test weight, ear head weight and grain yield). These crosses were considered promising for their use in yield improvement because of having high heterotic effects for yield and its component characters. Similar results for standard heterosis were also reported by Vetriventhan *et al.* (2008), Chotaliya *et al.* (2009), Jethva *et al.* (2012), Kapadia *et al.* (2016), Patel *et al.* (2016), Bhasker *et al.* (2017) and Chittora and Patel (2017) in pearl millet.

**Table 5.3.1 The Best performing cross combinations on the basis of standard heterosis**

| Characters | cross combination |
|---|---|
| Days to 50% flowering | 1 ICMA 98222 × 481-500 (-15.69**)<br>1. ICMA 88004 × 501-510 (-15.69**)<br>1. ICMA 04999 × 511-520 (-15.69**)<br>1. ICMA 88004 × 511-520 (-15.69**)<br>1. ICMA 97444 × 511-520 (-15.69**)<br>1. ICMA 97444 × 531-540 (-15.69**)<br>2. ICMA 93333 × 511-520 (-13.73**)<br>2. ICMA 93333 × 531-540 (-13.73**)<br>3. ICMA 93333 × 481-500 (-11.76**)<br>3. ICMA 98222 × 501-510 (-11.76**)<br>3. ICMA 93333 × 551-560 (-11.76**)<br>4. ICMA 88004 × 481-500 (-9.8**)<br>4. ICMA 88004 × 551-560 (-9.8**)<br>5. ICMA 04999 × 551-560 (-7.84**)<br>5. ICMA 97111× 481-500 (-7.84**)<br>5. ICMA 30200 × 481-500 (-7.84**)<br>5. ICMA 97111 × 501-510 (-7.84**)<br>5. ICMA 10444 × 501-510 (-7.84**)<br>5. ICMA 30200 × 531-540 (-7.84**)<br>5. ICMA 30201 × 531-540 (-7.84**)<br>5. ICMA 98222 × 551-560 (-7.84**) |
| Days to maturity | 1. ICMA 98222 × 481-500 (-9.88**)<br>1. ICMA 88004 × 501-510 (-9.88**)<br>1. ICMA 04999 × 511-520 (-9.88**)<br>1. ICMA 88004 × 511-520 (-9.88**)<br>1. ICMA 97444 × 511-520 (-9.88**)<br>1. ICMA 97444 × 531-540 (-9.88**)<br>2. ICMA 93333 × 511-520 (-8.64**)<br>2. ICMA 93333 × 531-540 (-8.64**)<br>3. ICMA 93333 × 481-500 (-7.41**)<br>3. ICMA 98222 × 501-510 (-7.41**)<br>3. ICMA 93333 × 551-560 (-7.41**)<br>4. ICMA 88004 × 481-500 (-6.9**)<br>4. ICMA 88004 × 551-560 (-6.9**)<br>5. ICMA 04999 × 551-560 (-4.94**)<br>5. ICMA 97111× 481-500 (-4.94**)<br>5. ICMA 30200 × 481-500 (-4.94**)<br>5. ICMA 97111 × 501-510 (-4.94**)<br>5. ICMA 10444 × 501-510 (-4.94**)<br>5. ICMA 30200 × 531-540 (-4.94**)<br>5. ICMA 30201 × 531-540 (-4.94**)<br>5. ICMA 98222 × 551-560 (-4.94**) |
| Plant height (cm) | 1. ICMA 93333 × 531-540 (21.54**)<br>2. ICMA 93333 × 481-500 (20.77**)<br>3. ICMA 88004 × 481-500 (19.23**)<br>4. ICMA 93333 × 551-560 (18.46**)<br>5. ICMA 04999 × 481-500 (17.69**)<br>6. ICMA 30209 × 551-560 (17.69**) |
| Productive tillers per plant | 1. ICMA 30201 × 511-520 (90.48**)<br>1. ICMA 30201 × 551-560 (90.48**)<br>2. ICMA 98222 × 481-500 (80.95**)<br>3. ICMA 30199 × 481-500 (71.43**)<br>4. ICMA 97444 × 511-520 (66.67**)<br>4. ICMA 88004 × 571-580 (66.67**)<br>5. ICMA 30201 × 481-500 (61.90**)<br>5. ICMA 30209 × 531-540 (61.90**)<br>5. ICMA 97444 × 561-570 (61.90**)<br>5. ICMA 04999 × 571-580 (61.90**) |

| | |
|---|---|
| | 5. ICMA 30199 × 571-580 (61.90**) |
| Ear head length (cm) | 1. ICMA 93333 × 551-560 (29.41**)<br>2. ICMA 98222 × 481-500 (28.05**)<br>3. ICMA 10444 × 551-560 (19.46**)<br>4. ICMA 98222 × 551-560 (17.65**)<br>5. ICMA 30201 × 551-560 (15.84**) |
| Ear head diameter (cm) | 1. ICMA 98222 × 481-500 (0.36) |
| Test weight (g) | 1. ICMA 88004 × 501-510 (30.49**)<br>2. ICMA 93333 × 551-560 (30.39**)<br>3. ICMA 98222 × 481-500 (28.05**)<br>4. ICMA 30201 × 531-540 (20.33**)<br>5. ICMA 88004 × 511-520 (20.22**) |
| Ear head weight (g) | 1. ICMA 30201 × 561-570 (134.35**)<br>2. ICMA 93333 × 551-560 (112.20**)<br>3. ICMA 98222 × 481-500 (96.18**)<br>4. ICMA 88004 × 501-510 (83.97**)<br>5. ICMA 10444 × 511-520 (80.15**) |
| Dry stover yield per plant (g) | 1. ICMA 30201 × 481-500 (132.06**)<br>2. ICMA 30201 × 561-570 (114.50**)<br>3. ICMA 98222 × 481-500 (104.58**)<br>4. ICMA 30199 × 501-510 (89.31**)<br>5. ICMA 10444 × 511-520 (68.69**) |
| Grain yield per plant (g) | 1. ICMA 98222 × 481-500 (101.39**)<br>2. ICMA 88004 × 501-510 (71.61**)<br>3. ICMA 93333 × 551-560 (38.17**)<br>4. ICMA 97444 × 571-580 (36.50**)<br>5. ICMA 30199 × 571-580 (32.86**) |
| Harvest index (%) | 1. ICMA 98222 × 481-500 (71.02**)<br>2. ICMA 97444 × 551-560 (66.82**)<br>3. ICMA 88004 × 501-510 (62.25**)<br>4. ICMA 04999 × 511-520 (58.58**)<br>5. ICMA 97111 × 551-560 (58.17**) |
| Threshing index (%) | 1. ICMA 30201 × 481-500 (177.28**)<br>2. ICMA 04999 × 551-560 (69.36**)<br>3. ICMA 97444 × 551-560 (64.02**)<br>4. ICMA 88004 × 551-560 (62.37**)<br>5. ICMA 30209 × 501-510 (51.26**) |

Thus, from the present investigation it is clear that for almost all the characters variable number of crosses depicted standard heterosis in both positive and negative direction which indicated that genes with negative as well as positive effects were dominant. This type of unpredictability highlights the non-additive gene actions which may be due to dominance or/and epistasis.

## 5.4 Phenotypic stability analysis

Most of the literature reported on genotype x environment interactions refers to the differential response of a genotype in a set of environments. However, the G x E interactions, in some cases may also include components like additive x environment and non-additive x environment interactions. Varietal adaptability to environmental fluctuations is important for the stabilization of crop production both over regions and years. Adaptability is the ability of a genotype to produce a relatively narrow range of phenotypes in different environments. This interaction is a result of changes in cultivar's relative performance across environments due to differential responses of the genotype to various edaphic, climatic and biotic factors (Dixon and Nukenine, 1997). Therefore, the analysis of genotype x environment interaction becomes an important tool employed by breeders for evaluating varietal adaptation.

The genotype x environment (G x E) is a common phenomenon present in crop plant species (Allard and Bradshaw, 1964). The first approach (Yates and Cochran, 1938; Finlay and Wilkinson, 1963 and Eberhart and Russell, 1966) provides estimate of stability parameters while second approach (Mather and Jones, 1958; Jinks and Stevens, 1959; Bucio-Alanis and Hill, 1966) is based on fitting models which specify g, e and g x e interaction means and variances. Eberhart and Russell (1966) emphasized the need of considering both linear ($b_i$=regression coefficient) and non-linear ($S^2d_i$=deviation from regression) components of G x E interaction for judging the phenotypic stability of a genotype.

The estimates of genetic parameters obtained in one environment are biased due to the confounding of the G x E interaction effect with the genotype effects. It is therefore, necessary to take into account the G x E interaction while determining the estimates of various genetic parameters to have unbiased picture in the expression of various characters. Considering these facts, the need of the hour is to develop varieties that would give stable production from year to year and place to place even under different moisture stress conditions. Therefore, for the development of hybrid varieties, the information regarding G x E interaction is essential to determine the adaptability of different hybrids under different environments.

The significant variability in environment highly influences the performance of genotypes in terms of yield potential. As we know that one of the major objectives of plant breeding is to develop varieties with consistently good performance in different environments, so that unfavorable effects of environments on yield are minimized. Thus, identification of stable genotypes over the environments is an important task to breeders. Therefore, the present study is an effort to understand the differential behavior of g x e interactions for grain yield per plant and its component characters of 77 $F_1$ hybrids along with three standard check hybrids in three environments.

In the present investigation, the G x E interaction was found significant for majority of characters which indicated the influence of environment on the expression of genotypes. The mean sum of squares due to G x E (linear) were significant for most of the characters under study. The mean sum of squares due to pooled deviations was non-significant for all the characters which indicated that prediction across the environments was possible for all characters. It has been stated by Dabholkar (1998) that when the mean sum of square for pooled deviation is significant but mean sum of square for G x E (linear) is non-significant; variation in the performance of genotype is entirely unpredictable. Similar findings have also been reported by Dakheel *et al.* (2009), Rajpurohit *et al.* (2012), Singh and Singh (2015), Sumathi *et al.* (2017), Dadarwal *et al.* (2018) and Lagat *et al.* (2018) in pearl millet.

Out of the 80 hybrids including checks, five best stable crosses for various environments *i.e* average environment presented in (Table

5.4.1), better environment presented in (Table 5.4.2) and poor environment presented in (Table 5.4.3). The joint consideration of mean performance of genotypes over environments and stability parameters revealed that out of 80 genotypes, genotypes *viz.,* ICMA 98222 × BIB 481-500 (42.89), ICMA 88004 × BIB 501-510 (42.89), ICMA 93333 × BIB 531-540 (44.33), ICMA 97444 × BIB 571-580 (44.89) ICMA 93333 × BIB 481-500 (45.00) and ICMA 88004 × BIB 571-580 (45.00) were most suitable for early flowering in average environment (mean<population mean, $b_i$=1 and $S^2d_i$=0). Genotypes *viz.,* ICMA 97111 × BIB 571-580 (44.44), ICMA 97111 × BIB 501-510 (46.44), ICMA 97444 × BIB 561-570 (46.44), ICMA 98222 × BIB 531-540 (46.67), ICMA 30201 × BIB 531-540 (47.00), ICMA 98222 × BIB 551-560 (47.00) and ICMA 04999 × BIB 571-580 (47.67) were considered stable for early flowering in better environment (mean>population mean, $b_i$>1 and $S^2d_i$=0). Genotypes *viz.,* ICMA 93333 × BIB 561-570 (45.22), ICMA 10444 × BIB 531-540 (47.89) and ICMA 30209 × BIB 551-560 (48.78) were found stable for early flowering in poor environment (mean<population mean, $b_i$<1 and $S^2d_i$=0). The genotypes *viz.,* ICMA 98222 × BIB 481-500 (73.00), ICMA 88004 × BIB 501-510 (73.00), ICMA 04999 × BIB 511-520 (73.33), ICMA 97444 × BIB 511-520 (73.33), ICMA 97444 × BIB 531-540 (73.33), ICMA 98222 × BIB 561-570 (73.33), ICMA 93333 × BIB 531-540 (74.33), ICMA 97111 × BIB 571-580 (74.33), ICMA 93333 × BIB 551-560 (74.67), ICMA 93333 × BIB 481-500 (75.00) and ICMA 88004 × BIB 571-580 (75.00) were most suitable for early maturity in average environment (mean<population mean, $b_i$=1 and $S^2d_i$=0). Genotypes *viz.,* ICMA 98222 × BIB 531-540 (76.00), ICMA 97111 × BIB 501-510 (76.67), ICMA 30201 × BIB 531-540 (77.00), ICMA 98222 × BIB 551-560 (77.00), ICMA 04999 × BIB 571-580 (77.33) and ICMA 93333 × BIB 501-510 (78.67) were considered for better environment for early maturity (mean>population mean, $b_i$>1 and $S^2d_i$=0). Munawwar *et al.*

(2007), Sumathi *et al.* (2017) and Singhal *et al.* (2018) also reported stability for earliness.

In the present study, the crosses *viz.,* ICMA 93333 × BIB 531-540 (157.59), ICMA 88004 × BIB 481-500 (155.17), ICMA 93333 × BIB 551-560 (154.45), ICMA 30209 × BIB 551-560 (153.12) and ICMA 04999 × BIB 481-500 (152.52) were considered stable for plant height in average environments (mean>population mean, $b_i$=1 and $S^2d_i$=0), the crosses *viz.,* ICMA 88004 × BIB 551-560 (150.08), ICMA 93333 × BIB 501-510 (147.98), ICMA 88004 × BIB 571-580 (146.75), ICMA 30209 × BIB 531-540 (145.38) and ICMA 30199 × BIB 531-540 (145.21) considered for plant height in better environments (mean>population mean, $b_i$>1 and $S^2d_i$=0). While cross ICMA 30200 × BIB 481-500 (143.74) and ICMA 30199 × BIB 571-580 (141.58) were suitable for plant height in poor environment (mean>population mean, $b_i$<1 and $S^2d_i$=0) Similar findings were also reported by Singh and Singh (2015), Lagat *et al.* (2018) and Singhal *et al.* (2018).

Productive tillers per plant are important characters from the point of view of dry stover as well as grain yield. In the present study, the crosses *viz.,* ICMA 30199 × BIB 571-580 (3.43), ICMA 97444 × BIB 561-570 (3.37), ICMA 04999 × BIB 511-520 (3.13), ICMA 98222 × BIB 561-570 (2.93) and ICMA 88004 × BIB 561-570 (2.80) were considered stable for productive tillers per plant in average environments (mean>population mean, $b_i$=1 and $S^2d_i$=0). The crosses *viz.,* ICMA 30201 × BIB 511-520 (4.00), ICMA 88004 × BIB 571-580 (3.53), ICMA 30209 × BIB 531-540 (3.40), ICMA 04999 × BIB 571-580 (3.37), ICMA 93333 × BIB 511-520 (3.30) and ICMA 30199 × BIB 561-570 (3.30) were considered for productive tillers per plant in better environments (mean>population mean, $b_i$>1 and $S^2d_i$=0). While crosses ICMA 30199 × BIB 481-500 (3.57), ICMA 30209 × BIB 511-520 (3.07), ICMA 30209 × BIB 551-560 (2.73), ICMA 97444 × BIB 481-500 (2.70) and ICMA 93333 × BIB 561-570 (2.53) were considered for productive tillers per plant in poor environments (mean>population mean, $b_i$<1 and $S^2d_i$=0), Rajpurohit *et al.* (2012) and Dadarwal *et al.* (2018) also reported similar results for productive tillering.

The ear head length and ear head diameter are also important characters from the point of view of high grain yield. In the present study, the crosses *viz.,* ICMA 88004 × BIB 501-510 (26.34), ICMA 98222 × BIB 551-560 (26.00), ICMA 97111 × BIB 501-510 (24.92), ICMA 30201 × BIB 481-500 (24.35) and ICMA 93333 × BIB 531-540 (23.94) were considered stable for ear head length in average environments (mean>population mean, $b_i$=1 and $S^2d_i$=0). The crosses *viz.,* ICMA 10444 × BIB 511-520 (23.17), ICMA 98222 × BIB 531-540 (23.08), ICMA 30209 × BIB 531-540 (22.63), ICMA 04999 × BIB 571-580 (22.39) and ICMA 10444 × BIB 571-580 (22.16) were considered stable for ear head length in better environments (mean>population mean, $b_i$>1 and $S^2d_i$=0). The crosses *viz.,* ICMA 30200 × BIB 561-570 (22.86), ICMA 30199 × BIB 551-560 (22.55), ICMA 97444 × BIB 511-520 (21.67), ICMA 30200 × BIB 571-580 (21.62) and ICMA 88004 × BIB 571-580 (21.05) were considered stable for ear head length in poor environments (mean>population mean, $b_i$<1 and $S^2d_i$=0). For ear head diameter the crosses ICMA 98222 × BIB 501-510 (25.46), BHB-1602 (23.44), ICMA 10444 × BIB 531-540 (23.25), ICMA 97111 × BIB 501-510 (22.88) and ICMA 88004 × BIB 561-570 (20.20) were considered stable for ear head diameter in average environments (mean>population mean, $b_i$=1 and $S^2d_i$=0). The crosses *viz.,* ICMA 30201 × BIB 561-570 (22.39), ICMA 97444 × BIB 501-510 (21.58), ICMA 10444 × BIB 551-560 (21.45), ICMA 30200 × BIB 561-570 (19.60) and ICMA 10444 × BIB 501-510 (19.32) were considered stable for ear head diameter in better environments (mean>population mean, $b_i$>1 and $S^2d_i$=0). The crosses *viz.,* HHB-67 Improved (27.48), ICMA 98222 × BIB 571-580 (25.64), ICMA 30201 × BIB 511-520 (24.20), ICMA 30201 × BIB 481-500 (22.65) and ICMA 98222 × BIB 551-560 (22.44) were considered stable for ear head diameter in poor environments (mean>population mean, $b_i$<1 and $S^2d_i$=0). Abuali and

Abdelmula (2008), Bhuri *et al.* (2015) and Dadarwal *et al.* (2018) also reported similar results for ear head length and diameter in pearl millet.

