GENETICAL STUDIES RELATED TO AGRONOMICAL AND SEED SETTING TRAITS IN SELECTED B-LINES OF PEARL MILLET (*Pennisetum Glaucum*)

THESIS

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Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior

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By

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CERTIFICATE – I

This is to certify that the thesis entitled **"Genetical studies related to agronomical and seed setting traits in selected B-lines of Pearl millet (*Pennisetum glaucum*)"** submitted in partial fulfilment of the requirement of the degree of **Master of Science in Agriculture (Plant Breeding & Genetics)** of the **Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior** is a record of the bonafide research work carried out by **Shri Mahesh Birla** under my guidance and supervision. The subject of the thesis has been approved by Students Advisory Committee and the Director of Instruction.

000588

No part of the thesis has been submitted for any degree or diploma (Certificate/award etc.) or has been published. All the assistance and help received during the course of investigations have been duly acknowledged by him.

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Date : 3/6/13

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Thesis approved by the students advisory committee

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CERTIFICATE – II

This is to certify that the thesis entitled **"Genetical studies related to agronomical and seed setting traits in selected B-lines of Pearl millet (*Pennisetum glaucum*)"** submitted by **Shri Mahesh Birla** to the **Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior** in partial fulfilment of the requirements for the degree of **M.Sc. (Ag.)** in the **Department of Plant Breeding & Genetics, College of Agriculture, Gwalior,** has after evaluation, been approved by the external examiner and by the Students Advisory Committee after an oral examination of same.

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CHAPTER-I
INTRODUCTION

Pearl millet (*Pennisetum glaucum*) belongs to family poaceae (graminae) and genus *Pennisetum*. It is a highly cross-pollinated crop with protogynous nature and wind borne pollination mechanism, which fulfils one of the essential biological requirements for hybrid development. Pearl millet is diploid (2n=14) in nature and is commonly known as bajra, cat tail millet and bulrush millet in different parts of the world.

In India pearl millet occupies fourth position among cereal crops next to rice, wheat and sorghum. In India, pearl millet is grown on about 9.1 million hectares with an annual production of about 7.3 million tones. The average productivity of pearl millet is approximately 780 kg/ha (2010-11). In Madhya Pradesh, the area under pearl millet is about 0.17 million hectares majority of hybrids which produces seed yield approximately 0.25 million tones annually and productivity is approximately 1453 kg/ha (2010-011). Major Pearl millet growing districts in M.P. are Morena, Bhind, Gwalior and part of Shivpuri.

Pearl millet is drought tolerant warm-season cereal crop predominantly grown as a staple food grain and source of feed and fodder. It provides nutritionally superior and staple food for millions of people living in harsh environments characterized by erratic rainfall and poor soil. In fact, Pearl millet is the only suitable and efficient crop for arid and semi-arid conditions because of its efficient utilization of soil moisture and higher level of heat tolerance than sorghum and maize. Farmers prefer the crop as low cost, low risk option by necessity.

Genetical studies provide basic information regarding the genetic properties of the population based on which breeding methods are formulated for further improvement of the crop. These studies are also helpful to know about the nature and extent of variability that can be attributed to different causes, sensitive nature of the crop to environmental influences, heritability of the characters and genetic advance that can be realized in practical breeding. Progress in any crop improvement venture depends mainly on the magnitude of genetic variability and heritability present in the source material. The extent of variability is measured by GCV (Genotypic coefficient of variation) and PCV (Phenotypic coefficient of variation) which provides information about relative amount of variation in different characters. Hence, to have a thorough comprehensive idea, it is necessary to have an analytical assessment of yield components. Since heritability is also influenced by environment, the information on heritability alone may not help in pin pointing characters enforcing selection. Nevertheless, the heritability estimates in conjunction with the predicted genetic advance will be more reliable (Johnson *et al.*, 1955).

It is well known that yield is a polygenic trait and is considerably influenced by environment. It is also an established fact that yield components are governed by relatively less number of genes and less affected by environmental fluctuations. Thus, the selection based on the yield components, rather than yield alone, is more reliable.

Therefore, the knowledge of direct and indirect influence of yield contributing characters on yield is of prime importance to select high yielding genotypes. The correlation and path coefficient analysis, provides information on the relative importance of various yield contributing characters and, thus, increases the efficiency of selection for higher yields based on yield components.

Selection of parents is the pre-requisite for the development of hybrids diversification in seed parent depends upon the variability of maintainer lines (B-line).Therefore the present investigation was aimed with the following objective:

1. To estimate the character variability in B-lines for various traits.
2. To estimate the heritability and genetic gain of the traits.
3. To estimate the correlation coefficient and path of various traits.

CHAPTER-II
REVIEW OF LITERATURE

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

2.1. Variability, heritability and genetic advance

2.2. Correlation analysis

2.3. Path analysis

2.1 Variability, Heritability and Genetic advance:

Tewari (1971) studied seven exotic and indigenous inbreeds and observed highly significant variability for height and number of leafs and branches on the main stem. Heritability was highest for number of leaves on main stem and expected that genetic advance was highest for number of branches on the main stem.

Singh (1974) reported high heritability for number of tillers, grain yield and low heritability for days to 50% flowering. They also reported response to selection high for grain yield and low for tillers number and negative for days to 50% heading.

Results of the analysis presented on *Pennisetum typhoides* revealed that selection should be based on yield/plant, number of fertile tillers and tillers/plant and ear length, all of which showed comparatively high heritability and high genetic advance (Singh, *et al.,* 1979).

Sodani *et al.* (1981) observed that the varieties differed significantly for all the characters except number of tillers/plant, ear girth and 100 grain weight. They further reported that heritability was high for ear length (89.9%) and number of days to flowering (61.7%).

Mukherji *et al.* (1982) reported in 52 inbred of pearl millet, variability, heritability and genetic advance showed high GCA for plant and ear length and genetic advance as percentage of mean. Heritability ranged from 16.21% for effective tillers per plant to 91.44% for ear girth.

Reddy and Sharma (1982) reported that the inbred showed significant variability for days to earing, days to maturity, ear length, ear girth, protein content of grain yield/plant. For these characters high estimates of the broad sense heritability were accompanied with high genetic advance.

Vyas and Srikant (1984) reported that all the 11 agronomic and morphological traits studied in 122 selected landraces on *Pennisetum americanum* showed significant variation among landraces. They also reported that the estimates of heritability and genetic advance were high for tiller number, grain yield and ear length.

Das *et al.* (1986) reported that the heritability of ear girth was high and expected genetic advance in this traits was moderate. It was judge to be the most valuable in indirect selection for higher yield.

Kunjir and Patil (1986) reported that genotypic, phenotypic variability were high for ear length and tiller number. Heritability and genetic advance were high for tiller number, 500 grain weight and plant height indicating additive gene action for these characters.

Ahuja *et al.* (1989) reported that effective tillers/plant and harvest index showed moderate heritability while grain yield and biological yield showed poor heritability.

Tomar *et al.* (1995a) investigated 21 *Pennisetum typhoides* (*Pennisetum glaucum*) genotypes and found wide variation for all characters except spike circumference.

The variability and heritability is derived from data on seven yield related characters in seventeen *Pennisetum glaucum* genotypes. The grain yield showed the widest range of genotypic and phenotypic variation. Heritability estimates were highest for plant height (90.7%) (Saraswathi *et al.* 1995).

Aryana *et al.* (1996) computed the estimates of genetic variability, heritability and genetic advance for grain size, yield and yield contributing characters in 64 genotypes of 8 × 8 full diallel of pearl millet. They reported that the genotypic and phenotypic variability was highest for flag leaf area and plant height and lowest for productive tillers. High estimates of heritability coupled with high genetic advance as recorded for plant height and flag leaf area should be considered as important parameters.

Berwal and Khairwal (1997) data were recorded on days to 50% flowering, plant height, tiller number, stem thickness, leaf length, fodder yield, 500 grain weight and grain yield/plant. Analysis of variance revealed highly significant differences among the entries for all characters indicating adequate genetic variability among the entries.

Harer and Karad (1999) reported that GCV and PCV were higher for number of productive tillers, grain and fodder yield/plant. The PCV were higher than GCV for all the characters studied. High genetic advance combine with high percentage of broad sense heritability were observed for grain yield and plant height.

Yadav *et al.* (1999) observed significant genetic variability among landraces for days to flowering, plant height, panicle length, panicles/plant, grain yield and stover yield. Genetic variance with in landraces was higher. Results suggest that landraces are amenable to further improvement for stover yield and other yield contributing traits.

Kulkarni *et al.* (2000) observed magnitude of phenotypic (PCV) (39.50%) and genotypic coefficient of variation (GCV) (24.83%) were highest for grain yield. Days to 50% flowering recorded (77.48%) heritability estimates. The minimum differences between GCV and PCV for days to 50% flowering, plant height, test weight and grain number/cm^2 indicated less environmental effect and was reflected in the high heritability estimates for these traits.

Berwal *et al.* (2001) observed significant differences among accessions for all the twelve characters studied. The magnitude of both the phenotypic and genotypic coefficients of variation for all the characters was more or less the same. The estimates of heritability in broad sense and genetic advance as percentage of mean were observed to be from high to moderate for all the characters.

