

## *DEDICATION*

*In my Life my Parents, Family Members  
and God Almighty are the most Precious*

*So, all valuable things in my Life,*

*I want to dedicate to them,*

*this thesis is the*

*beginning ...*

*... Tulasi*

**“PATH ANALYSIS AND GENETIC DIVERSITY IN  
FINGER MILLET (*Eleusine coracana* Gaertn L.)”**

A thesis submitted to the

**MAHATMA PHULE KRISHI VIDYAPEETH,  
RAHURI-413722, DIST. AHMEDNAGAR,  
MAHARASHTRA STATE, INDIA**

by

**MISS. VANKA TULASI MANI**

**Reg. No. 05/173**

In partial fulfilment of the requirements for the degree of

**MASTER OF SCIENCE (AGRICULTURE)**

in

**AGRICULTURAL BOTANY  
(CYTOGENETICS AND PLANT BREEDING)**

**DEPARTMENT OF AGRICULTURAL BOTANY**

**MAHATMA PHULE KRISHI VIDYAPEETH**

**COLLEGE OF AGRICULTURE**

**PUNE - 411005**

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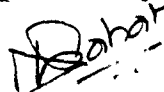
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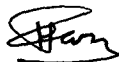
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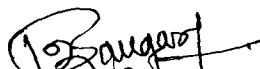
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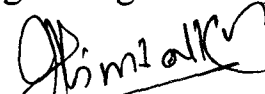
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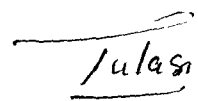
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I hereby declare that the thesis entitled "**Path analysis and genetic diversity in finger millet (*Eleusine coracana* Gaertn L.)**" or part thereof has not been submitted by me or any other person to any other University or Institute for a Degree or Diploma.

**Place :** Pune

**Date :** 19 / 5 / 2007



**(Vanka Tulasi Mani)**

**Prof. D. V. Dahat**  
Assistant Professor of Agril. Botany  
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## **CERTIFICATE**

This is to certify that the thesis entitled, “**Path analysis and genetic diversity in finger millet (*Eleusine coracana* Gaertn L.)**” submitted to the faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra, in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE (Agriculture) in Agricultural Botany (Cytogenetics and Plant Breeding)** embodies the results of a piece of *bonafide* research work carried out by **Miss. Vanka Tulasi Mani** under my guidance and supervision, and that no part of the thesis has been submitted for any other Degree or Diploma.

The assistance and the help received during the course of this investigation have been duly acknowledged.

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**Place : Pune**

**Date : 19/5/07**

**(R. N. Sabale)**

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*V. Mani*  
 (Vanka Tulasi Mani)

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i.e.	:	That is
m	:	meter
N	:	Nitrogen
NARP	:	National Agricultural Research Project
No.	:	Number
<i>Per se</i>	:	Actual
P <sub>2</sub> O <sub>5</sub>	:	Phosphate
PCV	:	Phenotypic coefficient of variation
R	:	Residual effect
S.E.	:	Standard error
SLA	:	Specific leaf area
$\bar{X}$	:	General mean
x	:	Multiplication
Y	:	Yield
<i>via</i>	:	through
<i>viz.</i> ,	:	Videlicent (namely)

**ABSTRACT****“Path analysis and genetic diversity in finger millet****(*Eleusine coracana* Gaertn L.)”**

by

**Miss. Vanka Tulasi Mani**

A candidate for the degree of

**Master of Science (Agriculture)**

in

**Agricultural Botany****(Cytogenetics and Plant Breeding)**

---

**Research Guide : Prof. D. V. Dahat****Discipline : Agricultural Botany****Major Field : Cytogenetics and Plant Breeding**

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The present investigation “Path analysis and genetic diversity in finger millet (*Eleusine coracana* Gaertn L.)” was undertaken to estimate the correlation coefficients, direct and indirect effects of eleven yield contributing characters along with genetic divergence and grouping of 50 finger millet genotypes into suitable clusters. All the 50 genotypes were evaluated during *kharif*, 2006 in randomized block design in three replications at the Farm of Botany Section, College of Agriculture, Pune-5. The observations were recorded on days to 50 per cent flowering, days to maturity, plant height (cm), number of total tillers per plant, number of productive tillers per plant, number of fingers per head, finger length (cm), 1000-grain weight (g), dry biomass (g), harvest index (per cent), grain yield per plant (g), stem pigmentation, foliage colour, natural incidence of pests and diseases, finger arrangement and grain colour.

There was appreciable amount of variability in all the characters with a greater amount being observed in number of productive tillers per plant, finger length, grain yield per plant and 1000-grain weight indicated by GCV and PCV. Heritability in broad sense was higher for finger length (98.67 %) followed by plant height (97.27 %) and days to maturity (96.93 %). Genetic advance was highest for plant height (29.72) followed by days to maturity (23.88) and dry biomass (21.31).

Number of productive tillers per plant was significantly and positively correlated with grain yield at both genotypic and phenotypic levels. Plant height was negatively and significantly correlated with grain yield. Number of productive tillers per plant recorded highest direct effect on yield and its correlation with yield was significantly positive indicating true and perfect association between these characters and suggested to rely upon this character while selecting high yielding genotypes in *ragi*.

The  $D^2$  values ranged between 178.58 and 12378.53 exhibiting substantial diversity. Fifty genotypes were grouped into seven clusters. Cluster I was the largest with thirty five genotypes followed by cluster II with six, cluster III with three, cluster IV and cluster V with two genotypes each. While, the clusters VI and VII were monogenotypic. The inter-cluster distance (D) ranged between 28.48 (cluster II and cluster III) and 111.26 (cluster VI and cluster VII).

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The variance of cluster means revealed that the 1000-grain weight, plant height and finger length had maximum contribution towards divergence in the present material. The following parents are suggested for tentative breeding programme based on divergence studies.

- (1) GE-6004 (2) GE-6021 (3) GE-4866 (4) GE-2222 (5) GE-1247  
(6) GE-2022 (7) GE-4731 (8) GE-4440 and (9) GE-5949.

Chapter Opener Page

# INTRODUCTION

# 1. INTRODUCTION

Finger millet (*Eleusine coracana* Gaertn L.) is also known as 'ragi' or 'Nagali' or 'Nachani' in India. It is one of the most important food crops of the poor marginal farmers and especially of the tribal people in India and is believed to be indigenous to India. The cultivation of finger millet is widely extended from Tamil Nadu in South to Uttaranchal in North, Gujarat in West to Orissa in East and even extended to North-Eastern regions including Sikkim. It is said to have derived its name 'Eleusine' from the Greek Goddess of cereals Eleusine (Kulkarni, 1980). According to Burkil (1935) it is named after a Greek town 'Eleusine' where cereals (ceres) are worshipped. Its specific name coracana comes from its Ceylonese name 'Kurakkan'. This crop is known by various names in different parts of the world viz., Birds foot millet in England, Dagussa in Ethiopia and Wimbe in Swahili in East Africa. T-6338

Finger millet is a short duration crop grown in different seasons in different parts of the country. It is usually grown under rainfed conditions on the less fertile and droughty soils. In India finger millet is grown on an area of 1.8 million hectare with an annual production of 2.6 million tonnes whereas, in Maharashtra, it occupies an area of 1.26 lakh hectares with the production of 0.82 lakh tonnes. The average productivity of ragi in Maharashtra was 650 kg per ha during 2005-2006 (Anonymous 2006).

It belongs to the family Graminae and has a chromosome number of  $2n = 36$ . Several other species of *Eleusine* are known in the tropical areas of the old world. Of these, the most common is *Eleusine indica*, which has a chromosome number  $2n = 18$ . *Eleusine coracana* is supposed to have been derived from *Eleusine indica*.



The plant is three to four feet high with flattened stem. The leaf bases which overlap each other cover the base of the stem closely. It is dwarf in habit. It tillers profusely and bears at the end of the clumps earheads.

The root system of the *ragi* plant consists of a remarkably large number of strong slender fibrous roots, which radiate from the base of the plant all round.

The inflorescence of *ragi* consists of a group of digitately arranged spikes, with one spike, the thumb, generally below the main terminal group. The spikes are otherwise called fingers. The spikes may take 6 to 8 days to complete flowering. Pollen viability is very short, lasting only for 10 to 15 minutes. The stigma remains receptive for about five minutes after emergence from the glumes. Since the period of anthesis is very short, self pollination is the rule. However, a small per cent of natural cross pollination may occur.

It is mainly grown for the sake of grain. It has an excellent food value as its seeds contain protein ranging from 7 to 14 per cent and is particularly rich in methionine aminoacid, iron and calcium. It is favourite food of hard toiling class and also very useful to person suffering from diabetes. It plays an important role in the nutrition of millions of people in the semi-arid topics, particularly India and East Africa. With the use of white *ragi*, the products *viz.*, *Chakli*, *Pappads*, *Sandage and Sheviya* can be prepared.

Good amount of variability has been reported in this crop for the various characters such as height, flowering, maturity, tillering, branching, finger characters, seed colour, irrigation response and disease reaction. However, their utilization in breeding programmes has not been fully exploited. It is therefore, felt necessary to study the genetic

variability in various indigenous and exotic genotypes of finger millet and suggest a sound breeding programme based on the studies.

An insight into the magnitude of variability present in a crop species is of utmost importance as it provides the basis for effective selection. Recognition or knowledge of genetic variability in respect of yield structure in any species is a very valuable adjunct in a planned breeding programme, since it helps in the choice of the best yield attribute either for selection or hybridization for effective selection. Knowledge of relative heritable and non-heritable components of phenotypic variability is of imperative need. This may be achieved by estimating the genetic parameters like genotypic coefficient of variation, heritability and genetic advance for grain yield and its component characters.

Yield being a quantitative character is affected by various component characters that are highly subjected to environmental variations. The knowledge on the association of yield components with yield forms a pre-requisite for making effective selection when two or more characters are simultaneously considered in selection programme. This can be done by ascertaining the degree of correlation which enables to eliminate the characters with little or no importance in selection programme.