For test weight, the crosses *viz.,* ICMA 88004 × BIB 501-510 (12.84), ICMA 93333 × BIB 551-560 (12.83), ICMA 30201 × BIB 531-540 (11.84), ICMA 88004 × BIB 511-520 (11.83) and ICMA 04999 × BIB 531-540 (10.99) were considered stable for test weight in average environments (mean>population mean, $b_i$=1 and $S^2d_i$=0). ICMA 98222 × BIB 531-540 (11.65), ICMA 98222 × BIB 501-500 (10.89), ICMA 97111 × BIB 501-510 (10.89), ICMA 10444 × BIB 511-520 (10.73), ICMA 10444 × BIB 551-560 (10.21) ICMA 88004 × BIB 561-570 (9.93) were considered for test weight in better environments (mean>population mean, $b_i$>1 and $S^2d_i$=0). Similar results for test weight were also reported by Gebre (2014) and Al-Naggar *et al.* (2018).

Ear head weight also very important character for grain yield and dry fodder weight of pearl millet. ICMA 30201 × BIB 561-570 (170.56), ICMA 93333 × BIB 531-540 (101.11), ICMA 30209 × BIB 511-520 (90.55), ICMA 30200 × BIB 561-570 (86.11) and ICMA 04999 × BIB 511-520 (85.00) for ear head weight in average environment (mean>population mean, $b_i$=1 and $S^2d_i$=0). The crosses *viz.,* ICMA 93333 × BIB 551-560 (154.44), ICMA 97111 × BIB 501-510 (116.11), ICMA 97444 × BIB 511-520 (95.00), ICMA 30199 × BIB 481-500 (86.11) and ICMA 88004 × BIB 481-500 (85.56) for ear head weight in better environment (mean>population mean, $b_i$>1 and $S^2d_i$=0). The crosses *viz.,* ICMA 30201 × BIB 511-520 (120.56), ICMA 30199 × BIB 511-520 (112.78), ICMA 30200 × BIB 481-500 (86.67), ICMA 98222 × BIB 551-560 (83.89) and ICMA 30199 × BIB 571-580 (50.51) for ear head weight in poor environment (mean>population mean, $b_i$<1 and $S^2d_i$=0). Similar results for ear head weight were also reported by Wedajo (2014) and Singh and Singh (2016).

The dry stover yield per plant is a desirable character for sustainable production of pearl millet in western Rajasthan. For dry stover yield per plant, the cross *viz.,* ICMA 10444 × BIB 511-520 (245.55), ICMA 30199 × BIB 571-580 (201.11), ICMA 30200 × BIB 531-540 (196.67), ICMA 93333 × BIB 561-570 (166.67) and ICMA 04999 × BIB 481-500 (101.07) were considered stable for dry stover yield per plant in average environments (mean>population mean, $b_i$=1 and $S^2d_i$=0), the cross *viz.,* ICMA 30199 × BIB 511-520 (251.11), ICMA 30209 × BIB 531-540 (236.67), ICMA 93333 × BIB 551-560 (228.89), ICMA 93333 × BIB 531-540 (215.56) and ICMA 30199 × BIB 481-500 (207.78) were considered for dry stover yield per plant in better environments (mean>population mean, $b_i$>1 and $S^2d_i$=0), while crosses *viz.,* ICMA 98222 × BIB 561-570 (242.22), ICMA 30200 × BIB 481-500 (211.11), ICMA 93333 × BIB 481-500 (194.45), ICMA 98222 × BIB 551-560 (192.22) and ICMA 04999 × BIB 511-520 (188.89) were considered for dry stover yield per plant in poor environment (mean>population mean, $b_i$<1 and $S^2d_i$=0). Dakheel *et al.* (2009), Bhuri *et al.* (2015) and Dadarwal *et al.* (2018) also reported similar results.

The main aim of any crop breeding experiment as well as present investigation is to improve grain yield per plant. For grain yield per plant, ICMA 98222 × 481-500 (79.76), ICMA 97444 × BIB 511-520 (44.89), ICMA 98222 × BIB 551-560 (41.22), ICMA 30200 × BIB 571-580 (41.22), ICMA 30200 × BIB 481-500 (37.67) and BHB-1602 (37.67) were considered stable for grain yield per plant in average environments (mean>population mean, $b_i$=1 and $S^2d_i$=0). The crosses *viz.,* ICMA 93333 × BIB 551-560 (54.66), ICMA 30199 × BIB 551-560 (49.89), ICMA 30199 × BIB 481-500 (49.33), ICMA 04999 × BIB 561-570 (49.00) and ICMA 30200 × BIB 561-570 (48.44) were considered stable for grain yield per plant in better environments (mean>population mean, $b_i$>1 and $S^2d_i$=0), while the cross *viz.,* ICMA 97444 × BIB 571-580 (54.00), ICMA 10444 × BIB 511-520 (50.56), ICMA 30201 × BIB 511-520 (50.54), ICMA 93333 × BIB 571-580 (41.00) and ICMA 88004 × BIB 481-500 (40.11) considered for grain yield per plant in poor environments (mean>population mean, $b_i$<1 and $S^2d_i$=0). Similar finding were also reported by Yahaya *et al.* (2006), Gebre (2014) and Lagat *et al.* (2018).

For harvest index, the crosses *viz.,* ICMA 97444 × BIB 551-560 (40.92%), ICMA 30209 × BIB 501-510 (38.90%), ICMA 97111 × BIB 551-560 (38.80%), BBH-67 Improved (38.74%), ICMA 04999 × BIB 531-540 (%) were considered stable for harvest index in better environments (mean>population mean, $b_i$>1 and $S^2d_i$=0). For threshing index the crosses *viz.,* ICMA 88004 × BIB 571-580 (60.16%), ICMA 97444 × BIB 481-500 (59.07%), ICMA 30209 × BIB 551-560 (56.40%), ICMA 04999 × BIB 571-580 (55.43%) were for average environment (mean>population mean, $b_i$=1 and $S^2d_i$=0). The crosses *viz.,* ICMA 3020 × BIB 481-500 (134.48), ICMA 88004 × BIB 531-540 (88.46), ICMA 88004 × BIB 551-560 (78.75), BHB-1602 (70.40) and ICMA 30201 × BIB 531-540 (70.20) were suitable for threshing index in average environment (mean>population mean, $b_i$=1 and $S^2d_i$=0). Abuali and Abdelmula (2008), Pabale and Pandya (2010), Al-Naggar *et al.* (2018), Lagat *et al.* (2018) and Singhal *et al.* (2018) also reported for stability.

**Table 5.4.1: The best performing crosses/hybrids for average environments (ranked on the basis of means)**

| Characters | Cross combination for Average environment |
|---|---|
| Days to 50% flowering | 1. ICMA 98222 × BIB 481-500 (42.89)<br>1. ICMA 88004 × BIB 501-510 (42.89)<br>2. ICMA 93333 × BIB 531-540 (44.33)<br>3. ICMA 97444 × BIB 571-580 (44.89)<br>4. ICMA 93333 × BIB 481-500 (45.00)<br>5. ICMA 88004 × BIB 571-580 (45.00) |
| Days to maturity | 1. ICMA 98222 × BIB 481-500 (73.00)<br>1. ICMA 88004 × BIB 501-510 (73.00)<br>2. ICMA 04999 × BIB 511-520 (73.33)<br>2. ICMA 97444 × BIB 511-520 (73.33)<br>2. ICMA 97444 × BIB 531-540 (73.33)<br>2. ICMA 98222 × BIB 561-570 (73.33)<br>3. ICMA 93333 × BIB 531-540 (74.33)<br>3. ICMA 97111 × BIB 571-580 (74.33)<br>4. ICMA 93333 × BIB 551-560 (74.67)<br>5. ICMA 93333 × BIB 481-500 (75.00)<br>5. ICMA 88004 × BIB 571-580 (75.00) |
| Plant height (cm) | 1. ICMA 93333 × BIB 531-540 (157.59)<br>2. ICMA 88004 × BIB 481-500 (155.17)<br>3. ICMA 93333 × BIB 551-560 (154.45)<br>4. ICMA 30209 × BIB 551-560 (153.12)<br>5. ICMA 04999 × BIB 481-500 (152.52) |
| Productive tillers per plant | 1. ICMA 30199 × BIB 571-580 (3.43)<br>2. ICMA 97444 × BIB 561-570 (3.37)<br>3. ICMA 04999 × BIB 511-520 (3.13)<br>4. ICMA 98222 × BIB 561-570 (2.93)<br>5. ICMA 88004 × BIB 561-570 (2.80) |
| Ear head length (cm) | 1. ICMA 88004 × BIB 501-510 (26.34)<br>2. ICMA 98222 × BIB 551-560 (26.00)<br>3. ICMA 97111 × BIB 501-510 (24.92)<br>4. ICMA 30201 × BIB 481-500 (24.35)<br>5. ICMA 93333 × BIB 531-540 (23.94) |
| Ear head diameter (cm) | 1. ICMA 98222 × BIB 501-510 (25.46)<br>2. BHB-1602 (23.44)<br>3. ICMA 10444 × BIB 531-540 (23.25)<br>4. ICMA 97111 × BIB 501-510 (22.88)<br>5. ICMA 88004 × BIB 561-570 (20.20) |
| Test weight (g) | 1. ICMA 88004 × BIB 501-510 (12.84)<br>2. ICMA 93333 × BIB 551-560 (12.83)<br>3. ICMA 30201 × BIB 531-540 (11.84)<br>4. ICMA 88004 × BIB 511-520 (11.83)<br>5. ICMA 04999 × BIB 531-540 (10.99) |
| Ear head weight (g) | 1. ICMA 30201 × BIB 561-570 (170.56)<br>2. ICMA 93333 × BIB 531-540 (101.11)<br>3. ICMA 30209 × BIB 511-520 (90.55)<br>4. ICMA 30200 × BIB 561-570 (86.11)<br>5. ICMA 04999 × BIB 511-520 (85.00) |
| Dry stover yield per plant (g) | 1. ICMA 10444 × BIB 511-520 (245.55)<br>2. ICMA 30199 × BIB 571-580 (201.11)<br>3. ICMA 30200 × BIB 531-540 (196.67)<br>4. ICMA 93333 × BIB 561-570 (166.67)<br>5. ICMA 04999 × BIB 481-500 (101.07) |
| Grain yield per plant (g) | 1. ICMA 98222 × 481-500 (79.76)<br>2. ICMA 97444 × BIB 511-520 (44.89)<br>3. ICMA 98222 × BIB 551-560 (41.22)<br>3. ICMA 30200 × BIB 571-580 (41.22)<br>4. ICMA 30200 × BIB 481-500 (37.67)<br>4. BHB-1602 (37.67) |
| Threshing index (%) | 1. ICMA 88004 × BIB 571-580 (60.16)<br>2. ICMA 97444 × BIB 481-500 (59.07)<br>3. ICMA 30209 × BIB 551-560 (56.40)<br>4. ICMA 04999 × BIB 571-580 (55.43) |

Average environment (Average stability): mean >μ, $b_i$ =1 and $S^2d_i$ =0

**Table 5.4.2: The best performing crosses/hybrids for better environment (ranked on the basis of means)**

| Characters | Cross combination for better environment |
|---|---|
| Days to 50% flowering | 1. ICMA 97111 × BIB 571-580 (44.44)<br>2. ICMA 97111 × BIB 501-510 (46.44)<br>2. ICMA 97444 × BIB 561-570 (46.44)<br>3. ICMA 98222 × BIB 531-540 (46.67)<br>4. ICMA 30201 × BIB 531-540 (47.00)<br>4. ICMA 98222 × BIB 551-560 (47.00)<br>5. ICMA 04999 × BIB 571-580 (47.67) |
| Days to maturity | 1. ICMA 98222 × BIB 531-540 (76.00)<br>2. ICMA 97111 × BIB 501-510 (76.67)<br>3. ICMA 30201 × BIB 531-540 (77.00)<br>3. ICMA 98222 × BIB 551-560 (77.00)<br>4. ICMA 04999 × BIB 571-580 (77.33)<br>5. ICMA 93333 × BIB 501-510 (78.67) |
| Plant height (cm) | 1. ICMA 88004 × BIB 551-560 (150.08)<br>2. ICMA 93333 × BIB 501-510 (147.98)<br>3. ICMA 88004 × BIB 571-580 (146.75)<br>4. ICMA 30209 × BIB 531-540 (145.38)<br>5. ICMA 30199 × BIB 531-540 (145.21) |
| Productive tillers per plant | 1. ICMA 30201 × BIB 511-520 (4.00)<br>2. ICMA 88004 × BIB 571-580 (3.53)<br>3. ICMA 30209 × BIB 531-540 (3.40)<br>4. ICMA 04999 × BIB 571-580 (3.37)<br>5. ICMA 93333 × BIB 511-520 (3.30)<br>6. ICMA 30199 × BIB 561-570 (3.30) |
| Ear head length (cm) | 1. ICMA 10444 × BIB 511-520 (23.17)<br>2. ICMA 98222 × BIB 531-540 (23.08)<br>3. ICMA 30209 × BIB 531-540 (22.63)<br>4. ICMA 04999 × BIB 571-580 (22.39)<br>5. ICMA 10444 × BIB 571-580 (22.16) |
| Ear head diameter (cm) | 1. ICMA 30201 × BIB 561-570 (22.39)<br>2. ICMA 97444 × BIB 501-510 (21.58)<br>3. ICMA 10444 × BIB 551-560 (21.45)<br>4. ICMA 30200 × BIB 561-570 (19.60)<br>5. ICMA 10444 × BIB 501-510 (19.32) |
| Test weight (g) | 1. ICMA 98222 × BIB 531-540 (11.65)<br>2. ICMA 98222 × BIB 501-500 (10.89)<br>2. ICMA 97111 × BIB 501-510 (10.89)<br>3. ICMA 10444 × BIB 511-520 (10.73)<br>4. ICMA 10444 × BIB 551-560 (10.21)<br>5. ICMA 88004 × BIB 561-570 (9.93) |
| Ear head weight (g) | 1. ICMA 93333 × BIB 551-560 (154.44)<br>2. ICMA 97111 × BIB 501-510 (116.11)<br>3. ICMA 97444 × BIB 511-520 (95.00)<br>4. ICMA 30199 × BIB 481-500 (86.11)<br>5. ICMA 88004 × BIB 481-500 (85.56) |
| Dry stover yield per plant (g) | 1. ICMA 30199 × BIB 511-520 (251.11)<br>2. ICMA 30209 × BIB 531-540 (236.67)<br>3. ICMA 93333 × BIB 551-560 (228.89)<br>4. ICMA 93333 × BIB 531-540 (215.56)<br>5. ICMA 30199 × BIB 481-500 (207.78) |
| Grain yield per plant (g) | 1. ICMA 93333 × BIB 551-560 (54.66)<br>2. ICMA 30199 × BIB 551-560 (49.89)<br>3. ICMA 30199 × BIB 481-500 (49.33)<br>4. ICMA 04999 × BIB 561-570 (49)<br>5. ICMA 30200 × BIB 561-570 (48.44) |
| Harvest index (%) | 1. ICMA 97444 × BIB 551-560 (40.92)<br>2. ICMA 30209 × BIB 501-510 (38.90)<br>3. ICMA 97111 × BIB 551-560 (38.80)<br>4. BBH-67 Improved (38.74)<br>1. ICMA 04999 × BIB 531-540 (38.15) |
| Threshing index (%) | 1. ICMA 30201 × BIB 481-500 (134.48)<br>2. ICMA 88004 × BIB 531-540 (88.46)<br>3. ICMA 88004 × BIB 551-560 (78.75)<br>4. BHB-1602 (70.40)<br>5. ICMA 30201 × BIB 531-540 (70.20) |

Better environment (Below average stability): mean >µ, $b_i$ >1 and $S^2d_i$= 0

**Table 5.4.3 The best performing crosses/hybrids for Poor environment (ranked on the basis of means)**

| **Characters** | **Cross combination for Poor environment** |
|---|---|
| Days to 50% flowering | 1. ICMA 93333 × BIB 561-570 (45.22)<br>2. ICMA 10444 × BIB 531-540 (47.89)<br>3. ICMA 30209 × BIB 551-560 (48.78) |
| Plant height (cm) | 1. ICMA 30200 × BIB 481-500 (143.74)<br>2. ICMA 30199 × BIB 571-580 (141.58) |
| Productive tillers per plant | 1. ICMA 30199 × BIB 481-500 (3.57)<br>2. ICMA 30209 × BIB 511-520 (3.07)<br>3. ICMA 30209 × BIB 551-560 (2.73)<br>4. ICMA 97444 × BIB 481-500 (2.70)<br>5. ICMA 93333 × BIB 561-570 (2.53) |
| Ear head length (cm) | 1. ICMA 30200 × BIB 561-570 (22.86)<br>2. ICMA 30199 × BIB 551-560 (22.55)<br>3. ICMA 97444 × BIB 511-520 (21.67)<br>4. ICMA 30200 × BIB 571-580 (21.62)<br>5. ICMA 88004 × BIB 571-580 (21.05) |
| Ear head diameter (cm) | 1. HHB-67 Improved (27.48)<br>2. ICMA 98222 × BIB 571-580 (25.64)<br>3. ICMA 30201 × BIB 511-520 (24.20)<br>4. ICMA 30201 × BIB 481-500 (22.65)<br>5. ICMA 98222 × BIB 551-560 (22.44) |
| Ear head weight (g) | 1. ICMA 30201 × BIB 511-520 (120.56)<br>2. ICMA 30199 × BIB 511-520 (112.78)<br>3. ICMA 30200 × BIB 481-500 (86.67)<br>4. ICMA 98222 × BIB 551-560 (83.89)<br>5. ICMA 30199 × BIB 571-580 (50.51**) |
| Dry stover yield per plant (g) | 1. ICMA 98222 × BIB 561-570 (242.22)<br>2. ICMA 30200 × BIB 481-500 (211.11)<br>3. ICMA 93333 × BIB 481-500 (194.45)<br>4. ICMA 98222 × BIB 551-560 (192.22)<br>5. ICMA 04999 × BIB 511-520 (188.89) |
| Grain yield per plant (g) | 1. ICMA 97444 × BIB 571-580 (54.00)<br>2. ICMA 10444 × BIB 511-520 (50.56)<br>3. ICMA 30201 × BIB 511-520 (50.54)<br>4. ICMA 93333 × BIB 571-580 (41.00)<br>5. ICMA 88004 × BIB 481-500 (40.11) |

Poor environment (Above average stability): mean >µ, $b_i$ <1 and $S^2d_i$ = 0

## 5.5 Categorizing of crosses based on moisture stress indices

In agriculture, drought is by far the most important environmental stress that constrains crop yield (Blum, 2011). More than 40% of the world is classified as dry land, of which 8% is sub humid and 16% is semiarid (Pretty *et al.*, 2005; Middleton *et al.*, 2011). In addition, increasing temperature is an important component of climate change and its negative impact on yield is expected to increase in the future. Drought is a major cause of yield loss for many important crops. Therefore, the development and release of drought tolerant varieties that will yield well under a broad range of environmental conditions is an important breeding goal. Several stress indices have been developed, aiming to assist identification and selection of stable, high-yielding, drought tolerant genotypes. The simple and reliable methods for screening of moisture stress tolerant genotypes are necessary. Various screening parameters have been assumed by different workers in different crops (Pancholi, 1992). The stability of yield is a measure of variation between potential and actual yield of a genotype in varying environments and could results from various causes like genetic heterogeneity, stress tolerance and capacity to recover rapidly from stress (Heinrich *et al.,* 1983). The need to accelerate the selection of crop genotypes that are both resistant to and productive under abiotic stress is enhanced by global warming and the increase in demand for food by a growing world population.

