Study of D^2-Analysis Related to Some Grain and Fodder Traits in Pearl Millet (*Pennisetum glaucum*)

THESIS

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In

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By

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CERTIFICATE – I

This is to certify that the thesis entitled **"Study of D^2-analysis related to some grain and fodder traits in pearl millet (*Pennisetum glaucum*)"** submitted in partial fulfilment of the requirements of the degree of **Master of Science in Agriculture (Plant Breeding & Genetics)** of the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by **Mr. Pushpendra Singh Bhadauria** under my guidance and supervision. The subject of the thesis has been approved by Student's Advisory Committee and the Director of Instruction.

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

Place : Gwalior
Date :

(A.K. Singh)
Chairman
Advisory Committee

Thesis approved by the Student's Advisory Committee

Chairman	**(A.K. Singh)**	________________
Member	**(Y. M. Indrapurkar)**	________________
Member	**(R.L. Rajput)**	________________
Member	**(M.S. Kakran)**	________________

CERTIFICATE – II

This is to certify that the thesis entitled **“Study of D^2-analysis related to some grain and fodder traits in pearl millet (*Pennisetum glaucum*)”** submitted by **Mr. Pushpendra Singh Bhadauria** to the **J. N. Krishi Vishwa Vidyalaya, Jabalpur** in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture (Plant Breeding & Genetics)** in the **Department of Plant Breeding & Genetics, College of Agriculture, Gwalior** has been, after evaluation, approved by the External Examiner and by the Student’s Advisory Committee after an oral examination of the same.

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VITA

The author of the thesis **Mr. Pushpendra Singh Bhadauria** S/o Shri Jagbir Singh Bhadauria was born on 28^{th} June, 1985.

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After completing graduation he was selected for M.Sc. (Ag.) degree program in Plant Breeding and Genetics and was admitted in College of Agriculture, Gwalior (M.P.). He has passed all the required courses in M.Sc. by obtaining approximately 70 percent marks.

During the entire period of his education, from schooling to post graduation he was very sincere and honest towards his studies.

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CHAPTER-I
INTRODUCTION

Pearl millet is an assured crop of fluctuating environment. Its plant is robust and quick growing cereal with strong leaves and heads. It thrives well on light textured and well-drained soil, but does not tolerate water logging and flooding. Pearl millet is most extensively grown as a cereal in the drier areas of West and South India and along the southern peripheries of the Sahara desert in Africa. It is also grown in the south eastern United States, Australia, South Africa and other regions as a forage and pasture crop.

In India, pearl millet is being grown on about 9.41 million hectares with an annual production of about 7.36 million tonnes. The average productivity of pearl millet is approximately 783 kg/ha (Anonymous 2005-06). In Madhya Pradesh, the area under pearl millet is about 0.18 million hectares which produces seed yield approximately 0.27 million tonnes annually and productivity is 1375 kg/ha (2006-07). The major growing districts in M.P. are Morena, Bhind, Gwalior and part of Shivpuri.

Pearl millet has very high photosynthetic efficiency with wide range of adaptability. Due to these attributes it is assumed to be a very potential species to be manipulated for high grain and fodder production per unit time through appropriate procedures and technologies. Being protogynous in nature this crop is highly cross-pollinated with more than 80% out crossing. Presence of cytoplasmic genetic male sterility and protogyny are the salient features of this species, which have been utilized for commercial exploitation of heterosis and genetic improvement.

The importance of genetic diversity in choosing parents for hybridization has been emphasized by several workers. The utility of Multivariate analysis such as Mahalanobis D^2 statistic for quantifying the degree of divergence between biological populations at genotypic level is well established (Mahalanobis, 1936, Singh and Gupta, 1979, Thete and Bapat, 1986, Ouendeba *et al.* 1999). In economic breeding programme diversity of parents is always emphasized. More diverse the parents better are the chances of improving economic characters under consideration.

Knowledge of genetic divergence among genotypes, amount of variability, extent of heritability and expected genetic advance association between characters, cause and effect relationship are the pre-requisites for precise evaluation and successful utilization of available germplasm for the development of high yielding genotypes.

The ultimate goal of pearl millet improvement is to increase yield potential per unit area. Keeping in view an attempt was made to select potential germplasm suitable for this zone. The existing variability present in the material was studied with the following objectives:

1. To study the amount of variability present among the genotypes for various characters.
2. To estimate the genetic divergence between different genotypes through D^2 statistic.
3. To workout direct and indirect relationships with yield and its components by path coefficient analysis.
4. To estimate heritability and genetic advance for yield and its components.
5. To identify diverse genotypes for hybridization.

CHAPTER-II
REVIEW OF LITERATURE

The literature pertaining to various aspects of the present study has been reviewed under the following heads:

1. Variability, heritability and genetic advance
2. Genetic divergence
3. Correlation
4. Path analysis

1. Variability, heritability and genetic advance:

Tewari (1971) studied seven exotic and indigenous inbred and observed highly significant variability for height and number of leaves and branches on the main stem. Heritability was highest for number of leaves on the main stem and expected 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 that was 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 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 judged 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 data were derived from 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 variabilities were 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) recorded data 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 combined 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 had 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 genotypic 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 coupled 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 were 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.

Bokhataria *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 indicating the role of fixable type of gene effects.

Varu *et al.* (2005) observed a wide range of genotypic and phenotypic variabilities 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 (h2m) 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 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%).

2 Genetic divergence:

Availability of sufficient genetic diversity in the germplasm collection, which the breeder is handling, is the basis of all breeding programmes. The present method of assessing genetic divergence of the varieties is based on geographical and phenotypic divergence. However, these two criteria may not always be the true representative of genetic diversity. Mahalanobis technique of D^2, statistic, which is based on multivariate analysis of quantitative traits, has been developed to measure genetic diversity in a given population in respect of an aggregate of characters.

Mahalanobis (1936) introduced a concept to measure the distance between two populations with differing means but identical dispersion metrics. The distance between the population is known as Mahalanobis' generalized distance or D^2 statistic. Mahalanobis (1936) indicated that "a normal p-variate population usually described by p-dimension frequency distribution can be conveniently represented by a density cluster in p-dimensional space". He introduced the idea of a statistical field in which each point represented the centre of a density cluster belonging to a particular normal population specified by (1) the mean of the characters and (2) the variances and covariances at that particular point in the field, using such a representation Mahalanobis derived a general expression for the distance between two normal populations.

The importance of genetic diversity in choosing parents for hybridization has been stressed by many workers. A knowledge of genetic diversity and its quantitative assessment usually help a plant breeder to select desirable parents for breeding programme.

In pearl millet few studies have been conducted on multivariate analysis.

Murty and Arunachalam (1966) did not find any relationship between genetic and geographic diversity.

Ram and Pawar (1970) reported genetic diversity to be associated with the geographical diversity.

Singh and Gupta (1979) conducted D^2 analysis in 34 strains of pearl millet based on 13 characters. They reported that in environment I where fertilizer was applied was suitable for expressing the diversity between the strains. They found no relationship between geographic and genetic diversity.

Basavararaju *et al.* (1981) suggested that the diversity of interaction in different crosses implies more than one mechanism of resistance.

Rao *et al.* (1982) reported that the genetic diversity to be associated with the geographical diversity.

Kushwaha and Singh (1985) studied the canonical analysis and reported divergence among genotypes included in each cluster. They found variability grouped in canonical analysis was in complete agreement with those which were grouped by D^2 statistic.

Thete and Bapat (1986) conducted D^2 analysis in 45 diverse varieties in pearl millet and showed that there was adequate diversity between strains. Based on D^2 analysis all these strains were grouped into 12 clusters with substantial genetic divergence between them. Clustering pattern of these strains revealed that geographical diversity was not related to genetic diversity. Characters like number of internode, stem girth, leaf length, plant height, length of head, effective tillers, total number of leaves, yield/main shoot and grain yield/plant were potent in contributing to diversity.

Singh *et al.* (1987) conducted D^2 analysis with 50 cultivars of low land rice and reported that genetic diversity was not related to geographical diversity.

Joshi *et al*. (1988) studied canonical analysis in 13 yield components and found that there was no relationship between genetic and geographic diversity.

Singh (1988) examined genetic diversity for 13 quantitative characters involving leaf, tiller, grain and yield characters in *Pennisetum typhoides* and reported presences of considerable diversity among the strains and 13 clusters were identified.

Virk (1988) studied D^2 analysis and showed that there was no relationship between phenotypic diversity and geographic diversity in the expression of heterosis.

Mangat and Virk (1991) studied biological diversity in hybrids and composite in different locations and observed wide diversity among hybrids and populations from the same or different geographic regions. Grouping of hybrids and populations into different clusters was independent of the centre of origin and presence of the same parent hybrids of some male sterile lines tended to have less diversity, while populations exhibited wide diversity.

Singh (1994) studied genetic diversity in 90 durum wheat of indigenous as well as exotic origin and reported that genetic diversity showed no parallelism with geographic diversity.

Yadav (1994) indicated that geographic diversity could not be taken as the sole criterion of genetic diversity.

Hepziba *et al*. (1995) reported that there was no significant association between genetic diversity and geographic diversity. Single plant yield contributed most to the genetic divergence.

Suthamathi and Dorairaj (1995) did not find any relationship between genetic and geographic diversity.

Tomar *et al.* (1995b) studied 21 genotypes for genetic divergence and the genotypes were grouped into four clusters and observed no correlation between genetic diversity and geographical origin.

Berwal and Khairwal (1997) indicated that analysis of variance revealed highly significant differences among the entries for days to 50% flowering, plant height, tiller number, leaf length, fodder yield, 500 grain weight, grain yield, indicating adequate genetic variability among the entries. Based on D^2 statistic, the 42 entries were grouped into 9 clusters.

Katiyar *et al*. (1999) studied genetic diversity and characters associated among 109 male sterile lines. The selection index should be based on number of leaves/plant, leaf width and stem girth for identifying genotype for high yield and on plant height and leaf length for high sugar percentage. These male sterile lines could be used as sources of resistance for various foliar diseases. They further reported on the basis of the clustering analysis that sufficient genetic variability was present among the male sterile lines and could be used in future breeding programmes with various restorer lines having desirable characters and similar time of flowering.

Ouendeba *et al.* (1999) using D^2 analysis reported that all landraces populations were significantly different for one or more of the characters evaluated. Days to flowering, plant height, stem diameter, primary spike length and spike yield/plot were the major sources of diversity among the landrace populations.

Srivastava *et al.* (2002) planned the investigation for molecular characterization of sixteen hybrids along with their parental lines. They observed that the genetic diversity in parental lines was related to yield performance. The hybrids PHB 2107 and PHB 2110 giving high yield performance had very high diversity in respective parents indicating its implication in conventional breeding technique. Diversity at molecular level can be used for choosing parents for attempting new hybrid combinations.

Mahawar *et al.* (2004) carried out studies on genetic divergence to judge the genetic diversity among the 100 genotypes of bajra along with three control cultivars for green fodder yield and its components (days to heading, plant height, tillers per plant, leaves per plant, leaf to stem ratio, and stem thickness). The genotypes were grouped into three clusters. The genotypes of cluster II had higher mean value for days to heading, plant height, green fodder yield per plant and green fodder yield per plot. On the basis of this analysis, genetically diverse genotypes with desirable level of particular characters have been identified and crossing programme has been suggested.

Radhouane (2004) reported that ear length, ear width, ear diameter and plant height were the principal sources of diversity between the accessions. Moreover, it allowed a rather satisfactory regrouping of the same geographical origin of accessions.

3 Correlation:

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 environmental 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 highly 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.

Bokhataria *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.

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).

4. 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 for 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 inbreds 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 were 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 number of productive tillers had the greatest direct effect on grain yield.

Harer and Karad (1998) reported that productive tillers/plant had highest positive direct effects on grain yield, followed by ear length, plant height and ear girth.

Kulkarni *et al.* (2000) reported that ear girth, test and fodder weight, and days to 50% flowering exhibited high correlation coefficients and direct effects in the desired direction and hence were considered important in selecting for high grain yield.