Correlation studies are helpful in determining the components of a complex trait like yield. But they do not provide an exact picture of the relative importance of direct and indirect influences of each of the component characters towards the yield. Path coefficient analysis suggested by Dewey and Lu (1959) proves helpful in partitioning the correlation coefficients into the measure of direct and indirect effects of a set of independent variables on the dependent variable. If the correlation

is due to direct effect, it reflects true relationship and for improving the yield, such characters can be selected.

Genetic diversity is the variability available among the different genotypes of a species. The genetic diversity, which is the basis of plant breeding, is produced due to inherent genetic differences in the plant species and is of major interest to the plant breeders. A method used by Mahalanobis (1936) known as “Mahalanobis  $D^2$  statistic” is widely used to know genetic diversity in the available genotypes. This technique measures the force of differentiation at intra-cluster and inter-cluster levels and thus helps in the selection of genetically divergent parents for their exploitation in hybridization programme. The  $D^2$  statistics also measures the degree of diversification and determines the relative proportion of each component character to the total divergence.

Looking to the available variability and immediate need of undertaking the improvement of this crop, it is felt necessary to study the genetic diversity and path analysis in *ragi* with the following objectives.

1. To study the correlation between yield and yield contributing characters.
2. To measure the direct and indirect contribution of various characters to yield.
3. To measure the genetic divergence among different genotypes of finger millet.
4. To group different genotypes into suitable clusters.

Chapter Opener Page

REVIEW OF  
LITERATURE

## **2. REVIEW OF LITERATURE**

Success of any breeding programme depends on the availability of variation and selection practiced. The selection of elite genotypes depends on the knowledge of the quantitative traits. Regarding finger millet, very limited literature is available, however, in the present chapter attempt has been made to review the published literature by earlier authors under the following subheads.

2.1 Genetic variability and heritability

2.2 Correlations

2.3 Path analysis

2.4 Genetic divergence

### **2.1 Genetic variability and heritability**

Most of the quantitative plant characters are highly influenced by environmental conditions. The progress of breeding in such a population is primarily conditioned by the magnitude, nature and interaction of genotypes with non-genotypic variation in the various plant characters. This suggests the importance of partitioning the overall variability into its heritable and non heritable components with the help of suitable genetic parameters such as heritability estimates, coefficient of variation and genetic advance.

The observable variation in the population is the result of interaction of genotypic and the environmental factors. The effects due to these two factors are found to be blended together and hence cannot be resolved directly.

Fisher (1930) first presented the method to separate the effects due to the genotype and environment. The extent of genotypic variability was

presented by him with appropriate statistical method and the value was expressed as genotypic coefficient of variation.

Ayyangar *et al.* (1933) reported variability in the earhead types of *nachani*, which comprised regular open, top-curved and incurved. Significant differences for average length of finger and average number of seed content per centimeter length of finger were observed. However, there were no significant differences in number of fingers and number of seed content per earhead among the different genotypes.

The utility of estimates of genetic variance components as a basis for prediction of the response of quantitative characters for selection in breeding programme have been emphasized by Burton (1952) and Panse (1957).

Burton (1952) proposed that heritability in narrow sense is more valuable in crop improvement programme

The broad sense heritability is always the best since it is not only due to additive gene action but also the epistatic action which is influenced by environment (Comstock and Robinson, 1952).

Johnson *et al.* (1955) suggested that heritability estimates accompanied by high expected genetic advance are usually more helpful than heritability values alone in predicting the effect of selecting the best individuals.

Panse (1957) reported that the genetic part of heritable variation in a genotype is result of additive gene action which excludes dominance and epistatic action. He also suggested that high heritability is not always accompanied by high genetic gain but whatever this association occurs additive gene effects are probably important.

Kempanna and Thirumalachar (1968) reported that the cultivars differed significantly in number of tillers per plant, grain bearing area per ear and yield per plant, the variation in tiller number being the most

influenced by environment. Heritability value was high for grain yield per plant. They also observed high genetic advance for grain yield per plant in *nachani*.

Higher genetic coefficient of variation for grain yield, plant height, panicle length and panicle weight in 14 varieties of *Eleusine coracana* was reported by Narsimha Rao and Parthosarathi (1968). They also recorded greater phenotypic variation for the characters *viz.*, plant height, tiller number and grain yield. High genetic advance was reported for panicle length in *nagali*.

Patnaik (1968) reported that the maximum phenotypic variation was found for grain yield in *nachani*. The least phenotypic variation was indicated for heading date. The highest genetic coefficient of variation was recorded for yield followed by plant height and 1000-grain weight. While, low values for finger length and yield.

Chaudhari and Acharya (1969) studied 47 varieties of *nagali* and observed that the phenotypic and genotypic coefficients of variation varied from 6.4 to 7.6 for days to heading and 40.4 to 40.9 for straw yield, respectively. High heritability was found for characters *viz.*, plant height, length of main ear, seed yield and straw yield. Genetic advance was high for straw yield and plant height.

Ahluwalia *et al.* (1970) studied the genetic variability in *Eleusine coracana* and *Setaria italica*. The data showed that number of tillers per plant and number of ears offered scope for improvement in all these species. The weight of main ear and grains in main ear were also important in *Eleusine coracana* and ear width and grain yield per plant were important in *Setaria italica*.

Dhagat *et al.* (1972) observed that genotypic coefficient of variation was higher for grain weight of main ear and low for grain yield. The heritability values were high for grain yield of main ear, days to

flowering, tiller number and low for grain yield. High genetic advance was reported in grain weight of main ear, days to flowering, tiller number and low for grain yield.

Mahudeswaran and Murugesan (1973) reported high heritability for plant height, straw yield and low for grain weight in *ragi*. High genetic advance was reported for plant height, straw yield and 1000-grain weight.

High genotypic coefficient of variation for number of days to maturity and grain yield in 18 varieties of *nagali* was reported by Patnaik and Jana (1973). They also recorded high heritability values for days to flowering, days to maturity, number of tillers, grain yield and length of main finger. Genetic advance was high for days to maturity, days to flowering, plant height and number of fingers per ear in *nagali*.

Setty *et al.* (1974) in their studies with 81 genotypes of finger millet, representing different agroclimatic regions of India and Africa, found significant variation for all the characters. High heritability values were recorded for days to heading (92.38), plant height (94.29) and grain yield (81.68). But low heritability was found for tiller number (69.57) and number of fingers (77.36). Genetic advance was high for grain yield (50.86) in *ragi*.

Kempanna (1975) concluded that *Eleusine coracana* having been subjected to the pressure of evolutionary forces both natural and artificial, necessitated by its long ancestral history and wide geographical distribution must have developed diversified forms.

Appadurai *et al.* (1977) found significant differences for all the characters studied in *ragi*. Relatively low genotypic coefficient of variation was observed for number of fingers (6.60) and length of finger (13.59) as compared to that of number of tillers (27.10) and straw weight (44.10). Days to 50 per cent bloom showed the highest heritability (98.

The genetic diversity in African collection of finger millet was studied by Swaminath (1978). He reported that both phenotypic and genotypic variances were highest for density of seed followed by plant height, earhead weight, fodder weight and days to maturity.

In finger millet, Agalodia *et al.* (1979) found that the genotypic coefficient of variability ranged from 5.18 for plant height to 29.75 for weight of main ear. The length and width of the main ear, finger per ear and grain weight of main ear had high genotypic coefficient of variation. Heritability was high for all the characters except for plant height (29.03). The genetic advance expressed as percentage of mean was high for length and width of main ear (57.68 and 50.73, respectively) and fingers per ear (40.85).

The variability in *nagali* was studied by Kulkarni (1980). He found maximum genotypic variance for number of days to maturity (124.55) and the minimum for 1000-grain weight (0.188). The phenotypic coefficient of variation (PCV) was highest for number of effective tillers per plant (33.11) and lowest for number of days to maturity (8.88), while the genotypic coefficient of variation (GCV) was highest for finger length (25.75) and lowest for finger width (9.66). The genetic advance was highest for number of days to flowering (21.85) and plant height (16.38).

Mishra *et al.* (1980) studied the 480 indigenous types of finger millet and found that the number of effective tillers had the highest phenotypic coefficient of variation (33.7) followed by yield (33.5) but the latter had the highest genotypic coefficient of variation. Days to maturity had the lowest PCV and GCV (9.8 and 9.7, respectively). The heritability estimates ranged from 66.01 per cent for fingers per ear to 99 per cent for days to maturity. The predicted genetic advance at 5 per cent selection intensity ranged between 19.2 per cent for fingers per ear and 57.2 per cent for yield.

Sarvaiya *et al.* (1982) in their studies recorded maximum variability in *ragi* for plant height followed by days to maturity. High GCV was observed for 1000-grain weight, weight of main ear and tillers per plant. Higher estimates of heritability was observed for days to flowering, days to maturity, straw yield per plant, weight of main earhead, 1000-grain weight, length of main earhead and plant height. High genetic advance as percentage of mean values was found in straw yield per plant, weight of main earhead and tillers per plant.

Prabhakar and Prasad (1983) reported high phenotypic coefficient of variability for grain yield and number of productive tillers.

High genetic coefficient of variability was observed for grain yield (34.35) followed by length of finger (27.23), number of fingers on main tillers (14.48), days to flowering (12.29), days to maturity (10.95) and plant height (9.73) in finger millet by Goswami and Asthana (1984).

Shankar (1986) studied grain yield and eight related characters in three generations of crosses in finger millet. Heritability was high for number of spikes, grain yield, height and number of days to maturity.

In 20 diverse genotypes of finger millet both PCV and GCV were high for grain yield per plant (33.7 and 14.6, respectively). High heritability was observed for days to maturity (99.5), days to flowering (97.7), fingers per ear (83.3) and 1000-grain weight (98.1) and low heritability was recorded in effective tillers per plant (39.6). Estimates of genetic advance expressed as percentage of mean, ranged from 7.79 for plant height to 56.23 for grain yield per plant (Abraham *et al.*, 1989).