Lakshmana and Guggari (2001) studied the magnitude of variation and genetic parameters of 7 quantitative characters in 32 white grain pearl millet genotypes. Grain yield, fodder yield, ear length exhibited high heritability and genetic advance. These characters were of major importance and should be given due weight while making selection programme for the improvement of these characters. High heritability and low genetic advance as per cent mean was observed for days to 50% flowering indicating that it was under the influence of non-additive gene action. High estimates of heritability and genetic coefficient of variability for grain yield, ear length, fodder yield and plant height were observed. Thus, these characters were important for yield improvement in pearl millet.

Sabharwal and Singh (2001) reported that the phenotypic coefficient of variation of the whole collection was higher for the number of productive tillers per plant, dry fodder yield per plant and grain yield per plant.

Sachan and Singh (2001) reported high genetic coefficient of variation (GCV) for grain yield per plant. The high heritability coupled with moderate genetic advance in grain yield per plant revealed the preponderance of the additive and non-additive gene effects for the control of this trait. Moderate heritability with low genetic advance was observed for 1000-grain weight.

Sharma (2002) reported low to moderate estimates of heritability for plant height, tillers per plant, leaves per plant and stem thickness.

Solanki *et al.* (2002a) reported that the genetic and phenotypic coefficients of variation were highest for grain yield and panicle number and lowest for days to 50% flowering across the composites. High estimates of heritability couples with genetic advance were recorded for grain yield and panicle number.

Solanki *et al.* (2002b) observed high phenotypic (PCV) and genotypic coefficient of variation (GCV) for grain yield and panicle surface area. Grain yield, grain number per panicle and 1000-grain weight showed high heritability. The highest genetic gain was recorded for panicle surface area. The expected genetic advance for grain yield per panicle and for grain number per panicle was also high.

Lakshmana *et al.* (2003) observed significant genetic differences in thirty-five genotypes of pearl millet for all the traits under study. High genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and heritability were observed for plant height and earhead weight. High PCV and heritability were observed for number of days to 50% flowering, grain weight per plant and number productive tillers per plant.

Mahawar *et al.* (2003) recorded high heritability (in broad sense) for number of days to heading, plant height, number of tillers per plant and stem thickness. The phenotypic coefficient of variation was generally higher than the genotypic coefficient of variation, indicating the significant effect of the environment on the expression of the characters. The number of days to heading, plant height and number of tillers per plant, which exhibited low to moderate genetic advance and non-additive gene action, can be improved through indirect selection.

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

Unnikrishnan *et al.* (2004a) observed high variability for yield and yield contributing characters in pearlmillet.

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

Varu *et al.* (2005) observed a wide range of genotypic and phenotypic variability for grain yield per plant, ear head girth, effective tillers per plant, ear head length, plant height, days to maturity and days to 50% flowering in 70 genotypes of pearl millet during *kharif* 2001 in Jamnagar. High heritability and high genetic advance were observed for ear head girth, ear head length and plant height, indicating the prevalence of additive gene action.

Costa *et al.* (2006) reported that panicle dry weight offered the largest selection opportunity, with a mean heritability (h^2m) of 0.51 and a response to family selection, in percent of the mean (GSEF%) of 2.60. Straw (stems and leafs) dry weight recorded h2m=0.53 and GSEF%=19.33; total dry weight (stems, leafs and panicles) recorded h2m=0.54 and GSEF%=20.37; average length of panicles recorded h2m=0.69 and GSEF%=12.37 and main grain yield recorded h2m=0.54 and GSEF%=35.32. The h2m (0.06) and GSEF% (1.65) values for number of panicles showed that this characteristic should not be recommended as a selection criteria.

Vidyadhar *et al.* (2006) conducted a study to estimate the heritable variation of yield components in 75 germplasm lines of pearl millet. The analysis of variance revealed significant differences among varietal means for all the characters indicating the presence of adequate variability in the germplasm lines. The maximum variation was recorded for plant height (128.48 cm), ear length (20.2 cm), days to 50% flowering and days to maturity (14). The genotypic coefficient of variation (GCV) was higher for grain yield (48.14 kg), followed by tiller number (31.43) and fodder yield (23.28 kg), indicating that the observed variation was due to genetic influence. The estimates of higher heritability was observed for tiller number (96%) followed by grain yield (95%), days to 50% flowering (88%) and fodder yield (59%), while it was low for days to maturity (17%), plant height (9.8%), ear girth (7.5%) and ear length (5.9%).

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

Govindaraj *et al*. (2010) conducted a study to asses the genetic variability, heritability, and genetic advance for yield and yield contributing characters in twenty one diverse elite lines and cultivars of pearl millet was conductd during 2007 at the Millet Breeding Station, Tamil Nadu Agricultural University, Coimbatore. The phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV). Low, medium and high estimates of broad sense heritability were found in different plant characters under the study.

Sumathi *et al.* (2010) observed 47 pearl millet genotypes to assess the magnitude of variability and to understand the heritable component of variation present in the biometrical characters. The phenotypic coefficient of variation (PCV) was greater than genotypic coefficient of variation (GCV) for all the characters under studied showing the influence of the environmental effect on the characters. High heritability was observed for all the traits under study. High heritability combined with high genetic advance (as per cent of mean) was observed.

2.2 Correlation analysis:

Correlation studies in the F_2 revealed that grain weight/plant was positively correlated with number of tillers/plant and number ear bearing tillers/plant while fodder weight/plant was correlated with plant height, number of ear bearing tillers/plant and grain weight/plant (Yadav 1977).

Mukherji *et al.* (1982) reported that the correlation of grain yield with plant height, ear length, ear girth and test weight was significant and positive. Effective tillers per plant showed a negative non-significant total correlation with yield.

Reddy and Sharma (1982) reported that the yield/plot and per plant were highly correlated. Both these attributes were positively correlated with plant height, tiller/plant, ear/plant, ear length and test weight and negatively correlated with days to earing, days to maturity and protein content.

Kunjir and Patil (1986) reported that tiller number had strong positive correlation with yield.

Rao *et al.* (1987) found that plant height, length, and girth of ear and tiller number were positively and significantly correlated with yield. But days to flowering was negatively correlated with yield and its components. The results are suggestive to develop early maturing, profusely tillering and high yielding varieties with long and thick ears in pearl millet.

Mangat and Satija (1991) observed that head yield was positively correlated with grain yield, with higher correlation coefficient in the medium and small seed size groups. In the low and medium groups, tiller number showed the highest correlation with grain yield.

Bhamre and Harinarayana (1992) reported that grain yield was depended, to varying degrees, on ear girth, ear length and total and effective number of tillers.

Diz *et al.* (1994) reported that phenotypic and genotypic correlation differed in several cases due to large environment variance and covariance. Phenotypically all components were positively and significantly associated with seed yield/plant. Genotypically only seed/panicle and 1000 grain weight were significantly correlated. These two components were also positive correlated to each other indicating that simultaneous improvement of both the components would be feasible, panicles/tiller and seeds/panicle were negatively correlated, the direct effect of these components on seed yield/plant was positive. Phenotypic indirect effects were not as important as genetic indirect effects. The components seed/panicle and 100 seed weight made the greatest contributions to seed yield/plant, both directly and indirectly.

Savery and Prasad (1994) advocated that days to flowering and plant height were positively correlated with grain yield.

Poongodi and Palanisamy (1995) reported that grain yield/plant showed high positive and significant correlation with plant height, ear length, ear girth and total number of tillers.

Tomar *et al.* (1995c) reported that plant girth, length of first internode, effective tillers/plant, spike length and girth and 1000 seed weight exhibited significant and positive correlation with seed yield, both at the phenotypic and genotypic level.

Harer and Karad (1999) reported that grain yield was highly correlated with plant height, 100-grain weight, fodder yield per plant, ear girth and flag leaf area.

Kulkarni *et al.* (2000) observed that flag leaf area, ear length and plant height exhibited significant correlation with grain yield.

Navale *et al.* (2000) reported that plant height, peduncle length and 500 grain weight were significantly correlated with grain yield/plant.

Anarase and Ugale (2001) observed strong positive significant correlation of plant height, ear length and ear girth with grain yield. The number of total tillers per plant and 1000-grain weight were strongly correlated with both grain and fodder yield per plant. These characters were also positively and significantly correlated among themselves.

Pol *et al.* (2001) reported significant correlation of grain yield per plant with plant height, number of total and productive tillers per plant and biomass production per plant.

Pareek (2002) reported that grain yield had positive and significant association with plant height, effective tillers per plant, panicle length and panicle girth.

Chikurte *et al.* (2003) revealed through correlation studies that the panicle length, number of tillers per plant, number of grains per cm^2, test weight and main stem girth were strongly and positively associated with grain yield and among themselves in all the environments.

Thangasamy and Gomathinayagam (2003) in pearl millet, estimated high significant positive correlation of grain yield with plant height, earhead length, earhead girth and productive tillers. The leaf width showed very high positive association with earhead length, earhead girth, and 100-grain weight with grain yield.

Shukla and Parihar (2004) reported substantial correlations between days to 50% flowering and ear length, plant height and stem girth, ear length and leaf length, ear length and leaf width, leaf length and leaf width, leaf width and stover yield, and stem girth and stover yield.