Anarase and Ugale (2001) undertook correlation and path coefficient analyses in 40 different genotypes of pearl millet for the days for 50% flowering, plant height, number of total tillers per plant, number of effective tillers per plant, ear length, ear girth, 1000-grain weight, number of grains/cm^2, fodder yield per plant and grain yield per plant. Path coefficient analyses revealed that direct effects of the number of grains/cm^2, 1000-grain weight and ear girth on grain yield were large and positive.

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 taller 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) worked out correlation and path coefficients in 15 inbreds of pearl millet for 12 characters in four environments. Path coefficient analysis revealed that all the characters except days to 50% flowering showed positive direct effects in two or more environments. Considering both the phenotypic correlation and path coefficient analysis, it is concluded that the panicle length, number of tillers per plant, number of grains per cm^2, test weight and main stem girth showed positive and significant correlation with grain yield and 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) carried out correlation and path co-efficient analysis in twenty-one parents and hundred and ten F1 genotypes in pearl millet for ten characters and reported that the grain yield had high significant positive correlation with plant height, earhead length, earhead girth and productive tillers. The path coefficient study revealed that the earhead length had high positive direct effect 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.

Maman *et al.* (2004) in correlation and path analysis indicated that the number of kernels per panicle and kernel weight were associated with grain yield but in the path analysis, kernel weight was more highly associated with grain yield for grain sorghum than the number of kernels per panicle, Plant breeding and production research to increase pearl millet and grain sorghum yield should consider all yield components, but increased emphasis on kernel weight is merited for grain sorghum.

Unnikrishnan *et al.* (2004a) reported on the basis of correlation and path analysis that in both populations tiller number played a significant role in making the yield followed by 1000-grain weight, ear length and ear girth. It can be concluded that while making further selection tiller number should be given maximum weightage followed by grain weight, ear length and ear girth.

Unnikrishnan *et al.* (2004b) reported that ear girth had the highest direct positive effect on grain yield followed by ear length, plant height and 1000-grain weight.

Yadav *et al.* (2004) suggested the importance of biological yield, plant height and effective tillers, as these traits had positive direct and indirect effects on stover yield.

Bokhataria *et al.* (2005) observed highly significant and positive correlation of 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) identified on the basis of path coefficient analysis that 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. 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) carried out correlation and path coefficient analyses in 72 hybrids of pearl millet under terminal water stress conditions. Path coefficient analysis revealed that under stress condition, total number of tillers 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. Thus, for improving grain yield per plant of pearl millet under stress environments, besides total number of tillers per plant, total number of productive tillers per plant, ear head length, ear head weight, ear head girth and test weight, emphasis should also be given to days to maturity.

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

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.

Ram et al. (2007) reported that tillers per plant were the major yield component, because it had high positive significant association and positive direct effect on green fodder yield.

CHAPTER-III
MATERIALS AND METHODS

The present investigation "Study of D^2-analysis related to some grain and fodder traits in pearl millet (*Pennisetum glaucum*)", was carried out during *kharif* 2008 at Research Farm, College of Agriculture, Gwalior, which is situated between latitude 26°13' N and longitude 78°14' E and at an altitude of 211.51 metres above the mean sea level.

Experimental material:

The experimental material used in the present study comprised two hundred twenty five germplasm lines. The lines were:

Table 3.1: Name of the germplasm

S. No.	Germplasm	S. No.	Germplasm	S. No.	Germplasm
1	IP-2	38	PP29C-4 (Check)	75	IP-281
2	IP-3	39	IP-137	76	IP-283
3	IP-9	40	IP-141	77	IP-284
4	IP-10	41	IP-170	78	IP-276
5	IP-13	42	IP-172	79	IP-285
6	IP-15	43	IP-178	80	IP-286
7	IP-26	44	IP-181	81	IP-289
8	IP-29	45	IP-187	82	IP-290
9	C1J210 (Check)	46	IP-192	83	C3H77-48-33-2 (Check)
10	IP-33	47	IP-197	84	IP-291
11	IP-36	48	IP-212	85	IP-294
12	IP-37	49	IP-215	86	IP-299
13	IP-38	50	IP-220	87	IP-300
14	IP-39	51	IP-225	88	IP-305
15	IP-40	52	IP-226	89	IP-309
16	IP-42	53	IP-228	90	IP-310
17	IP-50	54	IP-231	91	IP-313
18	IP-56	55	IP-236	92	IP-315
19	J2-90C2 (Check)	56	IP-238	93	IP-318
20	IP-53	57	IP-253	94	IP-319
21	IP-55	58	IP-254	95	IP-323
22	IP-57	59	IP-265	96	IP-326
23	IP-61	60	IP-266	97	IP-327
24	IP-63	61	IP-267	98	IP-328
25	IP-79	62	IP-268	99	IP-329
26	IP-87	63	CIJ2405 (Check)	100	IP-331
27	IP-96	64	IP-263	101	IP-333
28	477/1833-2-3 (Check)	65	IP-262	102	IP-334
29	IP-97	66	IP-260	103	IP-335
30	IP-103	67	IP-269	104	IP-336
31	IP-104	68	IP-271	105	IP-338
32	IP-106	69	IP-272	106	IP-339
33	IP-113	70	IP-273	107	IP-343
34	IP-119	71	IP-274	108	IP-344
35	IP-121	72	IP-275	109	IP-345
36	IP-128	73	C2J22-90 (Check)	110	IP-346
37	IP-129	74	IP-278	111	IP-349

S. No.	Germplasm	S. No.	Germplasm	S. No.	Germplasm
112	IP-352	150	IP-475	188	C1 (Check)
113	PP-29-C-4 (Check)	151	IP-476	189	IP-556
114	IP-353	152	IP-478	190	IP-558
115	IP-355	153	C3 (Check)	191	IP-559
116	IP-358	154	IP-477	192	IP-561
117	IP-363	155	IP-480	193	IP-563
118	IP-364	156	IP-479	194	IP-564
119	IP-365	157	IP-482	195	IP-565
120	IP-366	158	IP-485	196	IP-569
121	IP-368	159	IP-486	197	IP-572
122	IP-371	160	IP-487	198	C2 (Check)
123	C4 (Check)	161	IP-488	199	IP-574
124	IP-373	162	IP-489	200	IP-575
125	IP-374	163	C2 (Check)	201	IP-579
126	IP-376	164	IP-493	202	IP-590
127	IP-378	165	IP-498	203	IP-592
128	IP-379	166	IP-500	204	IP-602
129	IP-382	167	IP-501	205	IP-604
130	IP-388	168	IP-504	206	IP-630
131	IP-389	169	IP-505	207	IP-642
132	IP-395	170	IP-509	208	C3 (Check)
133	IP-396	171	IP-512	209	IP-646
134	IP-399	172	IP-510	210	IP-647
135	IP-410	173	IP-515	211	IP-651
136	IP-405	174	IP-517	212	IP-682
137	IP-413	175	IP-525	213	IP-700
138	IP-415	176	IP-531	214	IP-709
139	IP-416	177	IP-534	215	IP-718
140	IP-419	178	C1 (Check)	216	IP-724
141	IP-420	179	IP-540	217	IP-734
142	IP-422	180	IP-541	218	IP-737
143	IP-426	181	IP-543	219	IP-743
144	IP-427	182	IP-544	220	IP-747
145	IP-428	183	IP-545	221	IP-750
146	IP-429	184	IP-549	222	IP-753
147	IP-434	185	IP-550	223	IP-755
148	IP-470	186	IP-551	224	IP-758
149	IP-469	187	IP-553	225	IP-760

The experiment was laid down in a randomized block design with two replications. Each entry was sown in two rows of 5 m length adopting a row spacing of 75 cm. The material was planted on 29/7/2008. All recommended package of practices were followed during the conduct of experiment.

Observations recorded:

Observations were recorded on 10 plants basis. The observations were recorded on days to 50% flowering, days to maturity, plant height, number of effective tillers per plant, number of heads per plant, flag leaf length, panicle length, main stem diameter, panicle weight per plant, panicle index per plant and seed weight per plant.

1. Days to 50% flowering:

The number of days taken from sowing to the date of flowering of the main ear of 50 per cent plants in each row was recorded as days to 50% flowering.

2. Days to maturity:

Days taken from sowing to physiological maturity were worked out.

3. Dry shoot weight/plant (g):

Shoots of 10 randomly selected plants were sun dried and their average weight was recorded in gram.

4. Number of tillers per plant:

Tillers of 10 randomly selected plants were counted and averaged.

5. Stem girth (3-4) internode:

Stem girth of the 10 selected plants at 3-4 internode was measured using vernier calliper and then average was recorded.

6. Flag leaf length:

The length was recorded from the base to the tip of the leaf.

7. Panicle index:

$$\text{Panicle index} = \frac{\text{Weight of seed per plant}}{\text{Weight of total panicle per plant}} \times 100$$

8. Seed density/cm^2:

The number of seeds occupying an area of 1 cm^2 were counted.

9. 10 ml seed volume weight (g):

The weight of seeds displacing 10 ml volume of water was recorded.

10. Harvest index:

Harvest index was worked out the following formula:-

$$\text{Harvest index} = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100$$

11. Seed weight per plant (g):

The randomly selected 10 plants were harvested and threshed. The total of seed collected from each single plant were weighed in grams up to second decimal place and mean was worked out.

Statistical procedures:

(i) Analysis of variance:

Data were analysed by method outlined by Panse and Sukhatme (1954) using the mean values of ten 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, and

σ_p = Phenotypic standard deviation

(iv) Multivariate analysis:

(a) Estimation of Wilk's (Λ) criterion:

To test the significance of difference between lines, taking all the characters simultaneously, 'V' statistic was calculated which was based on Wilk's (Λ) criterion (Wilks, 1932). The sum of squares and sum of products of error and error + lines were utilized for estimation of "Λ".

To calculate the value of "Λ" following relationship was used:

$$\text{"}\Lambda\text{"} = \frac{|E|}{|E+V|}$$

where,

$|E|$ was the determinant of error sum of squares and sum of products matrix and $|E+V|$ was the determinant of the "error + variety' sum of squares and sum of products matrix.

χ^2 was used to test the significance of "Λ" as

$$\chi^2_{pq} = V = -\, m \log_e \Lambda$$

where,

$$m = n - \frac{p+q+1}{2}$$ with pq degree of freedom.

where,

n = total number of observations –1,

p = number of characters,

q = k – 1, and

k = number of lines

(b) Estimation of D^2-statistic:

To estimate divergence between two lines Mahalanobis (1936) D^2- statistic was used. He defined generalized distance between two lines as:

$$\Delta^2 = \sum\sum \lambda^{ij}\delta_i\delta_j$$

where,

λ^{ij} = Reciprocal matrix of the common dispersion matrix λ_{ij},

δ_i = Difference between mean values of the two lines for the i^{th} character, and

δ_j = Difference between mean values of the two lines for the j^{th} character.

D^2-statistic is the sample estimate of the generalized distance which is estimated as:

$$D^2 = \sum_{i,j=1}^{P} s^{ij} d_i d_j$$

where, s^{ij} and d_i are the sample estimates of λ^{ij} and δ_i, respectively. For calculating D^2 values inversion of matrix was required which is quite cumbersome. To overcome this difficulty original correlated, unstandardized character means (X_i) were transformed to uncorrelated, standardized variables (Y_i) by Pivotel condensation method (Rao, 1952). D^2 between any pairs of populations, for example population 1 and 2, was then estimated as:

$$D_p^2 = \sum_{i=1}^{p} (Y_{i1} - Y_{i2})^2$$

where, p = number of characters used for estimation of divergence.

(c) Determination of population constellations:

Population constellations were determined by Tocher's method described by Rao (1952). A cluster or constellation may be explained as a group of populations or genotypes such that any two populations belonging to the same cluster showed, on the average, a smaller D^2 value than those belonging to different clusters.

Rao (1952) suggested that two closely related populations of low D^2 value be pooled together and then a third population of similar D^2 value be added to this group such that it did not increase the average D^2 value appreciably. This process is continued. Any population, which sharply increases the average D^2 value should not be included in that group.

After formation of first cluster, the process is repeated to form second, third, etc., clusters using remaining populations until all populations are included in one or the other cluster. After cluster formation average intra and inter-cluster distances were calculated. The square root of corresponding average D^2 values represents the distance within and between groups.

(v) 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).

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

where,

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

Cov $_{x,y}$ = Co-variance between 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%.