In finger millet  $F_1$ ,  $F_2$  and  $F_3$  generation of crosses were studied by Shanthakumar (1989) and reported a fairly moderate to high heritability for days to flowering, length of finger and length of ear in both the crosses. In contrast, a low heritability in both the crosses was recorded for

number of productive tillers per plant, ear weight per plant and grain yield per plant.

Tyagi and Koranne (1989) studied 29 genotypes of finger millet from different agroclimatic regions of India. Phenotypic variance for all the characters was higher than the genotypic variance. The characters *viz.*, main panicle length and 100-seed weight showed comparatively low variability. The GCV expressed as percentage over mean of various characters ranged between 3.14 for length of main panicle and 20.99 for grain yield per plant. Heritability was the highest for days to maturity (94.00) and days to 50 per cent flowering (94.94). Higher heritability values were also obtained for grain yield per plant (62.96) and fingers per ear (59.06). The lowest heritability was noticed in case of length of main panicle.

In 23 cultivars of finger millet, Verma (1989) found that the magnitude of PCV was higher than GCV in all the characters. Genetic coefficient of variation ranged from 4.95 per cent for plant height to 37.50 per cent for grain yield. Characters like days to flowering, grain yield, number of fingers per ear and total number of ears per plant revealed high heritabilities.

Significant differences among the genotypes of *ragi* for all the characters except tillers per plant were observed by Devkota and Mohapatra (1991). Heritability estimates ranged from 3.9 per cent for tiller number to 95.3 per cent for days to heading and predicted genetic advance at 5 per cent selection intensity ranged between 0.59 per cent for tiller number and 20.51 per cent for single plant yield.

Gontia *et al.* (1992) found that twelve genotypes of *ragi* varied significantly for all the characters studied except dry matter production. HR-91B produced significantly higher grain yield than the other genotypes. Harvest index of PR-109L was very low (0.14 %).

High genetic advance for characters like yield per plant, days to flowering and plant height in finger millet was recorded by Ravikumar and Seetharam (1994). These characters also indicated high heritability. However, total and productive tillers recorded moderate to high heritability but low genetic advance.

Thakur and Saini (1995) reported that the range of gcv, pcv, heritability and genetic advance were high for grain yield in finger millet. They also recorded high heritability and genetic advance for days to flowering, plant height and days to maturity.

Haider and Mahto (1995) reported variation for eleven yield contributing characters in 46 genotypes.

Mohammed *et al.* (1998) evaluated the eleven *ragi* varieties for grain yield, fodder yield and six yield related traits in trials conducted at Hagari under rainfed conditions during 1992-94. KM-221 and Rau-8 (average grain yields of 3875 and 3520 kg/ha, respectively) were the most promising genotypes. These genotypes matured four and ten days earlier, respectively than Kudligi local (mean grain yield of 3200 kg/ha). High grain yield in KM-221 was attributed to its higher mean productive tillers per plant (7.25), number of fingers per ear (8.2) and mean ear length (9.25 cm).

Bandyopadhyay (1998) studied the variability, heritability and correlation among seven quantitative characters of 20 finger millet genotypes under rainfed conditions at high altitude of Garhwal hills in the Himalayas. Significant differences were observed for all the characters under study. Higher estimates of heritability, GCV and genetic advance were registered in grain yield. It was assumed that the grain yield was controlled by additive gene effect. Days to 50 per cent heading, number of productive tillers, number of fingers per ear and days to maturity showed non-additive gene effects except days to maturity.

Bendale *et al.*, (2002) studied 29 phenotypically diverse genotypes of finger millet and revealed that genotypic coefficients of variation were high for number of tillers, number of effective tillers, grain yield per plant, straw yield per plant and weight of grains of main earhead.

## 2.2 Correlation studies

Yield is the complex outcome of certain components. These components either singly or jointly contribute to grain yield. Selection, therefore, based on yield itself would be misleading. Therefore, selection has to be employed on yield components. Thus, the information on nature and extent of association between component character pairs would strengthen the selection programme, aiming at the improvement in grain yield.

Estimation of correlation coefficient provides a measure of association between characters. The correlations provide basic information to the breeders to identify characters that have little or no importance in the selection programme.

Narismha Rao and Parthosarathi (1968) estimated positive and significant correlation both at phenotypic and genotypic level between tiller number and finger number with yield in the 14 varieties of *nagali*.

Patnaik (1968) revealed moderate correlation between number of fingers and finger length with grain yield of *nagali*. Number of tillers, density of grains and seed size were rather closely associated with yield while, heading date and plant height showed good association with it.

Chaudhari and Acharya (1969) in their studies with *nagali* reported that seed yield was positively correlated with plant height, number of productive tillers, length of finger and straw yield. The only character negatively correlated with yield was days to heading.

Dhagat *et al.* (1972) observed that grain yield was positively correlated with plant height, grain weight of main ear and 1000-grain weight and negatively correlated with number of days to maturity in *nagali*.

Mahudeswaran and Murugesan (1973) reported that the grain yield was significantly and positively correlated with number of productive tillers; whereas numbers of fingers were negatively associated with 1000-grain weight in *nagali*.

In *nagali*, positive association of grain yield with straw yield and number of tillers was observed by Appadurai *et al.* (1977). However, number of fingers was negatively correlated with yield. There was a very strong negative phenotypic correlation between grain yield and finger length.

Goud and Lakshmi (1977) in their studies with *nagali* found that the correlations between plant height and number of tillers and ear weight were negative and significant. Grain yield was positively correlated with plant height, number of fingers and weight of main ear.

Ranganathan *et al.* (1977) observed that number of fingers and number of productive tillers per plant were positively correlated with yield in *ragi*. The number of productive tillers was also positively correlated with number of fingers per plant.

Positive association was observed by Shanthappa (1978) between ear length and grain yield in the cross Indaf x Purna of *ragi*, whereas positive association between these two characters was found in the cross PR-202 x IK-927. However, yield was positively associated with number of productive tiller, earhead weight, harvest index, plant height and 500-grain weight in both the crosses.

Agalodia *et al.* (1979) found in finger millet that the grain yield was significantly and positively correlated with the width of the main ear,

number of fingers per ear and grain weight of main ear and indicated that the weight of main ear should be given more importance for improvement of grain yield in finger millet.

Xavier (1979) reported that the characters like earhead weight, straw weight, plant height, 1000-grain weight and length of finger recorded comparatively higher magnitude of correlation with grain yield than the other characters in *nagali*.

It was reported by Kulkarni (1980) that all the characters were positively and significantly correlated with yield per plant in *nagali*. Days to flowering showed positive genotypic correlation with number of fingers on main earhead, finger length and grain weight of main earhead. The plant height showed positive correlation with number of effective tillers per plant, grain weight of main earhead and 1000-grain weight. The number of fingers of main earhead showed positive correlation with finger length and grain weight of main earhead. Finger length was positively correlated with grain weight of main earhead.

In *nagali*, Prabhu (1980) reported that the productive tillers per plant had the highest correlation in positive direction with yield. For other yield contributors, the correlations with yield were non significant.

Chaugule *et al.* (1982) observed that harvest index and biological yield were positively correlated with grain yield in *nagali*. A non-significant and negative correlation between harvest index and biological yield was observed. Harvest index did not show any association with number of days to maturity, number of fingers per head and length of fingers.

In their studies with finger millet, Krishnasastry *et al.* (1982) reported that shoot dry weight was significantly and positively correlated with yield and also the average ear weight per unit area was significantly correlated with yield.

Prabhakar and Prasad (1983) studied three inter-varietal crosses of *ragi* and reported that productive tillers were highly and positively associated with grain yield. The 1000-grain weight was also positively associated with yield. The productive tillers were also consistently and positively correlated with 1000-grain weight.

Dhanakodi (1988) studied the positive association of fodder yield with plant height, days to flowering, internodal length, leaf length, leaf number and leaf width. Number of tillers had negative association with fodder yield.

Abraham *et al.* (1989) found that genotypic correlation coefficients were slightly higher than the respective phenotypic correlation coefficients. The positive genotypic association of grain yield was observed with days to flowering and days to maturity, significant positive correlation was observed only between days to flowering and days to maturity. While, significant negative correlation was observed between productive tillers per plant and fingers per ear and fingers per ear and 1000-grain weight in finger millet.

The correlations studied by Shanthakumar (1989) showed that grain yield per plant was positively associated with number of productive tillers per plant, number of fingers per ear, number of grains per centimeter length of finger and ear weight per plant in both  $F_2$  and  $F_3$  generations of both the crosses in finger millet.

Basavaraja and Sheriff (1991) studied two  $F_2$  and  $F_3$  populations in finger millet. The phenotypic correlation between yield and its components revealed that grain yield had highly significant positive association with ear weight followed by number of productive tillers, harvest index and straw weight in  $F_2$  and  $F_3$  generations of both the crosses. Plant height also showed significant positive correlation with grain yield.

Ravikumar and Seetharam (1993) studied five quantitative characters in four crosses of finger millet. The plant height, total tillers, productive tillers and fingers per ear showed significant positive association with yield. The strongest association of yield was with productive tillers. The days to flowering had significant negative correlation with total and productive tillers, thus adversely affecting grain yield.

In finger millet, grain yield had significant and positive phenotypic and genotypic association with ear bearing tillers per plant, test weight, harvest index, total dry matter production and total tillers per plant. The characters total tillers per plant had its high influence on ear bearing tillers per plant (Reddy *et al.*, 1994).

Thakur and Saini (1995) found that genotypic correlations with yield were high and negative for days to germination, heading and maturity. Genotypic correlation of fingers per plant with yield was high and positive and that of tillers per plant was low and positive. Plant height did not show any association with yield.

From their correlation studies in 21 diverse genotypes of finger millet, Singh *et al.* (1995) revealed that tillers per plant and ears per plant showed positive significant association with grain yield and were the most important yield contributing characters for yield improvement in finger millet.

Haider and Mahto (1995) in the association analysis in 46 land races of finger millet reported significant positive association at genotypic level between plant height and ear length, biological yield, ear weight, days to flowering and days to maturity. Effective tillers per plant also showed significant positive correlation with ear weight, days to flowering and days to maturity.