Unnikrishnan *et al.* (2004a) observed highly significant positive correlations for ear girth, ear length, days to 50% flowering, 1000-grain weight and grain yield in 244 pearl millet genotypes.

Yadav *et al.* (2004) observed higher estimated values of genotypic correlation coefficients than their corresponding phenotypic correlation coefficients.

Bortkhataria *et al.* (2005) observed highly significant and positive correlation for earhead girth, number of effective tillers per plant, plant height and 1000-seed weight with grain yield indicating the major role of these characters in grain yield.

Chandolia and Sagar (2005) reported that the grain yield exhibited significant positive association with ear, grain and biomass characters, viz. ear weight per plant, ear girth, 500-grain weight, dry fodder yield per plant, plant height and ear diameter. The very high association of ear weight and 500-grain weight with grain yield and with grain filling rate and also their inter-associations suggest that ear weight and 500-grain weight merit maximum emphasis in selection for improvement of grain filling rate and grain yield in pearl millet.

Patil and Jadeja (2005) reported that grain yield per plant was positively and significantly associated with days to 50% flowering, days to maturity, total number of tillers per plant, total number of productive tillers per plant, ear head weight, test weight and total biomass accumulation per plant, and negatively with ear head length and ear head girth. Days to maturity had shown significant association with most of the characters, indicating the importance of early maturity in crop growth and development and ultimately grain yield under moisture stress condition.

Varu *et al.* (2005) reported effective tillers per plant, followed by ear head length, had the highest significant and positive correlation with grain yield and suggested that selection for these characters may result in yield improvements in pearl millet.

Izge *et al.* (2006) observed strong and significant genotypic and phenotypic correlations between total grain yield with yield/plant, number of tillers/plant, number of leaves/plant, plant height, panicle length and number of seeds/panicle.

Salunke *et al.* (2006) reported that grain yield had a highly significant positive correlation with days to 50% flowering, days to physiological maturity, total number of tillers per plant, number of productive tillers per plant, plant height, ear length, ear girth, 1000-grain weight, dry fodder weight per plant, at both phenotypic and genotypic levels. The difference between genotypic and phenotypic correlation was of lower magnitude, indicating less influence of environment in the expression for traits.

Vidyadhar *et al.* (2006) conducted a correlation study and reported days to 50% flowering was significant and positively correlated with days to maturity (0.484), fodder yield (0.306) and ear length (0.210). The only positive correlation was observed with plant height (0.134), ear girth (0.095) and tiller number (0.057). Grain yield showed positive and significant correlation with tiller number (0.414), ear girth (0.331), ear length (0.254) and plant height (0.201), and these characters showed correlation among themselves except tiller number with ear length (-0.006) and ear girth (-0.044).

Govindaraj *et al.* (2009) reported that the number of productive tillers, panicle length, panicle girth, days to maturity, 100-grain weight were most important traits for maximizing grain yield in pearl millet owing to their high significant positive association with grain yield.

Vagadiya *et al.* (2010) reported that the characters viz., ear head weight, number of nodes per plant and plant height exhibited significant positive correlation with grain yield, which indicated major role of these traits in contribution of grain yield.

2.3 Path analysis:

Gupta *et al.* (1976) reported that the number of tillers/plant and the grain size had the greatest effect on grain yield, and the “earing span” had a large direct effect on the protein content.

Pokhriyal *et al.* (1976) reported that 1000 grain weight, leaf area and seed set had a direct positive effect on the yield and height and days to flowering had a negative effect.

Singh and Singh (1976) reported that days to flower, total tillers number and number of leaves showed a positive direct contribution to grain yield while plant height showed a direct positive contribution through days to flower, total tiller number and number of leaves. Total tiller number contributed most of yield, followed by days to flower.

Mukherji *et al.* (1982) reported that direct effect of effective tillers/plant analysed was highly positive, other important positive direct effects were noticed for plant height and 1000 grain weight. Plant height contributed indirectly on the total correlation of most of the characters with yield.

Reddy and Sharma (1982) advocated that progress in selection for high yielding inbreeds could be made through selection for yield/plant, plant height, tiller/plant and yield/plot. The protein content had negative indirect effect on yield/plot via yield/plant.

Jindla *et al.* (1984) reported that ear weight was the most important characters effecting yield.

Raveendran and Appadurai (1984) reported that 5 yield components viz., grains per unit length of panicle, panicle length and productive tillers/plant contributed positively and directly to grain yield.

Das *et al.* (1986) reported that the highest direct and indirect contribution to yield was those of ear girth, while grain density, ear length and days to flowering made significant indirect contribution acting mainly through ear girth.

Khairwal *et al.* (1990) reported from their studies carried out on path analysis that on both sowing dates (1) Biological yield contributed directly towards grain yield (2) Smut severity had negative and days to 50% heading had very poor effects on grain yield. Findings indicated that early hybrids with high biological yield and resistance to smut would be suitable for high grain yield in pearl millet.

Das and Balakrishnan (1994) reported that leaf number, productive tiller number, node number, and 100 grains weight had positive direct effect on grain yield. Productive tillers had the greatest effect and seven components had negative direct effects.

Poongodi and Palanisamy (1995) reported that the highest positive direct effect on grain yield per plant was exhibited by number of productive tillers followed by ear girth. Plant height, ear length and 1000 grain weight had positive indirect effect through ear girth and the total number of tillers had indirect effect through the number of productive tillers on grain yield.

Anarase and Ugale (2001) reported large and positive direct effects of the number of grains/cm^2, 1000-grain weight and ear girth on grain yield than other characters.

Madhusudhana and Govila (2001) reported that tillers/plant and spike length possess high degree of direct effect on grain yield and moderate direct effect on spike width and grain density. Days to 50% flowering, plant height and 1000-grain weight was significantly correlated with grain yield whereas their direct effect on grain yield was negligible.

Pareek (2002) reported that dry fodder yield had maximum direct effect on grain yield followed by panicle girth and effective tillers per plant. Effective tillers per plant had maximum indirect effect via fodder yield. Days to heading had maximum direct effect on grain yield. Selection of comparatively tall hybrids with high biomass and more effective tillers coupled with greater panicle girth could be a visual selection criterion for selection of high yielding hybrids.

Chikurte *et al.* (2003) concluded on the basis of phenotypic path coefficient analysis that characters viz., panicle length, number of tillers per plant, number of grains per cm^2, test weight and main stem girth, which showed positive and significant correlation with grain yield, also had direct or indirect positive influence on their correlation with grain yield uniformly in all the environments. Therefore, these characters are considered as important components of grain yield and selection for these characters in one environment might improve grain yield for other environments under study.

Thangasamy and Gomathinayagam (2003) reported high positive direct effect of earhead length on grain yield followed by plant height, earhead girth and productive tillers. The 100-grain weight showed high indirect effect through leaf number, plant height and leaf length and the leaf number exhibited high indirect effect on leaf length and earhead length on grain yield..

Unnikrishnan *et al.* (2004a) reported highest direct contribution of ear girth on grain yield followed by ear length, plant height and 1000-grain weight.

Unnikrishnan *et al.* (2004b) on the basis correlation and path analysis concluded that tiller number played a significant role in making the yield followed by 1000-grain weight, ear length and ear girth in pearl millet.

Chandolia and Sagar (2005) reported that the path coefficient analysis identified ear weight as the direct contributor to grain yield and also an indirect channel in influencing the grain yield via ear girth, 500-grain weight, grain filling rate, dry fodder yield, plant height and ear diameter.

Patil and Jadeja (2005) revealed through path coefficient analysis that total numbers of tiller per plant and days to maturity had the highest positive direct effect on grain yield per plant. Days to 50% flowering, plant height and total biomass accumulation per plant had negative direct effect on grain yield per plant.

Izge *et al.* (2006) reported that grain yield/plant, days to 50% flowering and plant height had the highest direct effects on total grain yield. The panicle length and the threshing percentage had the least direct effects on total grain yield. The direct effect of yield/plant was greatly reduced by the negative indirect effects through days to 50% flowering and downy mildew incidence, even though it was not significant. Similarly, the direct effect of plant height was very much influence by the negligible indirect effects of threshing percentage, downy mildew incidence and 100-grain weight. The grain yield/plant, number of seed/panicle, and plant height in this study has been identified as selection criteria for obtaining good parental lines and hybrids in a pearl millet breeding program.

Salunke *et al.* (2006) reported that the number of productive tillers per plant had the highest and positive direct effect on grain yield followed by plant height, 1000-grain weight and ear length. Days to 50% flowering and ear girth showed small and positive direct effect on grain yield. Days to physiological maturity, number of total tillers per plant and dry fodder weight per plant had negative direct effects on grain yield.

Vagadiya *et al.* (2010) reported that number of nodes per plant, ear head length, ear head weight and ear head girth were the most important characters manifesting large direct effects on grain yield. The high association of ear head weight and number of nodes per plant with grain yield and their inter-associations and also their large direct effect on grain yield suggest that ear head weight and number of nodes per plant merit maximum emphasis in selection for improvement of grain yield in pearl millet.