(vi) Path coefficient analysis:

The proportion of direct and indirect contributions of various characteristics to the total correlation coefficients with seed weight, 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.

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

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

.

.

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

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 present study was conducted with 225 germplasm of pearl millet, which were subjected to statistical analysis for different characters. The experimental results obtained in respect of "Study of D^2 – analysis related to some grain and fodder traits in Pearl millet (*Pennisetum glaucum*)" on different aspects of grain and fodder traits in pearl millet germplasm are presented in this chapter, under the following heads:

4.1 Analysis of variance

4.2 Parameters of genetic variability

4.3 Genetic divergence

4.4 Correlation studies

4.5 Path analysis

4.1. Analysis of variance:

Analysis of variance (Table 4.1) showed highly significant differences among the germplasm lines for days to 50% flowering, days to maturity, dry shoot weight per plant, number of tillers per plant, stem girth (3-4) internodes, flag leaf length, panicle index, seed density, 10 ml seed volume weight, harvest index and seed yield per plant indicating the presence of considerable variability among the germplasm lines and justifying the selection of the material for the study.

4.2. Parameters of genetic variability:

Results on various variability parameters viz., mean, range, phenotypic and genotypic coefficients of variation (PCV and GCV), heritability, genetic advance and genetic advance as per cent of mean for eleven characters were furnished in Table 4.2.

(i) Mean and Range:

The estimates of mean and range for all the 11 characters (Table 4.2) have shown a wide range of variation among the germplasm lines. The variation was almost uniform on both sides of mean indicating normal distribution of the lines.

The range of various characters showed that seed density was the most variable ranging from 46.00 to 110.66/cm^2 followed by flag leaf length per plant (18.60 to 51.49 cm), panicle index (31.25 to 76.06), days to maturity (60 to 97 days), harvest index (10.46 to 44.44 %), seed yield per plant (7.00 to 40.00g) and days to 50% flowering (35 to 57 days).

(ii) Phenotypic and genotypic coefficients of variation:

The estimates of phenotypic and genotypic coefficient of variation are presented in table 4.2. In general, the values of phenotypic coefficient of variation were higher than that of the genotypic coefficient of variation for all the characters. The highest coefficient of variation (GCV) of 46.37 per cent was observed for number of tillers per plant followed by stem girth (3-4) internodes, dry shoot weight per plant, seed yield per plant and harvest index recording 38.65, 34.96, 30.16 and 29.37 per cent, respectively (Table 4.2). The characters days to maturity recorded the least GCV of 4.89 per cent followed by 10 ml seed volume weight (5.83%) and days to 50% flowering (8.39%). Phenotypic coefficient of variation (PCV) exhibited similar trend, with number of tillers per plant recording the maximum PCV of 50.39 per cent followed by stem girth (3-4) internodes, dry shoot weight per plant, seed yield per plant and harvest index recording 39.17, 37.65, 30.53 and 29.55 per cent, respectively. The character days to maturity recorded the minimum PCV of 5.26 per cent.

The maximum difference of 4.02 between PCV and GCV estimates was observed for number of branches per plant followed by plant height (2.69). The characters viz., number of pods per plant, length of pod, days to maturity, plant population and 1000 seed weight recorded the least difference of 0.05, 0.08, 0.10, 0.17 and 0.18, respectively.

(iii) Heritability:

The estimates of broad-sense heritability in percent have been presented in Table 4.2. All the characters exhibited high estimates of heritability in broad sense. The maximum heritability estimate of 99.4 per cent was recorded by flag leaf length, followed by panicle index (99.0%), harvest index (98.6%), seed yield per plant (97.5%), stem girth (3-4) internodes (97.4%), seed density (97.2%), 10 ml seed volume weight (96.6%), days to 50% flowering (96.2%), days to maturity (86.5%), dry shoot weight per plant (86.2%) and panicle length (84.7%).

(iv) Genetic advance:

The estimates of expected genetic advance (Table 4.2) revealed that the maximum genetic advance as per cent of mean was expected from number of tillers per plant (88.02%) followed by stem girth (3-4) internodes (78.95%), dry shoot weight per plant (66.67%), seed yield per plant (61.33%) and harvest index (60.04%). The moderate values were observed for seed density (41.03%), flag leaf length (37.53%) and panicle index (33.79%) while for days to maturity (9.37%), 10 ml seed volume weight (11.76%) and days to 50% flowering (16.97%) was reported to be low.

4.3. Genetic divergence:

The pooled divergence for all the characters within germplasm lines, tested by the Wilk's criterion, was significant. Hence the analysis of genetic divergence among germplasm lines used in the study was considered relevant.

D^2 analysis:

The mean values of the two hundred twenty five germplasm lines were transformed into standardized uncorrelated mean values and thereafter D^2 values were computed for all possible 25200 pairs of germplasm lines. The highest D^2 value of 9864.29 was observed between the germplasm lines, IP-345 and IP-579 and the lowest D^2 value of 39.08 between the germplasm lines, C3 (check) and IP-682. Analysis of variance revealed significant differences among the germplasm lines for all the characters studied indicating wider variability in the experimental material. Through multivariate analysis, the 225 germplasm lines were grouped into 12 clusters (Table 4.3). The composition of different clusters varied from 7 to as much as 33. The cluster IX comprised maximum number of germplasm lines (33) followed by cluster XII, V, VI and IV consisting 31, 28, 24 and 23 germplasm lines, respectively. Clusters II, I, III, X, XI, VII and VIII were found to have 19, 16, 14, 13, 9, 8 and 7 germplasm lines, respectively.

(i) The intra and inter-cluster average distance:

The intra and inter cluster distances (D) as well as divergence (D^2) values among the eleven clusters are presented in Table 4.4 and Table 4.5, respectively. Cluster III recorded the highest intra-cluster distance of 2.737, while the lowest intra-cluster distance of 2.188 was registered by cluster IX. Maximum inter-cluster distance were observed between cluster I and VIII (5.723) followed by cluster VII and VIII (5.580), cluster X and VIII (5.182), cluster VI and VIII (5.163), cluster II and XI (4.940), cluster VII and X (4.850), cluster II and VII (4.834), cluster X and XI (4.871), cluster VI and XI (4.707) and cluster VIII and XI (4.704) indicating maximum diversity between the genotypes of these clusters with respect to the traits considered. However, the lowest inter-cluster distance was observed between cluster II and V (2.2.402) inferring the similarity for most of the characters among the genotypes of both clusters. These results in regard to inter cluster distance indicated that cluster VIII was highly divergent from all other clusters followed by cluster XI.

(ii) Cluster mean:

The cluster means for each of eleven characters are presented in Table 4.6.

1. Days to 50% flowering:

Cluster mean was highest (48.81days) for cluster VI and lowest (39.87 days) for cluster IV followed by cluster X (41.54 days) and cluster I (41.69 days).

2. Days to maturity:

Cluster mean was highest (91.71 days) for cluster VIII and lowest (79.97 days) for cluster III.

3. Dry shoot weight per plant:

Cluster mean was highest (0.76 g) for cluster II closely followed by cluster V (0.66 g) and lowest (0.28 g) for cluster XI.

4. Number of tillers per plant:

Cluster mean was highest (4.78) for cluster VIII and lowest (1.14) for cluster I.

5. Stem girth (3-4) internodes:

Cluster mean was highest (1.15 cm) for cluster VII and lowest (0.39 cm) for cluster VIII.

6. Flag leaf length:

Cluster mean was highest (42.98 cm) for cluster VII and lowest (27.59 cm) for cluster IX.

7. Panicle index:

Cluster mean was highest (60.28) for cluster II closely followed by cluster I (60.26) and lowest (44.10) for cluster X.

8. Seed density:

Cluster mean was highest ($87.47/cm^2$) for cluster VIII and lowest ($57.45/cm^2$) for cluster VI.

9. 10 ml seed volume weight:

Cluster mean was highest (8.37 g) for cluster III and lowest (7.39 g) for cluster I.

10. Harvest index:

Cluster mean was highest (35.79%) for cluster XI and lowest (15.97%) for cluster II.

11. Seed weight per plant:

Cluster mean was highest (29.72 g) for cluster XI and lowest (11.15 g) for cluster X.

(iii) Cluster characteristics:

Table 4.6 revealed that cluster I was characterized by panicle index, which had maximum mean value for this trait and also by days to 50% flowering, which had minimum value for this trait.

Cluster II was characterized by dry shoot weight per plant and panicle index, which had highest mean values for these traits.

Cluster III was characterized by 10 ml seed volume weight, which had highest value for this trait and also by days to maturity, which had lowest value for this trait.

Cluster IV was characterized by days to 50% flowering, which had lowest value for this trait.

Cluster V was characterized by dry shoot weight per plant, which had maximum value for this trait.

Cluster VII was characterized by stem girth (3-4) internodes and flag leaf length, which had highest value for these traits.

Cluster VIII was characterized by number of tillers per plant and seed density, which had highest values for these traits.

Cluster X was characterized by days to 50% flowering, which had minimum value for this trait.

Cluster XI was characterized by harvest index and seed weight per plant, which had highest values for these traits.

Cluster VI, IX and XII did not show desirable mean level for any of the characters, under study.

(iv) Contribution of the characters towards the divergence:

Cluster means for 11 characters (Table 4.6) suggested that contribution of seed density was the maximum (range 30.02) towards genetic divergence, followed by harvest index, seed weight per plant, panicle index, flag leaf length and days to maturity, and least contribution towards genetic divergence was observed by dry shoot weight per plant (0.48) closely followed by stem girth (3-4) internodes and panicle index.

4.3. Correlation studies:

Correlation coefficients measure the degree and direction of association between two or more variables. Thus, to understand the mutual relationship between various characters, phenotypic, genotypic and environmental correlation coefficients were estimated and have been presented in Table 4.7. 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:

With seed weight per plant:

It is evident from Table 4.7 that seed weight per plant showed positive correlation with number of tillers per plant, flag leaf length, seed density and harvest index.

Among contributing traits:

Days to 50% flowering showed positive association with days to maturity.

Days to maturity exhibited positive association with days to 50% flowering.

Dry shoot weight per plant had negative correlation with harvest index.

Number of tillers per plant showed positive correlation with seed density and 10 ml seed volume weight while negative with stem girth (3-4) internodes and panicle index.

Stem girth (3-4) internodes showed positive correlation with flag leaf length while negative with number of tillers per plant and 10 ml seed volume weight.

Flag leaf length exhibited positive association with stem girth (3-4) internodes while negative with 10 ml seed volume weight.

Panicle index had positive correlation with harvest index and negative with number of tillers per plant.

Seed density showed positive association with number of tillers per plant and 10 ml seed volume weight.

10 ml seed volume weight showed positive association with number of tillers per plant and seed density while negative with stem girth (3-4) internodes and flag leaf length.

Harvest index exhibited positive association with panicle index while negative with dry shoot weight per plant.

(ii) Genotypic correlation coefficients:

With seed weight per plant

The seed weight per plant exhibited positive association with number of tillers per plant, flag leaf length, seed density and harvest index.

Among contributing traits:

Days to 50% flowering showed positive correlation with days to maturity.

Days to maturity had positive correlation with days to 50% flowering and number of tillers per plant.

Dry shoot weight per plant showed positive correlation with number of tillers per plant while negative with harvest index.

Number of tillers per plant had positive correlation with days to maturity, dry shoot weight per plant, seed density and 10 ml seed volume weight while negative with stem girth (3-4) internodes and panicle index.

Stem girth (3-4) internodes had positive correlation with flag leaf length while negative with number of tillers per plant and 10 ml seed volume weight.

Flag leaf length exhibited positive association with stem girth (3-4) internodes while negative with 10 ml seed volume weight.

Panicle index had positive correlation with harvest index while negative with number of tillers per plant.

Seed density showed positive association with number of tillers per plant and 10 ml seed volume weight.

10 ml seed volume weight showed positive association with number of tillers per plant and seed density while negative with stem girth (3-4) internodes and flag leaf length.

Harvest index exhibited positive association with panicle index while negative with dry shoot weight per plant.

(iii) Environmental correlation coefficients:

With seed weight per plant

Seed weight per plant exhibited positive association with stem girth (3-4) internodes while negative with days to 50% flowering and flag leaf length.