In genetic analysis of finger millet, Singh *et al.* (1995) reported positive correlation between the grain yield, ear length, ear per plant and 100-seed weight, confirming the findings of Abraham *et al.* (1989). In their findings grain yield, ear length, ear per plant and 100-seed weight was also significantly and positively correlated with each other indicating possibility of improving these characters simultaneously.

Mishra (1996) in the correlation studies in *ragi*, observed significant positive association between seed yield and days to flowering, plant height, panicle length at genotypic level confirming the findings of Gomez *et al.* (1986).

Ravindran *et al.* (1996) in their studies with *nagali* revealed that the number of productive tillers per plant and fingers per main ear had high direct effect with yield, while plant height had a negative and indirect effect with yield.

Marimuthu (1997) studied the eight quantitative characters in the parental and F<sub>2</sub> progeny of four finger millet Co9 x Co13, Co9 x Indaf 9, Co9 x Co7, and MS2863 x MS2655 crosses and observed the positive association of ear weight, number of productive tillers, finger number, finger length, plant height, days to 50 per cent flowering and 1000-seed weight with grain yield.

Shanthakumar *et al.* (1997) studied the ten quantitative characters in F<sub>2</sub> and F<sub>3</sub> segregating populations of the finger millet cross WR9 (green plant pigmentation) x U6 (purple plants). They recorded that grain yield was positively associated with ear weight per plant, productive tillers per plant, fingers per ear and grain per centimeter length of finger.

Vadivoo *et al.* (1998) analyzed 36 genotypes of finger millet with varying seed colour. They revealed that seed colour had significant negative association with protein content. They observed that white

seeded genotypes had highest protein content, while brown seeded types had a wide range of values.

Gowda *et al.* (1999) studied the F<sub>2</sub> and F<sub>3</sub> generations of two finger millet crosses involving genotypes differing in protein content and blast resistance and revealed that the relationship between protein content and blast resistance and protein content and grain yield was significantly negative.

Jain *et al.* (1999) evaluated the 40 genotypes of finger millet to investigate the heritable genetic variability and correlated response for blast (*Magnaporthe grisea*) resistance and morphological traits. They observed that leaf, neck and finger blast showed significant positive association with plant height, leaf angle, leaf area and number of stomata per unit area. From their studies they revealed that, selection of a dwarf plant with narrow and vertical leaves coupled with reduced number of stomata per unit area would increase blast resistance in finger millet.

Bendale *et al.* (2002) reported that grain yield had significant positive correlation with days to emergence of finger, days to maturity, finger length, weight of grains of main earhead and straw yield per plant in the 29 genotypes of finger millet.

In their studies with 50 genotypes of finger millet, Anantharaju and Meenakshiganesan (2005) reported positive and significant correlation between grain yield, number of tillers and culm thickness.

Bedis *et al.* (2006) in their studies in *nagali* found that the grain yield per plant was positively correlated with days to flowering, days to maturity, plant height, main ear length, number of fingers per ear and fodder yield.

Upadhyaya *et al.* (2006) developed a core subset of finger millet germplasms (622 accessions) based on origin and data on 14 quantitative characters. The correlation analysis studies in this core subset indicated

that panicle exertion and longest finger length could be given lower priority in the selection of elite genotypes for breeding programme.

### 2.3 Path analysis

Though the correlation studies are helpful in measuring the association between yield and yield components; they do not provide the exact picture of the direct and indirect causes of such associations which can be had through path analysis (Wright, 1921). Thus, the path coefficient analysis is very helpful to pin-point the important yield components which can be utilized for construction of selection indices.

Dewey and Lu (1959) gave the detailed procedure for path analysis which was quite a different technique in eliminating the environmental variances.

In *nagali*, Chaudhari and Acharya (1969) reported that number of productive tillers and weights of main ear were the major components of seed yield.

Dhagat *et al.* (1973) reported that out of five yield components in *nagali*, number of days to maturity and 100-grain weight were important components of yield.

Mahudeswaran and Murugesan (1973) studied the path coefficient and reported very high contribution of productive tillers and plant height towards yield. The seed size showed low indirect effect with grain yield. Number of productive tillers and plant height were two components that showed the largest influences both directly and indirectly on grain yield.

Appadurai *et al.* (1977) reported that plant height influenced the grain yield indirectly through tillers. Number of ear bearing tillers was the most important yield contributing factor in *ragi*. The contribution towards grain yield by days to flowering and number of fingers per panicle was found to be negligible in the material studied.

High positive direct effect of number of fingers on yield of *ragi* was reported by Ranganthan *et al.* (1977). Its indirect effect *via* other attributes was positive. The direct effect of 1000-grain weight on yield was positive and the indirect effect of 1000-grain weight *via* number of fingers was negative. The direct and indirect effect of productive tillers was positive.

Path analysis worked out by Shanthappa (1978) in the cross Indaf-1 x Purna, revealed direct relationship of earhead weight, harvest index, plant height and 500-grain weight with yield and were influenced by straw weight, harvest index and 500-grain weight.

Agalodia *et al.* (1979) deduced that the grain weight of the main ear was the only character which had a high positive direct effect. The direct effect of ears per plant and tillers per plant were negative. The direct effect of the length of finger, width of main ear and fingers per ear were negligible. These characters affected yield through grain weight of main ear.

Higher magnitude of positive direct effect of earhead weight, straw yield and tiller number on grain yield was reported by Xavier (1979) in *ragi*. Likewise, the direct effect of component characters other than tiller number *via* earhead weight and straw yield were maximum and positive.

In studies on *nagali*, Prabhu (1980) found that plant height had maximum positive direct effect on grain yield at genotypic level but its indirect effect *via* other components were negative. Tillers per plant showed positive direct effect and also had positive indirect effect *via* fingers per earhead, finger length and 100-grain weight.

Path analysis in finger millet indicated that productive tillers had positive direct effect in F<sub>3</sub> generation whereas; it showed negative direct effect in cross A in F<sub>4</sub> generation. Also plant height and earhead length

contributed more towards yield while other characters showed high negative direct effect on grain yield. In cross B in F<sub>4</sub>, 1000-grain weight showed positive direct effect with yield. The indirect effect of component characters *via* productive tillers and 1000-grain weight were high and positive (Prabhakar and Prasad, 1983).

Dhanakodi (1988) reported that days to flowering and tiller number had positive direct effect on fodder yield. The plant height showed high and positive direct effect on fodder yield.

Shanthakumar (1989) reported highest direct effect of ear weight on grain yield in *ragi* and was confirmed in F<sub>2</sub> and F<sub>3</sub> generations. In addition, the indirect effects of component traits *via* productive tillers, straw weight and harvest index exerted strong direct effect on grain yield in addition to ear weight. Ear length exerted highest negative effect on grain yield.

The harvest index followed by total dry matter production had high direct effects on grain yield along with high correlations in *ragi*. The characters ear bearing tillers, effective tillers per plant and test weight contributed indirectly to grain yield *via* total dry matter production and harvest index. Main ear length had showed negative direct effect. The phenotypic direct effect of ear bearing tillers per plant on grain yield was moderate (Reddy *et al.*, 1994).

Thakur and Saini (1995) reported that days to germination, days to flowering and fingers per plant showed high and positive direct genotypic effects but plant height showed low and positive direct genotypic effect on yield. Days to flowering and days to germination revealed high and positive indirect effect through tillers per plant and fingers per plant. Days to maturity had high positive indirect effect through tillers per plant and fingers per plant on yield.

In genetic association analysis, Haider and Mahto (1995) observed that seed yield, 50 per cent flowering and ear length had direct positive effect (phenotypic level) on harvest index and in conclusion they suggested to select early flowering and high leaf area per plant to develop high yielding strains in *ragi*.

Singh *et al.* (1995) showed that the ear per hill had highest positive direct effect on grain yield followed by ear per plant and tillers per plant. They also had high indirect effect through each other confirming earlier results of Chaudhary (1989) who concluded that tillers per plant and ears per plant were the most important characters to improve yield potential in finger millet.

Mishra (1996) observed the highest direct effect of plant height along with its significant positive association towards yield. He suggested giving maximum weightage to the plant height while selecting or breeding for high yielding types in finger millet.

Ravindran *et al.* (1996) in their studies with *nagali* revealed that the number of productive tillers per plant and fingers per main ear had high direct effect with yield, while plant height had a negative and indirect effect with yield.

Marimuthu (1997) recorded that ear weight, number of productive tillers and finger length showed positive direct effect on grain yield while studying the eight quantitative characters in the parental and F<sub>2</sub> progeny of four finger millet crosses.

In their path analysis studies in 50 genotypes of finger millet, Anantharaju and Meenakshiganesan (2005) reported that number of productive tillers showed high positive direct effect and culm thickness and number of leaves had moderate direct effect on grain yield. They also observed that finger length had high indirect effect on grain yield *via* number of leaves and days to 50 per cent flowering.

Bedis *et al.* (2006) studied the path coefficient in *ragi* and reported direct positive contribution of the number of days to maturity, plant height, number of fingers per ear and fodder yield towards grain yield.

#### 2.4 Genetic divergence

Coleman (1920) was the pioneer to initiate the studies on intra-specific diversity based on the earhead types, glume and grain colour in *nachani*. He classified the material into seven groups.

Among several statistical methods developed for measuring the genetic divergence the analysis based on Mahalanobis's  $D^2$  statistics had been found essential (Rao, 1960). It is also proved to be useful tool for finding out the relative contribution of individual characters to the total divergence.

The use of multivariate analysis to measure the degree of divergence among the population helps to understand the pattern of evolution and to assess the contribution of different characters towards the total divergence along with nature of expression at intra and inter cluster levels (Murthy and Quadri, 1966). Further this study has been carried out extensively for the choice of distinct divergent parents for obtaining recombination in segregating populations. T-6338

Genetic diversity was reported by Hussaini *et al.* (1977) in 640 genetic stocks from the world collection of finger millet. Twelve broad groups were identified from plotting the first two standardized principle components. Indian material showed clinal variation with southern and eastern samples forming the extremes. The pattern of variation in African material was markedly different from that found in Indian collection. Ugandan material exhibited distinct separation and isolation from the rest.