CHAPTER-III

MATERIALS AND METHODS

The present investigation was undertaken at the Research Farm, College of Agriculture, Gwalior in kharif season 2011-12. The geographical situation of the experimental site is as under:

Altitude	:	211.51 m
Latitude	:	26°13' N
Longitude	:	78°14' E

Experimental material:

The experimental material used in the present study comprised of twenty eight B-lines of Pearl millet.

The experiment was laid down in a randomized block design with two replications. Each entry was sown in single row of 5 m length adopting a row spacing of 50 cm. The material was planted on 27th July, 2012. All recommended package of practices were followed during the conduct of experiment.

Observations recorded:

Observations were recorded on five plants at random basis. The observations were recorded on days to flowering initiation, inter node length, plant height, maximum panicle thickness, panicle length, number of tillers per plant, 4th leaf length, maximum width of 4th leaf, pollen weight per panicle at blooming stage, seed setting, seed density/cm^2, 1000 seed weight, head yield and seed yield per plant.

1. Days to flowering initiation:

Days taken from planting to first flower initiation were counted as days to initiation of flowering.

2. Internode length (cm):

Length of Internode of the five randomly tagged plants were measured with the help of scale and averaged.

3. Plant height (cm):

Length of main tiller from ground to the tip of the panicle was measured in centimeters.

4. Maximum panicle thickness (cm):

The middle girth of panicle of five randomly selected plants was recorded with the help of Vernier callipers in centimetres and averaged.

5. Panicle length (cm):

The length was measured in centimeters from the base to the tip of the panicle.

6. Number of tillers per plant:

Number of tillers of five randomly selected plants were counted and averaged.

7. 4th leaf length (cm):

The length of the 4^{th} leaf of the five randomly selected plants was recorded and averaged.

8. Maximum width of 4th leaf:

The middle width of the 4^{th} leaf of the five randomly selected plants was recorded and averaged.

9. Pollen weight per panicle (gm):

The pollens dehisced from the anthers of a hand were collected at the time of full bloom and weighed from five randomly selected plants and averaged.

10. Seed setting (%):

Randomly selected ten plants were selfed at the time of initiation of flowering and at the time of maturity the observation of seed setting is recorded on anualy.

11. Seed density/cm^2:

The number of total seeds in a 1 cm^2 area of head were counted and recorded.

12. 1000 seed weight:

One thousand seed lot of from plot were taken at random and then counted and weighed.

13. Seed yield per plant (g):

Grains obtained by threshing the panicles of ten randomly tagged plants of each plot separately. These were sun dried completely and then weighted for yield per plant recorded.

14. Head yield per plant (g):

The head yield of five tagged plants was weighted in grams and averaged.

Statistical procedures:

(i) Analysis of variance:

Data were analysed by method outlined by Panse and Sukhatme (1954) using the mean values of five randomly selected plants in each treatment for each replication. The model of analysis of variance table is given below:

ANOVA table for the design of experiment:

Source	**Degree of freedom**	**Mean sum of squares**	**Variance ratio**
Replication	(r-1)	M_r	M_r/M_e
Treatment	(t-1)	M_t	M_t/M_e
Error	(r-1) (t-1)	M_e	-
Total	rt-1	-	-

where, r = Number of replications

t = Number of treatments

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

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

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

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

where,

PCV = Phenotypic coefficient of variation

GCV = Genotypic coefficient of variation

(iii) Estimation of heritability and genetic advance:

Heritability:

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

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

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

Phenotypic variance = Genotypic variance + M_e

where,

M_t = Treatment mean sum of square

M_e = Error mean sum of square

r = Number of replications

Genetic advance:

The estimates of expected genetic advance from selection, G(s), was obtained by the formula suggested by Robinson, Comstock, and Harvey (1949).

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

where,

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

h^2 = Heritability in broad sense,

σ_p = Phenotypic standard deviation

(iv) Estimation of correlations:

Phenotypic, genotypic and environmental correlation coefficients between characters were computed utilizing respective components of variance and co-variance, by following formula suggested by Miller *et al.* (1958).

$$r_{xy} = \frac{Cov._{x,y}}{\sqrt{V_x \times V_y}}$$

where,

r_{xy} = Correlation coefficient between character x and y,

$Cov_{x,y}$ = Co-variance of character x and y,

V_x = Variance of character x, and

V_y = Variance of character y.

To test the significance of phenotypic and environmental correlation coefficients, the estimated values were compared with the tabulated values of Fisher and Yates (1938) at n-2 d.f. at two levels of probability, viz., 5% and 1%.

(v) Path coefficient analysis:

The proportion of direct and indirect contributions of various characteristics to the total correlation coefficients with grain yield per plant, was estimated through path coefficient analysis as suggested by Wright (1921, 1934) and elaborated by Dewey and Lu (1959).

Path coefficient is a standardized partial regression, which measures the direct influence of one variable upon another and allows partition of correlation coefficient into components of direct and indirect effects.

To estimate various direct and indirect effects, the following set of simultaneous equations were formed and solved.

$r_{1y} = P_{1y} + r_{12}P_{2y} + r_{13}P_{3y} + \ldots + r_{1l}P_{ly}$

$r_{2y} = r_{2y}P_{1y} + P_{2y} + r_{23}P_{3y} + \ldots + r_{2l}P_{ly}$

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$r_{ly} = r_{l1}P_{1y} + r_{l2}P_{2y} + r_{l3}P_{3y} + \ldots + P_{ly}$

where,

r_{1y} to r_{ly} = Coefficient of correlation between causal factor 1 to l and dependent character y,

r_{12} to $r_{l-1,l}$ = Coefficient of correlation among causal factors themselves, and

P_{1y} to P_{ly} = Direct effects of characters 1 to l on character y.

Residual effect, which measures the contribution of the characters not considered in the causal scheme, was obtained as:

Residual effect (P_{RY}) = $\sqrt{1 - R^2}$

where,

$$R^2 = \sum_{iy} P_{iy}^2 + 2\sum_{\substack{i \neq j \\ i > j}} P_{iy} P_{jy} r_{ij}$$

CHAPTER IV
RESULTS

The results of the present study are reported in this chapter under the following headings:

1. Analysis of variance
2. Mean and range
3. Phenotypic and genotypic coefficient of variation
4. Heritability (broad sense)
5. Genetic advance
6. Correlation studies
7. Path analysis

1. Analysis of variance:

Analysis of variance (Table 4.1) showed highly significant differences among the B- lines for days to flowering initiation, inter node length, plant height, maximum panicle thickness, panicle length, number of tillers per plant, 4th leaf length, maximum width of 4th leaf, pollen weight per panicle, seed setting, seed density/cm^2, 1000 seed weight, seed yield per plant and head yield per plant indicating the presence of considerable variability among the B- lines and justifying the selection of the material for the present investigation.

2. Mean and Range:

The estimate of mean and range for all the 14characters (Table 4.2) have shown a wide range of variation among the B- lines. The variation was almost uniform on both sides of mean indicating normal distribution of the B-lines.

The range of various characters showed that plant height was the most variable ranging from 83.25 to 129.65 cm followed by head yield per plant (59.35 to 91.75 g), seed yield per plant (27.75 to 58.35 g), days to flowering initiation

(41.95 to 71.15 days), 4th leaf length (45.8 to 68.35 cm), panicle length (17.55 to 29.50 cm), seed density/cm^2 (16.8 to 25.58), seed setting (89.80 to 98.10%), inter node length (9.62 to 17.15 cm), 1000 seed weight (6.65 to 9.45 g), maximum panicle thickness (3.15 to 4.90 cm), number of tillers per plant (1.25 to 2.45), maximum width of 4th leaf (3.05 to 3.95 cm) and pollen weight per panicle (0.17 to 0.36 g).

3. Phenotypic and genotypic coefficient of variation:

The estimates of phenotypic and genotypic coefficient of variation are presented in table 4.2. The highest genotypic coefficient of variation (GCV) of 28.31 per cent was observed for the pollen weight per panicle followed by seed yield per plant (22.01%). The character number of tillers per plant recorded the moderate GCV of 15.71 per cent followed by inter node length (15.31%), panicle length (14.73%), days to flowering initiation (14.46%), head yield per plant (12.08%), plant height (11.27%), 4th leaf length (11.00%), seed density/cm^2 (10.54%), maximum panicle thickness (10.47%) and 1000 seed weight (10.25%). The characters like seed setting and maximum width of 4th leaf recorded the low GCV. Phenotypic coefficient of variation (PCV) exhibited almost similar trend, with pollen weight per panicle recorded the maximum PCV of 29.29 per cent followed by seed yield per plant (22.17%). The character seed setting recorded the minimum PCV of 2.70 per cent followed by maximum width of 4th leaf (7.76%). Rest of studied characters recorded moderate PCV.

Differences between PCV and GCV estimates were observed least for all the characters. However, the maximum difference of 1.25 between PCV and GCV estimates was observed for maximum width of 4th leaf followed by number of tillers per plant (1.07).

4. Heritability (broad sense):

The estimates of heritability in broad sense are reported in Table 4.2. The estimates of heritability in broad sense were high for all the characters. It ranged from 70.40% (maximum width of 4th leaf) to 99.40% (days to flowering initiation).