Among contributing traits:

Days to 50% flowering had negative correlation with 10 ml seed volume weight.

Stem girth (3-4) internodes showed negative association with flag leaf length and panicle index.

Flag leaf length had negative correlation with stem girth (3-4) internodes.

Panicle index showed negative association with stem girth (3-4) internodes.

10 ml seed volume weight exhibited negative correlation with days to 50% flowering.

4.5. Path coefficient analysis:

Partitioning of the correlation coefficients of the various characters under study was done with the help of path coefficient analysis to expound the direct and indirect effects of all these characters on seed weight per plant. The path coefficient results obtained at genotypic level have been boxed in Table 4.8 and presented below.

(a) Direct effect:

The trait harvest index (0.832) exhibited maximum positive direct effect on seed yield per plant, followed by dry shoot weight per plant and number of tillers per plant recording 0.487 and 0.209 respectively. Characters like stem girth (3-4) internodes, flag leaf length and 10 ml seed volume weight also registered positive direct effect but were negligible whereas, days to 50% flowering, days to maturity, panicle index and seed density exhibited negative but negligible effect.

(b) Indirect effects:

(i) Days to 50% flowering:

Days to 50% flowering recorded the maximum positive effect of 0.020 *via* dry shoot weight per plant whereas negative effect from harvest index (-0.026).

(ii) Days to maturity:

Days to maturity recorded the maximum positive effect of 0.032 *via* number of tillers per plant whereas negative effect from panicle weight per plant (-0.102).

(iii) Dry shoot weight per plant:

Maximum negative effect was exerted through harvest index (-0.478) while the positive effects observed by dry shoot weight per plant were small.

(iv) Number of tillers per plant:

The positive and negative effects observed by number of tillers per plant were small.

(v) Stem girth (3-4) internodes:

The positive and negative effects observed by stem girth (3-4) internodes were small.

(vi) Flag leaf length:

Flag leaf length recorded the maximum positive effect of 0.100 *via* harvest index, while the negative effects observed by flag leaf length were small.

(vii) Panicle index:

Panicle index recorded the maximum positive effect of 0.284 *via* harvest index, while the negative effects observed by panicle index were small.

(viii) Seed density:

Seed density registered positive effects via most of the traits but were small.

(ix) 10 ml seed volume weight:

The positive and negative effects observed by 10 ml seed volume weight were small.

(x) Harvest index:

Harvest index recorded the maximum negative effect of –0.280 *via* dry shoot weight per plant, while the positive effects observed by flag harvest index were small.

CHAPTER-V
DISCUSSION

The findings of the present investigation have been interpreted and discussed in this chapter in the light of the similar research work carried out by other research workers.

5.1 Genetic variability

It is very difficult to create something new from the genetically uniform material. Hence, search for the existing genetic variability is a prerequisite for any breeding programme. It provides not only a sound basis for selection but also provides some valuable information regarding selection of diverse parents to be used in hybridization programme. Since, environment has a good impact on many quantitative traits; it becomes essential to measure error by analysis of variance. The observed variability may be grouped under heritable and non-heritable components with the help of suitable parameters like genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance so as to give basis for selection of desirable genotypes to breeders.

Analysis of variance indicated highly significant differences among the germplasm lines for seed weight per plant and component characters indicating considerable genetic variation in the material. High magnitude of variation in the experimental material was also reflected by high value of mean and range for almost all the characters.

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. Substantial values of genotypic coefficient of variation were in line with phenotypic coefficient of variation. The maximum phenotypic coefficient of variation was observed for number of tillers per plant, stem girth (3-4) internodes, dry shoot weight per plant, seed weight per plant and harvest index, which suggested that selection might be effective for these traits. These results were in agreement with the findings of Kunjir and Patil (1986), Harer and Karad (1999), Sabharwal and Singh (2001), Bortkhataria *et al.* (2005), Varu *et al.* (2005) and Vidyadhar *et al.* (2006) for number of tillers per plant; and Saraswathi *et al.* (1995), Harer and Karad (1999), Kulkarni *et al.* (2000), Lakshmana and Guggari (2001), Sabharwal and Singh (2001), Sachan and Singh (2001), Solanki *et al.* (2002a), Solanki *et al.* (2002b), Lakshmana *et al.* (2003), Varu *et al.* (2005) and Vidyadhar *et al.* (2006) for seed weight per plant in pearl millet.

The magnitude of genotypic coefficient of variation suggested that dry shoot weight per plant, number of tillers per plant, stem girth (3-4) internodes, harvest index and seed weight per plant which showed high heritability coupled with high genetic advance had better chance for improvement. Flag leaf length, panicle index and seed density showed moderate scope. However, the trait like days to maturity, days to 50% flowering and 10 ml seed volume weight showed the least genotypic coefficient of variation. Hence, there is limited scope for further improvement of this trait.

5.2 Heritability and genetic advance:

Selection based on particular character will be effective when its heritability estimate is high. Burton (1952) suggested that GCV together with heritability estimates would give the best picture of the extent of advance to be expected by selection.

Heritability estimates in broad sense is the ratio of genotypic variance to the total phenotypic variance and is expressed in percentage. It is an ability of a genotype to express the observed variation in the next generation. It is the statistical tool to determine the masking role of environment in the expression of a character. It helps the plant breeders in the selection of superior genotypes from the genetically variable population. Robinson *et al.* (1949) has classified heritability estimate in broad sense as high (above 70%), medium (50-70%) and low (below 50%). The estimates of heritability are influenced by various factors such as, sampling material, effects of linkage and method of its estimation. Thus, heritability estimate is not only the property of the character but it is the property of population and environmental factors. Also, alteration in any of the component will bring change in the heritability estimate. When the estimate of heritability are high, the phenotypic appearance would provide a close measure of genotypic value and thus, a breeder can make selection on the basis of the *per se* performance of the individuals.

In the present investigation, estimates of heritability in broad sense were high i.e., more than 84.6 percent for all the characters studied. This suggests that phenotypic variability for all the traits were largely determined by genetic cause and thus, these traits can be improved by practicing simple selection procedures.

The genetic gain that can be expected by selection for a character was estimated by another genetic parameter namely, genetic advance. It measures the genetic gain under selection. It is influenced by the genetic variability present in the base population for a particular trait, heritability estimate for the character under selection and the proportion of individuals selected for study i.e., selection intensity. Since, the genetic advance is affected by the unit of measurement, expected genetic advance as percent of mean was calculated which is free from unit and thus, facilitate the comparison of genetic gain for various characters.

In the present study, the high estimates of expected genetic advance as percent of mean was recorded for the characters viz., number of tillers per plant, stem girth (3-4) internodes, dry shoot weight per plant, seed weight per plant and harvest index. It indicates that substantial improvement in these traits can be achieved through simple selection.

Since heritability estimates are influenced by environmental, genetic material and also other factors hence their utility will be restricted. Thus, heritability in conjunction with genetic advance would give a more reliable index of selection value (Johnson *et al.*, 1955).

The high heritability together with high genetic advance as per cent of mean was observed for dry shoot weight per plant, number of tillers per plant, stem girth (3-4) internodes, harvest index and seed weight per plant which pointed to the fact that phenotypic variability for these traits was largely determined by genetic cause hence simple selection could lead to substantial improvement in these characters. These results were in accordance with the reports of Singh, *et al.,* (1979), Vyas and Srikant (1984), Kunjir and Patil (1986), Bortkhataria *et al.* (2005) and Vidyadhar *et al.* (2006) for number of tillers per plant; and Vyas and Srikant (1984), Saraswathi *et al.* (1995), Harer and Karad (1999), Lakshmana and Guggari (2001), Solanki *et al.* (2002a) and Vidyadhar *et al.* (2006) for seed weight per plant.

High heritability with moderate genetic advance as per cent of mean was recorded for flag leaf length, panicle index and seed density indicating that the characters were less influenced by environment but governed by both non-additive and additive gene action. Hence simple selection is suggested for further improvement in the later generations.

High heritability with low genetic advance as per cent of mean was recorded for days to 50% flowering, days to maturity and 10 ml seed volume weight revealing prevalence of non-additive gene action and expression of character largely due to environment effects. For this character selection will be less dependable.

From the foregone discussion, it can be concluded that number of tillers per plant, stem girth (3-4) internodes, flag leaf length, harvest index and seed weight 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 and simple selection may be effective to improve these characters.

5.3 Genetic divergence:

Genetic divergence studies are the vital tools for the evaluation of germplasm lines and selection of parents for the breeding programme. So, present study was mainly aimed at analysis of genetic divergence among the 225 germplasm lines and to identify the superior and divergent lines for formulating the crossing programme.

Wilk’s lambda criterion was used for simultaneous test of significance of the differences in the mean values of the eleven characters and the pooled effect was found significant indicating a wide spectrum of diversity among the germplasm lines.

5.4 D^2 analysis:

The multivariate analysis giving the D^2 values between 225 germplasm lines all these lines can be grouped into twelve clusters. The estimates of D^2 values varied substantially from 39.08 to 9864.29. The highest D^2 value of 9864.29 was recorded between germplasm lines IP-345 and IP-549. These two germplasm lines also showed significant differences between them in respect of all the characters except number of tillers per plant (Appendix-I). A cross between these two lines is expected to give heterotic hybrid and wide spectrum of variability. On the other hand, minimum divergence (D^2 = 39.08) was observed between germplasm lines C3 (Check) and IP-682, which did not differ significantly form each other in respect of most of the characters under study, therefore these may be related in evolution.

Using Tocher's methods as suggested by Rao (1952), 225 germplasm were grouped into 12 clusters. As many as 33 lines were accommodated in cluster IX, 31 in cluster XII, 28 in cluster V, 24 in cluster VI, 23 in cluster IV, 19 in cluster II, 16 in cluster I, 14 in cluster III, 13 in cluster X, 9 in cluster XI, 8 in cluster VII and 7 in cluster VIII.

Inter-cluster distance is the main criterion for selection of germplasm lines using D^2 analysis. Lines belonging to the clusters with maximum inter-cluster distance are genetically more divergent and hybridization between lines of divergent clusters are likely to produce wide variability with desirable segregants. The maximum inter-cluster distance was recorded between cluster I and VIII closely followed by cluster VII and VIII, cluster X and VIII, cluster VI and VIII, cluster II and XI, cluster VII and X, cluster II and VII, cluster X and XI, cluster VI and XI and cluster VIII and XI. In general, cluster VIII was situated maximum apart from all the other clusters followed by XI. Therefore, it is suggested that if the diverse germplasm lines from these groups are used in breeding programme, it is expected to throw a wide range of segregants. The minimum inter-cluster distance between cluster II and V indicates that the lines of these clusters are genetically less diverse and were almost with same genetic makeup.

Cluster means for different yield characters indicated that number of tillers per plant and seed density was highest in cluster VIII. Cluster I, IV and X showed early in 50% flowering while cluster III showed early in maturity and recorded highest value for 10 ml seed volume weight. Cluster II recorded highest mean value for dry shoot weight per plant and panicle index while cluster XI recorded highest mean value for harvest index and seed weight per plant. Cluster VII recorded highest mean for stem girth (3-4) internodes and flag leaf length, whereas cluster V recorded high mean for dry shoot weight per plant. Cluster I recorded high mean value for panicle index. Thus, the germplasm lines of outstanding mean performance from most distant clusters may be identified as potential parents and could be utilized in hybridization programme for developing new varieties.

The characters contributing maximum to the divergence i.e. seed density, harvest index, seed weight per plant, panicle index, flag leaf length and days to maturity should be given more emphasis for the purpose of further selection and choice of parents for hybridization. Considerable contribution of seed weight per plant and flag leaf towards genetic diversity has been reported by Thete and Bapat (1986) and Katiyar *et al*. (1999).

Based on the study of genetic divergence, the following germplasm lines were identified which can be used in breeding programme.