The various researchers like Kiani (2013) Abraha *et al.* (2015) and Arisandy *et al.* (2017) found that various indices like TOL, STI SSI, SDI, MP, GMP, YI, YSI and HM exhibited good correlation with grain yield under stress and non-stress conditions which may be used as selection criteria for moisture stress tolerant genotypes in different crops. Thus, these indices are used as selection criteria for moisture stress tolerant crosses in present study. To evaluate moisture stress

**Table 5.5.1: The overall rank of crosses based upon yield and moisture stress tolerance indices**

| Crosses/hybrids | Rank | | | | | | | | Rank total | Overall rank | Rank | | | Rank total | Overall rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $Y_P$ | $Y_S$ | STI | MP | GMP | YI | YSI | HM | | | TOL | SSI | SDI | | |
| ICMA 04999 × 481-500 | 16 | 36 | 31 | 23 | 31 | 36 | 59 | 36 | 268 | 34 | 66 | 59 | 59 | 184 | 60 |
| ICMA 88004 × 481-500 | 44 | 20 | 30 | 35 | 30 | 20 | 22 | 26 | 227 | 27 | 20 | 22 | 22 | 64 | 20 |
| ICMA 93333 × 481-500 | 69 | 18 | 42 | 57 | 42 | 18 | 7 | 33 | 286 | 36 | 8 | 7 | 7 | 22 | 6 |
| ICMA 97111 × 481-500 | 61 | 36 | 50 | 59 | 50 | 36 | 29 | 45 | 366 | 46 | 23 | 29 | 29 | 81 | 25 |
| ICMA 97444 × 481-500 | 26 | 58 | 43 | 40 | 43 | 58 | 63 | 52 | 483 | 48 | 62 | 63 | 63 | 188 | 63 |
| ICMA 98222 × 481-500 | 1 | 1 | 1 | 1 | 1 | 1 | 15 | 1 | 22 | 1 | 45 | 15 | 15 | 75 | 24 |
| ICMA 10444 × 481-500 | 72 | 33 | 67 | 72 | 67 | 33 | 5 | 58 | 407 | 52 | 5 | 5 | 5 | 15 | 5 |
| ICMA 30199 × 481-500 | 11 | 8 | 6 | 7 | 6 | 8 | 33 | 6 | 85 | 6 | 51 | 33 | 33 | 117 | 37 |
| ICMA 30200 × 481-500 | 39 | 28 | 34 | 36 | 34 | 28 | 34 | 29 | 262 | 32 | 35 | 34 | 34 | 103 | 33 |
| ICMA 30201 × 481-500 | 44 | 13 | 23 | 28 | 23 | 13 | 16 | 18 | 178 | 18 | 15 | 16 | 16 | 47 | 15 |
| ICMA 30209 × 481-500 | 78 | 60 | 77 | 77 | 77 | 60 | 4 | 75 | 508 | 71 | 4 | 4 | 4 | 12 | 4 |
| ICMA 04999 × 501-510 | 74 | 65 | 76 | 76 | 76 | 65 | 18 | 74 | 524 | 72 | 12 | 18 | 18 | 48 | 16 |
| ICMA 88004 × 501-510 | 6 | 3 | 2 | 2 | 2 | 3 | 26 | 2 | 46 | 2 | 57 | 26 | 26 | 109 | 35 |
| ICMA 93333 × 501-510 | 44 | 68 | 68 | 64 | 68 | 68 | 74 | 70 | 524 | 72 | 51 | 74 | 74 | 199 | 70 |
| ICMA 97111 × 501-510 | 34 | 65 | 57 | 48 | 57 | 65 | 67 | 60 | 453 | 63 | 58 | 67 | 67 | 192 | 68 |
| ICMA 97444 × 501-510 | 66 | 79 | 75 | 70 | 75 | 79 | 68 | 77 | 589 | 80 | 40 | 68 | 68 | 176 | 56 |
| ICMA 98222 × 501-510 | 22 | 79 | 63 | 44 | 63 | 79 | 79 | 71 | 500 | 68 | 74 | 79 | 79 | 232 | 79 |
| ICMA 10444 × 501-510 | 72 | 52 | 71 | 73 | 71 | 52 | 9 | 63 | 463 | 64 | 10 | 9 | 9 | 28 | 8 |
| ICMA 30199 × 501-510 | 61 | 10 | 28 | 39 | 28 | 10 | 8 | 21 | 205 | 24 | 13 | 8 | 8 | 29 | 9 |
| ICMA 30200 × 501-510 | 67 | 68 | 74 | 71 | 74 | 68 | 65 | 76 | 563 | 79 | 34 | 65 | 65 | 164 | 53 |
| ICMA 30201 × 501-510 | 56 | 68 | 69 | 66 | 69 | 68 | 72 | 72 | 540 | 74 | 46 | 72 | 72 | 190 | 65 |
| ICMA 30209 × 501-510 | 26 | 64 | 52 | 42 | 52 | 64 | 69 | 57 | 426 | 56 | 63 | 69 | 69 | 201 | 71 |
| ICMA 04999 × 511-520 | 44 | 14 | 24 | 30 | 24 | 14 | 19 | 19 | 188 | 20 | 17 | 19 | 19 | 55 | 18 |
| ICMA 88004 × 511-520 | 61 | 62 | 60 | 65 | 60 | 62 | 46 | 59 | 475 | 65 | 30 | 46 | 46 | 122 | 41 |
| ICMA 93333 × 511-520 | 61 | 36 | 50 | 59 | 50 | 36 | 29 | 45 | 366 | 46 | 23 | 29 | 29 | 81 | 25 |
| ICMA 97111 × 511-520 | 44 | 58 | 56 | 56 | 56 | 58 | 54 | 55 | 437 | 59 | 44 | 54 | 54 | 152 | 49 |
| ICMA 97444 × 511-520 | 26 | 8 | 14 | 19 | 14 | 8 | 21 | 9 | 119 | 10 | 28 | 21 | 21 | 70 | 23 |

| Crosses/hybrids | Rank | | | | | | | | Rank total | Overall rank | Rank | | | Rank total | Overall rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $Y_P$ | $Y_S$ | STI | MP | GMP | YI | YSI | HM | | | TOL | SSI | SDI | | |
| ICMA 98222 × 511-520 | 26 | 68 | 62 | 48 | 62 | 68 | 77 | 67 | 478 | 66 | 68 | 77 | 77 | 222 | 77 |
| ICMA 10444 × 511-520 | 26 | 5 | 7 | 16 | 7 | 5 | 11 | 5 | 82 | 5 | 16 | 11 | 11 | 38 | 12 |
| ICMA 30199 × 511-520 | 38 | 52 | 46 | 46 | 46 | 52 | 55 | 49 | 384 | 49 | 49 | 55 | 55 | 159 | 52 |
| ICMA 30200 × 511-520 | 79 | 68 | 79 | 79 | 79 | 68 | 12 | 79 | 543 | 77 | 6 | 12 | 12 | 30 | 10 |
| ICMA 30201 × 511-520 | 22 | 6 | 5 | 11 | 5 | 6 | 14 | 4 | 73 | 4 | 22 | 14 | 14 | 50 | 17 |
| ICMA 30209 × 511-520 | 22 | 56 | 41 | 29 | 41 | 56 | 64 | 47 | 356 | 43 | 65 | 64 | 64 | 193 | 69 |
| ICMA 04999 × 531-540 | 16 | 68 | 59 | 36 | 59 | 68 | 78 | 66 | 450 | 62 | 75 | 78 | 78 | 231 | 78 |
| ICMA 88004 × 531-540 | 79 | 68 | 79 | 79 | 79 | 68 | 12 | 79 | 543 | 77 | 6 | 12 | 12 | 30 | 10 |
| ICMA 93333 × 531-540 | 55 | 7 | 17 | 22 | 17 | 7 | 6 | 11 | 142 | 13 | 11 | 6 | 6 | 23 | 7 |
| ICMA 97111 × 531-540 | 39 | 68 | 65 | 59 | 65 | 68 | 75 | 68 | 507 | 69 | 58 | 75 | 75 | 208 | 72 |
| ICMA 97444 × 531-540 | 26 | 28 | 27 | 27 | 27 | 28 | 42 | 27 | 232 | 28 | 46 | 42 | 42 | 130 | 43 |
| ICMA 98222 × 531-540 | 56 | 68 | 69 | 66 | 69 | 68 | 72 | 72 | 540 | 74 | 46 | 72 | 72 | 190 | 65 |
| ICMA 10444 × 531-540 | 39 | 68 | 65 | 59 | 65 | 68 | 75 | 68 | 507 | 69 | 58 | 75 | 75 | 208 | 72 |
| ICMA 30199 × 531-540 | 56 | 36 | 47 | 54 | 47 | 36 | 37 | 42 | 355 | 42 | 27 | 37 | 37 | 101 | 32 |
| ICMA 30200 × 531-540 | 67 | 62 | 64 | 68 | 64 | 62 | 43 | 61 | 491 | 67 | 26 | 43 | 43 | 112 | 36 |
| ICMA 30201 × 531-540 | 26 | 36 | 36 | 30 | 36 | 36 | 51 | 39 | 290 | 37 | 53 | 51 | 51 | 155 | 50 |
| ICMA 30209 × 531-540 | 13 | 36 | 26 | 20 | 26 | 36 | 61 | 34 | 252 | 30 | 69 | 61 | 61 | 191 | 67 |
| ICMA 04999 × 551-560 | 74 | 36 | 72 | 74 | 72 | 36 | 3 | 62 | 429 | 57 | 3 | 3 | 3 | 9 | 3 |
| ICMA 88004 × 551-560 | 7 | 19 | 8 | 6 | 8 | 19 | 49 | 13 | 129 | 12 | 71 | 49 | 49 | 169 | 55 |
| ICMA 93333 × 551-560 | 2 | 14 | 3 | 3 | 3 | 14 | 56 | 7 | 102 | 7 | 77 | 56 | 56 | 189 | 64 |
| ICMA 97111 × 551-560 | 77 | 67 | 78 | 78 | 78 | 67 | 17 | 78 | 540 | 74 | 9 | 17 | 17 | 43 | 14 |
| ICMA 97444 × 551-560 | 76 | 36 | 73 | 75 | 73 | 36 | 2 | 64 | 435 | 58 | 2 | 2 | 2 | 6 | 2 |
| ICMA 98222 × 551-560 | 34 | 20 | 21 | 25 | 21 | 20 | 27 | 23 | 191 | 22 | 32 | 27 | 27 | 86 | 27 |
| ICMA 10444 × 551-560 | 44 | 47 | 44 | 51 | 44 | 47 | 40 | 43 | 360 | 44 | 37 | 40 | 40 | 117 | 37 |
| ICMA 30199 × 551-560 | 9 | 23 | 13 | 11 | 13 | 23 | 48 | 15 | 155 | 15 | 69 | 48 | 48 | 165 | 54 |
| ICMA 30200 × 551-560 | 61 | 47 | 54 | 63 | 54 | 47 | 32 | 48 | 406 | 51 | 25 | 32 | 32 | 89 | 30 |
| ICMA 30201 × 551-560 | 44 | 32 | 38 | 44 | 38 | 32 | 31 | 35 | 294 | 39 | 29 | 31 | 31 | 91 | 31 |

| Crosses/hybrids | Rank | | | | | | | | Rank total | Overall rank | Rank | | | Rank total | Overall rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $Y_P$ | $Y_S$ | STI | MP | GMP | YI | YSI | HM | | | TOL | SSI | SDI | | |
| ICMA 30209 × 551-560 | 16 | 23 | 18 | 18 | 18 | 23 | 39 | 17 | 172 | 17 | 53 | 39 | 39 | 131 | 44 |
| ICMA 04999 × 561-570 | 3 | 26 | 10 | 4 | 10 | 26 | 66 | 16 | 161 | 16 | 79 | 66 | 66 | 211 | 74 |
| ICMA 88004 × 561-570 | 16 | 36 | 31 | 23 | 31 | 36 | 59 | 36 | 268 | 34 | 66 | 59 | 59 | 184 | 60 |
| ICMA 93333 × 561-570 | 69 | 52 | 61 | 69 | 61 | 52 | 25 | 56 | 445 | 61 | 14 | 25 | 25 | 64 | 20 |
| ICMA 97111 × 561-570 | 56 | 51 | 55 | 58 | 55 | 51 | 44 | 51 | 421 | 55 | 31 | 44 | 44 | 119 | 40 |
| ICMA 97444 × 561-570 | 34 | 60 | 48 | 47 | 48 | 60 | 62 | 54 | 413 | 53 | 56 | 62 | 62 | 180 | 58 |
| ICMA 98222 × 561-570 | 5 | 47 | 20 | 10 | 20 | 47 | 71 | 31 | 251 | 29 | 78 | 71 | 71 | 220 | 75 |
| ICMA 10444 × 561-570 | 39 | 35 | 39 | 43 | 39 | 35 | 45 | 41 | 316 | 41 | 42 | 45 | 45 | 132 | 45 |
| ICMA 30199 × 561-570 | 4 | 36 | 19 | 7 | 19 | 36 | 70 | 28 | 219 | 26 | 80 | 70 | 70 | 220 | 75 |
| ICMA 30200 × 561-570 | 11 | 14 | 9 | 13 | 9 | 14 | 38 | 10 | 118 | 9 | 58 | 38 | 38 | 134 | 46 |
| ICMA 30201 × 561-570 | 71 | 3 | 33 | 41 | 33 | 3 | 1 | 25 | 210 | 25 | 1 | 1 | 1 | 3 | 1 |
| ICMA 30209 × 561-570 | 26 | 36 | 36 | 30 | 36 | 36 | 51 | 39 | 290 | 37 | 53 | 51 | 51 | 155 | 50 |
| ICMA 04999 × 571-580 | 13 | 12 | 11 | 14 | 11 | 12 | 36 | 8 | 117 | 8 | 50 | 36 | 36 | 122 | 41 |
| ICMA 88004 × 571-580 | 9 | 26 | 16 | 15 | 16 | 26 | 57 | 22 | 187 | 19 | 72 | 57 | 57 | 186 | 62 |
| ICMA 93333 × 571-580 | 44 | 14 | 24 | 30 | 24 | 14 | 19 | 19 | 188 | 20 | 17 | 19 | 19 | 55 | 18 |
| ICMA 97111 × 571-580 | 13 | 68 | 58 | 30 | 58 | 68 | 80 | 65 | 440 | 60 | 76 | 80 | 80 | 236 | 80 |
| ICMA 97444 × 571-580 | 21 | 2 | 4 | 5 | 4 | 2 | 10 | 3 | 51 | 3 | 19 | 10 | 10 | 39 | 13 |
| ICMA 98222 × 571-580 | 56 | 28 | 40 | 48 | 40 | 28 | 23 | 38 | 301 | 40 | 21 | 23 | 23 | 67 | 22 |
| ICMA 10444 × 571-580 | 44 | 52 | 49 | 53 | 49 | 52 | 47 | 50 | 396 | 50 | 41 | 47 | 47 | 135 | 47 |
| ICMA 30199 × 571-580 | 22 | 11 | 15 | 17 | 15 | 11 | 24 | 12 | 127 | 11 | 39 | 24 | 24 | 87 | 29 |
| ICMA 30200 × 571-580 | 34 | 20 | 21 | 25 | 21 | 20 | 27 | 23 | 191 | 22 | 32 | 27 | 27 | 86 | 27 |
| ICMA 30201 × 571-580 | 44 | 47 | 44 | 51 | 44 | 47 | 40 | 43 | 360 | 44 | 37 | 40 | 40 | 117 | 27 |
| ICMA 30209 × 571-580 | 7 | 23 | 12 | 7 | 12 | 23 | 53 | 14 | 151 | 14 | 73 | 53 | 53 | 179 | 57 |
| RHB - 177 (Check-1) | 44 | 56 | 53 | 54 | 53 | 56 | 50 | 53 | 419 | 54 | 43 | 50 | 50 | 143 | 48 |
| HHB-67 Improved (Check-2) | 16 | 34 | 29 | 21 | 29 | 34 | 58 | 32 | 253 | 31 | 64 | 58 | 58 | 180 | 58 |
| BHB - 1602 ( Check-3) | 39 | 28 | 34 | 36 | 34 | 28 | 34 | 29 | 262 | 32 | 35 | 34 | 34 | 103 | 33 |

tolerance of various crosses, nine stress indices *viz.,* TOL, STI SSI, SDI, MP, GMP, YI, YSI and HM were calculated using grain yield per plant in stress ($Y_s$) and non-stress ($Y_p$) condition (Table 5.6.1).