5. Genetic advance:

The genetic advance as per cent of mean ranged from 4.43 to 54.17 per cent (Table 4.2). The maximum genetic advance as per cent of mean (54.17%) was recorded by pollen weight per panicle while minimum (4.43%) by seed setting.

Table 4.1: Analysis of variance for 14 characters in selected B-lines of Pearl millet

S. No.	Characters	Mean sum of squares		
		Replication	Genotypes	error
1.	Days to flowering initiation	0.0156	136.0405**	0.4305
2.	Inter node length (cm)	0.3232	7.8327**	0.1967
3.	Plant height (cm)	5.0625	278.8727**	8.1273
4.	Maximum panicle thickness (cm)	0.7545**	0.3674**	0.0237
5.	Panicle length (cm)	0.1836	26.1613**	0.2484
6.	Number of tillers/plant	0.0401	0.1595**	0.01055
7.	4^{th} leaf length (cm)	2.6406**	73.6169**	0.3003
8.	Maximum width of 4^{th} leaf (cm)	0.1501*	0.1247**	0.02166
9.	Pollen weight/panicle (g)	0.002451	0.09257**	0.003163
10.	Seed setting (%)	1.9062	11.7257**	1.3333
11.	Seed density/cm^2	0.03516	9.0697**	0.1311
12.	1000 seed weight (g)	0.2324*	1.4056**	0.04137
13.	Seed yield/plant (g)	5.1406	175.2728**	1.3106
14.	Head yield/plant (g)	4.3750	169.9363**	7.7292

* Significant at p=0.05, ** Significant at p=0.01

The characters, seed yield per plant, inter node length, number of tillers per plant, panicle length, days to flowering initiation, head yield per plant, 4th leaf length, plant height, seed density/cm^2, 1000 seed weight and maximum panicle thickness, the value being 45.01, 30.78, 30.46, 30.03, 29.69, 23.78, 22.57, 22.55, 21.39, 20.50 and 20.20 per cent, respectively. The lowest genetic advance as per cent of mean, 4.43 per cent, was recorded by seed setting while moderate genetic advance as per cent of mean, 11.17 per cent, was recorded by maximum width of 4th leaf.

Table 4.2: Estimates of various parameters of genetic variability for different traits in selected B-lines of Pearl millet

S. No	Characters	Mean	Range	PCV (%)	GCV (%)	Heritability (Broad sense) (%)	Genetic advance	Genetic advance as % of mean
1	Days to flowering initiation	56.95	41.95-71.15	14.51	14.46	99.40	16.91	29.69
2	Inter node length (cm)	12.77	9.62-17.15	15.69	15.31	95.10	3.93	30.78
3	Plant height (cm)	103.26	83.25-129.65	11.60	11.27	94.30	23.28	22.55
4	Maximum panicle thickness (cm)	3.96	3.15-4.90	11.17	10.47	87.90	0.80	20.20
5	Panicle length (cm)	24.44	17.55-29.50	14.87	14.73	98.10	7.34	30.03
6	Number of tillers/plant	1.74	1.25-2.45	16.78	15.71	87.60	0.53	30.46
7	4^{th} leaf length (cm)	55.03	45.8-68.35	11.05	11.00	99.20	12.42	22.57
8	Maximum width of 4^{th} leaf (cm)	3.49	3.05-3.95	7.76	6.51	70.40	0.39	11.17
9	Pollen weight/panicle (g)	0.24	0.17-0.36	29.29	28.31	93.40	0.13	54.17
10	Seed setting (%)	94.57	89.8-98.10	2.70	2.41	79.60	4.19	4.43
11	Seed density/cm^2	20.06	16.8-25.58	10.69	10.54	97.10	4.29	21.39
12	1000 seed weight (g)	8.05	6.65-9.45	10.56	10.25	94.30	1.65	20.50
13	Seed yield/plant (g)	42.37	27.75-58.35	22.17	22.01	98.50	19.07	45.01
14	Head yield/plant (g)	74.56	59.35-91.75	12.64	12.08	91.30	17.73	23.78

6. Correlation studies:

Phenotypic, genotypic and environmental correlation coefficients between seed yield per plant and contributing characters and among contributing characters were calculated and presented in Table 4.3, 4.4 and 4.5, respectively. Correlation studies showed that for most character pairs, genotypic and phenotypic associations were in same direction and the genotypic estimates were higher than the phenotypic ones, indicating an inherited association between the characters.

(i) Phenotypic correlation:

Association with seed yield per plant

It is evident from Table 4.3 that seed yield per plant showed highly significant and positive correlation with days to flowering initiation, plant height, maximum panicle thickness, panicle length and head yield per plant while significant and negative one with pollen weight per panicle.

Association among contributing traits

Days to flowering initiation showed positive association with plant height, maximum panicle thickness, panicle length, 4th leaf length and head yield per plant and negative one with pollen weight per panicle.

Internode length exhibited positive association with plant height, 4th leaf length and pollen weight per panicle and negative with 1000 seed weight.

Plant height had positive correlation with days to flowering initiation, inter node length, maximum panicle thickness, panicle length, 4th leaf length, seed setting and head yield per plant.

Maximum panicle thickness showed positive correlation with days to flowering initiation, plant height, panicle length, 4th leaf length and head yield per plant while negative with pollen weight per panicle.

Panicle length showed strong positive correlation with days to flowering initiation, plant height, maximum panicle thickness and head yield per plant.

4th leaf length exhibited positive association with days to flowering initiation, inter node length, plant height, maximum panicle thickness and seed setting.

Pollen weight per panicle had positive correlation with inter node length and seed density/cm^2. However, its associations with days to flowering initiation, maximum panicle thickness, 1000 seed weight and head yield per plant were negative.

Seed setting showed positive association with plant height and 4th leaf length and seed density/cm^2 showed positive association with pollen weight per panicle.

1000 seed weight exhibited negative association with internode length and pollen weight per panicle.

Seed yield per plant had positive correlation with days to flowering initiation, plant height, maximum panicle thickness and panicle length. However, its association with pollen weight per panicle was negative.

(ii) Genotypic correlation coefficients:

With seed yield per plant

The seed yield per plant exhibited positive association with days to flowering initiation, plant height, maximum panicle thickness, panicle length and head yield per plant and negative with pollen weight per panicle.

Among contributing traits

Days to flowering initiation showed positive correlation with plant height, maximum panicle thickness, panicle length, 4th leaf length and head yield per plant while negative with pollen weight per panicle.

Inter node length had positive correlation with plant height, 4th leaf length and pollen weight per panicle while negative one with pollen weight per panicle.

Plant height showed positive correlation with days to flowering initiation, inter node length, maximum panicle thickness, panicle length, 4th leaf length, seed setting and head yield per plant.

Maximum panicle thickness had positive correlation with days to flowering initiation, plant height, panicle length, 4th leaf length, 1000 seed weight and head yield per plant while negative with pollen weight per panicle.

Panicle length had positive correlation with days to flowering initiation, plant height, maximum panicle thickness and head yield per plant.

4th leaf length exhibited positive association with days to flowering initiation, inter node length, plant height, maximum panicle thickness and seed setting.

Pollen weight per panicle had positive correlation with internode length and seed density/cm2 while negative one with days to flowering initiation, maximum panicle thickness, 1000 seed weight and head yield per plant.

Seed setting showed positive association with plant height and 4th leaf length.

Seed density/cm^2 showed positive association with pollen weight per panicle while negative with 1000 seed weight.

1000 seed weight exhibited positive association with maximum panicle thickness while negative with inter node length, pollen weight per panicle and seed density/cm^2.

Seed yield per plant showed positive association with days to flowering initiation, plant height, maximum panicle thickness and panicle length while negative with pollen weight per panicle.

(iii) Environmental correlation coefficients:

With seed yield per plant

Seed yield per plant exhibited positive association with days to flowering initiation, inter node length, maximum panicle thickness, panicle length and head yield per plant while negative with 4th leaf length and seed setting.

Among contributing traits

Internode length had positive correlation with plant height, maximum panicle thickness, panicle length and head yield per plant while negative one with 4th leaf length.

Plant heights showed positive association with inter node length and panicle length while negative with 4th leaf length.

Maximum panicle thickness had positive correlation with inter node length, panicle length and head yield per plant.

Panicle length showed positive association with inter node length, plant height, maximum panicle thickness and head yield per plant and negative with 4th leaf length.

Number of tillers per plant exhibited positive correlation with maximum width of 4th leaf and pollen weight per panicle.

4th leaf length had positive correlation with seed setting while negative one with internode length, plant height and panicle length.

Maximum width of 4th leaf showed positive correlation with number of tillers per plant, pollen weight per panicle and seed density/cm^2.

Pollen weight per panicle had positive correlation with number of tillers per plant and maximum width of 4th leaf.

Seed setting showed positive association with 4th leaf length.

Seed density/cm^2 exhibited positive association with maximum width of 4th leaf.

Head yield per plant showed positive association with inter node length, maximum panicle thickness and panicle length.