Germplasm lines	**Desirable characteristics**
IP-545, IP-758	Early in flowering
IP-42	Early in maturity
IP-37	Highest dry shoot weight per plant
477/183 3-2-3	Highest tillers per plant
IP-517	Highest stem girth (3-4) internodes
IP-549	Longest flag leaf length
IP-363	Highest seed density and harvest index
IP-563	Highest seed weight per plant

5.5 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 correlation, 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 weight per 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 weight per plant was positively and strongly associated with number of tillers per plant, flag leaf length, seed density and harvest index. Apart from showing positive and highly significant association with seed weight per plant, the characters, number of tillers per plant and seed density also positively and significantly associated to each other at 1% level of significance. This suggested that these traits could be used as selection indices. Similar association was also reported by Yadav (1977), Reddy and Sharma (1982), Kunjir and Patil (1986), Rao *et al.* (1987), Bhamre and Harinarayana (1992), Poongodi and Palanisamy (1995), Pol *et al.* (2001), Pareek (2002), Chikurte *et al.* (2003), Thangasamy and Gomathinayagam (2003), Shukla and Parihar (2004), Bortkhataria *et al.* (2005), Chandolia and Sagar (2005), Patil and Jadeja (2005), Varu *et al.* (2005) and Salunke *et al.* (2006).

Correlation studies at environmental level revealed that stem girth (3-4) internodes had strong and positive association with seed weight per plant indicating that the environmental factors leading to the high seed weight per plant had resulted in an improvement in its component character stem girth (3-4) internodes.

From the foregoing discussion, it is concluded that among the characters studied, number of tillers per plant, flag leaf length, seed density and harvest index had strong positive association with seed weight per plant. Furthermore, the characters like number of tillers per plant and seed density were also strongly associated to each other. Thus, these characters should be given due importance while breeding for higher seed yield.

5.6 Path analysis:

The genotypic correlations were further partitioned into direct and indirect effects to establish the cause and effects relationship between the yield and its component characters. 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 studied yield components, harvest index and number of tillers per plant had positive direct effect on seed weight 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. Furthermore, both these characters, which had high magnitude of positive direct effects, also showed positive correlation with seed weight per plant indicating that these traits were of great importance for improvement in seed yield.

The results were in accordance with the findings of Gupta *et al.* (1976), Singh and Singh (1976), Mukherji *et al.* (1982), Reddy and Sharma (1982), Raveendran and Appadurai (1984), Das and Balakrishnan (1994), Poongodi and Palanisamy (1995), Harer and Kharad (1998), Anarase and Ugale (2001), Madhusudhana and Govila (2001), Chikurte *et al.* (2003), Unnikrishnan *et al.* (2004a), Borkhataria *et al.* (2005), Patil and Jadeja (2005), Varu *et al.* (2005), Salunke *et al.* (2006) and Ram et al. (2007) for number of tillers per plant.

It is interesting to note that the characters flag leaf length and seed density, which showed positive association with seed weight per plant, did not exhibit any direct contribution. The positive correlation of these traits with seed weight per plant was mainly due to its positive indirect effects *via* harvest index and number of tillers per plant.

The direct effect of dry shoot weight per plant was high, though this trait did not show any association with seed weight per plant. This strong positive direct contribution was converted into negligible correlation mainly due to its strong negative indirect effect *via* harvest index.

The character days to 50% flowering, days to maturity, stem girth (3-4) internodes, panicle index and 10 ml seed volume weight, which did not show association with seed weight per plant, also, did not have direct contribution.

The results obtained from genotypic correlation coefficient and path analysis indicated that the characters harvest index and number of tillers per plant had strong positive correlation and high magnitude of positive direct effects on seed weight per plant. Hence, it is suggested that while exercising selection for seed yield, more weightage should be given to harvest index and number of tillers per plant and they could be regarded as important components influencing seed yield of pearl millet. However, to improve yield indirect selection for seed density can also be utilized, as this character had positive correlation with seed yield and number of tillers per plant.

CHAPTER-VI
SUMMARY, CONCLUSIONS AND SUGGESTIONS

A field experiment was conducted at Research Farm, College of Agriculture, Gwalior, with 225 pearl millet germplasm lines, raised in Randomized Block design with two replications during *kharif* season of 2008-09. Data relating to days to 50% flowering, days to maturity, dry shoot weight per plant, number of tillers per plant, stem girth (3-4) internodes, flag leaf length, panicle index, seed density, 10 ml seed volume weight, harvest index and seed weight per plant were collected from five randomly selected plants in each replication. The variability existing for these characters in germplasm lines were statistically assessed. Their heritability and genetic advance were worked out. The correlation of seed weight per plant with its component characters and among the components was examined. The magnitude of influence of the characters on seed weight per plant was worked out through path analysis. The genetic divergence was estimated using Mahalanobis's D^2 statistics (1936) followed by Rao's (1952) clustering pattern. The following conclusions were arrived at:

1. The analysis of variance showed significant differences among the germplasm lines for all the characters studied. The pooled divergence for all the characters within the lines was significant.
2. Number of tillers per plant followed by stem girth (3-4) internodes, dry shoot weight per plant, seed weight per plant and harvest index had high phenotypic and genotypic coefficient of variation values suggesting that these characters are under the influence of genetic control.
3. The characters flag leaf length, panicle index, 10 ml seed volume weight, days to 50% flowering, harvest index, days to maturity, seed density, seed weight per plant and stem girth (3-4) internodes showed least differences among PCV and GCV estimates indicating greater role of genetic factors influencing the expression of these characters. Whereas, the influence of environment was more on the characters number of tillers per plant and dry shoot weight per plant.

4. The heritability estimates were high for all the characters ranging from 84.7 to 99.4. The maximum and minimum were recorded by flag leaf length and number of tillers per plant, respectively.
5. Number of tillers per plant, stem girth (3-4) internodes, dry shoot weight per plant, seed weight per plant and harvest index have high values of heritability coupled with high genetic advance as per cent of mean indicating lesser influence of environment on these characters and prevalence of more additive gene action in their inheritance, hence, are amenable for simple selection.
6. The characters, number of tillers per plant, flag leaf length, seed density and harvest index recorded positive correlation with seed weight per plant both at phenotypic and genotypic level.
7. The number of tillers per plant and seed density recorded positive inter-correlation among themselves, indicating the possibility of simultaneous improvement of these traits by selection programme.
8. Path analysis revealed that the characters harvest index and number of tillers per plant, which were found to have direct contribution to correlation coefficients along with positive correlation with seed weight per plant, should be given more weightage in selection of parents for hybridization for yield improvement.
9. The two hundred twenty five germplasm lines of pearl millet were grouped into twelve clusters by D^2 analysis. Cluster VI consisted maximum germplasm lines (33) and cluster VIII consisted only 7 germplasm lines.
10. Cluster VIII was situated maximum apart from all other clusters followed by cluster XI. The highest inter-cluster distance was recorded between the cluster I and VIII closely followed by cluster VII and VIII, cluster X and VIII and cluster VI and VIII. Hence crosses between the genotypes of these clusters may rise to better hybrid vigour and segregating population. The highest intra-cluster distance was recorded for III and lowest for IX.

11. Contribution of seed density was the maximum towards genetic divergence, followed by harvest index, seed weight per plant, panicle index, flag leaf length and days to maturity.

12. The germplasm line IP-563 may serve as potential parent for hybridization programme in the improvement of yield.

13. The germplasm lines IP-253, IP-395, IP-396, IP-545 and IP-758 for early in 50% flowering; IP-42 for early in maturity; IP-37, IP-56, IP-63, IP-121, IP-271, IP-374, IP-376, IP-389 and IP-477 for dry shoot weight per plant; 477/183 3-2-3 for number of tillers per plant; IP-517 for stem girth (3-4) internodes; IP-549 for flag leaf length; IP-505 for panicle index; IP-268 and IP-363 for seed density; IP-50 for 10 ml seed volume weight and IP-363 for harvest index may be used as suitable parents.

Suggestions:

- On the basis of genetic divergence revealed by D^2-analysis and *per se* performance of germplasm lines, 9 entries, viz., IP-37, IP-42, IP-363, IP-517, IP-545, IP-549, IP-563, IP-758, and 477/183 3-2-3 have been recommended for further use in breeding programmes.
- Direct selection is most effective for harvest index and number of tillers per plant. However, to improve yield indirect selection for seed density can also be utilized, as this character had positive correlation with seed yield and number of tillers per plant.

Table 4.3. Distribution of pearl millet germplasm lines into different clusters

Cluster	No. of germplasm lines	Germplasm lines number
I	16	108,120,134,135,148,156,157,167,178,181,184,188,201,215,217,224
II	19	2,9,12,18,35,41,60,68,76,77,79,82,126,149,150,154,161,205,214,
III	14	11,13,16,17,25,51,54,55,56,83,127,137,218,219
IV	23	3,4,5,8,10,14,23,30,34,36,42,53,57,62,64,65,80,81,132,133,136,158,159
V	28	15,24,47,63,85,86,89,97,105,107,116,121,122,123,125,131,146,152,153 160,164,176,190,194,195,197,207,222
VI	24	90,92,93,140,145,147,151,162,166,170,171,175,179,187,189,196,204,206 208,210,211,212,220,221
VII	8	84,112,115,117,124,155,174,177
VIII	7	7,21,26,27,28,29,31
IX	33	37,67,71,72,88,91,94,95,96,98,106,109,110,111,113,118,129,139,141,142, 144,165,168,169,173,191,199,200,202,203,209,213,216
X	13	19,99,100,101,103,104,128,180,182,183,185,192,223
XI	9	1,32,87,114,163,172,186,193,198
XII	31	6,20,22,33,38,39,40,43,44,45,46,48,49,50,52,58,59,61,66,69,70,73,74,75, 78,102,119,130,138,143,225

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Appendix I: Mean performance of pearl millet germplasm lines for various characters under study

S. No.	Germ-plasm lines	Days to 50% flowering	Days to maturity	Dry shoot weight/ plant	No. of tillers/ plant	Stem girth (3-4) inter node	Flag leaf length (cm)	Panicle index	Seed density /cm^2	10 ml seed volume wt.(g)	Harvest index	Seed weight per plant (g)
1	IP-2	51.00	87.00	0.31	2.33	0.68	36.78	50.87	65.00	8.13	32.95	28.50
2	IP-3	50.00	81.00	0.53	2.00	0.43	35.67	56.25	83.66	7.65	21.17	18.00
3	IP-9	39.00	80.00	0.67	3.00	0.46	31.69	55.88	65.66	8.10	19.00	19.00
4	IP-10	40.00	84.00	0.69	2.00	0.56	35.92	48.33	85.33	7.64	22.48	29.00
5	IP-13	41.00	89.00	0.66	3.00	0.41	32.04	51.85	94.66	8.13	18.34	20.00
6	IP-15	39.00	91.00	0.70	3.00	0.41	30.50	41.93	65.66	7.88	16.86	14.00
7	IP-26	48.00	90.00	0.63	3.33	0.55	31.54	50.00	78.00	7.88	20.80	26.00
8	IP-29	40.00	85.00	0.41	2.66	0.50	32.56	50.00	87.00	8.32	21.91	16.00
9	C1J210	47.00	83.00	0.79	3.33	0.31	38.06	57.50	69.00	8.06	13.76	15.00
10	IP-33	42.00	84.00	0.45	3.33	0.28	31.50	52.63	80.33	8.33	27.05	23.00
11	IP-36	46.00	84.00	0.38	4.00	0.81	33.54	63.63	78.33	8.48	26.31	20.00
12	IP-37	46.00	81.00	0.95	3.66	0.33	33.49	51.11	60.00	6.62	11.96	14.00
13	IP-38	46.00	78.00	0.55	2.00	0.28	38.04	50.00	78.00	8.73	23.00	23.00
14	IP-39	38.00	77.00	0.34	3.00	0.43	35.55	59.18	85.33	7.66	25.71	18.00
15	IP-40	45.00	82.00	0.66	3.00	0.41	32.55	54.71	67.66	7.69	25.21	29.00
16	IP-42	50.00	60.00	0.26	2.00	0.51	39.54	46.51	94.00	8.52	36.70	29.00
17	IP-50	48.00	80.00	0.29	2.33	0.27	39.05	57.74	84.33	9.06	21.42	15.00
18	IP-56	47.00	82.00	0.87	2.33	0.27	31.35	60.00	59.00	7.83	16.85	15.00
19	J2-90C2	46.00	83.00	0.32	4.00	0.37	39.50	34.42	62.66	6.95	12.50	11.00
20	IP-53	49.00	81.00	0.41	3.00	0.47	37.50	50.00	72.66	7.72	15.76	17.00
21	IP-55	46.00	96.00	0.40	5.00	0.41	29.97	33.92	83.66	7.80	20.21	19.00
22	IP-57	47.00	92.00	0.62	2.66	0.48	30.55	40.00	88.66	8.42	15.09	16.00