In 175 African collections of finger millet, performance of the African genotypes was better than the Indian genotypes during *kharif* and

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*rabi* seasons. However, performance of the African and Indian genotypes was similar in the summer season (Swaminath, 1978).

Jain *et al.* (1981) grouped 30 genetic stocks of finger millet into 13 clusters. In their analysis the varieties from distant places were grouped together and strains from one eco-geographical region were grouped in different clusters indicating substantial variability within them. Their study also brought out two important facts that EC-4840 and IC-28 were genetically the most divergent and there was no parallelism between genetic diversity and geographical region.

Patil (1982) reported that  $D^2$  values computed for all possible 780 pairs of strains in *nagali* ranged from 2.13 to 407.81 showing higher magnitude of divergence. Forty strains were grouped into fifteen clusters. Strains from different geographic origin were randomly distributed among these groups. He recorded wide range of inter-cluster  $D^2$  values. The cluster means revealed that plant height, days to flowering, days to maturity, number of fingers per earhead and weight of main earhead were the important characters towards the maximum divergence.

Eight traits were used as indicators of early growth in 55 varieties of *Eleusine coracana*. Principal component analysis based on those traits plus leaf number, plant height and specific leaf area (SLA) resulted in four varietal groupings which related in parts of their geographical origin (Japan, India and Africa). Improved Indian varieties were highly variable and some were quite distinct from local cultivars (Shimizu *et al.*, 1982).

Information on genetic divergence from the data on nine metric traits in 20 *Eleusine coracana* varieties grown under rainfed and irrigated conditions was reported by Sheriff (1992). Genetic clusters were identified on the basis of  $D^2$  analysis; four under rainfed and eleven under irrigated conditions. The same six traits contributed most to genetic diversity under both environments. Varieties Indaf-3, Indaf-8, Indaf-9,

ROH-2 and HR- 7302 were markedly diverse under irrigated conditions and were suggested for use in breeding programme.

The nature and extent of genetic diversity in Indian and African finger millets was reported by Naik (1993). Indian accession exhibited greater variability for characters like grain weight, ear weight, finger length, stem weight, stover weight and leaf number compared to African accessions. The existence of greater variability in vegetative characters in African genotypes suggested that Africa is the primary centre of origin and India is the secondary centre of diversity. Mahalanobis's  $D^2$  statistics analysis results in the formation of 13 clusters in African and 17 clusters in Indian accession. African accessions were distinct in clustering pattern.

In the analysis of fifty genotypes of finger millet collected from different eco-geographical regions of the world, the  $D^2$  values ranged from 38.67 to 6686.53. All genotypes were grouped into twelve clusters. Genetic diversity was independent of geographic origin. The lowest intra cluster distance of 15.51 (D) ( $D^2 = 240.68$ ) was observed for cluster III indicating closeness of genotypes in this cluster, cluster III, IX and XII were highly divergent form each other and also had maximum mean values for most of the characters. Days to flowering displayed maximum contribution towards total divergence (Reddy *et al.*, 1993).

Jaylal and Haider (1994) studied divergence in 46 genotypes of finger millet collected from different agroclimatic regions. Based on relative magnitude of  $D^2$  values, all the 46 genotypes were grouped into five clusters. The cluster constellations obtained by  $D^2$  analysis were also confirmed by canonical analysis. The three-vectors accounted for 99.48 per cent variability. The analysis for estimating the contribution of various characters towards the expressions of genetic divergence indicated that days to maturity (28.05 per cent), ear length (23.23 per cent), harvest index (19.23 per cent), number of fingers per ear (19.08 per

cent), grain yield per hill (10.18 per cent) and number of effective tillers per hill contributed maximum to the total divergence.

Kailash Kumar *et al.* (1997) estimated the nature and magnitude of genetic divergence of 36 genotypes of finger millet *via*  $D^2$  analysis for seven characters. The genotypes were grouped into seven clusters. The clustering pattern did not suggest any correlations between the geographic and genetic diversity.

Suryakumar *et al.* (1999) studied seven metric characters in 99 genotypes of finger millet and grouped them into ten clusters. They observed that the genotypes from the cluster II, X, V, and VII had moderate to high genetic divergence with high mean performance for yield and its important components such as productive tillers and straw yield.

Jain *et al.* (2002) evaluated 40 genotypes of finger millet of diverse origin to assess the genetic diversity based on morphological characters related to blast (*Magnaporthe grisea*) resistance and grain yield. They recorded the percentage of leaf blast, neck blast and finger blast incidences and revealed that the genotypes GE-3022, GE-3024, GE-3058, GE-3060, VL 146 and IE 1012 exhibited real genetic diversity with high degree of blast resistance.

Chapter Opener Page

**MATERIAL AND  
METHODS**

### **3. MATERIAL AND METHODS**

The present investigation on “Genetic diversity and path analysis in finger millet (*Eleusine coracana* Gaertn L.) was conducted at the Farm of Botany section, College of Agriculture, Pune during *Kharif*, 2006. The details of the material and methods used to carry out the experiment and statistical procedures followed are described in this chapter.

#### **3.1 Material**

The experimental material for the present investigation consisted of fifty genotypes of finger millet (*Eleusine coracana* Gaertn L.) procured from the Project Co-ordinator, All India Co-ordinated Research Project (Small millet), Gandhi Krishi Vignyan Kendra, University of Agricultural Sciences, Bangalore. The list of genotypes is given in table 3.1.

#### **3.2 Methods**

##### **3.2.1 Experimental Design**

The experiment was laid out in randomised block design. The field was divided into three homogenous replication blocks. The 50 genotypes were sown in a single row each of 4.5 m length in three replications, at the Botany Farm, College of Agriculture, Pune.

##### **3.2.2 Sowing and cultural practices**

A uniform piece of land was selected and was brought to fine tilth by ploughing and harrowing. A basal dose of 50 kg N, 25 kg P<sub>2</sub>O<sub>5</sub> per hectare was applied at the time of sowing. The seeds were directly sown by dibbling. The spacing of 30 cm between the rows and 15 cm between the plants within row was followed.

Sowing was done on 26<sup>th</sup> June, 2006. The thinning operation was carried out at 20 days after sowing. All the recommended cultural practices were carried out to raise a good crop.

### **3.2.3 Harvesting**

When the ear heads attained physiological maturity, harvesting was carried out in phases by cutting the crop at the ground level and seeds were separated by threshing.

## **3.3 Recording of observations**

### **3.3.1 Plant sampling**

Five plants were selected at random from each genotype in each replication. The randomly selected plants were tagged for recording observations on various morphological characters. At the time of harvest, these five selected plants were harvested separately.

### **3.3.2 Characters studied**

The characters were studied on individual plant basis except days to 50 per cent flowering and maturity which were recorded on plot basis. The procedure adopted in recording the observations on different characters is given below.

#### **3.3.2.1 Days to 50 per cent flowering (No.)**

The number of days required from the date of sowing to the stage when ears have emerged from 50 per cent of main tillers.

#### **3.3.2.2 Days to maturity (No.)**

The number of days required from sowing to the date on which plants showed earhead browning prior to drying up (confirmed by grain hardness to bite) was taken as days to maturity.

#### **3.3.2.3 Total tillers per plant (No.)**

The number of tillers that arises from the base of the erect stem were counted for each selected plant at the time of maturity.

**Table 3.1. Genotypes included in the studies**

<b>Sr. No.</b>	<b>Genotype</b>	<b>Sr. No.</b>	<b>Genotype</b>
1	GE – 435	26	GE – 4731
2	GE – 978	27	GE – 4754
3	GE – 995	28	GE – 4799
4	GE – 1116	29	GE – 4839
5	GE – 1235	30	GE – 4840
6	GE – 1247	31	GE – 4846
7	GE – 1317	32	GE – 4849
8	GE – 1603	33	GE – 4862
9	GE – 1639	34	GE – 4866
10	GE – 1799	35	GE – 4872
11	GE – 1834	36	GE – 4941
12	GE – 2022	37	GE – 5005
13	GE – 2027	38	GE – 5194
14	GE – 2147	39	GE – 5257
15	GE – 2222	40	GE – 5388
16	GE – 2644	41	GE – 5628
17	GE – 2912	42	GE – 5652
18	GE – 3200	43	GE – 5702
19	GE – 3314	44	GE – 5889
20	GE – 3322	45	GE – 5908
21	GE – 3434	46	GE – 5936
22	GE – 3443	47	GE – 5949
23	GE – 3474	48	GE – 6004
24	GE – 4440	49	GE – 6012
25	GE – 4708	50	GE – 6029

#### **3.3.2.4 Productive tillers (No.)**

The number of tillers bearing productive earheads were counted for each selected plant at the time of maturity and recorded as productive tillers per plant.

#### **3.3.2.5 Plant height (cm)**

Height of the main tiller from the base of the plant to the tip of the earhead was recorded at dough stage, in centimeters.

#### **3.3.2.6 Fingers per head (No.)**

The numbers of fingers per earhead were recorded on observational plant at dough stage.

#### **3.3.2.7 Finger length (cm)**

Finger length was recorded from the base to tip of the longest spike of the earhead at dough stage.

#### **3.3.2.8 1000-grain weight (g)**

The 1000 grains were counted at random and their weight in grams was recorded as test weight.

#### **3.3.2.9 Dry biomass (g)**

After harvesting, the entire plant was dried and the weight of the dry biomass was recorded in grams.

#### **3.3.2.10 Harvest index (%)**

By taking the economic and biological yield (above ground level) of randomly selected five different plants, harvest index was calculated.

#### **3.3.2.11 Grain yield / plant (g)**

The grain yield obtained from each of the selected plant was recorded in grams.

#### **3.3.2.12 Foliage colour**

The foliage colour was recorded on the basis of visual observation of plants at flowering stage. It was scored as 1 for 'dark green', 2 for 'green' and 3 for 'yellowish green'.