Table 4.3: Estimates of phenotypic correlation coefficients

Characters	INL	PH	MPT	PL	NT	LL	MWL	PW	SS	SD	TW	HY	Seed yield/ plant
Days to flowering initiation (DFI)	0.045	0.534**	0.537**	0.648**	0.240	0.266*	-0.093	-0.320*	0.042	0.102	0.102	0.472**	0.521**
Inter node length (INL)		0.365**	0.008	0.230	-0.241	0.364**	0.066	0.375**	0.225	0.026	-0.310*	0.124	0.082
Plant height (PH)			0.425**	0.495**	0.218	0.760**	0.158	0.033	0.301*	0.061	-0.080	0.347**	0.391**
Maximum panicle thickness (MPT)				0.430**	0.016	0.268*	0.023	-0.51**	0.171	-0.076	0.260	0.467**	0.457**
Panicle length (PL)					0.128	0.152	0.010	-0.149	0.073	0.008	-0.193	0.816**	0.871**
Number of tillers/plant (NT)						0.144	0.083	-0.100	0.007	-0.001	0.049	0.227	0.110
4th leaf length (LL)							0.093	0.157	0.299*	0.208	-0.176	0.022	0.048
Maximum width of 4th leaf (MWL)								0.126	0.203	0.004	-0.025	-0.119	-0.131
Pollen weight/panicle (PW)									0.128	0.317*	-0.35**	-0.338*	-0.297*
Seed setting (SS)										0.155	0.073	0.044	0.034
Seed density/cm^2 (SD)											-0.264	-0.076	-0.054
1000 seed weight (g) (TW)												-0.051	-0.185
Head yield/plant (g) (HY)													0.932**

* - Significant at p =0.05 ** - Significant at p = 0.01

Table 4.4: Estimates of genotypic correlation coefficients

Characters	INL	PH	MPT	PL	NT	LL	MWL	PW	SS	SD	TW	HY	Seed yield/ plant
Days to flowering initiation (DFI)	0.042	0.555	0.571	0.656	0.251	0.267	-0.114	-0.334	0.049	0.104	0.106	0.496	0.524
Inter node length (INL)		0.368	-0.020	0.221	-0.262	0.383	0.058	0.385	0.252	0.023	-0.334	0.104	0.073
Plant height (PH)			0.450	0.501	0.243	0.797	0.215	0.040	0.350	0.071	-0.082	0.358	0.400
Maximum panicle thickness (MPT)				0.431	0.044	0.288	0.027	-0.568	0.182	-0.082	0.306	0.470	0.473
Panicle length (PL)					0.140	0.159	0.012	-0.164	0.084	0.013	-0.199	0.835	0.874
Number of tillers/plant (NT)						0.159	0.038	-0.152	-0.027	-0.018	0.032	0.242	0.116
4th leaf length (LL)							0.106	0.167	0.323	0.208	-0.179	0.028	0.052
Maximum width of 4th leaf (MWL)								0.108	0.228	-0.030	-0.068	-0.192	-0.149
Pollen weight/panicle (PW)									0.151	0.327	-0.381	-0.380	-0.316
Seed setting (SS)										0.169	0.052	0.063	0.065
Seed density/cm² (SD)											-0.267	-0.069	-0.052
1000 seed weight (g) (TW)												-0.054	-0.186
Head yield/plant (g) (HY)													0.958

Table 4.5: Estimates of environmental correlation coefficients

Characters	INL	PH	MPT	PL	NT	LL	MWL	PW	SS	SD	TW	HY	Seed yield/ plant
Days to flowering initiation (DFI)	0.203	-0.168	0.130	0.032	0.194	0.097	0.072	0.101	-0.031	0.044	-0.037	-0.030	0.293*
Inter node length (INL)		0.312*	0.340*	0.538**	-0.020	-0.366**	0.152	0.216	0.067	0.102	0.118	0.423**	0.397**
Plant height (PH)			0.185	0.390**	-0.037	-0.515**	-0.131	-0.068	-0.020	-0.160	-0.049	0.212	0.212
Maximum panicle thickness (MPT)				0.615**	-0.185	-0.036	0.011	0.022	0.118	-0.064	-0.216	0.451**	0.381**
Panicle length (PL)					-0.047	-0.359**	0.003	0.228	-0.014	-0.206	-0.062	0.642**	0.656**
Number of tillers/plant (NT)						-0.114	0.276*	0.411**	0.181	0.255	0.228	0.104	0.063
4^{th} leaf length (LL)							0.096	-0.151	0.285*	0.250	-0.138	-0.188	-0.310*
Maximum width of 4^{th} leaf (MWL)								0.279*	0.133	0.316*	0.237	0.214	-0.109
Pollen weight/panicle (PW)									-0.015	0.118	0.169	0.173	0.192
Seed setting (SS)										0.076	0.257	-0.070	-0.437**
Seed density/cm^2 (SD)											-0.213	-0.235	-0.161
1000 seed weight (g) (TW)												-0.008	-0.206
Head yield/plant (g) (HY)													0.638**

* - Significant at p =0.05 ** - Significant at p = 0.01

7. Path coefficient analysis:

The path coefficient analysis was carried out at genotypic level, taking seed yield per plant as dependent variable. The direct and indirect effects have been presented in Table 4.6 and reported under:

(a) Direct effect:

Path coefficient analysis revealed that substantial positive direct effect was exerted by head yield per plant (0.902), whereas intersnode length (-0.219) and 1000 seed weight (-0.207) exhibited negligible effect.

(b) Indirect effects:

(i) Days to flowering initiation:

Days to 50% flowering recorded the substantial positive indirect effect of 0.448 *via* head yield per plant.

(ii) Inter node length:

Inter node length recorded negligible indirect effects *via* rest of the traits.

(iii) Plant height:

Positive indirect effect was exerted through head yield per plant (0.323).

(iv) Maximum panicle thickness:

Positive indirect effect was exerted through head yield per plant (0.323).

(v) Panicle length:

Substantial positive indirect effect of 0.753 was exhibited *via* head yield per plant.

(vi) Number of tillers per plant:

Positive indirect effect was exerted through head yield per plant (0.219).

(vii) 4th leaf length:

4th leaf length recorded negligible indirect effects *via* rest of the traits.

(viii) Maximum width of 4th leaf:

Negative indirect effect was exerted through head yield per plant (-0.173).

(ix) Pollen weight per panicle:

Negative indirect effect was exerted through head yield per plant (-0.343).

(x) Seed setting:

Seed setting recorded negligible indirect effects *via* rest of the traits.

(xi) Seed density/cm^2:

Seed density/cm^2 exhibited negligible indirect effects *via* rest of the traits.

(xii) 1000 seed weight:

1000 seed weight exerted negligible indirect effects *via* rest of the traits.

(xiii) Head yield per plant:

Head yield per plant recorded negligible indirect effects *via* rest of the traits.

Table 4.6: Genotypic path

Characters	DFI	INL	PH	MPT	PL	NT	LL	MWL	PW	SS	SD	TW	HY	GCWSY
Days to flowering initiation	**0.075**	-0.009	0.084	0.028	0.022	-0.049	-0.016	0.001	-0.030	0.001	-0.008	-0.022	0.448	0.524
Inter node length	0.003	**-0.219**	0.056	-0.001	0.007	0.051	-0.023	0.000	0.034	0.006	-0.002	0.069	0.093	0.073
Plant height	0.042	-0.081	**0.151**	0.022	0.016	-0.047	-0.049	-0.001	0.004	0.008	-0.006	0.017	0.323	0.400
Maximum panicle thickness	0.043	0.004	0.068	**0.049**	0.014	-0.009	-0.018	0.000	-0.050	0.004	0.006	-0.063	0.424	0.473
Panicle length	0.049	-0.049	0.076	0.021	**0.033**	-0.027	-0.010	0.000	-0.015	0.002	-0.001	0.041	0.753	0.874
Number of tillers/plant	0.019	0.057	0.037	0.002	0.005	**-0.194**	-0.010	0.000	-0.013	-0.001	0.001	-0.007	0.219	0.116
4th leaf length	0.020	-0.084	0.120	0.014	0.005	-0.031	**-0.061**	-0.001	0.015	0.007	-0.016	0.037	0.025	0.052
Maximum width of 4th leaf	-0.009	-0.013	0.032	0.001	0.000	-0.007	-0.006	**-0.006**	0.010	0.005	0.002	0.014	-0.173	-0.149
Pollen weight/panicle	-0.025	-0.084	0.006	-0.028	-0.005	0.029	-0.010	-0.001	**0.089**	0.003	-0.026	0.079	-0.343	-0.316
Seed setting	0.004	-0.055	0.053	0.009	0.003	0.005	-0.020	-0.001	0.013	**0.022**	-0.013	-0.011	0.057	0.065
Seed density/cm^2	0.008	-0.005	0.011	-0.004	0.000	0.003	-0.013	0.000	0.029	0.004	**-0.079**	0.055	-0.062	-0.052
1000 seed weight (g)	0.008	0.073	-0.012	0.015	-0.007	-0.006	0.011	0.000	-0.034	0.001	0.021	**-0.207**	-0.049	-0.186
Head yield/plant	0.037	-0.023	0.054	0.023	0.027	-0.047	-0.002	0.001	-0.034	0.001	0.005	0.011	**0.902**	0.958

DFI=days to flowering initiation, **INL**=inter node length, **PH**=plant height, **MPT**=maximum panicle thickness, **PL**=panicle length, **NT**=number of tillers per plant, **LL**=4th leaf length, **NWL**=maximum width of 4th leaf, **PW**=pollen weight per panicle, **SS**=seed setting, **SD**=seed density/cm^2, **TW**=1000 seed weight, **HY**=head yield per plant, **GCWSY**=genotypic correlation with seed yield per plant

Note: Underlined and bold values denote direct effect

Residual = 0.0082

CHAPTER-V
DISCUSSION

The findings of the present investigation have been interpreted and discussed in this chapter in the light of similar research work carried out by other research workers. The discussion is confined to the relevant topics, viz., variability, heritability, genetic advance, correlation and path coefficient analysis.