23	IP-61	39.00	80.00	0.57	3.20	0.54	30.55	60.00	77.00	8.04	25.00	18.00
24	IP-63	49.00	82.00	0.81	2.00	0.41	40.19	37.50	65.66	7.49	26.92	21.00
25	IP-79	47.00	80.00	0.29	2.00	0.52	32.64	74.07	85.33	7.56	28.16	20.00
26	IP-87	48.00	97.00	0.74	4.00	0.37	30.70	55.76	94.00	8.01	28.33	29.00
27	IP-96	47.00	85.00	0.40	4.00	0.34	35.58	57.77	83.33	8.03	23.42	26.00
28	477/183 3-2-3	47.00	91.00	0.42	7.00	0.17	34.33	40.81	98.33	8.72	31.25	20.00
29	IP-97	44.00	92.00	0.58	5.16	0.34	34.30	51.42	91.33	7.66	18.00	18.00
30	IP-103	41.00	89.00	0.77	3.00	0.39	35.34	55.26	88.33	7.44	16.53	21.00
31	IP-104	47.00	91.00	0.56	5.00	0.57	36.31	39.21	83.66	7.68	18.51	20.00
32	IP-106	41.00	79.00	0.40	1.33	0.41	32.14	50.00	99.00	7.19	36.70	29.00
33	IP-113	49.00	82.00	0.49	2.75	0.57	30.69	42.10	82.00	7.95	18.32	16.00
34	IP-119	42.00	83.00	0.32	2.66	0.51	31.30	60.60	70.33	8.16	21.27	20.00
35	IP-121	48.00	81.00	0.85	2.00	0.37	32.55	55.55	79.00	7.60	17.09	20.00
36	IP-128	41.00	79.00	0.81	1.33	0.59	24.25	55.55	99.00	7.98	23.80	15.00
37	IP-129	43.00	86.00	0.49	1.33	0.47	31.43	64.28	79.66	8.42	22.50	18.00
38	PP29C-4	49.00	83.00	0.47	2.66	0.47	30.30	43.24	94.66	8.75	13.44	16.00
39	IP-137	47.00	89.00	0.64	3.00	0.64	30.65	57.89	78.66	8.66	13.58	11.00
40	IP-141	49.00	84.00	0.80	2.66	0.54	30.50	37.83	99.00	7.60	16.66	14.00
41	IP-170	49.00	94.00	0.80	1.33	0.74	32.57	69.56	83.00	7.49	18.39	16.00
42	IP-172	43.00	90.00	0.59	2.66	0.67	29.30	63.33	93.33	8.56	18.44	19.00
43	IP-178	48.00	88.00	0.40	2.33	0.81	29.55	44.73	78.66	7.80	23.94	17.00
44	IP-181	48.00	87.00	0.23	3.33	0.71	26.95	44.44	94.33	8.08	16.12	20.00
45	IP-187	41.00	88.00	0.32	2.66	0.77	26.49	43.75	93.00	7.61	16.80	21.00
46	IP-192	44.00	92.00	0.59	2.66	0.61	26.58	51.61	78.66	7.83	23.28	17.00
47	IP-197	49.00	94.00	0.79	2.66	0.91	35.44	57.14	80.66	8.06	28.07	16.00

48	IP-212	49.00	81.00	0.85	2.66	0.81	42.52	33.33	80.00	8.02	14.52	17.00
49	IP-215	48.00	89.00	0.49	2.00	0.51	19.39	41.46	105.66	8.15	18.88	17.00
50	IP-220	45.00	84.00	0.70	3.00	0.47	26.43	40.74	71.66	7.91	13.41	11.00
51	IP-225	46.00	84.00	0.49	3.66	0.51	38.69	50.00	73.66	8.28	27.08	26.00
52	IP-226	44.00	81.00	0.67	3.66	0.57	29.42	40.54	83.33	8.42	14.42	15.00
53	IP-228	44.00	84.00	0.52	3.00	0.64	30.19	50.84	78.00	7.33	20.68	30.00
54	IP-231	48.00	86.00	0.40	3.00	0.54	30.15	63.33	95.00	8.03	26.25	21.00
55	IP-236	46.00	81.00	0.40	1.66	0.60	36.46	60.60	98.66	7.86	21.97	19.50
56	IP-238	45.00	84.00	0.60	2.33	0.50	43.54	59.57	92.33	8.54	28.28	28.00
57	IP-253	36.00	86.00	0.23	3.33	0.71	31.18	43.47	68.00	8.13	17.24	20.00
58	IP-254	42.00	88.00	0.44	3.00	0.44	27.36	39.53	91.33	7.93	14.40	17.00
59	IP-265	45.00	82.00	0.70	3.00	0.64	30.30	44.44	87.00	7.69	17.97	16.00
60	IP-266	46.00	84.00	0.64	1.33	0.54	31.55	58.82	96.00	7.68	21.73	10.00
61	IP-267	48.00	86.00	0.65	3.33	0.64	31.47	47.22	97.00	8.25	17.17	17.00
62	IP-268	39.00	88.00	0.43	2.66	0.40	29.46	58.09	110.66	7.64	21.66	13.00
63	CIJ2405	48.00	84.00	0.70	2.33	0.67	41.80	58.82	95.00	7.38	20.20	20.00
64	IP-263	43.00	81.00	0.62	2.00	0.57	32.49	51.21	85.66	8.01	21.42	21.00
65	IP-262	43.00	82.00	0.64	2.00	0.84	31.28	60.71	81.00	7.77	19.54	17.00
66	IP-260	50.00	85.00	0.35	2.00	1.00	28.55	55.00	103.66	7.88	20.00	10.00
67	IP-269	44.00	89.00	0.33	2.33	1.00	26.55	47.61	72.33	7.74	28.57	20.00
68	IP-271	46.00	90.00	0.86	3.00	0.70	32.35	56.15	78.00	7.43	11.53	12.00
69	IP-272	41.00	88.00	0.60	2.66	0.97	30.65	52.00	82.00	7.00	15.85	13.00
70	IP-273	40.00	87.00	0.53	1.33	0.60	31.48	53.84	97.33	8.10	13.15	10.00
71	IP-274	47.00	86.00	0.52	1.66	0.47	26.35	62.85	87.33	8.06	29.76	22.00
72	IP-275	47.00	87.00	0.38	1.33	0.50	30.29	52.06	72.00	7.61	27.69	18.00
73	C2J22-90	44.00	85.00	0.56	2.66	0.70	31.30	31.25	83.00	8.72	17.24	20.00

74	IP-278	51.00	89.00	0.70	2.33	0.47	30.61	41.66	86.00	8.70	17.24	20.00
75	IP-281	51.00	83.00	0.54	2.66	0.30	24.17	53.12	95.00	7.62	20.98	17.00
76	IP-283	47.00	86.00	0.54	2.66	0.60	30.93	70.58	96.33	7.72	18.18	12.00
77	IP-284	47.00	84.00	0.68	1.66	0.64	24.82	53.12	78.33	7.59	17.52	17.00
78	IP-276	49.00	83.00	0.64	1.66	0.67	39.27	38.46	85.00	7.74	18.01	20.00
79	IP-285	48.00	85.00	0.74	3.33	0.34	31.51	55.00	86.00	7.72	16.23	19.00
80	IP-286	39.00	79.00	0.46	1.66	0.27	33.24	48.14	72.33	8.23	18.33	13.00
81	IP-289	39.00	81.00	0.63	2.33	0.60	27.37	53.57	86.00	8.10	27.77	30.00
82	IP-290	50.00	78.00	0.64	1.33	0.50	27.70	64.70	83.33	7.60	14.10	11.00
83	C3H77-48-33-2	48.00	80.00	0.40	2.33	0.83	41.52	65.85	87.66	8.05	30.25	27.00
84	IP-291	46.00	89.00	0.30	2.66	0.87	45.23	59.37	92.66	7.81	31.14	19.00
85	IP-294	44.00	88.00	0.70	2.33	0.52	31.18	63.41	67.66	7.71	24.07	26.00
86	IP-299	48.00	86.00	0.76	3.00	0.54	48.58	46.42	72.00	7.53	20.47	26.00
87	IP-300	47.00	84.00	0.33	2.00	0.37	27.35	67.44	81.00	7.86	39.72	29.00
88	IP-305	52.00	92.00	0.46	1.66	0.47	27.59	52.94	84.33	7.93	23.68	18.00
89	IP-309	52.00	90.00	0.53	2.00	0.42	38.41	52.63	65.00	8.13	22.72	20.00
90	IP-310	51.00	89.00	0.37	1.66	0.40	31.74	55.00	55.66	7.13	20.37	11.00
91	IP-313	51.00	80.00	0.30	1.33	0.40	26.76	53.84	48.66	8.36	27.45	14.00
92	IP-315	53.00	88.00	0.51	1.00	0.75	25.54	43.47	50.00	7.65	14.49	10.00
93	IP-318	50.00	86.00	0.70	1.66	0.50	29.47	46.42	57.00	7.49	13.40	13.00
94	IP-319	46.00	87.00	0.30	1.00	0.27	22.39	58.82	54.66	8.27	22.22	10.00
95	IP-323	47.00	81.00	0.40	1.00	0.44	25.37	65.51	61.66	8.13	28.78	19.00
96	IP-326	44.00	94.00	0.40	1.33	0.50	25.11	68.78	52.00	7.81	23.43	15.00
97	IP-327	47.00	86.00	0.50	1.00	0.54	49.45	60.86	62.33	8.10	20.00	16.50
98	IP-328	47.00	87.00	0.43	1.00	0.40	26.65	59.09	71.00	7.93	20.96	13.00
99	IP-329	43.00	88.00	0.44	1.00	0.32	41.54	39.28	71.66	8.20	16.17	11.00

100	IP-331	47.00	86.00	0.36	1.00	0.27	43.60	50.00	63.00	8.03	19.23	10.00
101	IP-333	44.00	81.00	0.58	1.66	0.27	49.39	54.54	74.00	7.32	14.81	12.00
102	IP-334	44.00	87.00	0.44	1.66	0.47	30.12	36.95	77.66	8.00	21.51	17.00
103	IP-335	41.00	86.00	0.20	1.10	0.40	31.37	43.47	56.66	8.33	24.39	10.00
104	IP-336	40.00	91.00	0.35	1.00	0.44	33.60	52.05	54.00	7.08	21.42	12.00
105	IP-338	44.00	90.00	0.75	1.00	1.00	42.67	55.00	64.66	8.18	19.81	22.00
106	IP-339	42.00	88.00	0.45	1.33	0.54	28.72	66.66	70.91	7.68	21.53	14.00
107	IP-343	44.00	89.00	0.58	1.00	0.70	37.98	58.97	70.66	7.99	26.74	23.00
108	IP-344	43.00	86.00	0.24	1.00	0.64	36.16	59.09	55.33	7.07	29.54	13.00
109	IP-345	47.00	89.00	0.43	1.00	0.32	18.60	60.00	53.00	8.96	20.00	12.00
110	IP-346	46.00	87.00	0.34	2.00	0.47	22.34	52.17	53.66	7.65	22.64	12.00
111	IP-349	47.00	85.00	0.38	2.33	0.74	23.77	57.89	62.00	7.96	30.13	22.00
112	IP-352	47.00	88.00	0.50	2.00	1.03	44.59	61.11	61.66	7.57	22.68	22.00
113	PP-29-C-4	42.00	89.00	0.50	2.66	0.57	24.57	54.54	48.33	7.87	17.14	12.00
114	IP-353	46.00	86.00	0.18	3.00	0.50	33.11	50.87	76.33	7.94	42.02	29.00
115	IP-355	46.00	87.00	0.28	2.00	1.03	44.65	61.76	82.66	7.42	33.33	21.00
116	IP-358	47.00	91.00	0.73	2.33	0.50	37.76	61.29	57.91	7.46	18.26	19.00
117	IP-363	44.00	84.00	0.19	1.33	1.42	44.38	64.00	102.00	7.11	44.44	16.00
118	IP-364	45.50	87.00	0.11	2.00	0.56	31.44	59.45	84.66	7.69	18.33	22.00
119	IP-365	45.00	89.00	0.76	2.66	0.57	34.63	51.16	91.00	7.73	20.56	22.00
120	IP-366	45.00	81.00	0.35	1.66	0.87	39.60	63.15	63.33	7.55	24.28	24.00
121	IP-368	48.00	88.00	0.58	3.00	0.80	31.58	63.63	58.00	7.78	28.28	28.00
122	IP-371	47.00	86.00	0.68	2.33	0.65	40.44	55.83	83.33	8.25	19.13	22.00
123	C4	49.00	92.00	0.68	2.66	0.67	30.41	54.66	56.33	7.68	24.07	26.00
124	IP-373	49.00	90.00	0.46	2.33	1.22	41.55	51.85	80.33	7.82	28.28	28.00
125	IP-374	43.00	89.00	0.82	1.66	0.74	31.64	57.89	71.33	7.41	18.64	22.00