Perusal of table 5.6.1 indicated that different indices introduced different crosses as tolerant. To determine the most tolerant cross, the sum of rank of all indices including rank of yield ($Y_s$ and $Y_p$) were used to calculate overall rank of crosses and based on this criteria the most desirable and tolerant crosses were identified (Table 5.6.1). A cross with least rank total was considered to be the best cross. According to this criteria crosses ICMA 98222 x BIB 481-500, ICMA 97444 x BIB 571-580, ICMA 88004 x BIB 501-510, ICMA 30201 x BIB 511-520, and ICMA 10444 x BIB 511-520 for STI, MP, GMP, YI, YSI, HM and crosses ICMA 97444 x BIB 571-580, ICMA 10444 x BIB 511-520, ICMA 93333 x BIB 531-540, ICMA 30201 x BIB 561-570 and ICMA 30201 x BIB 511-520 for TOL, SSI and SDI were identified as the most tolerant under moisture stress condition. Such strategies of using different tolerance indices and ranking pattern for screening of tolerant genotypes were used by several other workers such as Kharrazi and Rad (2011), Kiani (2013), Abraha *et al.* (2015), Kumawat *et al.* (2017) and El-Sabagh *et al.* (2018) in different crops.

## 5.6 Findings of the present investigation in pearl millet for future breeding programme

In the present study, the ANOVA indicated sufficient variability for all the traits among the crosses. Significant crosses x environment interaction for all the traits studied indicated that environment has influence the expression of genotypes significantly. Significant variance due to GCA and SCA indicated the importance of additive as well as non-additive components in the inheritance of different characters under study. The ratio of additive to dominance variance was less than unity for all the traits over the environments which indicated the preponderance of non-additive gene action in the inheritance of majority of the characters. Therefore, recurrent selection or mass selection with concurrent random mating may be adopted for population improvement to exploit additive gene action in the present material. Heterosis breeding may be adopted to exploit non-additive gene action for improving the grain yield and its contributing traits in pearl millet. In present study, GCA effects revealed that a number of parent *viz.,* BIB 571-580, BIB 561-570, BIB 511-520 and BIB 481-500 (testers or male parents) can be utilized for development of synthetic populations.

From the results of SCA effects, the crosses *viz.,* ICMA 97111 x BIB 561-570, ICMA 98222 x BIB 481-500, ICMA 88004 x BIB 501-510 and ICMA 93333 x BIB 551-560 were identified as superior for seed yield and related traits. Therefore, these crosses can be utilized for development of promising hybrids. The crosses *viz.,* ICMA 98222 x BIB 481-500, ICMA 88004 x BIB 501-510, ICMA 10444 x BIB 511-520, ICMA 30201 x BIB 511-520, ICMA 93333 x BIB 551-560, ICMA 97444 x BIB 571-580, and ICMA 30199 x BIB 571-580 were found positive significant standard heterosis for grain yield and its attributing characters over the environments. These crosses were considered promising for their use in yield improvement because of having high heterotic effect for yield as well as some other component characters. This suggests the potentiality of heterosis breeding in pearl millet.

The joint consideration of mean performance and stability parameters revealed that the crosses *viz.,* ICMA 98222 x BIB 481-500, ICMA 93333 x BIB 531-540, ICMA 04999 x BIB 511-520 and ICMA 93333 x BIB 551-560 were found stable for eight or more character over the environments. Therefore, these crosses are recommended for growing in wide range of environments for stability of yield and its attributes. On the basis of different moisture stress tolerance indices, the crosses *viz.,* ICMA 98222 x BIB 481-500, ICMA 97444 x BIB 571-580, ICMA 88004 x BIB 501-510, ICMA 30201 x BIB 511-520, ICMA 10444 x BIB 511-520, ICMA 93333 x BIB 531-540 and ICMA 30201 x BIB 561-570 were identified as most tolerant for moisture stress conditions. Therefore, these crosses can be adopted for higher yield in drought affected areas and can be used as parent for hybridization programmes for moisture stress tolerance breeding as well as developing moisture stress tolerant populations.

Out of 77 crosses, the five crosses *viz.,* ICMA 98222 x BIB 481-500, ICMA 88004 x BIB 501-510, ICMA 93333 x BIB 551-560, ICMA 97444 x BIB 571-580and ICMA 30199 x BIB 571-580 had high per se performance, high standard heterosis, high significant SCA effects, high stability for different characters and found tolerant for moisture stress conditions on the basis of stress indices. Thus, these crosses could be included in multi-locational testing programme to identify the suitability as commercial hybrid in arid and semi-arid regions of Rajasthan for high yield and its attributes. The various parameters of these superior crosses are presented in Table 5.6.1 as below:

**Table 5.6.1 Best cross combination on the bases of high grain yield and related characters**

| Crosses | Yield* | Standard heterosis | SCA effect | GCA effect | GCA effect |
|---|---|---|---|---|---|
| | | | | $P_1$ | $P_2$ |
| ICMA 98222 x BIB 481-500 | 79.67 | 101.39** | 35.89** | 4.27** | 3.33** |
| ICMA 88004 x BIB 501-510 | 67.89 | 71.61** | 33.46** | 4.15** | -5.89** |
| ICMA 93333 x BIB 551-560 | 54.66 | 38.17** | 17.67** | 1.18 | -0.35 |
| ICMA 97444 x BIB 571-580 | 54.00 | 36.50** | 19.67** | -1.49 | 5.41** |
| ICMA 30199 x BIB 571-580 | 52.56 | 32.86** | 10.04** | 6.70** | 5.41** |
| HHB-67 Improved | 39.56 | - | - | - | - |

* Mean grain yield per plant over the environments (g)

# 6. SUMMARY AND CONCLUSION

The present investigation entitled **"Genetic Architecture of Seed Yield and Its Component Character Using Line × Tester Analysis in Pearl Millet [*Pennisetum glaucum* (L.) R. Br.]"** was undertaken to assess the magnitude of combining ability variances, effects and gene action for grain yield and its attributes, standard heterosis and to identify phenotypically stable crosses suitable for moisture stress affected areas in pearl millet. Eleven MS lines were crossed with seven restorer lines in line x tester fashion at ICRISAT, Patancheru, Hyderabad, during summer-2019 to develop 77 $F_1$ hybrids. These 77 $F_1$ hybrids (crosses) along with three standard checks (HHB 67 Improved, RHB-177 and BHB-1602) hybrids were evaluated in randomized block design with three replications under three environments created by different number of irrigations during *Kharif*-2019 at Agriculture Research Station Bikaner. Observations were recorded on twelve different characters *viz.,* days to 50% flowering, days to maturity, plant height (cm), productive tillers per plant, ear head length (cm), ear head diameter (mm), test weight (g), ear head weight (g), dry stover yield per plant (g), grain yield per plant (g), harvest index (%) and threshing index (%). The data were subjected to various standard statistical analyses and the important findings and conclusions are summarized as follows:

1. The analysis of variance for individual environments as well as in pooled analysis indicated significant differences among crosses for all the traits indicating the sufficient variability for the traits studied. Significant differences among the environments were also observed which indicated influence of environments on the character expression. The crosses x environment interaction were also significant for all the characters, indicating existence of differential responses of crosses to the varying environments.

2. The significant variance due to GCA and SCA indicated the importance of additive as well as non-additive components in the inheritance of different concerned characters. The ratio of GCA/SCA variances was less than unity which indicated the preponderance of non-additive components for all the characters over the environments.
3. From the results of present investigation, it was evident that the additive as well as non-additive gene action was responsible in governing the characters under study. Therefore, mass or recurrent selection with concurrent random mating may also be adopted for population improvement to exploit additive gene action in present material and heterosis breeding may be adopted to exploit non-additive gene action.
4. From the results of GCA effects, it was revealed that a number of parents *viz.,* ICMA 98222, ICMA 88004, ICMA 93333, ICMA 30199 ICMA 30201, and ICMA 10444, (female parents), BIB 511-520, BIB 481-500, BIB 561-570, and BIB 571-581 (male parents) were found to be better general combiner for grain yield and most of its component characters. Therefore, these can be utilized in multiple crossing programmes to synthesize a dynamic population with accumulation of the most of the favorable genes.
5. Based on SCA effects, the crosses *viz.,* ICMA 98222 x BIB 481-500, ICMA 10444 x BIB 481-500, ICMA 30201 x BIB 481-500, ICMA 88004 x BIB 501-510, ICMA 30200 x BIB 501-510, ICMA 98222 x BIB 511-520, ICMA 30200 x BIB 511-520, ICMA 88004 x BIB 531-540, ICMA 30201 x BIB 531-540, ICMA 04999 x BIB 551-560, ICMA 88004 x BIB 551-500, ICMA 97111 x BIB 551-560, and ICMA 97444 x BIB 551-560 were identified as superior for grain yield and related traits. Therefore, these crosses can be utilized for development of promising hybrids.

6. The crosses with high SCA effects were ICMA 97111 x BIB 561-570, ICMA 98222 x BIB 481-500, ICMA 88004 x BIB 501-510 and ICMA 93333 x BIB 551-560 for grain yield and related traits therefore, it was expected that these crosses may offer desirable transgressive segregants in the later generations.
7. The crosses *viz.,* ICMA 843-22 x BIB-343, ICMA 843-22 x BIB-451, RMS 7A x BIB-407, ICMA 843-22 x BIB-423 and ICMA 88004 x BIB-423 showed high and significant standard heterosis for grain yield and its attributing characters over the environments. These crosses were considered promising for their use in yield improvement because of having high heterotic effect for yield as well as some other component characters.
8. The highest and desirable standard heterosis was recorded for the maximum values of standard heterosis were 101.39 (ICMA 98222 x BIB 481-500) for grain yield per plant and related traits were -15.69 (ICMA 98222 x BIB 481-500) for days to 50% flowering, -9.88 (ICMA 98222 x BIB 481-500) for days to maturity, 21.54 (ICMA 93333 x BIB 531-540) for plant height, 90.48 (ICMA 30201 x BIB 511-520) for productive tillers per plant, 29.41 (ICMA 93333 x BIB 551-560) for ear head length, 0.36 (ICMA 98222 x BIB 481-500) for ear head diameter, 30.49 (ICMA 88004 x BIB 501-510) for test weight, 134.35 (ICMA 30201 x BIB 561-570) for ear head weight per plant, 132.06 (ICMA 30201 x BIB 481-500) for dry stover yield per plant 71.02 (ICMA 98222 x BIB 481-500) for harvest index and 177.28 (ICMA 30201 x BIB 481-500) for threshing index. This suggested potentiality of heterosis breeding in pearl millet.
9. In the present investigation, the G x E interaction was found significant for majority of characters which indicated the influence of

environment on the expression of genotypes. The mean sum of squares due to pooled deviations found non significant for all the characters which indicated that prediction across the environments was possible for all characters.

10. Joint consideration of mean performance and stability parameters revealed that the crosses *viz.,* ICMA 98222 x BIB 481-500, ICMA 93333 x BIB 531-540, ICMA 04999 x BIB 511-520 and ICMA 93333 x BIB 551-560, were found stable .Therefore, these crosses can offer a good opportunity for future pearl millet improvement programmers in wide range of environments in terms of stability of grain yield and its contributing characters.
11. On the basis of different moisture stress tolerance indices, the crosses *viz.,* ICMA 98222 x BIB 481-500, ICMA 97444 x BIB 571-580, ICMA 88004 x BIB 501-510, ICMA 30201 x BIB 511-520, ICMA 10444 x BIB 511-520, ICMA 93333 x BIB 531-540 and ICMA 30201 x BIB 561-570 were identified as most tolerant for moisture stress conditions. Therefore, these crosses can be adopted for higher yield in drought affected areas and can be used as parent for hybridization programmers for moisture stress tolerance breeding as well as developing moisture stress tolerant populations.
12. The five crosses *viz.,* ICMA 98222 x BIB 481-500, ICMA 88004 x BIB 501-510, ICMA 93333 x BIB 551-560, ICMA 97444 x BIB 571-580and ICMA 30199 x BIB 571-580 had high per se performance, high standard heterosis, high significant SCA effects, high stability for different characters and found tolerant for moisture stress conditions on the basis of stress indices. Thus, these crosses could be included in multi- locational testing programme to identify the suitability as commercial hybrid in arid and semi-arid regions of Rajasthan for high grain yield and its attributes.

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# Genetic Architecture of Seed Yield and Its Component Character Using Line × Tester Analysis in Pearl Millet [*Pennisetum glaucum* (L.) R. Br.]

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## ABSTRACT

The present investigation was undertaken to study the combining ability, standard heterosis, phenotypic stability and moisture stress indices in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. Eleven male sterile lines and seven restorer lines were crossed into line x tester design to develop 77 hybrids during summer, 2019 at ICRISAT, Hyderabad. The resultant hybrids along with three standard check hybrids were evaluated in randomized block design with three replications under three environments (created by differentiating number of irrigations) during *Kharif*, 2019 at Agriculture Research Station, Bikaner. Observations were recorded on twelve characters *viz.,* days to 50% flowering, days to maturity, plant height, productive tillers per plant, ear head length, ear head diameter, test weight, ear head weight, dry stover yield per plant, grain yield per plant harvest index and threshing index in each environment.

Analysis of variance for means and combining ability indicated that sufficient variability existed among the crosses. Significant variance due to GCA and SCA indicated importance of additive and non-additive components in the inheritance of majority of characters. The ratio of GCA/SCA variances hinted towards preponderance of non-additive component for all the characters over environments. On the basis of GCA effects, parents *viz.,* ICMA 98222, ICMA 88004, ICMA 93333, ICMA 30199 ICMA 30201, and ICMA 10444, (female parents), BIB 511-520, BIB 481-500, BIB 561-570, and BIB 571-581 (male parents) were found good general combiner for grain yield and most of its component characters. On the basis of SCA effects, the crosses *viz.,* ICMA 98222 x BIB 481-500, ICMA 10444 x BIB 481-500, ICMA 30201 x BIB 481-500, ICMA 88004 x BIB 501-510, ICMA 30200 x BIB 501-510, ICMA 98222 x BIB 511-520, ICMA 30200 x BIB 511-520, ICMA 88004 x BIB 531-540, ICMA 30201 x BIB 531-540, ICMA 04999 x BIB 551-560, ICMA 88004 x BIB 551-500, ICMA 97111 x BIB 551-560, and ICMA 97444 x BIB 551-560 were identified as superior for grain yield and related traits. Therefore, these parents and crosses can be utilized for development of promising hybrids as well as their use in population improvement.

Crosses namely ICMA 97111 x BIB 561-570, ICMA 98222 x BIB 481-500, ICMA 88004 x BIB 501-510 and ICMA 93333 x BIB 551-560 showed high and significant standard heterosis for grain yield and its component characters over

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the environments.

Crosses like ICMA 98222 x BIB 481-500, ICMA 93333 x BIB 531-540, ICMA 04999 x BIB 511-520 and ICMA 93333 x BIB 551-560 were found stable for more characters for average environments. On the basis of moisture stress indices, the crosses namely ICMA 98222 x BIB 481-500, ICMA 97444 x BIB 571-580, ICMA 88004 x BIB 501-510, ICMA 30201 x BIB 511-520, ICMA 10444 x BIB 511-520, ICMA 93333 x BIB 531-540 and ICMA 30201 x BIB 561-570 were identified as most tolerant for moisture stress conditions.

The five crosses *viz.,* ICMA 98222 x BIB 481-500, ICMA 88004 x BIB 501-510, ICMA 93333 x BIB 551-560, ICMA 97444 x BIB 571-580 and ICMA 30199 x BIB 571-580 had high per se performance, high standard heterosis, high significant SCA effects, high stability for different characters and found tolerant for moisture stress conditions on the basis of stress indices. Thus, these crosses could be tested in pearl millet improvement programmes to identify the suitability as commercial hybrid in arid and semi-arid areas.