Variability:

The analysis of variance revealed highly significant differences among the B- lines for seed yield and component characters indicating considerable genetic variation present in the material under study. This was also evident from values of range for each trait.

The study showed that phenotypic coefficient of variation was higher than genotypic coefficient of variation for all the characters revealing the significant effect of environment. Estimated values of genotypic coefficient of variation were in line with phenotypic coefficient of variation. The maximum phenotypic coefficient of variation was observed for pollen weight per panicle and seed yield per plant which suggested that selection may be effective for these traits. These results were in agreement with the findings of Singh (1974), Harer and Karad (1999), Yadav *et al.* (1999), Kulkarni *et al.* (2000), Sabharwal and Singh (2001), Sachan and Singh (2001, Solanki *et al.* (2002a), Solanki *et al.* (2002b), Unnikrishnan *et al.* (2004a), Varu *et al.* (2005), Vidyadhar *et al.* (2006), Govindaraj *et al.* (2010) and Sumathi *et al.* (2010).

The magnitude of genotypic coefficient of variation suggested that pollen weight per panicle and seed yield per plant which showed high heritability coupled with high genetic advance had better chance for improvement. Maximum width of 4th leaf showed moderate scope. However, traits like maximum width of 4th leaf and seed setting showed the least genotypic coefficient of variation. Hence, there is limited scope for further improvement of these traits.

B-lines selected based on variability studies

The B-lines v19 was found early in days to flowering initiation. Hence, this can be used for developing early flowering varieties. V13 had highest inter node length and can be used for developing this character. Plant height was found to be more for V13 and V12, which can be used for developing taller varieties. For increasing panicle thickness B-lines can be planned with V14, V10 and V11, which were found to be containing highest panicle thickness through present studies. V8, V10 and V7 can be used for increasing panicle length and for increasing number of tillers per plant, B-line V12 can be used which had highest number of tillers per plant in the present studies. Similarly, B- line V28 had highest 4th leaf length; V22, V19, V26, and V5 had highest width of 4th leaf; V24, V25, V27 and V26 had highest pollen weight per panicle; V15, V9, V10, V13 and V14 had highest seed setting; V24 and V9 had highest seed density/cm^2; V5, V9, V14 and V17 had highest 1000 seed weight; V8 and V10 had highest head yield per plant and seed yield per plant and these B-lines can be used for developing respective characters.

Heritability and genetic advance:

Heritability provides the information about the degree of inheritance of a particular character. Broad sense heritability, which is the proportion of genotypic variance to the phenotypic variance, is a useful estimate since selections have to base on the phenotypic values of the characters, which are the results of breeding values and their interplay with environmental values. Traits with high heritability and high desirable correlation would yield correlated response and thus ease the task of the plant breeder.

The high heritability coupled with high genetic advance was observed for days to flowering initiation, plant height, 4th leaf length, head yield per plant and seed yield per plant, which pointed the fact that phenotypic variability for these traits was mainly determined by genetic causes hence simple selection could lead to substantial improvement in these characters.

Selection days to flowering initiation, plant height and head yield per plant would give correlated response since correlation of yield with these traits is significant.

Since heritability estimates are influenced by environment, genetic material and also some other factors hence their utility will be restricted. Thus, heritability in conjunction with genetic advance as percent of mean would give a more reliable index of selection value (Johnson *et al.*, 1995).

High heritability with high genetic advance as percent of mean was recorded for days to flowering initiation, internode length, plant height, maximum panicle thickness, panicle length, number of tillers per plant, 4th leaf length, pollen weight per panicle, seed density/cm^2, 1000 seed weight, head yield per plant and seed yield per plant, which revealed that these traits are governed as additive gene action and selection will be effective. These results are in conformity with the results of Reddy and Sharma (1982), Vyas and Srikant (1984), Kunjir and Patil (1986), Harer and Karad (1999), Lakshmana and Guggari (2001), Solanki *et al.* (2002a), Varu *et al.* (2005), Bhoite *et al.* (2008), Govindaraj *et al.* (2010) and Sumathi *et al.* (2010).

High heritability with low genetic advance was recorded for seed setting revealing prevalence of non-additive gene action and expression of character largely due to environment effects. So to improve this character selection will be less dependable.

High heritability with moderate genetic advance was recorded for maximum width of 4th leaf indicating that the character were less influenced by environment but governed by both additive and non-additive gene action. Hence simple selection is suggested for further improvement in the later generations

From the foregone discussion, it can be concluded that pollen weight per panicle and seed yield per plant recorded high genotypic and phenotypic coefficient of variation, heritability and genetic advance as per cent of mean indicating prevalence of additive gene action in the control of these characters, so simple selection may be effective to improve these characters.

Correlation:

For plant breeders, knowledge of correlation is of paramount significance, since all the biological attributes are the interplay of several genetic factors among themselves and their individual and combined interactions with the environmental factors. The knowledge of correlations supplies information about how important is a particular character, which is not amenable to direct selection, can be made through indirect selection. It also provides information about the correlated response to directional selection to predict genetic advance and thus can be used as selection indices for operating more efficient selection programmes. Correlation could be phenotypic, genotypic or environmental. Phenotypic correlation is between values directly measured on individual and includes genetic and non-genetic effects. Genotypic correlation is between breeding values and amounts for only genetic causes, which could be pleiotrophy, linkage or gene frequency disequilibrium. Environmental correlation is between non-genetic values and arises due to the fact that several observations are affected by the same amount of environment. Therefore, knowledge of the correlations is of great significance.

The association of seed yield/plant with contributing characters as well as correlation among different pairs of contributing characters revealed that genotypic correlation coefficients were higher in magnitude than phenotypic correlation in most of the cases indicating that the environmental influences were not marked enough to alter the degree of association amongst the characters studied.

The estimates of phenotypic correlation coefficient revealed that the seed yield per plant was positively and significantly associated with days to flowering initiation, plant height, maximum panicle thickness, panicle length and head yield per plant. This suggested that these traits could be used as selection indices. Similar association was also reported by Mangat and Satija (1991), Bhamre and Harinarayana (1992), Savery and Prasad (1994), Poongodi and Palanisamy (1995), Harer and Karad (1999), Anarase and Ugale (2001), Pareek (2002), Thangasamy and Gomathinayagam (2003), Shukla and Parihar (2004), Unnikrishnan *et al.* (2004a), Salunke *et al.* (2006), Govindaraj *et al.* (2009) and Vagadiya *et al.* (2010).

Positive correlation of seed yield per plant with days to flowering initiation was undesirable since the farmers prefer short duration genotypes for their suitability owing to various reasons.

This to be broken need and if possible, reversed. Pollen weight per panicle was found negatively correlated with seed yield per plant. Negative correlation of pollen weight per panicle with seed yield per plant is undesirable and need to be broken. Correlation with other yield contributing traits was desirable and improvement in any one or more would ultimately improve yield.

The correlation study further revealed that magnitude of the correlations of the characters, plant height, maximum panicle thickness, panicle length and head yield per plant with seed yield per plant was high. Apart from showing strong correlations with seed yield per plant, these characters also showed positive correlations among themselves. These results indicated that simultaneous improvement of plant height, maximum panicle thickness, panicle length and head yield per plant can be achieved within a short period by selection. Apart from this the heritability study revealed high heritability estimate for plant height, maximum panicle thickness, panicle length and head yield per plant, indicating that indirect selection for seed yield per plant could be achieved through selection of plant height, maximum panicle thickness, panicle length and head yield per plant based on its phenotypes.

Correlation studies at environmental level revealed that days to flowering initiation, internode length, maximum panicle thickness, panicle length and head yield per plant had strong and positive association with seed yield per plant indicating that the environmental factors leading to the high seed yield per plant had resulted in an all around improvement in its component characters days to flowering initiation, inter node length, maximum panicle thickness, panicle length and head yield per plant.

From the foregoing discussion, it may be concluded that among the characters studied, plant height, maximum panicle thickness, panicle length and head yield per plant had positive association with seed yield per plant and also with one another. Thus, these characters should be given due importance while breeding for higher seed yield.

Path analysis:

Estimates of correlation coefficients measure the strength of relationship among different traits. However, these do not contribute any information about the relative contribution to the ultimate correlation *via* other traits. Thus, the cryptic information of association among different traits leads to ambiguity in defining precisely the traits to be used as selection indices. The true picture can be elucidated through the path analysis of ultimate correlation.

The information on the direct and indirect influences of yield components helps in making selection more effective for simultaneous improvement in seed yield and its components.