126	IP-376	44.00	83.00	0.94	1.00	0.30	21.42	66.66	64.66	8.68	13.79	16.00
127	IP-378	46.00	81.00	0.47	1.00	0.54	34.63	62.05	76.33	8.06	25.64	19.00
128	IP-379	45.00	86.00	0.36	1.00	0.47	39.52	41.66	46.00	7.45	16.94	10.00
129	IP-382	43.00	88.00	0.40	1.66	0.57	29.51	53.33	85.66	8.14	23.18	16.00
130	IP-388	44.00	90.00	0.64	1.00	1.00	27.51	53.12	85.66	7.55	18.27	17.00
131	IP-389	44.00	85.00	0.84	1.00	0.80	28.38	63.63	74.33	7.94	22.22	28.00
132	IP-395	36.00	79.00	0.80	1.00	0.77	31.34	64.28	64.33	8.41	17.14	18.00
133	IP-396	35.00	80.00	0.75	1.66	0.90	34.66	56.09	84.66	8.33	20.35	23.00
134	IP-399	38.00	81.00	0.40	1.00	0.40	39.52	63.64	79.33	7.68	23.42	14.00
135	IP-410	39.00	86.00	0.36	1.00	0.70	39.40	55.83	67.33	7.35	30.00	21.00
136	IP-405	42.00	79.00	0.53	2.00	0.27	31.75	58.82	69.33	7.55	23.80	20.00
137	IP-413	49.00	83.00	0.50	1.33	0.44	45.69	56.66	74.33	8.81	21.51	17.00
138	IP-415	46.00	88.00	0.67	1.33	0.54	26.73	41.37	82.66	7.90	12.76	12.00
139	IP-416	47.00	89.00	0.36	1.00	0.40	28.41	53.57	65.33	8.45	24.59	15.00
140	IP-419	49.00	93.00	0.34	1.33	1.00	32.32	54.54	61.00	7.86	23.07	12.00
141	IP-420	47.00	90.00	0.29	1.00	0.34	24.46	48.27	66.66	7.67	24.56	14.00
142	IP-422	46.00	86.00	0.40	1.33	0.84	31.49	70.37	58.00	7.99	28.78	19.00
143	IP-426	49.00	88.00	0.69	1.33	0.40	26.30	44.82	77.33	8.12	13.97	13.00
144	IP-427	50.00	90.00	0.38	1.33	0.44	33.31	56.09	57.66	8.01	31.08	23.00
145	IP-428	48.00	89.00	0.27	1.00	0.74	37.73	41.55	79.33	7.47	25.00	15.00
146	IP-429	46.00	82.00	0.68	1.33	0.54	31.75	47.85	65.00	8.01	21.36	25.00
147	IP-434	50.00	87.00	0.40	1.00	0.57	41.48	39.24	64.66	7.40	16.66	11.00
148	IP-470	46.00	81.00	0.20	1.00	0.50	32.68	54.50	66.33	7.40	34.00	17.00
149	IP-469	48.00	88.00	0.80	1.66	0.24	25.46	56.68	71.00	7.56	13.13	13.00
150	IP-475	46.00	89.00	0.71	1.66	0.32	31.53	56.71	80.66	7.36	15.00	16.00
151	IP-476	51.00	90.00	0.87	1.33	0.47	31.59	41.64	66.33	7.76	13.89	18.00
152	IP-478	50.00	87.00	0.66	2.33	0.50	37.76	46.64	67.33	7.53	18.91	21.00

153	C3	47.00	88.00	0.47	1.00	0.27	41.62	59.22	62.33	7.32	24.69	20.00
154	IP-477	46.00	87.00	0.94	1.00	0.34	36.79	48.10	64.66	7.90	14.39	19.00
155	IP-480	49.00	86.00	0.20	1.00	0.74	43.78	61.39	79.33	7.79	37.20	16.00
156	IP-479	40.00	77.00	0.34	1.33	0.74	43.28	62.00	62.66	7.59	32.78	20.00
157	IP-482	39.00	80.00	0.51	1.00	0.34	38.36	66.07	82.66	7.24	32.60	30.00
158	IP-485	38.00	82.00	0.65	1.66	0.29	29.16	55.42	59.00	7.80	19.79	19.00
159	IP-486	37.00	79.00	0.89	2.63	0.47	32.60	50.31	68.00	7.76	19.71	23.50
160	IP-487	47.00	86.00	0.49	2.63	0.34	40.30	66.06	58.00	7.44	22.53	16.00
161	IP-488	47.00	83.00	0.74	2.00	0.40	40.51	65.47	50.00	7.57	16.49	16.00
162	IP-489	45.00	81.00	0.57	1.66	0.90	40.58	41.89	59.33	7.67	15.90	14.00
163	C2	44.00	79.00	0.20	1.66	0.30	31.10	48.53	68.66	7.63	38.15	29.00
164	IP-493	46.00	81.00	0.73	2.33	0.40	43.12	55.10	64.33	8.32	18.34	20.00
165	IP-498	49.00	88.00	0.45	2.00	0.30	31.54	49.57	62.00	8.36	22.97	17.00
166	IP-500	49.00	85.00	0.76	1.00	0.47	31.56	45.58	50.00	7.54	14.28	15.00
167	IP-501	37.00	80.00	0.36	1.00	0.34	32.86	57.61	67.50	8.03	29.85	20.00
168	IP-504	50.00	81.00	0.19	1.00	0.33	20.90	49.49	62.00	8.02	28.57	12.00
169	IP-505	48.00	89.00	0.35	1.66	0.30	21.45	76.06	56.00	8.08	24.48	12.00
170	IP-509	48.00	83.00	0.54	1.00	0.57	35.34	51.82	52.66	7.51	17.64	15.00
171	IP-512	49.00	86.00	0.65	1.00	0.47	39.46	55.27	49.33	7.41	15.55	14.00
172	IP-510	50.00	87.00	0.27	1.66	0.44	36.24	57.47	58.66	8.11	40.50	32.00
173	IP-515	46.00	81.00	0.31	1.33	0.57	31.40	52.75	61.00	8.10	25.86	15.00
174	IP-517	49.00	89.00	0.35	1.33	1.53	37.35	53.74	75.33	6.91	24.28	17.00
175	IP-525	57.00	90.00	0.43	1.33	0.95	42.32	40.68	62.00	6.75	16.30	15.00
176	IP-531	50.00	83.00	0.80	1.00	0.86	49.38	61.81	65.66	6.99	20.33	24.00
177	IP-534	48.00	87.00	0.67	1.33	1.34	42.35	64.29	69.91	7.82	15.11	12.00
178	C1	48.00	81.00	0.31	1.33	0.67	40.36	62.32	57.33	7.52	29.33	19.00
179	IP-540	47.00	88.00	0.41	1.33	0.57	32.48	43.06	56.00	7.11	19.73	15.00

180	IP-541	40.00	91.00	0.36	1.66	0.77	36.44	46.68	57.66	8.47	16.83	17.00
181	IP-543	41.00	86.00	0.60	1.00	0.64	38.30	56.38	62.36	7.27	22.85	16.00
182	IP-544	40.00	88.00	0.41	1.00	0.70	28.46	37.02	59.33	7.37	20.33	12.00
183	IP-545	36.00	85.00	0.32	1.33	0.34	30.58	43.88	52.00	7.50	19.50	7.00
184	IP-549	38.00	81.00	0.19	1.00	0.84	51.49	52.35	49.66	7.71	25.00	19.00
185	IP-550	37.00	85.00	0.38	1.66	0.40	41.49	56.93	56.33	7.29	19.04	12.00
186	IP-551	38.00	83.00	0.29	1.33	0.44	33.18	48.54	58.00	8.81	30.10	28.00
187	IP-553	47.00	86.00	0.44	1.00	0.70	32.59	55.31	55.66	7.25	20.58	14.00
188	C1	41.00	81.00	0.75	1.66	0.60	37.40	62.14	56.00	7.50	22.97	17.00
189	IP-556	47.00	88.00	0.44	1.00	0.64	41.49	44.75	52.33	6.70	19.27	16.00
190	IP-558	47.00	86.00	0.54	1.66	0.47	38.26	52.83	67.00	7.24	25.58	22.00
191	IP-559	46.00	90.00	0.43	1.33	0.27	36.54	57.44	61.66	8.56	28.57	20.00
192	IP-561	43.00	83.00	0.37	1.66	0.40	35.47	38.24	59.00	7.41	14.63	12.00
193	IP-563	47.00	88.00	0.38	1.66	0.54	29.48	45.64	55.66	8.20	26.56	40.00
194	IP-564	46.00	87.00	0.56	1.00	0.40	39.31	55.82	52.33	7.07	29.29	29.00
195	IP-565	49.00	89.00	0.65	1.66	0.40	41.55	59.77	51.00	8.27	24.50	25.00
196	IP-569	47.00	85.00	0.62	1.00	0.50	36.13	44.31	61.00	7.29	14.94	16.00
197	IP-572	47.00	87.00	0.66	1.66	0.70	36.66	61.18	49.33	7.38	38.88	21.00
198	C2	52.00	90.00	0.20	1.33	0.47	46.14	47.27	61.33	7.75	35.38	23.00
199	IP-574	49.00	88.00	0.37	2.00	0.67	32.67	54.92	68.66	8.51	27.14	19.00
200	IP-575	51.00	81.00	0.48	2.00	0.57	29.20	55.43	56.00	7.75	25.35	18.00
201	IP-579	49.00	87.00	0.37	1.33	0.37	38.79	67.08	47.33	7.26	30.15	19.00
202	IP-590	45.00	89.00	0.25	1.33	0.47	30.35	63.82	52.33	7.38	30.00	12.00
203	IP-592	50.00	88.00	0.26	2.00	0.27	35.36	55.54	58.00	7.92	28.33	21.00
204	IP-602	48.00	86.00	0.55	1.00	0.47	34.36	34.76	62.66	7.71	15.15	15.00
205	IP-604	51.00	85.00	0.68	1.00	0.70	31.35	69.68	66.00	8.71	16.09	14.00
206	IP-630	52.00	87.00	0.51	1.33	0.77	42.17	46.78	51.33	7.87	10.93	7.00