# पंक्ति × परीक्षक विश्लेषण का उपयोग करते हुए बाजरा [*पेनिसेटम ग्लॉकम* (एल.) आर. बीआर..] में बीज उपज और उसके घटक लक्षणों की आनुवांशिक संरचना


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**डॉ. पी. सी. गुप्ता**** (प्रमुख सलाहकार)



अनुक्षेपण

वर्तमान अध्ययन बाजरा [*पेनिसेटम ग्लॉकम* (एल.) आर. बीआर.] में संयोजन क्षमता, संकर ओज, प्ररूपी स्थिरता और नमी प्रतिबल सूचकांकों का अध्ययन करने के लिए की गई थी । आंकलन हेतु सत्तर संकर को ग्यारह मादा जनको व सात नर जनको की सहायता से पंक्ति × परीक्षक पद्दित अनुसार ग्रीष्म ऋतु 2019 मे अर्धशुष्क प्रदेशों के लिए अंतराष्ट्रीय फसल शोध संस्थान, हैदराबाद मे तैयार किया गया । परिणामित संकरो को तीन मानक संकरो के साथ यादृच्छिक खंड अभिकल्पना मे तीन पुनरावर्तन सहित वातावरणों (सिंचाइयों की संख्या में अंतर द्वारा निर्मित) मे कृषि अनुसंधान केंद्र, बीकानेर मे खरीफ 2019 मे आकलित किया गया | प्रत्येक वातावरण मे बारह लक्षणों जैसे–पचास प्रतिशत पुष्पावस्था अवधि, परिपक्वन अवधि, पौधे की ऊंचाई, प्रति पौधा उत्पादक कल्लो की सख्या, सिट्टे की लंबाई, सिट्टे की मोटाई, परीक्षण भार, सिट्टे का भार, प्रति पौधा सूखा चारा उपज, प्रति पौधा दानो की उपज, उपज सूचकांक एवं खलिहान सूचकांक के लिए आकडे संकलित किए गए ।

मध्या व संयोजन क्षमता के विचरण विश्लेषण करने पर सभी लक्षणों के लिए सभी संकरो मे विभिन्नता पायी गयी । अधिकांश लक्षणों के लिए सामान्य एवं विशिष्ट संयोजन क्षमता विचरणों मे सार्थक भिन्नता पायी गयी जो इन गुणो के आनुवांशिक नियंत्रण मे योज्य एवं अयोज्य दोनों जीन प्रभावो को दर्शाता है । सामान्य एवं विशिष्ट संयोजन क्षमता अनुपातों से मुख्यतः अयोज्य जीन प्रभावो का सभी लक्षणों की वंशानुगति मे महत्व इंगित हुआ है। सामान्य संयोजन क्षमता के आधार पर आईसीएमए 98222, आईसीएमए 88004, आईसीएमए 93333, आईसीएमए 30199, आईसीएमए 30201, एवं आईसीएमए 10444, (मादा जनक), बीआईबी 511–520, बीआईबी 481–500, बीआईबी 561–570, एवं बीआईबी 571–581 (नर जनक) विभिन्न लक्षणों के बहुत अच्छे सामान्य संयोजन पाये गये । विशिष्ट संयोजन क्षमता के आधार पर निम्नलिखत संकरो जैसे– आईसीएमए 98222 × बीआईबी 481–500, आईसीएमए 10444 × बीआईबी 481–500, आईसीएमए 30201 × बीआईबी 481–500, आईसीएमए 88004 × बीआईबी 501–510, आईसीएमए 30200 × बीआईबी 501–510, आईसीएमए 98222 × बीआईबी 511–520, आईसीएमए 30200 × बीआईबी 511–520, आईसीएमए 88004 × बीआईबी 531–540, आईसीएमए 30201 × बीआईबी 531–540, आईसीएमए 04999 × बीआईबी 551–560, आईसीएमए 88004 × बीआईबी 551–500, आईसीएमए 97111 × बीआईबी 551–560, एवं आईसीएमए 97444 × बीआईबी 551–560 को अनाज की उपज और संबंधित लक्षणों के लिए बेहतर के रूप में पहचाना गया तथा जिनका उपयोग आशाजनक संकरो को विकसित करने के साथ – साथ जनसख्या सुधार मे भी किया जा सकता है ।

कुछ संकर जैसे– आईसीएमए 97111 × बीआईबी 561–570, आईसीएमए 98222 × बीआईबी 481–500, आईसीएमए 88004 × बीआईबी 501–510 एवं आईसीएमए 93333 × बीआईबी


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* विधावाचस्पति छात्रा, आनुवंशिकी एवं पादप प्रजनन विभाग, कृषि महाविधालय, स्वामी केशवानन्द राजस्थान कृषि विश्वविद्यालय, बीकानेर ।

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551–560 मे विभिन्न वातावरणों के अधीन बीज उपज एवं संबन्धित घटक लक्षणों हेतु उच्च संकर ओज पाया गया ।

कुछ संकर जैसे– आईसीएमए 98222 × बीआईबी 481–500, आईसीएमए 93333 × बीआईबी 531–540, आईसीएमए 04999 × बीआईबी 511–520 एवं आईसीएमए 93333 × बीआईबी 551–560 विभिन्न वातावरणों के अधीन अधिक लक्षणों के लिए स्थायित्व पाया गया । नमी प्रतिबल सूचकांकों के आधार पर संकर आईसीएमए 98222 × बीआईबी 481–500, आईसीएमए 97444 × बीआईबी 571–580, आईसीएमए 88004 × बीआईबी 501–510, आईसीएमए 30201 × बीआईबी 511–520, आईसीएमए 10444 × बीआईबी 511–520, आईसीएमए 93333 × बीआईबी 531–540 एवं आईसीएमए 30201 × बीआईबी 561–570 को नमी प्रतिकूल परिस्थितियो के लिए अधिक सहिष्णु पाया गया ।

पाँच संकर जैसे– आईसीएमए 98222 × बीआईबी 481–500, आईसीएमए 88004 × बीआईबी 501–510, आईसीएमए 93333 × बीआईबी 551–560, आईसीएमए 97444 × बीआईबी 571–580 एवं आईसीएमए 30199 × बीआईबी 571–580 के लिए तुलनात्मक निष्पादन, मानक संकर ओज, सार्थक विशिष्ट संयोजन क्षमता व विभिन्न लक्षणों के लिए स्थायित्व अधिक पाया गया तथा नमी प्रतिबल सूचकांकों के आधार पर नमी प्रतिकूल परिस्थितियो के लिए अधिक सहिष्णु पाया गया गया । अतः इन संकरो का परीक्षण बाजरा सुधार कार्यक्रम मे शुष्क व अर्धशुष्क क्षेत्रो के लिए वाणिज्यक संकर के तौर पर किया जा सकता है ।

## Appendix –I

| Weekly meteorological observations for Bikaner recorded during *Kharif*, 2019# | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Standard week** | **Duration** | **Temperature (°C)** | | **Relative humidity (%)** | | **Total rainfall (mm)** | **No. of rainy days*** | **Wind velocity (km/hr)** | **Evaporation (mm/day)** | **BSSH** |
| | | **Maximum** | **Minimum** | **Maximum** | **Minimum** | | | | | |
| 30 | 23 July to 29 July | 37.7 | 26.4 | 77.4 | 52.3 | 39 | 2.0 | 8.5 | 6.1 | 5.1 |
| 31 | 30 July to 05 Aug | 36.6 | 27.1 | 82.4 | 57.7 | 75.6 | 2.0 | 4.9 | 7.6 | 6.6 |
| 32 | 06 Aug to 12 Aug | 35.8 | 26.9 | 81.3 | 66.0 | 5.2 | 1.0 | 7.3 | 8.0 | 7.3 |
| 33 | 13 Aug to 19 Aug | 35.7 | 26.8 | 83.7 | 68.3 | 21.0 | 2.0 | 6.7 | 6.6 | 5.2 |
| 34 | 20 Aug to 26 Aug | 38.0 | 26.7 | 85.1 | 62.9 | 0.0 | 0.0 | 8.0 | 11.3 | 10.4 |
| 35 | 27 Aug to 02 Sep | 35.8 | 26.0 | 87.4 | 62.7 | 41.8 | 2.0 | 3.8 | 8.7 | 7.5 |
| 36 | 03 Sep to 09 Sep | 38.8 | 27.4 | 90.7 | 59.7 | 0.0 | 0.0 | 3.4 | 11.6 | 8.7 |
| 37 | 10 Sep to 16 Sep | 40.7 | 26.8 | 85.0 | 63.3 | 0.0 | 0.0 | 5.3 | 10.9 | 8.8 |
| 38 | 17 Sep to 23 Sep | 38.1 | 25.4 | 90.3 | 57.9 | 0.0 | 0.0 | 6.1 | 10.4 | 9.0 |
| 39 | 24 Sep to 30 Sep | 35.1 | 24.4 | 83.7 | 60.0 | 0.8 | 0.0 | 4.8 | 8.7 | 8.1 |
| 40 | 01 Oct to 07 Oct | 32.6 | 20.6 | 82.6 | 55.3 | 28.8 | 2.0 | 4.0 | 8.1 | 7.9 |
| 41 | 08 Oct to 14 Oct | 35.6 | 19.1 | 73.6 | 34.0 | 0.0 | 0.0 | 3.4 | 12.0 | 9.6 |
| 42 | 15 Oct to 21 Oct | 35.2 | 18.9 | 67.4 | 32.4 | 0.0 | 0.0 | 3.8 | 10.7 | 9.5 |

*2.5 mm or more rainfall is considered as a rainy day

# Data taken from Agro-meteorology observatory, Swami Keshwanand Rajasthan Agricultural University, Bikaner

## Appendix -II

| The grain iron (Fe) and zinc (Zn) content in some of the superior hybrids over the checks | | | |
|---|---|---|---|
| **S. No.** | **Name of the cross** | **Iron (Fe) content in grain (%)** | **Zinc (Zn) content in grain (%)** |
| 1. | ICMA 98222 x BIB 481-500 | 49 | 37 |
| 2. | ICMA 88004 x BIB 501-510 | 45 | 36 |
| 3. | ICMA 93333 x BIB 551-560 | 44 | 35 |
| 4. | ICMA 97444 x BIB 571-580 | 43 | 35 |
| 5. | ICMA 30199 x BIB 571-580 | 42 | 34 |

## Appendix -III

| Mean value of all the crosses/hybrids for days to 50% flowering, days to maturity, plant height and productive tillers per plant. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **crosses/hybrids** | **Days to 50% flowering** | | | | **Days to maturity** | | | | **Plant height (cm)** | | | | **Productive tillers per plant** | | | |
| | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean |
| ICMA 04999 × 481-500 | 44 | 45 | 51 | 47 | 74 | 75 | 81 | 77 | 166 | 161 | 130.55 | 153 | 3.4 | 1.6 | 1.1 | 2.0 |
| ICMA 88004 × 481-500 | 45 | 43 | 49 | 46 | 75 | 73 | 79 | 76 | 166 | 165 | 134.51 | 155 | 2.7 | 1.3 | 1.1 | 1.7 |
| ICMA 93333 × 481-500 | 43 | 43 | 49 | 45 | 73 | 73 | 79 | 75 | 161 | 168 | 141.32 | 157 | 2.8 | 2.3 | 1.5 | 2.2 |
| ICMA 97111 × 481-500 | 50 | 42 | 48 | 47 | 80 | 72 | 78 | 77 | 174 | 156 | 125.74 | 152 | 3.6 | 1.5 | 1.6 | 2.2 |
| ICMA 97444 × 481-500 | 42 | 55 | 61 | 53 | 72 | 85 | 91 | 83 | 176 | 138 | 107.54 | 141 | 3.4 | 2.3 | 2.4 | 2.7 |
| ICMA 98222 × 481-500 | 41 | 41 | 47 | 43 | 71 | 71 | 77 | 73 | 154 | 150 | 119.59 | 141 | 3.4 | 4.4 | 3.7 | 3.8 |
| ICMA 10444 × 481-500 | 46 | 55 | 61 | 54 | 76 | 85 | 91 | 84 | 133 | 129 | 102.59 | 122 | 3.5 | 1.3 | 1 | 1.9 |
| ICMA 30199 × 481-500 | 48 | 50 | 56 | 51 | 78 | 80 | 86 | 81 | 161 | 152 | 122 | 145 | 4.3 | 3.7 | 2.7 | 3.6 |
| ICMA 30200 × 481-500 | 44 | 46 | 52 | 47 | 74 | 76 | 82 | 77 | 151 | 155 | 125.21 | 144 | 3.6 | 3.6 | 2.6 | 3.3 |
| ICMA 30201 × 481-500 | 56 | 45 | 51 | 51 | 86 | 75 | 81 | 81 | 163 | 153 | 122.66 | 146 | 3.5 | 4 | 2.6 | 3.4 |
| ICMA 30209 × 481-500 | 51 | 55 | 61 | 56 | 81 | 85 | 91 | 86 | 120 | 125 | 94.78 | 113 | 1.3 | 1.5 | 1.2 | 1.3 |
| ICMA 04999 × 501-510 | 56 | 56 | 62 | 58 | 86 | 86 | 92 | 88 | 112 | 126 | 96.13 | 111 | 2.7 | 1.4 | 1 | 1.7 |
| ICMA 88004 × 501-510 | 41 | 41 | 47 | 43 | 71 | 71 | 77 | 73 | 163 | 154 | 124.23 | 147 | 4.6 | 2 | 1.6 | 2.7 |
| ICMA 93333 × 501-510 | 44 | 48 | 54 | 49 | 74 | 78 | 84 | 79 | 180 | 147 | 116.94 | 148 | 3.2 | 2 | 1.2 | 2.1 |
| ICMA 97111 × 501-510 | 42 | 46 | 52 | 47 | 72 | 76 | 82 | 77 | 153 | 141 | 111.3 | 135 | 4.5 | 1 | 1 | 2.2 |
| ICMA 97444 × 501-510 | 43 | 49 | 55 | 49 | 73 | 79 | 85 | 79 | 167 | 139 | 108.75 | 138 | 3.5 | 1.6 | 1.1 | 2.1 |
| ICMA 98222 × 501-510 | 42 | 44 | 50 | 45 | 72 | 74 | 80 | 75 | 162 | 139 | 109.28 | 137 | 2.7 | 2 | 1.2 | 2.0 |
| ICMA 10444 × 501-510 | 45 | 45 | 51 | 47 | 75 | 75 | 81 | 77 | 163 | 146 | 115.66 | 142 | 2.6 | 2.4 | 2.3 | 2.4 |
| ICMA 30199 × 501-510 | 51 | 53 | 59 | 54 | 81 | 83 | 89 | 84 | 171 | 133 | 109.7 | 138 | 3.8 | 1.2 | 1 | 2.0 |
| ICMA 30200 × 501-510 | 50 | 53 | 59 | 54 | 80 | 83 | 89 | 84 | 149 | 119 | 88.68 | 119 | 3 | 1.5 | 1.2 | 1.9 |
| ICMA 30201 × 501-510 | 48 | 55 | 61 | 55 | 78 | 85 | 91 | 85 | 151 | 112 | 82.42 | 115 | 4.1 | 1.2 | 1 | 2.1 |
| ICMA 30209 × 501-510 | 50 | 55 | 61 | 55 | 80 | 85 | 91 | 85 | 160 | 115 | 84.64 | 120 | 3.5 | 1 | 1 | 1.8 |
| ICMA 04999 × 511-520 | 42 | 41 | 47 | 43 | 72 | 71 | 77 | 73 | 144 | 135 | 105.09 | 128 | 4.2 | 2.9 | 2.3 | 3.1 |
| ICMA 88004 × 511-520 | 42 | 40 | 46 | 43 | 72 | 70 | 76 | 73 | 148 | 141 | 110.66 | 133 | 3.6 | 1.9 | 1.6 | 2.4 |
| ICMA 93333 × 511-520 | 43 | 41 | 47 | 44 | 73 | 71 | 77 | 74 | 153 | 153 | 122.51 | 143 | 4.9 | 2.6 | 2.4 | 3.3 |
| ICMA 97111 × 511-520 | 42 | 52 | 58 | 51 | 72 | 82 | 88 | 81 | 147 | 126 | 95.53 | 123 | 4.1 | 1.5 | 1.2 | 2.3 |
| ICMA 97444 × 511-520 | 42 | 41 | 47 | 43 | 72 | 71 | 77 | 73 | 147 | 153 | 122.63 | 141 | 3.2 | 4.1 | 3.1 | 3.5 |

| Mean value of all the crosses/hybrids for days to 50% flowering, days to maturity, plant height and productive tillers per plant. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| crosses/hybrids | Days to 50% flowering | | | | Days to maturity | | | | Plant height (cm) | | | | Productive tillers per plant | | | |
| | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean |
| ICMA 98222 × 511-520 | 46 | 54 | 60 | 53 | 76 | 84 | 90 | 83 | 128 | 134 | 103.87 | 122 | 2.7 | 1.5 | 1.1 | 1.8 |
| ICMA 10444 × 511-520 | 49 | 46 | 52 | 49 | 79 | 76 | 82 | 79 | 137 | 140 | 109.74 | 129 | 3 | 3.5 | 2.3 | 2.9 |
| ICMA 30199 × 511-520 | 46 | 52 | 58 | 52 | 76 | 82 | 88 | 82 | 148 | 136 | 106.06 | 130 | 3 | 1.8 | 1.4 | 2.1 |
| ICMA 30200 × 511-520 | 53 | 54 | 60 | 56 | 83 | 84 | 90 | 86 | 121 | 126 | 96.43 | 114 | 3.1 | 1.4 | 1 | 1.8 |
| ICMA 30201 × 511-520 | 45 | 45 | 51 | 47 | 75 | 75 | 81 | 77 | 161 | 146 | 115.65 | 141 | 6 | 3.5 | 2.5 | 4.0 |
| ICMA 30209 × 511-520 | 48 | 46 | 52 | 49 | 78 | 76 | 82 | 79 | 164 | 153 | 123.34 | 147 | 3.6 | 3.1 | 2.5 | 3.1 |
| ICMA 04999 × 531-540 | 47 | 54 | 60 | 54 | 77 | 84 | 90 | 84 | 171 | 122 | 91.82 | 128 | 6.3 | 1 | 1 | 2.8 |
| ICMA 88004 × 531-540 | 54 | 55 | 61 | 57 | 84 | 85 | 91 | 87 | 114 | 126 | 96.28 | 112 | 4.6 | 2.4 | 1.4 | 2.8 |
| ICMA 93333 × 531-540 | 43 | 42 | 48 | 44 | 73 | 72 | 78 | 74 | 177 | 163 | 132.76 | 158 | 5.3 | 2 | 1.3 | 2.9 |
| ICMA 97111 × 531-540 | 43 | 53 | 59 | 52 | 73 | 83 | 89 | 82 | 164 | 129 | 99.16 | 131 | 3.7 | 1 | 1 | 1.9 |
| ICMA 97444 × 531-540 | 42 | 41 | 47 | 43 | 72 | 71 | 77 | 73 | 166 | 155 | 124.74 | 149 | 4.4 | 2.2 | 1.4 | 2.7 |
| ICMA 98222 × 531-540 | 42 | 45 | 51 | 46 | 72 | 75 | 81 | 76 | 160 | 150 | 119.74 | 143 | 3.4 | 1.6 | 1.1 | 2.0 |
| ICMA 10444 × 531-540 | 46 | 47 | 53 | 49 | 76 | 77 | 83 | 79 | 170 | 145 | 115.16 | 143 | 2.9 | 1.3 | 1 | 1.7 |
| ICMA 30199 × 531-540 | 49 | 50 | 56 | 52 | 79 | 80 | 86 | 82 | 170 | 148 | 117.64 | 145 | 3 | 1.7 | 1.2 | 2.0 |
| ICMA 30200 × 531-540 | 46 | 45 | 51 | 47 | 76 | 75 | 81 | 77 | 167 | 146 | 115.85 | 143 | 3.6 | 1.6 | 1.2 | 2.1 |
| ICMA 30201 × 531-540 | 43 | 46 | 52 | 47 | 73 | 76 | 82 | 77 | 165 | 156 | 126.06 | 149 | 3.9 | 2 | 1.3 | 2.4 |
| ICMA 30209 × 531-540 | 46 | 48 | 54 | 49 | 76 | 78 | 84 | 79 | 170 | 148 | 118.15 | 145 | 5.5 | 2.8 | 1.9 | 3.4 |
| ICMA 04999 × 551-560 | 52 | 54 | 60 | 55 | 82 | 84 | 90 | 85 | 113 | 131 | 101.33 | 115 | 4.3 | 1 | 1 | 2.1 |
| ICMA 88004 × 551-560 | 43 | 45 | 51 | 46 | 73 | 75 | 81 | 76 | 174 | 153 | 123.25 | 150 | 4.4 | 1.8 | 1.3 | 2.5 |
| ICMA 93333 × 551-560 | 42 | 43 | 49 | 45 | 72 | 73 | 79 | 75 | 167 | 163 | 133.36 | 154 | 4.6 | 1.5 | 1.3 | 2.5 |
| ICMA 97111 × 551-560 | 54 | 54 | 60 | 56 | 84 | 84 | 90 | 86 | 116 | 123 | 93.36 | 111 | 1.1 | 1.3 | 1 | 1.1 |
| ICMA 97444 × 551-560 | 54 | 55 | 61 | 57 | 84 | 85 | 91 | 87 | 123 | 114 | 83.74 | 107 | 2.6 | 1.3 | 1 | 1.6 |
| ICMA 98222 × 551-560 | 43 | 46 | 52 | 47 | 73 | 76 | 82 | 77 | 157 | 141 | 110.53 | 136 | 3 | 1.6 | 1.5 | 2.0 |
| ICMA 10444 × 551-560 | 46 | 47 | 53 | 49 | 76 | 77 | 83 | 79 | 146 | 145 | 115.22 | 135 | 3.9 | 2.2 | 1.7 | 2.6 |
| ICMA 30199 × 551-560 | 50 | 51 | 57 | 53 | 80 | 81 | 87 | 83 | 160 | 149 | 119.12 | 143 | 3.3 | 2.2 | 1.7 | 2.4 |
| ICMA 30200 × 551-560 | 48 | 53 | 59 | 53 | 78 | 83 | 89 | 83 | 148 | 130 | 99.88 | 126 | 3.7 | 1.2 | 1 | 2.0 |
| ICMA 30201 × 551-560 | 46 | 47 | 53 | 49 | 76 | 77 | 83 | 79 | 154 | 151 | 121.19 | 142 | 4.4 | 4.2 | 3.3 | 4.0 |