### 3.3.2.13 Stem pigmentation

Stem pigmentation of the each genotype was recorded at flowering stage and was scored as 0 for 'non-pigmented' and + for 'pigmented'.

### 3.3.2.14 Natural incidence of pests and diseases

Natural incidence of major pests and diseases was recorded at different stages of crop growth and was scored on a 1-9 scale where 1 for 'extremely low susceptibility', 3 for 'low susceptibility', 5 for 'medium susceptibility', 7 for 'high susceptibility' and 9 for 'high to extremely high susceptibility'.

### 3.3.2.15 Finger arrangement

Finger arrangement in the ear head was recorded at dough stage and was scored as 1 for 'droopy fingers', 2 for 'open', 3 for 'semi-compact' 4 for 'compact' and 5 for 'fist-like'.

### 3.3.2.16 Grain colour

Grain colour was recorded after harvest and was scored as 1 for 'white colour', 2 for 'light brown', 3 for 'copper brown', 4 for 'purple brown' and 5 for 'red'.

## 3.4 Statistical analysis

### 3.4.1. Analysis of variance

The data recorded on individual characters were subjected to the analysis of variance following Panse and Sukhatme, 1987. The analysis of variance was done according to the table given below.

**Table 3.2 Analysis of variance**

Sr. No.	Source of variation	Degrees of freedom	M.S.S.	Expected mean sum of squares
1	Replications	r-1	RMS	$\sigma^2_e + \sigma^2_r$
2	Genotypes	g-1	GMS	$\sigma^2_e + \sigma^2_r + \sigma^2_g$
3	Error	(r-1)(g-1)	EMS	$\sigma^2_e$
	Total	(rg-1)		-

Where,

r = number of replications, e = random error,  
g = number of genotypes, MSS = mean sum of squares

The genotype mean square (GMS) was tested against error mean square (EMS) by 'F' test  $n_1 = (g-1)$  and  $n_2 = (r-1)(g-1)$  degrees of freedom.

### 3.4.2 Estimation of mean and range

The mean value for each character was worked out by using the following formula

$$\bar{x} = (1/n) \sum_{i=1}^n x_i$$

Where,

$\sum x_i$  = Sum total of the characters

n = number of observations

The difference between the highest and the lowest values, from mean of each character were recorded as range.

### 3.4.3 Estimation of standard error of mean, standard error of difference and critical difference

i) The S.E. of mean difference was calculated as:

$$\text{S.E. of mean [SEm]} = \sqrt{\sigma^2 e/r}$$

ii) The standard error of difference between two means was calculated as

$$\text{S.E. of difference [SE (d)]} = \text{SE m} \times \sqrt{2}$$

## 4. EXPERIMENTAL RESULTS

The present experiment “Path analysis and genetic diversity in finger millet (*Eleusine coracana* Gaertn L.)” was undertaken to study the genetic variability, correlations, path analysis and genetic divergence in finger millet during *Kharif*, 2006 at the Farm of Botany Section, College of Agriculture, Pune. The observations were recorded on eleven yield and yield contributing characters and the results obtained are presented below.

### 4.1 Analysis of variance

The analysis of variance (Table 4.1) revealed significant differences among genotypes, showing variations for all the eleven characters under study.

### 4.2 Mean performance

The mean values of 50 genotypes for eleven characters studied are presented in Table 4.2

#### 4.2.1 Days to 50 per cent flowering

The variation for days to 50 per cent flowering ranged between 53.67 and 92.67 days. The population mean for this character was 80.86 days. The genotype GE-5949 was the earliest to flower (53.67 days) followed by GE-2027 (63.00 days), GE-435 and GE-2222 (63.67 days). The genotype GE-1116 was late for 50 per cent flowering (92.67 days) followed by GE-4862, GE-487 and GE-5257 (91.00 days). Twenty five out of fifty genotypes flowered significantly earlier than the population mean.

#### 4.2.2 Days to maturity

Twenty four genotypes showed significantly early maturity when compared with the population mean of 110.75 days. The variation for this character ranged between 85.67 to 125.33 days. The genotypes GE-5949

## **5. DISCUSSION**

The extent of genetic variability available in a crop is prerequisite for its improvement, due to the fact that the efficiency of selection depends mainly on it. Genotypic and phenotypic coefficients of variation measure the extent of variability present in a population for a particular character. Heritability is an index of transmissibility of a character from parents to their offspring. The concept of heritability is important in determining whether the phenotypic differences among the individuals are genetically or the result of environmental factors. Genetic advance on the other hand measures the expected gain from the selection applied in a population. Heritability along with genetic advance gives the best picture of the efficiency of selection. Likewise, the correlations provide the interrelationships among the quantitative characters which facilitates the choice of suitable parents for the improvement in the crop, whereas path analysis helps in understanding the direct and indirect effects of various characters towards the yield. The genetic divergence enables the evaluation of genotypes without actual crossing and grouping the genetic material into few clusters in a significant pattern.

The results obtained on variability, correlations, path analysis and genetic divergence among 50 genotypes of finger millet are discussed under the following sub-heads.

- 5.1 Genetic variability
- 5.2 Genotypic and phenotypic coefficient of variation
- 5.3 Heritability and genetic advance
- 5.4 Correlations
- 5.5 Path analysis
- 5.6 Genetic divergence

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- iii) The critical difference between any two means was calculated as

$$\text{C.D.} = \text{SE (d)} \times 't' \text{ at error d.f.}$$

#### 3.4.4 Estimation of components of variation

The phenotypic and genotypic variances were calculated by utilizing the respective mean square values from the variance table (Johnson *et al.*, 1955).

- i) Environmental Variance =  $\sigma^2_e = \text{EMS}$
- ii) Genotypic Variance =  $\sigma^2_g = \frac{\text{GMS-EMS}}{r}$
- iii) Phenotypic Variance =  $\sigma^2_p = \sigma^2_g + \sigma^2_e$

Where,

GMS = Genotypic mean sum of squares

EMS = Error mean sum of squares

r = Number of replications

#### 3.4.5 Estimation of coefficient of variation

The genotypic and phenotypic coefficients of variation were calculated by the formulae as suggested by Burton and Devane (1953).

- i) Phenotypic coefficient of variation (PCV)

$$\text{PCV} = \left[ \sqrt{\sigma^2_p / \bar{x}} \right] \times 100$$

Where,

$\sigma^2_p$  = Phenotypic variance

$\bar{x}$  = General mean of the character

ii) Genotypic coefficient of variation (GCV)

$$\text{GCV} = \left[ \sqrt{\sigma^2_g / \bar{x}} \right] \times 100$$

Where,

$\sigma^2_g$  = Genotypic variance

$\bar{x}$  = General mean of the character

### 3.4.6 Estimation of heritability (b.s.)

Heritability in broad sense was estimated for various characters as per the formula suggested by Hanson *et al.* (1956).

$$H^2(\text{b. s.}) = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

Where,

$\sigma^2_g$  = Genotypic variance

$\sigma^2_p$  = Phenotypic variance

### 3.4.7 Estimation of genetic advance (G. A.)

The genetic advance was calculated in per cent by the formula suggested by Johnson *et al.* (1955).

$$\text{G. A.} = (\sigma^2_g / \sigma^2_p) \times \sigma_p \times K$$

or

$$\text{G. A.} = K \times h^2 \times \sigma_p$$

$$\text{G. A. as percentage of mean} = \frac{\text{G. A.}}{\bar{x}} \times 100$$

Where,

$\sigma^2_g$  = Genotypic variance

$\sigma^2_p$  = Phenotypic variance

$\sigma_p$  = Phenotypic standard deviation

K = Selection differential at 5 per cent selection intensity  
(i.e. 2.06)

$h^2$  = Heritability (broad sense)

$\bar{x}$  = Mean of the character

### 3.5 Estimation of correlation coefficients

The genotypic and phenotypic co-variances were calculated as per the formulae given by Singh and Chaudhari (1977).

a. Environmental co-variance

$$(\text{cov. } e_{1,2}) = \text{EMP}$$

b. Genotypic co-variance

$$(\text{cov. } g_{1,2}) = (\text{GMP} - \text{EMP}) / r$$

c. Phenotypic co-variance

$$(\text{cov. } p_{1,2}) = (\text{cov. } e_{1,2}) + (\text{cov. } g_{1,2})$$

The appropriate variances and co-variances were used for calculating phenotypic, genotypic and environmental correlation coefficients (Johnson *et al.*, 1955).

### 3.5.1 Phenotypic correlation coefficients ( $r_p$ )

It is derived by

$$r_{p\ 1.2} = \frac{(\text{cov}_{p\ 1.2})}{\sqrt{(\sigma^2 p_1) \cdot (\sigma^2 p_2)}}$$

Where,

$r_{p\ 1.2}$  = Phenotypic correlation between character 1 and 2

$\text{cov}_{p1.2}$  = Phenotypic co-variance between character 1 and 2

$\sigma^2 p_1$  and  $\sigma^2 p_2$  = Phenotypic variance of character 1 and 2, respectively.

### 3.5.2 Genotypic correlation coefficient ( $r_g$ )

It is derived by

$$r_{g\ 1.2} = \frac{(\text{cov}_{g\ 1.2})}{\sqrt{(\sigma^2 g_1) \cdot (\sigma^2 g_2)}}$$

Where,

$r_{g.1.2}$  = Genotypic correlation between character 1 and 2

$\text{Cov}_{g.1.2}$  = Genotypic co-variance between character 1 and 2

$\sigma^2 g_1$  and  $\sigma^2 g_2$  = Genotypic variance of character 1 and 2, respectively.

The significance of the phenotypic and genotypic correlation coefficients were tested by 't' test.

$$t = r \sqrt{(n-2)/(1-r^2)}$$

Where,

$r$  = Correlation coefficient

$n$  = Total number of observations

The calculated 't' value was tested with table 't' value for respective (n-2) degrees of freedom for significance.