207	IP-642	48.00	88.00	0.57	1.00	0.77	36.26	62.82	63.33	8.52	22.09	19.00
208	C3	48.00	86.00	0.29	1.33	0.94	33.65	51.51	56.66	7.11	28.33	17.00
209	IP-646	49.00	86.00	0.34	1.33	0.30	22.22	48.85	64.00	7.89	23.07	15.00
210	IP-647	47.00	87.00	0.64	1.33	0.77	37.24	61.23	58.66	7.49	15.18	12.00
211	IP-651	50.00	88.00	0.71	1.33	0.87	27.15	41.71	49.66	8.28	17.50	21.00
212	IP-682	48.50	89.00	0.28	1.66	0.90	32.35	51.57	61.33	7.21	27.11	16.00
213	IP-700	44.00	81.00	0.43	1.66	0.74	22.31	55.18	60.50	7.92	23.61	17.00
214	IP-709	48.00	80.00	0.70	1.00	0.60	27.55	73.66	60.33	8.31	16.09	14.00
215	IP-718	42.00	83.00	0.27	1.00	0.57	29.37	61.89	64.67	6.82	27.65	13.00
216	IP-724	46.00	85.00	0.40	1.00	0.44	31.38	60.33	61.83	7.41	20.35	18.00
217	IP-734	45.00	73.00	0.54	1.00	0.47	27.62	58.75	51.67	7.01	16.90	12.00
218	IP-737	43.00	75.00	0.54	1.33	0.94	34.32	53.72	55.00	8.58	25.28	22.00
219	IP-743	45.00	81.00	0.32	1.66	0.77	33.25	61.82	74.66	8.63	26.00	13.00
220	IP-747	46.00	80.00	0.54	1.00	0.77	31.39	43.68	49.00	7.97	11.59	8.00
221	IP-750	44.00	89.00	0.76	1.00	0.87	26.45	55.66	57.33	7.65	13.00	13.00
222	IP-753	46.00	83.00	0.70	1.00	0.67	31.47	63.83	48.66	7.32	22.52	25.00
223	IP-755	38.00	86.00	0.63	1.33	0.80	36.78	35.18	55.66	7.14	10.46	9.00
224	IP-758	36.00	80.00	0.14	1.00	0.90	26.58	61.32	61.66	7.32	39.39	13.00
225	IP-760	49.00	83.00	0.55	1.33	0.57	29.53	34.05	68.33	8.48	13.97	12.00
S.Em (d)±		0.76	1.65	0.07	0.38	0.04	0.46	0.87	0.46	0.09	0.77	0.86
C.D. (at 5%)		1.49	3.24	0.14	0.74	0.07	0.90	1.71	0.91	0.17	1.52	1.69

Table 4.2. Mean, range, coefficient of variation, heritability and genetic advance of different characters

S. No.	Characters	Range	Grand mean	PCV	GCV	Heritability (%)	Genetic advance	Genetic advance as per cent of mean
1	Days to 50% flowering	35-57	45.62	8.56	8.39	96.2	7.74	16.97
2	Days to maturity	60-97	85.34	5.26	4.89	86.5	8.00	9.37
3	Dry shoot weight/plant	0.13-0.95	0.51	37.65	34.96	86.2	0.34	66.67
4	No. of tillers/plant	1.00-7.00	1.92	50.39	46.37	84.7	1.69	88.02
5	Stem girth (3-4) internode (cm)	0.17-1.53	0.57	39.17	38.65	97.4	0.45	78.95
6	Flag leaf length (cm)	18.6-51.49	33.49	18.32	18.27	99.4	12.57	37.53
7	Panicle index	31.25-76.06	53.51	16.56	16.48	99.0	18.08	33.79
8	Seed density /cm^2	46.00-110.66	71.24	20.50	20.21	97.2	29.23	41.03
9	10 ml seed volume weight (g)	6.62-9.06	7.82	5.93	5.83	96.6	0.92	11.76
10	Harvest index	10.46-40.50	22.12	29.55	29.37	98.6	13.28	60.04
11	Seed weight/plant (g)	7.00-40.00	18.05	30.53	30.16	97.5	11.07	61.33

Table 4.6 Cluster mean

Clusters	Days to 50% flowering	Days to maturity	Dry shoot weight/ plant	No. of tillers/ plant	Stem girth (3-4) internode (cm)	Flag leaf length (cm)	Panicle index	Seed density /cm^2	10 ml seed volume wt. (g)	Harvest index	Seed weight per plant (g)
I	41.69	81.50	0.37	1.14	0.60	36.98	60.26	62.20	7.39	28.17	17.94
II	47.42	84.42	0.76	1.96	0.46	31.43	60.28	70.16	7.74	15.97	15.11
III	46.64	79.97	0.42	2.19	0.57	37.22	58.97	81.97	8.37	26.27	21.39
IV	39.87	82.61	0.58	2.42	0.52	31.51	54.94	80.58	7.97	21.17	20.24
V	47.04	86.75	0.66	1.85	0.59	38.07	56.98	65.24	7.72	23.35	22.55
VI	48.81	86.92	0.52	1.22	0.69	34.44	47.14	57.45	7.47	17.49	13.88
VII	47.25	87.50	0.37	1.75	1.15	42.98	59.69	80.49	7.53	29.56	18.88
VIII	46.71	91.71	0.53	4.78	0.39	33.25	46.98	87.47	7.97	22.93	22.57
IX	46.77	86.79	0.37	1.52	0.48	27.59	57.50	64.04	8.01	25.01	16.48
X	41.54	86.08	0.39	1.49	0.46	37.52	44.10	59.07	7.58	17.40	11.15
XI	46.22	84.78	0.28	1.81	0.46	33.94	51.85	69.29	7.96	35.79	29.72
XII	46.26	86.23	0.57	2.45	0.61	29.93	44.24	85.70	8.01	16.91	15.87
Range	8.94	11.74	0.48	3.64	0.72	15.39	16.18	30.02	0.98	19.82	18.57

Table 4.1. ANOVA for different traits

Sources of variation	d.f.	Days to 50% flowering	Days to maturity	Dry shoot weight/plant	No. of tillers/plant	Stem girth (3-4) internode (cm)
Replications	1	495.06**	348.50**	0.2126**	2.009**	0.0167**
Treatments	224	29.905**	37.6105**	0.0690**	1.733**	0.0984**
Error	224	0.5801	2.7299	0.00512	0.1439	0.001321

Sources of variation	d.f.	Flag leaf length (cm)	Panicle index	Seed density /cm^2	10 ml seed volume weight (g))	Harvest index	Seed weight/plant (g)
Replications	1	377.062**	492.12**	423.500**	442.889**	409.94**	551.109**
Treatments	224	75.0654**	156.328**	420.496**	0.4237**	84.8788**	59.995**
Error	224	0.2123	0.7578	6.0625	0.007394	0.5994	0.7450

** = Significant at p = 0.01

Table 4.4. Average intra and inter-cluster distance (D-values) of different clusters in pearl millet

Cluster	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
I	2.484	3.748	3.157	3.048	2.906	3.398	3.631	5.723	2.862	3.079	3.453	4.231
II		2.444	3.419	2.743	2.402	2.830	4.834	4.474	2.856	3.570	4.940	2.514
III			2.737	2.620	2.836	4.130	3.837	4.450	2.974	4.281	3.042	3.310
IV				2.337	2.809	3.884	4.584	3.966	3.000	3.391	3.872	2.507
V					2.373	2.629	3.487	4.132	2.728	3.508	3.355	3.061
VI						2.278	4.016	5.163	2.769	2.442	4.707	2.892
VII							2.532	5.580	4.291	4.850	4.405	4.548
VIII								2.334	4.548	5.182	4.704	3.410
IX									2.188	3.177	3.282	2.952
X										2.455	4.871	3.242
XI											2.532	4.552
XII												2.355

Table 4.5. Inter and intra (diagonal) cluster divergence (D^2) in pearl millet

Cluster	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
I	6.170	14.048	9.967	9.290	8.445	11.546	13.184	32.753	8.191	9.480	11.923	17.901
II		5.973	11.690	7.524	5.770	8.009	23.368	20.017	8.157	12.745	24.404	6.320
III			7.491	6.864	8.043	17.057	14.723	19.803	8.845	18.327	9.254	10.956
IV				5.462	7.890	15.085	21.013	15.729	9.000	11.499	14.992	6.285
V					5.631	6.912	12.159	17.073	7.442	12.306	11.256	9.370
VI						5.189	16.128	26.657	7.667	5.963	22.156	8.364
VII							6.411	31.136	18.413	23.523	19.404	20.684
VIII								5.448	20.684	26.853	22.128	11.628
IX									4.787	10.093	10.772	8.714
X										6.027	23.727	10.511
XI											6.411	20.721
XII												5.546

Table 4.7. Estimation of correlation

Characters		Days to maturity	Dry shoot weight/ plant	No. of tillers/ plant	Stem girth (3-4) inter node	Flag leaf length (cm)	Panicle index	Seed density /cm^2	10 ml seed volume wt. (g)	Harvest index	Seed weight/ plant (g)
Days to 50% flowering	P	0.208**	0.034	-0.007	0.026	0.061	-0.059	-0.060	0.015	-0.030	-0.010
	G	0.227	0.040	-0.009	0.026	0.062	-0.060	-0.063	0.027	-0.031	-0.035
	E	0.009	-0.030	0.015	0.011	0.001	-0.021	0.026	-0.327**	0.007	-0.152*
Days to maturity	P		0.030	0.128	0.087	-0.085	-0.101	-0.020	-0.060	-0.113	-0.078
	G		0.043	0.150	0.102	-0.101	-0.108	-0.021	-0.065	-0.122	-0.086
	E		-0.047	0.000	-0.098	0.331**	-0.014	-0.004	-0.013	-0.009	0.018
Dry shoot weight/plant	P			0.121	-0.040	-0.013	-0.022	0.089	0.011	-0.530**	0.038
	G			0.149	-0.042	-0.011	-0.024	0.090	0.003	-0.574	0.040
	E			-0.042	-0.026	-0.094	0.006	0.113	0.121	-0.020	0.018
No. of tillers/plant	P				-0.137*	-0.039	-0.199**	0.442**	0.157*	-0.075	0.219**
	G				-0.147	-0.042	-0.215	0.479	0.176	-0.079	0.245
	E				-0.050	0.012	-0.046	0.118	-0.026	-0.064	-0.060
Stem girth (3-4) internode (cm)	P					0.182**	0.063	0.048	-0.161*	0.074	0.016
	G					0.190	0.067	0.047	-0.167	0.076	0.007
	E					-0.395**	-0.195**	0.072	0.024	-0.046	0.349**
Flag leaf length (cm)	P						0.017	-0.075	-0.192**	0.118	0.174**
	G						0.016	-0.077	-0.195	0.120	0.181
	E						0.122	0.061	-0.102	-0.028	-0.36**
Panicle index	P							-0.051	-0.007	0.337**	0.123
	G							-0.051	-0.007	0.341	0.126
	E							-0.042	-0.010	-0.006	-0.069
Seed density/cm^2	P								0.202**	0.017	0.163**
	G								0.209	0.170	0.168
	E								-0.005	0.025	-0.009
10 ml seed volume weight (g)	P									-0.003	0.122
	G									-0.003	0.125
	E									-0.013	0.024
Harvest index	P										0.508**
	G										0.517
	E										0.015

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

Table 4.8: Genotypic path

Characters	Days to 50% flowering	Days to maturity	Dry shoot weight/ plant	No. of tillers/ plant	Stem girth (3-4) internode (cm)	Flag leaf length (cm)	Panicle index	Seed density /cm^2	10 ml seed volume wt. (g)	Harvest index	Genotypic correlation
Days to 50% flowering	**-0.009**	-0.006	0.020	-0.002	0.000	0.007	0.006	0.001	0.003	-0.026	-0.005
Days to maturity	-0.002	**-0.027**	0.021	0.0231	0.000	-0.012	0.011	0.000	-0.007	-0.102	-0.086
Dry shoot weight/plant	0.000	-0.001	**0.487**	0.031	0.000	-0.001	0.003	-0.001	0.000	-0.478	0.040
No. of tillers/plant	0.000	-0.004	0.073	**0.209**	0.000	-0.005	0.023	-0.005	0.020	-0.065	0.245
Stem girth (3-4) internode (cm)	0.000	-0.003	-0.021	-0.031	**0.003**	0.022	-0.007	-0.001	-0.019	0.063	0.007
Flag leaf length (cm)	-0.001	0.003	-0.005	-0.009	0.001	**0.116**	-0.002	0.001	-0.022	0.100	0.181
Panicle index	0.001	0.003	-0.012	-0.045	0.000	0.002	**-0.106**	0.001	-0.001	0.284	0.126
Seed density /cm^2	0.001	0.001	0.044	0.100	0.000	-0.009	0.005	**-0.011**	0.023	0.014	0.168
10 ml seed volume weight (g)	0.000	0.002	0.001	0.037	0.000	-0.023	0.001	-0.002	**0.112**	-0.002	0.125
Harvest index	0.000	0.003	-0.280	-0.016	0.000	0.014	-0.036	0.000	0.000	**0.832**	0.517

Residual = 0.4766

Note: Underlined and bold values denote direct effect