| Mean value of all the crosses/hybrids for days to 50% flowering, days to maturity, plant height and productive tillers per plant. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **crosses/hybrids** | **Days to 50% flowering** | | | | **Days to maturity** | | | | **Plant height (cm)** | | | | **Productive tillers per plant** | | | |
| | **$E_1$** | **$E_2$** | **$E_3$** | **Mean** | **$E_1$** | **$E_2$** | **$E_3$** | **Mean** | **$E_1$** | **$E_2$** | **$E_3$** | **Mean** | **$E_1$** | **$E_2$** | **$E_3$** | **Mean** |
| ICMA 30209 × 551-560 | 48 | 47 | 53 | 49 | 78 | 77 | 83 | 79 | 171 | 159 | 129.36 | 153 | 3.3 | 2.7 | 2.2 | 2.7 |
| ICMA 04999 × 561-570 | 46 | 53 | 59 | 53 | 76 | 83 | 89 | 83 | 141 | 123 | 93.3 | 119 | 5.3 | 2.3 | 1.5 | 3.0 |
| ICMA 88004 × 561-570 | 43 | 41 | 47 | 44 | 73 | 71 | 77 | 74 | 160 | 147 | 117.13 | 141 | 3.9 | 2.5 | 2 | 2.8 |
| ICMA 93333 × 561-570 | 44 | 43 | 49 | 45 | 74 | 73 | 79 | 75 | 165 | 147 | 117.36 | 143 | 3.3 | 2.4 | 1.9 | 2.5 |
| ICMA 97111 × 561-570 | 44 | 42 | 48 | 45 | 74 | 72 | 78 | 75 | 162 | 150 | 120.17 | 144 | 5.1 | 2.5 | 2 | 3.2 |
| ICMA 97444 × 561-570 | 43 | 45 | 51 | 46 | 73 | 75 | 81 | 76 | 162 | 135 | 104.82 | 134 | 4.7 | 3.1 | 2.3 | 3.4 |
| ICMA 98222 × 561-570 | 42 | 41 | 47 | 43 | 72 | 71 | 77 | 73 | 144 | 137 | 107.09 | 129 | 4.1 | 2.6 | 2.1 | 2.9 |
| ICMA 10444 × 561-570 | 50 | 50 | 56 | 52 | 80 | 80 | 86 | 82 | 133 | 125 | 101.45 | 120 | 4.4 | 1.8 | 1.6 | 2.6 |
| ICMA 30199 × 561-570 | 51 | 51 | 57 | 53 | 81 | 81 | 87 | 83 | 148 | 135 | 104.83 | 129 | 4.8 | 2.8 | 2.3 | 3.3 |
| ICMA 30200 × 561-570 | 46 | 46 | 52 | 48 | 76 | 76 | 82 | 78 | 143 | 143 | 112.54 | 133 | 4.9 | 4 | 2.4 | 3.8 |
| ICMA 30201 × 561-570 | 49 | 47 | 53 | 50 | 79 | 77 | 83 | 80 | 144 | 141 | 111.25 | 132 | 4.2 | 1.6 | 1.1 | 2.3 |
| ICMA 30209 × 561-570 | 47 | 46 | 52 | 48 | 77 | 76 | 82 | 78 | 149 | 138 | 108.06 | 132 | 4.7 | 2.4 | 1.6 | 2.9 |
| ICMA 04999 × 571-580 | 44 | 46 | 52 | 47 | 74 | 77 | 83 | 78 | 151 | 136 | 106.09 | 131 | 5 | 2.7 | 2.4 | 3.4 |
| ICMA 88004 × 571-580 | 43 | 43 | 49 | 45 | 73 | 73 | 79 | 75 | 170 | 150 | 120.25 | 147 | 5.2 | 3 | 2.4 | 3.5 |
| ICMA 93333 × 571-580 | 42 | 44 | 50 | 45 | 72 | 74 | 80 | 75 | 162 | 154 | 124.05 | 147 | 3.8 | 1.8 | 1.7 | 2.4 |
| ICMA 97111 × 571-580 | 41 | 43 | 49 | 44 | 71 | 73 | 79 | 74 | 161 | 141 | 111.29 | 138 | 5.2 | 1.6 | 1.1 | 2.6 |
| ICMA 97444 × 571-580 | 43 | 43 | 49 | 45 | 73 | 73 | 79 | 75 | 164 | 147 | 116.59 | 143 | 3.8 | 2.8 | 1.5 | 2.7 |
| ICMA 98222 × 571-580 | 44 | 44 | 50 | 46 | 74 | 74 | 80 | 76 | 143 | 131 | 100.89 | 125 | 3.2 | 2.3 | 1.8 | 2.4 |
| ICMA 10444 × 571-580 | 47 | 48 | 54 | 50 | 77 | 78 | 84 | 80 | 148 | 132 | 101.92 | 127 | 3.4 | 1.5 | 1.2 | 2.0 |
| ICMA 30199 × 571-580 | 50 | 50 | 56 | 52 | 80 | 80 | 86 | 82 | 151 | 152 | 121.73 | 142 | 4.8 | 3 | 2.5 | 3.4 |
| ICMA 30200 × 571-580 | 46 | 46 | 52 | 48 | 76 | 76 | 82 | 78 | 150 | 136 | 105.55 | 131 | 3.9 | 1.8 | 1.6 | 2.4 |
| ICMA 30201 × 571-580 | 48 | 50 | 56 | 51 | 82 | 80 | 86 | 83 | 157 | 131 | 100.68 | 130 | 4.1 | 1.8 | 1.4 | 2.4 |
| ICMA 30209 × 571-580 | 48 | 46 | 52 | 49 | 81 | 77 | 84 | 81 | 163 | 134 | 103.55 | 134 | 3.9 | 1.4 | 1 | 2.1 |
| RHB - 177 (Check-1) | 47 | 46 | 52 | 48 | 77 | 76 | 82 | 78 | 173 | 137 | 106.52 | 139 | 4.1 | 1.8 | 1.3 | 2.4 |
| BHB - 1602 ( Check-2) | 47 | 52 | 58 | 52 | 77 | 82 | 88 | 82 | 166 | 130 | 100.13 | 132 | 4.3 | 1.8 | 1.2 | 2.4 |
| HHB-67 Improved (Check-3) | 46 | 51 | 57 | 51 | 76 | 81 | 87 | 81 | 166 | 127 | 97.15 | 130 | 3.7 | 1.5 | 1.1 | 2.1 |

## Appendix - IV

Mean value of all the crosses/hybrids for Ear head length, Ear head diameter, Test weight, Ear head weight.

| crosses/hybrids | Ear head length (cm) | | | | Ear head diameter (mm) | | | | Test weight (g) | | | | Ear head weight (g) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean |
| ICMA 04999 × 481-500 | 22.6 | 20.7 | 15.27 | 19.5 | 25 | 19.2 | 16.41 | 20.2 | 9.74 | 9.92 | 9.62 | 9.76 | 110 | 63.33 | 58.33 | 77.22 |
| ICMA 88004 × 481-500 | 14 | 21.9 | 16.44 | 17.4 | 25.3 | 15.3 | 9.18 | 16.6 | 7.01 | 6.91 | 6.61 | 6.84 | 106.67 | 80 | 70 | 85.56 |
| ICMA 93333 × 481-500 | 20.3 | 17.2 | 10.1 | 15.9 | 22.7 | 20 | 17.3 | 20 | 10.38 | 10.91 | 10.61 | 10.63 | 80 | 76.67 | 71.67 | 76.11 |
| ICMA 97111 × 481-500 | 24.5 | 19 | 11.5 | 18.3 | 23.7 | 20.6 | 17.85 | 20.7 | 10 | 9.9 | 9.6 | 9.83 | 75 | 70 | 65 | 70.00 |
| ICMA 97444 × 481-500 | 25.7 | 21.1 | 15.69 | 20.8 | 25.7 | 9 | 6.29 | 13.7 | 9.45 | 9.35 | 9.05 | 9.28 | 100 | 28.33 | 23.33 | 50.55 |
| ICMA 98222 × 481-500 | 29.5 | 30.4 | 24.97 | 28.3 | 29.3 | 28.2 | 25.44 | 27.6 | 12.27 | 12.91 | 12.61 | 12.6 | 140 | 146.67 | 141.67 | 142.78 |
| ICMA 10444 × 481-500 | 21.8 | 16.2 | 9.75 | 15.9 | 15 | 9.3 | 6.57 | 10.3 | 8.01 | 7.91 | 7.61 | 7.84 | 25 | 29 | 26.67 | 26.89 |
| ICMA 30199 × 481-500 | 20.8 | 18.4 | 13.96 | 17.7 | 22.7 | 22.3 | 19.55 | 21.5 | 11.02 | 10.92 | 10.62 | 10.85 | 110 | 76.67 | 71.67 | 86.11 |
| ICMA 30200 × 481-500 | 24.5 | 21.6 | 16.19 | 20.8 | 25.3 | 20.1 | 19.37 | 21.6 | 6.01 | 5.91 | 5.61 | 5.84 | 131.67 | 66.67 | 61.67 | 86.67 |
| ICMA 30201 × 481-500 | 28.1 | 25.2 | 19.74 | 24.3 | 26.7 | 22 | 19.26 | 22.7 | 8.01 | 7.91 | 7.61 | 7.84 | 120 | 19.33 | 11.67 | 50.33 |
| ICMA 30209 × 481-500 | 22.3 | 14 | 7.56 | 14.6 | 15.3 | 8.4 | 5.65 | 9.8 | 7.24 | 7.14 | 6.84 | 7.07 | 26.67 | 26.67 | 23.33 | 25.56 |
| ICMA 04999 × 501-510 | 23.2 | 13.6 | 11.53 | 16.1 | 15.7 | 9 | 6.21 | 10.3 | 9.19 | 9.09 | 8.79 | 9.02 | 33.33 | 26.67 | 23.33 | 27.78 |
| ICMA 88004 × 501-510 | 30.1 | 27.2 | 21.71 | 26.3 | 25.3 | 26.2 | 23.4 | 25 | 13.01 | 12.91 | 12.61 | 12.84 | 130 | 136.67 | 135 | 133.89 |
| ICMA 93333 × 501-510 | 21.1 | 22.5 | 17.09 | 20.2 | 26 | 12.3 | 9.53 | 15.9 | 10.08 | 9.98 | 9.68 | 9.91 | 90 | 36.67 | 31.67 | 52.78 |
| ICMA 97111 × 501-510 | 27.6 | 26.3 | 20.85 | 24.9 | 27 | 22.2 | 19.43 | 22.9 | 11.17 | 11.07 | 10.42 | 10.89 | 133.33 | 113.33 | 101.67 | 116.11 |
| ICMA 97444 × 501-510 | 28 | 20.9 | 15.44 | 21.4 | 28.3 | 19.6 | 16.84 | 21.6 | 8.01 | 7.91 | 7.61 | 7.84 | 75 | 29.33 | 23.33 | 42.55 |
| ICMA 98222 × 501-510 | 27.1 | 23.7 | 18.2 | 23 | 30.3 | 24.4 | 21.69 | 25.5 | 11.16 | 11.06 | 10.44 | 10.89 | 123.33 | 126.67 | 121.67 | 123.89 |
| ICMA 10444 × 501-510 | 24.2 | 21.6 | 16.18 | 20.7 | 26 | 17.4 | 14.7 | 19.4 | 10.29 | 10.19 | 9.77 | 10.08 | 80 | 70 | 65 | 71.67 |
| ICMA 30199 × 501-510 | 22.5 | 17.1 | 11.65 | 17.1 | 26.3 | 8.6 | 5.89 | 13.6 | 9.87 | 9.98 | 9.68 | 9.84 | 93.33 | 56.67 | 51.67 | 67.22 |
| ICMA 30200 × 501-510 | 27.3 | 15.5 | 10.7 | 17.8 | 27.7 | 8.7 | 5.98 | 14.1 | 9.08 | 8.98 | 8.68 | 8.91 | 83.33 | 21 | 18.33 | 40.89 |
| ICMA 30201 × 501-510 | 27.4 | 15.4 | 9.95 | 17.6 | 25.7 | 8.9 | 6.15 | 13.6 | 10.5 | 10.91 | 10.61 | 10.67 | 126.67 | 28.67 | 23.33 | 59.56 |
| ICMA 30209 × 501-510 | 26.3 | 14.3 | 8.81 | 16.5 | 30.3 | 8.9 | 6.13 | 15.1 | 7.08 | 6.98 | 6.68 | 6.91 | 100 | 21 | 20 | 47.00 |
| ICMA 04999 × 511-520 | 25.9 | 27.4 | 21.94 | 25.1 | 24.7 | 22.1 | 19.37 | 22.1 | 11.01 | 10.91 | 10.61 | 10.84 | 120 | 70 | 65 | 85.00 |
| ICMA 88004 × 511-520 | 28.1 | 20.1 | 14.69 | 21 | 25.3 | 17.9 | 15.15 | 19.5 | 12 | 11.9 | 11.6 | 11.83 | 86.67 | 133.33 | 133.33 | 117.78 |
| ICMA 93333 × 511-520 | 22.4 | 23.4 | 17.91 | 21.2 | 23.7 | 19.5 | 16.76 | 20 | 10.03 | 9.93 | 9.63 | 9.86 | 100 | 56.67 | 51.67 | 69.45 |
| ICMA 97111 × 511-520 | 24.7 | 14.4 | 8.9 | 16 | 25 | 8.7 | 5.98 | 13.2 | 9 | 8.9 | 8.6 | 8.83 | 96.67 | 29.33 | 23.33 | 49.78 |
| ICMA 97444 × 511-520 | 23.4 | 23.5 | 18.1 | 21.7 | 24.3 | 18.8 | 16.07 | 19.7 | 8.01 | 7.91 | 7.61 | 7.84 | 110 | 90 | 85 | 95.00 |