### 3.6 Path coefficient analysis

Path coefficient analysis was done according to the procedure suggested by Dewey and Lu (1959). If 'y' is the effect and 'x<sub>1</sub>' is the cause, the path coefficient for the path from cause x<sub>1</sub> to the effect y is  $\delta_{x_1/\delta_y}$ . Direct and indirect effects were worked out by using genotypic correlations as below:

Direct effect of x<sub>1</sub> on y = P<sub>x<sub>1</sub>.y</sub>

Where,

P<sub>x<sub>1</sub></sub> = Path coefficient of x<sub>1</sub> on y. Similarly, direct effects of other attributes on yield were calculated.

Indirect effects of x<sub>1</sub> via x<sub>2</sub> on y = p<sub>x<sub>2</sub>.y</sub> x r<sub>x<sub>1</sub>. x<sub>2</sub></sub>

Where,

p<sub>x<sub>2</sub>.y</sub> = Path coefficient of the component character x<sub>2</sub> on y.

r<sub>x<sub>1</sub>.x<sub>2</sub></sub> = Genotypic correlation between x<sub>1</sub> and x<sub>2</sub>

Similarly, indirect effects on all possible combinations were calculated for all component characters. The residual effect (R) was calculated as below.

$$R = [1 - (P_{x_1y} \cdot r_{x_1y}) - (P_{x_2y} \cdot r_{x_2y}) \dots \dots (P_{x_ny} \cdot r_{x_ny})]^{1/2}$$

Where,

P<sub>x<sub>1</sub>y</sub>, P<sub>x<sub>2</sub>y</sub> -----, P<sub>x<sub>n</sub>y</sub> = Direct effects of respective character on seed yield.

r<sub>x<sub>1</sub>y</sub>, r<sub>x<sub>2</sub>y</sub> -----, r<sub>x<sub>n</sub>y</sub> = Correlation coefficient between respective characters and yield.

### 3.7 Genetic diversity

The generalized distance between two populations is defined by Mahalanobis (1936) as  $D^2 = \lambda_{i,j} d_{i,dj}$

Where,

$\lambda_{i,j}$  = Reciprocal matrix to the common dispersion matrix

$d_i$  = difference between the mean values of two populations for  $i^{\text{th}}$  character

$d_j$  = difference between the mean values of two populations for  $j^{\text{th}}$  character

Estimation of  $D^2$  values from the above formula is very complicated in the present study, since it requires the inversion of a thirteenth order determinant and then the evaluation of  $B(BH)/2$  terms whose sum is  $D^2$ . It was found convenient to work with a set of uncorrelated character constructed from the original measurements.  $D^2$  with such transformed variables reduced to the evaluation of simple sum of uncorrelated character constructed from the original measurements.  $D^2$  with such transformed variables reduced to the evaluation of simple sum of squares. Transformation was done by using pivotal condensation method (Singh and Chaudhary, 1977). The coefficients for the transformation were obtained by dividing the first row of the reduced matrix by the square root of the corresponding pivotal condensation elements.

### **3.7.1 Determination of group constellations**

No rules can be laid down for finding the clusters because a cluster is not well-defined term. The only criterion appeared to be that any two groups belonging to the same cluster should at least on the average show a smaller  $D^2$  value than those belonging to two different clusters. Tocher's method (Rao, 1952) was used for classifying the genotypes.

### **3.7.2 Average intra cluster distance**

The intra cluster distance was calculated as  $\Sigma D_i^2 / n$ ; where,  $\Sigma D_i^2$  is the sum of distances between all possible combinations (n) of the population included in a cluster.

### **3.7.3 Average inter cluster distance**

The average inter cluster distance was calculated as  $\Sigma D_i^2 / (n_i n_j)$  where  $n_i$  is the number of populations in cluster i and  $n_j$  is the number of populations in cluster j.

### **3.7.4 Cluster mean**

Cluster means were calculated for individual characters on the basis of mean performance of the genotypes included in that cluster.

### **3.7.5 Cluster diagram**

With the help of  $D^2$  values between the clusters, a diagram showing the relationship between different populations was drawn.

### **3.7.6 Relative contribution of characters towards genetic diversity**

With the help of  $D^2$  statistics, the relative contribution of each component trait to total divergence was worked out.

Chapter Opener Page

# RESULTS

## 4. EXPERIMENTAL RESULTS

The present experiment “Path analysis and genetic diversity in finger millet (*Eleusine coracana* Gaertn L.)” was undertaken to study the genetic variability, correlations, path analysis and genetic divergence in finger millet during *Kharif*, 2006 at the Farm of Botany Section, College of Agriculture, Pune. The observations were recorded on eleven yield and yield contributing characters and the results obtained are presented below.

### 4.1 Analysis of variance

The analysis of variance (Table 4.1) revealed significant differences among genotypes, showing variations for all the eleven characters under study.

### 4.2 Mean performance

The mean values of 50 genotypes for eleven characters studied are presented in Table 4.2

#### 4.2.1 Days to 50 per cent flowering

The variation for days to 50 per cent flowering ranged between 53.67 and 92.67 days. The population mean for this character was 80.86 days. The genotype GE-5949 was the earliest to flower (53.67 days) followed by GE-2027 (63.00 days), GE-435 and GE-2222 (63.67 days). The genotype GE-1116 was late for 50 per cent flowering (92.67 days) followed by GE-4862, GE-487 and GE-5257 (91.00 days). Twenty five out of fifty genotypes flowered significantly earlier than the population mean.

#### 4.2.2 Days to maturity

Twenty four genotypes showed significantly early maturity when compared with the population mean of 110.75 days. The variation for this character ranged between 85.67 to 125.33 days. The genotypes GE-5949

**Table 4.1. Analysis of variance for 11 characters in finger millet**

Source of variation	Degrees of freedom	Mean sum of squares										
		Days to 50% flowering	Days to maturity	Plant height (cm)	Total tillers / plant (No.)	Productive tillers / plant (No.)	Fingers / head (No.)	Finger length (cm)	1000-grain weight (g)	Dry biomass (g)	Harvest index (%)	Grain yield / plant (g)
<b>Replication</b>	2	2.9375	10.75	0.625	1.9970	1.0806*	1.3459	3.6376	6.0272*	3.4375	6.3281	0.8593
<b>Treatment</b>	49	277.5663*	420.3495*	648.3086*	12.5314*	9.8443*	4.5169*	14.0526*	0.6462*	350.3495*	98.1728*	19.7852*
<b>Error</b>	98	3.3207	4.3864	6.0127	0.9440	0.2035	0.8184	6.3038	1.1810	7.6772	5.9660	1.1138

\* – Significant at 5 per cent of probability

(85.67 days) matured early followed by GE-1235 (89.67 days), GE-2027 (90.67 days), GE-1603 and GE-2222 (91.00 days). The genotypes GE-4846 (125.33 days), GE-4849 and GE-4862 (125.00 days), GE-5936 (124.67 days), GE-4840 (124.33 days) and GE-5388 (124.00 days) were comparatively late in maturity.

#### **4.2.3 Plant height (cm)**

GE-4708 was the tallest genotype with maximum plant height of 121.57 cm. This was followed by GE-5005 (118.02cm), GE-2644 (117.14cm) and GE-3322 (115.96cm). The genotype GE-5949 was the dwarfest with 58.00 cm height. From the fifty genotypes studied, seven genotypes were significantly taller than the population mean of 91.15 cm.

#### **4.2.4 Total tillers per plant (No.)**

The genotype GE-1247 produced minimum number of total tillers (4.07) while they were maximum for the genotype GE-6004 (16.60). The genotypes GE-6029 (11.27), GE-3200 (9.33), GE-6012 (9.27) and GE-2222 (9.07) exhibited higher number of tillers. Six out of fifty genotypes showed significantly more tillers when compared with the population mean of 6.87 tillers per plant.

#### **4.2.5 Productive tillers per plant (No.)**

The genotype GE-4799 produced minimum number of productive tillers (1.07) while it was highest for the genotype GE-6004 (12.40). Ten out of fifty genotypes showed significant productive tillers when compared with the population mean of 3.63. The genotypes GE-6012 (6.87), GE-2022 and GE-2222 (6.00), GE-4440 (5.80), GE-6029 (5.80) and GE-5702 (5.67) have exhibited maximum number of productive tillers per plant.

#### **4.2.6 Fingers per head (No.)**

The population mean for this character was 6.69 fingers per head and the variation ranged from 5.07 to 9.47 fingers per head. The genotype GE-1639 had the maximum fingers per head (9.47) followed by GE-5936

(9.27), GE-435 (9.13) and GE-5889 (9.07). Nine genotypes had significantly higher number of fingers per head than the population mean.

#### **4.2.7 Finger length (cm)**

The variation for finger length ranged between 3.16 and 13.46 cm with a population mean of 6.59 cm. Twenty four genotypes had highest finger length than the population mean. The line GE-5005 showed higher finger length (13.46 cm) followed by GE-4941 (10.84 cm), GE-4731 (10.24 cm) and GE-2027 (10.17 cm). The genotype GE-1247 showed the least finger length (3.16 cm) as compared to other genotypes.

#### **4.2.8 1000-grain weight (g)**

Half of the genotypes recorded higher mean test weight than the population mean of 2.41. The variation for test weight ranged between 1.50 (GE-4872) and 3.58 g (GE-6004). The genotypes GE-6004 produced the boldest grains, followed by GE-4799 (3.48 g), GE-5702 (3.23 g) and GE-1639 (3.19 g). The genotype GE-4872 (1.50 g) exhibited the smallest grain size followed by GE-4941 (1.61 g) and GE-4862 (1.75 g).

#### **4.2.9 Dry biomass (g)**

The variation for dry biomass ranged between 52.67 (GE-1235) and 96.42 g (GE-6004). Twenty two genotypes recorded higher dry biomass than the population mean of 69.50 g. The genotype GE-6004 (96.42 g) produced highest dry biomass followed by GE-6029 (95.25 g), GE-5652 (87.68 g) and GE-2022 (85.09 g) while the least dry biomass was recorded in GE-1235 (52.67 g).

#### **4.2.10 Harvest index (%)**

Highest harvest index was recorded in GE-6004 (42.00 %) followed by GE-4440 (41.67 %) and GE-5936 (40.00 %). Genotype GE-4799 (20.33 %) showed the lowest harvest index. Twenty nine genotypes recorded higher harvest index than the population mean 30.61 per cent.