The results of path analysis based on genotypic correlation coefficient indicated that out of all observed yield components, head yield per plant had positive direct effect on seed yield per plant and also had strong positive correlation with seed yield per plant, indicating their importance in determining the seed yield and therefore, they should be kept in mind while practicing selection aimed at the improvement of seed yield.

The results were in accordance with the findings of Jindla *et al.* (1984), Chandolia and Sagar (2005) and Vagadiya *et al.* (2010).

Days to flowering initiation, plant height, maximum panicle thickness and panicle length had strong positive correlation with seed yield, but its direct effect was negligible. These strong positive correlations were mainly due to their high positive indirect effects through head yield per plant. Similarly pollen weight per panicle had negligible direct effect on seed yield per plant but their negative correlation with seed yield per plant were may be ascribed to the fact that this character had considerable negative indirect effects *via* head yield per plant.

The characters, inter node length, number of tillers per plant, 4th leaf length, maximum width of 4th leaf, seed setting, seed density/cm^2 and 1000 seed weight, which did not exhibit association with seed yield per plant, also did not have direct effect on seed yield per plant.

The results obtained from genotypic correlation coefficient and path analysis indicated that the characters head yield per plant had strong positive correlation and high magnitude of positive direct effects on seed yield. Moreover, the indirect effects of most of the characters *via* head yield per plant were positive and considerable. Hence, it is suggested that while exercising selection for seed yield, more weight age should be given to head yield per plant and since it is an important component influencing the seed yield of Pearl millet.

Residual effect was found to be very low 0.82% indicating there is no more yield components that are contributing towards seed yield per plant.

CHAPTER-VI

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

The experiment was carried out at Research Farm, College of Agriculture, Gwalior in *kharif* season of 2012-13 with 28 B-lines to meet the following objectives:

1. To estimate the character variability in B-lines for various traits.
2. To estimate the heritability and genetic gain of the traits.
3. To estimate the correlation coefficient and path of various traits.

The observations were recorded on days to flowering initiation, inter node length, plant height, maximum panicle thickness, panicle length, number of tillers per plant, 4th leaf length, maximum width of 4th leaf, pollen weight per panicle, seed setting, seed density/cm2, 1000 seed weight, head yield per plant and seed yield per plant. The data on all characters were subjected to statistical analysis and the following conclusions were drawn:

1. Analysis of variances showed highly significant differences for all the traits indicating the presence of considerable variability among the entries.
2. The estimates of population mean were high and range was wide for most of the traits. Trend of variability at genotypic level was similar to that of at phenotypic level for most of the characters. The genotypic coefficient of variation was highest for the pollen weight per panicle and head yield per plant and moderate for all rest of the traits except maximum width of 4th leaf and seed setting.
3. The estimates of heritability in broad sense for all the traits were high.
4. The expected genetic advance as per cent of mean was highest for all the traits except maximum width of 4th leaf and seed setting.
5. Days to flowering initiation, inter node length, plant height, maximum panicle thickness, panicle length, number of tillers per plant, 4th leaf length, pollen weight per panicle, seed density/cm2, 1000 seed weight, head yield per plant and seed yield per plant had high heritability coupled with high genetic advance as per cent of mean.

6. The characters days to flowering initiation, plant height, maximum panicle thickness, panicle length and head yield per plant showed strong positive association with seed yield per plant. Moreover, head yield per plant and panicle length showed high magnitude of positive association. Apart from showing strong correlation with seed yield per plant, these characters also showed positive inter correlation among themselves, indicating the possibility of simultaneous improvement of these traits by selection programme.
7. Path coefficient analysis of genotypic correlation revealed that the character head yield per plant had strong correlation and high magnitude of positive direct effect on seed yield. Further, the indirect effects of most of the other characters *via* head yield per plant were also positive and higher in magnitude.
8. Based on mean performance, the B-lines V-8, V-6, V-10, V-13, V-14, V-24, which possessed the most of desirable characteristics, were identified as superior B-lines and these B-lines can be used in breeding programme.

Suggestions:

On the basis of the results of present study, it can be suggested that direct selection is most effective for head yield per plant. However, to improve yield indirect selection for plant height, maximum panicle thickness and panicle length can also be utilized, as these characters had positive correlation with seed yield and between them.

APPENDIX-I

Mean performance of selected 28 B-lines of Pearl millet for fourteen characters

Lines	DFI	INL	PH	MPT	PL	NT	LL	MWL	PW	SS	SD	TW	HY	SY/P
V1	50.50	11.63	89.00	3.40	19.65	1.60	50.20	3.15	0.18	91.70	17.65	8.85	31.54	62.71
V2	53.95	9.62	94.90	3.90	21.60	2.05	54.90	3.35	0.20	95.10	20.30	7.35	38.60	66.83
V3	49.75	11.52	83.25	3.75	21.65	1.55	50.45	3.80	0.17	91.90	20.80	7.35	38.30	70.93
V4	55.70	11.66	96.15	4.10	24.50	1.35	47.60	3.20	0.19	89.80	18.50	9.00	47.34	79.73
V5	54.50	9.87	91.40	3.35	20.55	2.10	45.95	3.90	0.28	94.55	19.50	9.45	33.21	64.76
V6	57.00	11.35	86.55	4.15	21.60	1.55	45.80	3.35	0.19	93.05	20.30	7.35	36.48	68.86
V7	65.85	9.85	110.95	4.10	28.90	1.80	52.55	3.60	0.18	94.15	18.55	8.20	55.82	84.56
V8	70.16	14.65	106.50	4.25	29.50	2.05	56.65	3.45	0.18	92.65	17.65	7.20	58.35	91.75
V9	69.80	12.01	106.60	4.15	23.90	1.65	56.55	3.35	0.20	97.40	25.55	9.25	39.62	73.97
V10	67.75	11.55	113.60	4.75	29.10	1.75	60.20	3.60	0.17	97.40	23.55	8.60	56.45	89.15
V11	71.15	11.95	119.90	4.75	28.10	2.10	57.40	3.35	0.19	90.10	20.25	7.65	55.05	83.85
V12	65.90	10.00	124.85	4.10	26.90	2.45	62.85	3.60	0.18	94.55	19.40	8.65	41.86	77.35
V13	65.65	17.15	129.65	4.05	28.25	1.55	63.10	3.40	0.20	97.35	18.30	7.25	54.28	83.30
V14	60.30	15.10	107.40	4.90	23.10	1.75	61.90	3.25	0.18	96.40	20.55	9.40	38.58	73.70
V15	51.85	10.81	97.25	4.15	27.85	1.55	50.15	3.35	0.20	98.10	19.65	7.65	53.74	82.60

B-lines	DFI	INL	PH	MPT	PL	NT	LL	MWL	PW	SS	SD	TW	HY	SY/P
V16	59.35	12.95	94.55	3.90	23.25	1.40	51.50	3.25	0.30	95.10	18.60	8.55	37.81	71.92
V17	55.45	11.80	97.50	4.45	26.00	1.70	53.60	3.60	0.20	93.45	16.80	9.40	40.92	74.51
V18	54.00	13.40	92.55	3.60	21.55	2.10	48.90	3.40	0.17	95.90	17.60	8.85	37.27	77.31
V19	41.95	12.80	99.75	3.90	17.55	1.70	53.65	3.90	0.31	96.90	19.55	7.75	27.75	59.35
V20	50.60	13.30	87.15	3.35	29.10	1.65	46.65	3.05	0.29	92.85	21.35	7.15	56.38	86.80
V21	51.65	13.85	108.60	3.90	21.75	1.25	53.25	3.55	0.29	94.90	18.35	8.80	37.58	67.67
V22	51.40	15.45	103.80	4.10	26.85	1.60	50.50	3.95	0.20	96.75	19.50	7.90	42.05	76.74
V23	48.40	14.65	105.80	3.55	25.30	2.05	56.90	3.60	0.32	91.55	21.15	7.65	40.19	79.28
V24	50.25	13.40	97.40	3.15	20.85	1.70	54.70	3.35	0.36	92.55	25.58	6.65	31.62	62.72
V25	69.95	15.85	111.15	3.70	28.40	1.55	60.70	3.70	0.36	95.00	21.25	7.05	34.50	61.55
V26	55.15	15.25	119.65	4.05	27.95	1.65	63.25	3.90	0.34	97.75	21.35	7.15	53.66	83.21
V27	51.00	13.60	109.15	3.65	21.85	2.05	62.60	3.15	0.35	98.05	20.35	7.70	38.65	73.07
V28	45.55	12.45	106.35	3.70	18.65	1.40	68.35	3.55	0.23	93.15	19.85	7.70	28.92	59.59
C.D. (0.05)	1.32	0.89	5.73	0.31	1.00	0.21	1.10	0.30	0.04	2.32	0.73	0.41	2.30	5.59

DFI=days to flowering initiation, **INL**=inter node length, **PH**=plant height, **MPT**=maximum panicle thickness, **PL**=panicle length **NT**=number of tillers per plant, **LL**=4th leaf length, **NWL**=maximum width of 4th leaf, **PW**=pollen weight per panicle, **SS**=seed setting **SD**=seed density/cm^2, **TW**=1000 seed weight, **HY**=head yield per plant, **GCWSY**=genotypic correlation with seed yield per plant SY/P= seed yield per plant

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