| Mean value of all the crosses/hybrids for Ear head length, Ear head diameter, Test weight, Ear head weight. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| crosses/hybrids | Ear head length (cm) | | | | Ear head diameter (mm) | | | | Test weight (g) | | | | Ear head weight (g) | | | |
| | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean |
| ICMA 98222 × 511-520 | 24.1 | 12.1 | 6.63 | 14.3 | 31.7 | 9 | 6.28 | 15.7 | 10.74 | 10.91 | 10.61 | 10.75 | 110 | 26.67 | 23.33 | 53.33 |
| ICMA 10444 × 511-520 | 28 | 23.5 | 18.02 | 23.2 | 25.3 | 19.6 | 16.87 | 20.6 | 11.01 | 10.91 | 10.27 | 10.73 | 120 | 133.33 | 140 | 131.11 |
| ICMA 30199 × 511-520 | 20.5 | 13 | 7.53 | 13.7 | 27 | 19.3 | 16.52 | 20.9 | 8.02 | 7.92 | 7.62 | 7.85 | 210 | 66.67 | 61.67 | 112.78 |
| ICMA 30200 × 511-520 | 19.7 | 12.4 | 7 | 13 | 16.7 | 9.4 | 6.67 | 10.9 | 6.01 | 5.91 | 5.61 | 5.84 | 26.67 | 19.33 | 16.67 | 20.89 |
| ICMA 30201 × 511-520 | 24.7 | 22.5 | 17.09 | 21.4 | 27.7 | 23.8 | 21.1 | 24.2 | 11.03 | 10.93 | 10.63 | 10.86 | 210 | 76.67 | 75 | 120.56 |
| ICMA 30209 × 511-520 | 25.5 | 22.7 | 17.28 | 21.8 | 28 | 16.1 | 13.38 | 19.2 | 8.3 | 8.2 | 7.9 | 8.13 | 130 | 73.33 | 68.33 | 90.55 |
| ICMA 04999 × 531-540 | 27.2 | 15.9 | 10.42 | 17.8 | 24.7 | 9.1 | 6.36 | 13.4 | 11.16 | 11.06 | 10.76 | 10.99 | 153.33 | 28.33 | 21.67 | 67.78 |
| ICMA 88004 × 531-540 | 19.1 | 16.1 | 10.68 | 15.3 | 14.7 | 9.8 | 7.04 | 10.5 | 6.09 | 5.99 | 5.69 | 5.92 | 26.67 | 20.67 | 16.67 | 21.34 |
| ICMA 93333 × 531-540 | 26.7 | 25.3 | 19.81 | 23.9 | 20.7 | 16.1 | 13.36 | 16.7 | 10.24 | 10.14 | 9.84 | 10.07 | 140 | 83.33 | 80 | 101.11 |
| ICMA 97111 × 531-540 | 25.7 | 11.5 | 6.04 | 14.4 | 23.7 | 10.1 | 7.35 | 13.7 | 8.02 | 7.92 | 7.62 | 7.85 | 103.33 | 26.67 | 23.33 | 51.11 |
| ICMA 97444 × 531-540 | 24.5 | 23.4 | 17.91 | 21.9 | 21.7 | 16.3 | 13.54 | 17.2 | 10.16 | 10.06 | 9.76 | 9.99 | 120 | 63.33 | 46.67 | 76.67 |
| ICMA 98222 × 531-540 | 28.7 | 24.1 | 18.62 | 23.8 | 25.7 | 17.9 | 15.13 | 19.6 | 11.77 | 11.91 | 11.28 | 11.65 | 130 | 33.33 | 28.33 | 63.89 |
| ICMA 10444 × 531-540 | 25.5 | 24.6 | 19.15 | 23.1 | 28.3 | 22.1 | 19.36 | 23.3 | 11.01 | 10.91 | 10.61 | 10.84 | 100 | 33.33 | 28.33 | 53.89 |
| ICMA 30199 × 531-540 | 22.4 | 19.8 | 14.39 | 18.9 | 25.7 | 20 | 17.27 | 21 | 9.09 | 8.99 | 8.69 | 8.92 | 90 | 40 | 35 | 55.00 |
| ICMA 30200 × 531-540 | 27.6 | 23.8 | 18.33 | 23.2 | 22 | 20.2 | 17.42 | 19.9 | 9.65 | 9.93 | 9.63 | 9.74 | 63.33 | 33.33 | 28.33 | 41.66 |
| ICMA 30201 × 531-540 | 25.3 | 24 | 18.54 | 22.6 | 22.7 | 21.6 | 18.81 | 21 | 12.01 | 11.91 | 11.61 | 11.84 | 116.67 | 25 | 18.33 | 53.33 |
| ICMA 30209 × 531-540 | 26.9 | 23.9 | 17.09 | 22.6 | 26 | 17 | 14.27 | 19.1 | 9.04 | 8.94 | 8.64 | 8.87 | 128.33 | 50 | 60 | 79.44 |
| ICMA 04999 × 551-560 | 19.2 | 9.3 | 3.85 | 10.8 | 17.3 | 8.9 | 6.1 | 10.8 | 6.16 | 6.06 | 5.76 | 5.99 | 38.33 | 19.33 | 16.67 | 24.78 |
| ICMA 88004 × 551-560 | 26.2 | 25.3 | 19.89 | 23.8 | 26.3 | 21.5 | 18.79 | 22.2 | 10.02 | 9.92 | 9.62 | 9.85 | 133.33 | 30 | 45 | 69.44 |
| ICMA 93333 × 551-560 | 29.8 | 30.8 | 25.32 | 28.6 | 24.7 | 27.2 | 24.43 | 25.4 | 13 | 12.9 | 12.6 | 12.83 | 176.67 | 143.33 | 143.33 | 154.44 |
| ICMA 97111 × 551-560 | 17.5 | 12.2 | 6.78 | 12.2 | 17.3 | 9.1 | 6.33 | 10.9 | 7.45 | 7.35 | 7.05 | 7.28 | 36.67 | 19.33 | 16.67 | 24.22 |
| ICMA 97444 × 551-560 | 19.2 | 13.4 | 7.99 | 13.5 | 17.3 | 9.2 | 6.42 | 11 | 5 | 4.9 | 4.6 | 4.83 | 26.67 | 26.67 | 23.33 | 25.56 |
| ICMA 98222 × 551-560 | 29.1 | 27.2 | 21.7 | 26 | 26.3 | 21.9 | 19.13 | 22.4 | 10.02 | 9.92 | 9.62 | 9.85 | 136.67 | 70 | 45 | 83.89 |
| ICMA 10444 × 551-560 | 24.5 | 31.5 | 23.33 | 26.4 | 28.3 | 19.4 | 16.64 | 21.4 | 10.44 | 10.34 | 9.86 | 10.21 | 103.33 | 40 | 35 | 59.44 |
| ICMA 30199 × 551-560 | 24.5 | 24.3 | 18.86 | 22.6 | 25 | 22.3 | 19.51 | 22.3 | 8.05 | 7.95 | 7.65 | 7.88 | 153.33 | 60 | 46.67 | 86.67 |
| ICMA 30200 × 551-560 | 27.4 | 13.9 | 8.49 | 16.6 | 24.7 | 8.5 | 5.74 | 13 | 7.54 | 7.44 | 7.14 | 7.37 | 93.33 | 20.67 | 13.33 | 42.44 |
| ICMA 30201 × 551-560 | 23.2 | 30 | 23.57 | 25.6 | 23.7 | 16.6 | 13.87 | 18.1 | 5.08 | 4.98 | 4.68 | 4.91 | 106.67 | 53.33 | 48.33 | 69.44 |

| Mean value of all the crosses/hybrids for Ear head length, Ear head diameter, Test weight, Ear head weight. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| crosses/hybrids | Ear head length (cm) | | | | Ear head diameter (mm) | | | | Test weight (g) | | | | Ear head weight (g) | | | |
| | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean |
| ICMA 30209 × 551-560 | 24.2 | 27.6 | 22.2 | 24.7 | 25.7 | 17.9 | 15.19 | 19.6 | 10.24 | 10.14 | 9.84 | 10.07 | 123.33 | 55 | 40 | 72.78 |
| ICMA 04999 × 561-570 | 24.9 | 20.6 | 15.15 | 20.2 | 24.3 | 20 | 17.21 | 20.5 | 9.95 | 9.85 | 9.55 | 9.78 | 143.33 | 38.33 | 31.67 | 71.11 |
| ICMA 88004 × 561-570 | 23.4 | 21.5 | 16.06 | 20.3 | 26.3 | 20 | 17.22 | 21.2 | 10.12 | 9.98 | 9.68 | 9.93 | 106.67 | 36.67 | 33.33 | 58.89 |
| ICMA 93333 × 561-570 | 26.6 | 24.8 | 19.31 | 23.6 | 20.3 | 16.4 | 13.66 | 16.8 | 9.24 | 9.14 | 8.84 | 9.07 | 66.67 | 43.33 | 33.33 | 47.78 |
| ICMA 97111 × 561-570 | 24.8 | 23.1 | 17.64 | 21.8 | 22.7 | 14.6 | 11.85 | 16.4 | 12.02 | 11.02 | 11.62 | 11.55 | 86.67 | 30 | 31.67 | 49.45 |
| ICMA 97444 × 561-570 | 22.4 | 16.2 | 15.1 | 17.9 | 21.3 | 10 | 7.2 | 12.8 | 10.03 | 10.15 | 9.85 | 10.01 | 110 | 36.67 | 31.67 | 59.45 |
| ICMA 98222 × 561-570 | 23.4 | 22.1 | 16.63 | 20.7 | 23.7 | 26.5 | 23.72 | 24.6 | 13.01 | 12.34 | 12.61 | 12.65 | 120 | 130 | 123.33 | 124.44 |
| ICMA 10444 × 561-570 | 27.1 | 23.1 | 16.29 | 22.2 | 27 | 14.6 | 11.83 | 17.8 | 8.55 | 8.45 | 8.15 | 8.38 | 113.33 | 30 | 33.33 | 58.89 |
| ICMA 30199 × 561-570 | 21.3 | 19.6 | 14.2 | 18.4 | 25.7 | 16.2 | 13.45 | 18.5 | 10.67 | 10.57 | 10.27 | 10.5 | 143.33 | 43.33 | 38.33 | 75.00 |
| ICMA 30200 × 561-570 | 24.8 | 24.6 | 19.17 | 22.9 | 26 | 17.8 | 15 | 19.6 | 10.34 | 10.24 | 9.94 | 10.17 | 123.33 | 70 | 65 | 86.11 |
| ICMA 30201 × 561-570 | 24 | 24.6 | 19.11 | 22.6 | 28.7 | 20.6 | 17.88 | 22.4 | 10.44 | 9.67 | 10.04 | 10.05 | 196.67 | 160 | 155 | 170.56 |
| ICMA 30209 × 561-570 | 24.7 | 22.2 | 16.77 | 21.2 | 25 | 19.7 | 16.98 | 20.6 | 10.98 | 10.52 | 10.58 | 10.69 | 116.67 | 35 | 40 | 63.89 |
| ICMA 04999 × 571-580 | 27.1 | 23.6 | 16.48 | 22.4 | 23.7 | 20.2 | 17.46 | 20.5 | 10.81 | 10.92 | 10.62 | 10.78 | 143.33 | 53.33 | 50 | 82.22 |
| ICMA 88004 × 571-580 | 22.6 | 23 | 17.54 | 21 | 23.7 | 18.1 | 15.38 | 19.1 | 9.08 | 8.98 | 8.68 | 8.91 | 123.33 | 46.67 | 48.33 | 72.78 |
| ICMA 93333 × 571-580 | 22.6 | 24.1 | 18.65 | 21.8 | 23.3 | 18.6 | 15.84 | 19.2 | 8.39 | 8.29 | 7.99 | 8.22 | 120 | 70 | 58.33 | 82.78 |
| ICMA 97111 × 571-580 | 25.5 | 22.9 | 17.45 | 22 | 24.3 | 17.3 | 14.51 | 18.7 | 10.4 | 10.76 | 10.46 | 10.54 | 126.67 | 26.67 | 23.33 | 58.89 |
| ICMA 97444 × 571-580 | 23.4 | 21.6 | 16.2 | 20.4 | 23.7 | 17 | 14.26 | 18.3 | 9.69 | 9.93 | 9.63 | 9.75 | 126.67 | 66.67 | 50 | 81.11 |
| ICMA 98222 × 571-580 | 22 | 20 | 14.57 | 18.9 | 28.7 | 25.5 | 22.72 | 25.6 | 7.65 | 7.55 | 7.25 | 7.48 | 106.67 | 70 | 63.33 | 80.00 |
| ICMA 10444 × 571-580 | 25.7 | 23.2 | 16.46 | 21.8 | 28.7 | 27.7 | 24.94 | 27.1 | 10.97 | 10.87 | 10.57 | 10.8 | 106.67 | 50 | 45 | 67.22 |
| ICMA 30199 × 571-580 | 21 | 20 | 14.58 | 18.5 | 26 | 25.9 | 23.15 | 25 | 9.55 | 9.45 | 9.15 | 9.38 | 126.67 | 66.67 | 55 | 82.78 |
| ICMA 30200 × 571-580 | 23.5 | 23.4 | 17.95 | 21.6 | 23.7 | 24.3 | 21.53 | 23.2 | 9.78 | 9.91 | 9.61 | 9.77 | 103.33 | 81.67 | 70 | 85.00 |
| ICMA 30201 × 571-580 | 25.6 | 25.5 | 18.7 | 23.3 | 24 | 20.6 | 17.84 | 20.8 | 8.02 | 7.92 | 7.62 | 7.85 | 110 | 50 | 45 | 68.33 |
| ICMA 30209 × 571-580 | 24.5 | 22.6 | 17.14 | 21.4 | 24 | 21.2 | 18.44 | 21.2 | 10.25 | 10.2 | 10.25 | 10.23 | 120 | 40 | 36.67 | 65.56 |
| RHB - 177 (Check-1) | 25.7 | 25.7 | 18.93 | 23.4 | 25 | 16.1 | 10.01 | 17 | 10.24 | 10.14 | 9.84 | 10.07 | 106.67 | 48.33 | 43.33 | 66.11 |
| BHB - 1602 ( Check-2) | 21.3 | 20.1 | 14.65 | 18.7 | 28.7 | 22.2 | 19.41 | 23.4 | 9.98 | 9.97 | 9.67 | 9.87 | 93.33 | 36.67 | 28.33 | 52.78 |
| HHB-67 Improved (Check-3) | 25.8 | 23 | 17.52 | 22.1 | 30 | 27.6 | 24.83 | 27.5 | 10.01 | 9.91 | 9.61 | 9.84 | 133.33 | 53.33 | 31.67 | 72.78 |

## Appendix - V

| Mean value of all the crosses/hybrids for Dry stover yield per plant, Grain yield per plant, Harvest index, Threshing index. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| crosses/hybrids | Dry stover yield per plant (g) | | | | Grain yield per plant (g) | | | | Harvest index (%) | | | | Threshing index (%) | | | |
| | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean |
| ICMA 04999 × 481-500 | 246.67 | 150 | 96.67 | 164.45 | 66.67 | 35 | 21.33 | 41.00 | 27.12 | 23.25 | 41.67 | 30.68 | 61.21 | 55.56 | 51.08 | 55.95 |
| ICMA 88004 × 481-500 | 213.33 | 153.33 | 130 | 165.55 | 50 | 41.67 | 28.67 | 40.11 | 23.33 | 27.03 | 23.01 | 24.46 | 47.31 | 51.85 | 44.03 | 47.73 |
| ICMA 93333 × 481-500 | 226.67 | 190 | 166.67 | 194.45 | 36.67 | 40 | 29.67 | 35.45 | 16.16 | 21.85 | 21.98 | 20.00 | 45.77 | 51.79 | 43.97 | 47.18 |
| ICMA 97111 × 481-500 | 166.67 | 130 | 103.33 | 133.33 | 43.33 | 26.67 | 21.33 | 30.44 | 26.36 | 20.39 | 15.27 | 20.67 | 57.94 | 37.9 | 31.54 | 42.46 |
| ICMA 97444 × 481-500 | 263.33 | 60 | 38.33 | 120.55 | 60 | 19.33 | 17.33 | 32.22 | 22.93 | 32.63 | 26.67 | 27.41 | 60.1 | 68.45 | 48.67 | 59.07 |
| ICMA 98222 × 481-500 | 250 | 336.67 | 306.67 | 297.78 | 95 | 82.33 | 61.67 | 79.67 | 38.13 | 25.39 | 62.33 | 41.95 | 68 | 56.16 | 81.47 | 68.54 |
| ICMA 10444 × 481-500 | 80 | 46.67 | 16.67 | 47.78 | 26.67 | 19 | 22.33 | 22.67 | 33.13 | 40.83 | 40.67 | 38.21 | 106.67 | 65.43 | 36.44 | 69.51 |
| ICMA 30199 × 481-500 | 326.67 | 163.33 | 133.33 | 207.78 | 73.33 | 40 | 34.67 | 49.33 | 22.62 | 24.86 | 24.76 | 24.08 | 66.21 | 51.79 | 44.17 | 54.06 |
| ICMA 30200 × 481-500 | 270 | 196.67 | 166.67 | 211.11 | 53.33 | 35 | 24.67 | 37.67 | 19.64 | 18.02 | 15.05 | 17.57 | 40.3 | 53.18 | 35.9 | 43.13 |
| ICMA 30201 × 481-500 | 300 | 380 | 333.33 | 337.78 | 50 | 61.67 | 31.67 | 47.78 | 16.97 | 16.39 | 16.69 | 16.68 | 42.33 | 319.44 | 41.67 | 134.48 |
| ICMA 30209 × 481-500 | 76.67 | 66.67 | 36.67 | 60.00 | 19.33 | 18.67 | 16.67 | 18.22 | 25.24 | 28.25 | 35 | 29.50 | 74.45 | 71.11 | 36.44 | 60.67 |
| ICMA 04999 × 501-510 | 86.67 | 66.67 | 36.67 | 63.34 | 23.33 | 18.33 | 14.67 | 18.78 | 26.93 | 27.38 | 31 | 28.44 | 69.45 | 69.45 | 48.67 | 62.52 |
| ICMA 88004 × 501-510 | 266.67 | 250 | 220 | 245.56 | 83.67 | 77.67 | 42.33 | 67.89 | 31.79 | 31.12 | 56.48 | 39.80 | 64.78 | 59.3 | 71.84 | 65.31 |
| ICMA 93333 × 501-510 | 253.33 | 110 | 80 | 147.78 | 50 | 19 | 11.33 | 26.78 | 19.76 | 17.45 | 15.45 | 17.55 | 56.55 | 53.06 | 47.93 | 52.51 |
| ICMA 97111 × 501-510 | 226.67 | 90 | 60 | 125.56 | 56.67 | 15 | 14.67 | 28.78 | 25.1 | 16.62 | 15.7 | 19.14 | 42.05 | 13.54 | 64.33 | 39.97 |
| ICMA 97444 × 501-510 | 320 | 66.67 | 40 | 142.22 | 41.67 | 10.67 | 10.67 | 21.00 | 13.22 | 16.19 | 38 | 22.47 | 55.87 | 36.51 | 35 | 42.46 |
| ICMA 98222 × 501-510 | 160 | 93.33 | 63.33 | 105.55 | 63.33 | 13.33 | 10.67 | 29.11 | 40.21 | 14.46 | 14.78 | 23.15 | 52.37 | 10.71 | 61.67 | 41.58 |
| ICMA 10444 × 501-510 | 181.67 | 153.33 | 123.33 | 152.78 | 26.67 | 26.67 | 18.67 | 24.00 | 14.75 | 17.35 | 15 | 15.70 | 33.73 | 37.9 | 28.33 | 33.32 |
| ICMA 30199 × 501-510 | 250 | 300 | 276.67 | 275.56 | 43.33 | 30 | 34 | 35.78 | 17.46 | 9.86 | 14.81 | 14.04 | 45.83 | 52.22 | 25.27 | 41.11 |
| ICMA 30200 × 501-510 | 176.67 | 46.67 | 16.67 | 80.00 | 40 | 19.67 | 11.33 | 23.67 | 22.99 | 42.5 | 42.67 | 36.05 | 47.69 | 94.2 | 47.67 | 63.19 |
| ICMA 30201 × 501-510 | 253.33 | 46.67 | 16.67 | 105.56 | 46.67 | 19.33 | 11.33 | 25.78 | 19.05 | 41.67 | 34.67 | 31.80 | 36.84 | 67.52 | 48.67 | 51.01 |
| ICMA 30209 × 501-510 | 273.33 | 46.67 | 16.67 | 112.22 | 60 | 19.33 | 15.33 | 31.55 | 22.36 | 41.67 | 52.67 | 38.90 | 60.1 | 92.32 | 67.67 | 73.36 |
| ICMA 04999 × 511-520 | 220 | 183.33 | 163.33 | 188.89 | 50 | 36.67 | 31.33 | 39.33 | 23.84 | 20.25 | 19.23 | 21.11 | 42.04 | 52.38 | 37.91 | 44.11 |
| ICMA 88004 × 511-520 | 180 | 80 | 50 | 103.33 | 43.33 | 21.67 | 16.33 | 27.11 | 24.48 | 26.59 | 30.37 | 27.15 | 50.53 | 16.58 | 67.67 | 44.93 |
| ICMA 93333 × 511-520 | 226.67 | 113.33 | 83.33 | 141.11 | 43.33 | 29 | 21.33 | 31.22 | 20.17 | 25.67 | 23.91 | 23.25 | 42.5 | 51.33 | 40.18 | 44.67 |
| ICMA 97111 × 511-520 | 163.33 | 46.67 | 16.67 | 75.56 | 50 | 10.67 | 17.33 | 26.00 | 31.43 | 23.33 | 10.67 | 21.81 | 51.85 | 36.51 | 41 | 43.12 |
| ICMA 97444 × 511-520 | 226.67 | 163.33 | 130 | 173.33 | 60 | 40 | 34.67 | 44.89 | 26.39 | 24.4 | 28.51 | 26.43 | 55.1 | 45.65 | 43.36 | 48.04 |

| Mean value of all the crosses/hybrids for Dry stover yield per plant, Grain yield per plant, Harvest index, Threshing index. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **crosses/hybrids** | **Dry stover yield per plant (g)** | | | | **Grain yield per plant (g)** | | | | **Harvest index (%)** | | | | **Threshing index (%)** | | | |
| | **$E_1$** | **$E_2$** | **$E_3$** | **Mean** | **$E_1$** | **$E_2$** | **$E_3$** | **Mean** | **$E_1$** | **$E_2$** | **$E_3$** | **Mean** | **$E_1$** | **$E_2$** | **$E_3$** | **Mean** |
| ICMA 98222 × 511-520 | 196.67 | 50 | 20 | 88.89 | 60 | 19 | 11.33 | 30.11 | 30.44 | 38.61 | 41 | 36.68 | 55.1 | 72.78 | 48.67 | 58.85 |
| ICMA 10444 × 511-520 | 333.33 | 230 | 173.33 | 245.55 | 60 | 50 | 41.67 | 50.56 | 17.97 | 21.69 | 20.93 | 20.20 | 51.67 | 38.38 | 39.85 | 43.30 |
| ICMA 30199 × 511-520 | 510 | 136.67 | 106.67 | 251.11 | 55 | 26.67 | 18.67 | 33.45 | 10.79 | 19.41 | 56.67 | 28.96 | 28.54 | 39.68 | 29.84 | 32.69 |
| ICMA 30200 × 511-520 | 76.67 | 46.67 | 16.67 | 46.67 | 16.67 | 19.33 | 11.33 | 15.78 | 22.02 | 41.67 | 41.67 | 35.12 | 61.11 | 100 | 44.33 | 68.48 |
| ICMA 30201 × 511-520 | 313.33 | 150 | 120 | 194.44 | 63.33 | 46.67 | 41.33 | 50.44 | 20.26 | 31.05 | 32.13 | 27.81 | 30.61 | 61.31 | 55.67 | 49.20 |
| ICMA 30209 × 511-520 | 230 | 106.67 | 76.67 | 137.78 | 63.33 | 35 | 18 | 38.78 | 29.36 | 32.88 | 27.66 | 29.97 | 49.47 | 47.62 | 31.66 | 42.92 |
| ICMA 04999 × 531-540 | 373.33 | 46.67 | 16.67 | 145.56 | 66.67 | 19 | 11.33 | 32.33 | 17.94 | 40.83 | 55.67 | 38.15 | 44.02 | 67.11 | 48.67 | 53.27 |
| ICMA 88004 × 531-540 | 80 | 53.33 | 23.33 | 52.22 | 16.67 | 19.33 | 11.33 | 15.78 | 21.1 | 36.67 | 41.92 | 33.23 | 61.11 | 93.94 | 50.33 | 68.46 |
| ICMA 93333 × 531-540 | 416.67 | 126.67 | 103.33 | 215.56 | 48.33 | 50 | 40 | 46.11 | 11.81 | 39.31 | 33.23 | 28.12 | 34.64 | 60.19 | 47.23 | 47.35 |
| ICMA 97111 × 531-540 | 276.67 | 56.67 | 26.67 | 120.00 | 53.33 | 18.67 | 11.33 | 27.78 | 19.52 | 32.89 | 27.67 | 26.69 | 51.52 | 71.11 | 36.44 | 53.02 |
| ICMA 97444 × 531-540 | 220 | 126.67 | 96.67 | 147.78 | 60 | 30 | 24.67 | 38.22 | 27.56 | 23.74 | 23.17 | 24.82 | 50.23 | 46.82 | 39.98 | 45.68 |
| ICMA 98222 × 531-540 | 180 | 50 | 68.33 | 99.44 | 46.67 | 18.33 | 11.33 | 25.44 | 25.98 | 37.78 | 18.95 | 27.57 | 36.05 | 55.56 | 67.33 | 52.98 |
| ICMA 10444 × 531-540 | 200 | 90 | 66.67 | 118.89 | 53.33 | 18.33 | 11.33 | 27.66 | 26.9 | 20.56 | 22.9 | 23.45 | 53.37 | 55.56 | 32 | 46.98 |
| ICMA 30199 × 531-540 | 276.67 | 120 | 90 | 162.22 | 46.67 | 29 | 21.33 | 32.33 | 16.87 | 24.28 | 20.94 | 20.70 | 51.48 | 72.5 | 34.76 | 52.91 |
| ICMA 30200 × 531-540 | 280 | 170 | 140 | 196.67 | 40 | 25 | 16.33 | 27.11 | 14.2 | 14.63 | 17.54 | 15.46 | 63.06 | 77.78 | 32.22 | 57.69 |
| ICMA 30201 × 531-540 | 243.33 | 240 | 180 | 221.11 | 60 | 29 | 21.33 | 36.78 | 25.1 | 12.17 | 10.76 | 16.01 | 51.28 | 118.33 | 41 | 70.20 |
| ICMA 30209 × 531-540 | 340 | 200 | 170 | 236.67 | 70 | 28.33 | 21.33 | 39.89 | 20.58 | 14.23 | 12.79 | 15.87 | 55.06 | 58.89 | 29.22 | 47.72 |
| ICMA 04999 × 551-560 | 86.67 | 43.33 | 13.33 | 47.78 | 23.33 | 28.33 | 21.33 | 24.33 | 26.85 | 66.67 | 12 | 35.17 | 61.11 | 146.3 | 39 | 82.14 |
| ICMA 88004 × 551-560 | 306.67 | 90 | 60 | 152.22 | 80 | 35 | 29 | 48.00 | 26.17 | 38.8 | 34.64 | 33.20 | 60.73 | 123.61 | 51.9 | 78.75 |
| ICMA 93333 × 551-560 | 423.33 | 146.67 | 116.67 | 228.89 | 94.33 | 38.33 | 31.33 | 54.66 | 22.41 | 26.11 | 26.27 | 24.93 | 54.11 | 27.29 | 69 | 50.13 |
| ICMA 97111 × 551-560 | 106.67 | 50 | 20 | 58.89 | 20.67 | 19.33 | 13 | 17.67 | 19.39 | 38.67 | 58.33 | 38.80 | 57.22 | 100 | 62.33 | 73.18 |
| ICMA 97444 × 551-560 | 80 | 46.67 | 16.67 | 47.78 | 21.67 | 21.67 | 21.33 | 21.56 | 28.09 | 46.67 | 48 | 40.92 | 83.33 | 83.33 | 72 | 79.55 |
| ICMA 98222 × 551-560 | 246.67 | 180 | 150 | 192.22 | 56.67 | 38.33 | 28.67 | 41.22 | 22.94 | 21.34 | 17.84 | 20.71 | 41.9 | 55.56 | 40.84 | 46.10 |
| ICMA 10444 × 551-560 | 226.67 | 180 | 150 | 185.56 | 50 | 20.67 | 20.67 | 30.45 | 22.26 | 11.5 | 16.93 | 16.90 | 48.15 | 53.89 | 45.84 | 49.29 |
| ICMA 30199 × 551-560 | 290 | 160 | 130 | 193.33 | 76.67 | 45 | 28 | 49.89 | 26.91 | 28.27 | 23.44 | 26.21 | 50.54 | 75.87 | 58.16 | 61.52 |
| ICMA 30200 × 551-560 | 216.67 | 46.67 | 16.67 | 93.34 | 43.33 | 19.33 | 20.67 | 27.78 | 19.97 | 41.67 | 37.67 | 33.10 | 46.63 | 93.94 | 27.67 | 56.08 |
| ICMA 30201 × 551-560 | 220 | 170 | 140 | 176.67 | 50 | 31.67 | 24 | 35.22 | 23.25 | 18.67 | 17.11 | 19.68 | 46.89 | 60 | 46.3 | 51.06 |

| Mean value of all the crosses/hybrids for Dry stover yield per plant, Grain yield per plant, Harvest index, Threshing index. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| crosses/hybrids | Dry stover yield per plant (g) | | | | Grain yield per plant (g) | | | | Harvest index (%) | | | | Threshing index (%) | | | |
| | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean | $E_1$ | $E_2$ | $E_3$ | Mean |
| ICMA 30209 × 551-560 | 230 | 113.33 | 80 | 141.11 | 66.67 | 35 | 28 | 43.22 | 28.94 | 31.01 | 28.17 | 29.37 | 53.85 | 66.3 | 49.04 | 56.40 |
| ICMA 04999 × 561-570 | 246.67 | 123.33 | 113.33 | 161.11 | 90 | 31.67 | 25.33 | 49.00 | 36.89 | 26.08 | 38.33 | 33.77 | 64.11 | 83.33 | 60.24 | 69.23 |
| ICMA 88004 × 561-570 | 210 | 113.33 | 180 | 167.78 | 66.67 | 28.33 | 21.33 | 38.78 | 31.62 | 25.28 | 32.59 | 29.83 | 62.21 | 77.78 | 41.67 | 60.55 |
| ICMA 93333 × 561-570 | 253.33 | 130 | 116.67 | 166.67 | 36.67 | 23.33 | 18.67 | 26.22 | 14.86 | 18.53 | 18.79 | 17.39 | 54.76 | 55 | 30.32 | 46.69 |
| ICMA 97111 × 561-570 | 163.33 | 100 | 110 | 124.44 | 46.67 | 21.67 | 19 | 29.11 | 28.43 | 21.99 | 41.75 | 30.72 | 53.7 | 80.56 | 64.67 | 66.31 |
| ICMA 97444 × 561-570 | 343.33 | 83.33 | 60 | 162.22 | 56.67 | 19.33 | 16.67 | 30.89 | 16.85 | 23.57 | 22.05 | 20.82 | 51.77 | 53.33 | 32.94 | 46.01 |
| ICMA 98222 × 561-570 | 276.67 | 240 | 210 | 242.22 | 85 | 21.67 | 20.67 | 42.45 | 31.5 | 9.07 | 5.84 | 15.47 | 71.71 | 16.64 | 74.33 | 54.23 |
| ICMA 10444 × 561-570 | 303.33 | 70 | 40 | 137.78 | 53.33 | 25 | 21.67 | 33.33 | 17.69 | 35.81 | 42.33 | 31.94 | 46.9 | 87.5 | 37.67 | 57.36 |
| ICMA 30199 × 561-570 | 290 | 150 | 120 | 186.67 | 86.67 | 32.33 | 21.33 | 46.78 | 29.9 | 21.74 | 25.19 | 25.61 | 60.69 | 75.83 | 42.73 | 59.75 |
| ICMA 30200 × 561-570 | 233.33 | 120 | 90 | 147.78 | 73.33 | 40.67 | 31.33 | 48.44 | 31.25 | 34 | 41.67 | 35.64 | 60 | 59.05 | 47.63 | 55.56 |
| ICMA 30201 × 561-570 | 316.67 | 330 | 290 | 312.22 | 33.33 | 66.67 | 42.33 | 47.44 | 10.96 | 20.26 | 19.62 | 16.95 | 16.88 | 42.16 | 38.09 | 32.38 |
| ICMA 30209 × 561-570 | 240 | 76.67 | 46.67 | 121.11 | 60 | 28.33 | 21.33 | 36.55 | 24.91 | 36.9 | 39.33 | 33.71 | 51.84 | 82.14 | 49.25 | 61.08 |
| ICMA 04999 × 571-580 | 286.67 | 116.67 | 95 | 166.11 | 70 | 35 | 32.33 | 45.78 | 24.52 | 29.98 | 37.14 | 30.55 | 48.72 | 68.21 | 49.37 | 55.43 |
| ICMA 88004 × 571-580 | 290 | 116.67 | 86.67 | 164.45 | 76.67 | 31.67 | 25.33 | 44.56 | 27.25 | 27.39 | 29.83 | 28.16 | 62.12 | 69.17 | 49.19 | 60.16 |
| ICMA 93333 × 571-580 | 243.33 | 56.67 | 160 | 153.33 | 50 | 41.67 | 31.33 | 41.00 | 20.54 | 73.89 | 20.37 | 38.27 | 41.56 | 62.91 | 73.87 | 59.45 |
| ICMA 97111 × 571-580 | 210 | 66.67 | 90 | 122.22 | 70 | 21.67 | 11.33 | 34.33 | 33.46 | 32.54 | 41.67 | 35.89 | 55.16 | 86.11 | 47.33 | 62.87 |
| ICMA 97444 × 571-580 | 300 | 146.67 | 146.67 | 197.78 | 65 | 51.67 | 45.33 | 54.00 | 21.78 | 36.77 | 41.64 | 33.40 | 51.61 | 82.41 | 49.14 | 61.05 |
| ICMA 98222 × 571-580 | 200 | 123.33 | 93.33 | 138.89 | 46.67 | 34 | 24.67 | 35.11 | 23.5 | 27.95 | 28.85 | 26.77 | 43.94 | 48.75 | 41.58 | 44.76 |
| ICMA 10444 × 571-580 | 256.67 | 106.67 | 63.33 | 142.22 | 50 | 29.33 | 18.67 | 32.67 | 19.51 | 28.14 | 21.86 | 23.17 | 46.86 | 60.33 | 41.06 | 49.42 |
| ICMA 30199 × 571-580 | 280 | 190 | 133.33 | 201.11 | 63.33 | 61.67 | 32.67 | 52.56 | 23.07 | 33.13 | 30.44 | 28.88 | 50 | 94.45 | 23.83 | 56.09 |
| ICMA 30200 × 571-580 | 226.67 | 170 | 150 | 182.22 | 56.67 | 38.33 | 28.67 | 41.22 | 24.97 | 22.87 | 20.83 | 22.89 | 55.15 | 47.17 | 45.07 | 49.13 |
| ICMA 30201 × 571-580 | 220 | 113.33 | 83.33 | 138.89 | 50 | 25 | 20.67 | 31.89 | 22.69 | 21.97 | 18.41 | 21.02 | 45.41 | 50 | 40.76 | 45.39 |
| ICMA 30209 × 571-580 | 303.33 | 80 | 50 | 144.44 | 80 | 25 | 28 | 44.33 | 26.49 | 31.35 | 22.59 | 26.81 | 67.58 | 63.06 | 48.96 | 59.87 |
| RHB - 177 (Check-1) | 213.33 | 106.67 | 76.67 | 132.22 | 50 | 21.67 | 18 | 29.89 | 23.38 | 20.61 | 18.43 | 20.81 | 46.67 | 45.56 | 44.26 | 45.50 |
| BHB - 1602 ( Check-2) | 230 | 76.67 | 50 | 118.89 | 53.33 | 35 | 24.67 | 37.67 | 23.34 | 46.76 | 46.11 | 38.74 | 57.04 | 97.22 | 56.95 | 70.40 |
| HHB-67 Improved (Check-3) | 240 | 120 | 76.67 | 145.56 | 66.67 | 30 | 22 | 39.56 | 27.89 | 24.86 | 20.85 | 24.53 | 50.17 | 55.56 | 39.76 | 48.50 |