**Table 4.2. Mean performance of 50 genotypes of finger millet for eleven quantitative characters**

<b>Sr. No.</b>	<b>Genotypes</b>	<b>Days to 50% flowering</b>	<b>Days to maturity</b>	<b>Plant height (cm)</b>	<b>Total tillers / plant (No.)</b>	<b>Productive tillers / plant (No.)</b>	<b>Fingers / head (No.)</b>	<b>Finger length (cm)</b>	<b>1000-grain weight (g)</b>	<b>Dry biomass (g)</b>	<b>Harvest index (%)</b>	<b>Grain yield / plant (g)</b>
<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>	<b>12</b>	<b>13</b>
1	GE-435	63.67	94.33	88.47	4.47	2.67	9.13	4.24	2.12	57.13	25.33	11.05
2	GE-978	74.67	103.67	98.45	5.47	3.93	6.87	5.63	2.18	67.30	25.00	11.90
3	GE-995	73.33	105.00	77.79	7.20	4.67	5.20	5.45	1.86	63.45	33.00	15.52
4	GE-1116	92.67	121.67	87.52	5.13	2.67	6.13	4.38	2.35	54.64	22.00	11.00
5	GE-1235	64.33	89.67	80.13	4.20	2.13	6.53	3.47	2.53	52.67	32.67	12.75
6	GE-1247	89.67	120.33	64.08	4.07	2.27	6.80	3.16	3.07	76.42	23.33	11.32
7	GE-1317	67.67	95.33	86.89	5.67	1.73	6.93	3.61	2.68	66.56	28.33	10.35
8	GE-1603	64.00	91.00	72.01	5.60	3.20	7.33	4.41	2.57	61.42	24.33	12.51
9	GE-1639	65.00	94.33	73.57	6.67	4.27	9.47	4.87	3.19	68.18	24.00	12.10
10	GE-1799	72.67	103.33	83.21	7.20	4.00	5.13	5.41	2.36	66.84	35.00	11.81
11	GE-1834	71.33	104.67	77.32	7.53	3.80	8.27	3.71	3.00	72.43	37.33	12.50
12	GE-2022	85.67	120.33	96.58	7.40	6.00	5.07	7.27	3.15	85.09	34.67	15.64
13	GE-2027	63.00	90.67	69.51	5.47	2.13	6.07	10.17	2.23	62.89	39.33	11.00
14	GE-2147	72.33	105.33	72.56	7.40	4.73	5.33	6.35	2.21	56.51	32.00	14.33
15	GE-2222	63.67	91.00	82.16	9.07	6.00	6.40	4.25	2.35	73.56	28.33	15.75
16	GE-2644	82.67	105.67	117.14	7.27	2.47	7.40	6.96	2.64	66.17	27.00	12.18
17	GE-2912	86.33	114.67	99.89	8.60	3.87	6.67	5.61	1.91	83.37	34.33	12.29

Sr. No.	Genotypes	Days to 50% flowering	Days to maturity	Plant height (cm)	Total tillers / plant (No.)	Productive tillers / plant (No.)	Fingers / head (No.)	Finger length (cm)	1000-grain weight (g)	Dry biomass (g)	Harvest index (%)	Grain yield / plant (g)
1	2	3	4	5	6	7	8	9	10	11	12	13
18	GE-3200	82.67	105.33	103.30	9.33	4.60	5.20	4.63	2.29	65.88	32.67	12.06
19	GE-3314	80.67	105.00	107.29	7.93	4.00	5.53	5.28	2.56	64.45	32.00	12.46
20	GE-3322	84.67	110.00	115.96	6.27	2.07	7.27	4.36	2.86	64.82	27.00	11.30
21	GE-3434	81.67	95.33	95.60	6.27	2.00	5.53	6.88	2.58	72.38	25.67	8.47
22	GE-3443	83.67	103.00	98.63	6.67	3.27	5.73	7.09	2.79	72.04	36.33	12.78
23	GE-3474	87.00	120.33	102.81	8.07	2.87	5.27	6.19	2.55	74.62	34.67	11.67
24	GE-4440	76.67	98.00	86.16	7.20	5.80	7.07	6.13	2.43	64.30	41.67	16.60
25	GE-4708	87.33	114.67	121.57	5.47	2.00	6.47	8.35	2.79	60.81	23.33	8.32
26	GE-4731	85.00	120.33	92.17	8.20	4.60	6.90	10.24	2.59	65.57	34.00	14.00
27	GE-4754	81.00	121.00	102.08	7.33	3.27	5.47	8.16	2.42	56.13	32.67	12.09
28	GE-4799	90.33	121.00	107.15	4.60	1.07	6.07	8.48	3.48	55.17	20.33	7.47
29	GE-4839	81.67	104.67	96.93	8.07	4.07	8.33	7.00	2.31	79.94	20.67	12.89
30	GE-4840	84.67	124.33	102.81	5.20	3.13	6.40	9.21	2.45	62.75	31.33	13.34
31	GE-4846	90.00	125.33	96.17	5.13	3.47	8.07	5.61	2.21	83.41	23.00	13.43
32	GE-4849	86.33	125.00	103.58	5.00	2.33	6.80	6.97	1.84	58.15	33.67	12.10
33	GE-4862	91.00	125.00	90.57	5.07	1.87	5.80	9.66	1.75	74.62	31.33	10.19
34	GE-4866	88.33	119.00	93.17	7.20	4.13	5.53	8.99	1.85	81.47	32.0	13.56
35	GE-4872	91.00	121.33	93.83	7.33	3.40	6.07	7.42	1.50	74.94	36.33	11.98
36	GE-4941	74.00	101.67	79.93	6.27	2.87	7.07	10.84	1.61	72.45	26.00	13.37

Sr. No.	Genotypes	Days to 50% flowering	Days to maturity	Plant height (cm)	Total tillers / plant (No.)	Productive tillers / plant (No.)	Fingers / head (No.)	Finger length (cm)	1000-grain weight (g)	Dry biomass (g)	Harvest index (%)	Grain yield / plant (g)
1	2	3	4	5	6	7	8	9	10	11	12	13
37	GE-5005	88.00	118.33	118.02	5.40	2.33	5.93	13.46	2.23	59.47	28.00	12.21
38	GE-5194	89.67	123.00	102.93	6.67	2.67	7.07	7.37	2.43	70.31	24.67	12.62
39	GE-5257	91.00	123.67	102.91	5.07	2.53	5.13	6.06	2.24	66.62	25.00	11.85
40	GE-5388	88.67	124.00	105.93	6.87	2.13	5.53	8.88	2.47	62.49	32.00	11.75
41	GE-5628	83.67	119.33	94.67	7.27	2.80	8.33	8.40	1.83	74.11	35.00	12.37
42	GE-5652	87.67	117.67	89.48	8.13	3.93	8.33	8.06	1.78	87.68	25.00	13.92
43	GE-5702	89.67	121.33	102.04	7.33	5.67	5.73	6.66	3.23	81.69	30.67	17.37
44	GE-5889	86.67	116.33	79.70	7.13	3.33	9.07	5.41	2.51	62.69	38.00	13.54
45	GE-5908	87.33	118.67	73.82	6.47	3.00	8.67	7.51	2.35	58.50	34.00	12.29
46	GE-5936	83.33	124.67	90.86	5.33	2.47	9.27	7.05	2.15	84.32	40.00	11.60
47	GE-5949	53.67	85.67	58.00	5.60	4.13	5.53	3.58	2.08	52.87	31.00	12.53
48	GE-6004	77.33	103.67	78.53	16.60	12.40	7.47	6.26	3.58	96.42	42.00	23.71
49	GE-6012	85.33	108.00	68.41	9.27	6.87	6.40	5.40	2.62	84.04	39.00	17.23
50	GE-6029	90.67	121.67	75.31	11.27	5.80	6.60	5.31	1.89	95.25	25.00	16.37
	GM	80.86	110.75	91.75	6.87	3.63	6.69	6.59	2.41	69.50	30.61	12.82
	S.E.+	1.48	1.71	2.00	0.79	0.36	0.73	0.20	0.11	2.26	1.99	0.86
	C.D. at 5 at %	2.91	3.35	3.92	1.55	0.72	1.44	0.40	0.21	4.43	3.90	1.68
	C.V.	2.25	1.89	2.69	14.14	12.43	13.52	3.80	5.57	3.98	7.98	8.23

#### 4.2.11 Grain yield (g)

The variation for grain yield per plant ranged between 7.47 (GE-4799) and 23.71 g (GE-6004) with a population mean of 12.82 g per plant. Seventeen genotypes showed the higher grain yield than the population mean. The genotype GE-6004 showed highest grain yield followed by GE-5702 (17.37 g), GE-6012 (17.23 g), GE-4440 (16.60 g) and GE-6029 (16.37 g).

### 4.3 Parameters of genetic variability

The parameters of genetic variability *viz.*, range, mean, GCV, PCV, heritability percentage in broad sense, genetic advance and genetic advance expressed as per cent of mean are presented in Table 4.3. The important findings are given below.

#### 4.3.1 Coefficient of variation (Genotypic and Phenotypic)

It was observed that the estimates for genotypic coefficients of variation (GCV) were lower than the phenotypic coefficients of variation (PCV) for all the eleven characters studied. The character, number of productive tillers per plant recorded highest GCV (49.41) followed by finger length (32.76), total number of tillers per plant (28.61) and grain yield per plant (19.45). Similarly highest PCV was recorded in number of productive tillers per plant (50.95) followed by finger length (32.98), number of tiller per plant (31.92), number of fingers per head (21.41) and grain yield per plant (21.12). The lowest GCV and PCV were recorded for days to maturity i.e. 11.82 and 12.03, respectively.

The highest magnitudinal difference between GCV and PCV was recorded for number of fingers per head (4.81), followed by number of total tillers per plant (3.31), harvest index (1.68), grain yield per plant (1.67) and number of productive tillers per plant (1.54). The lowest difference was observed for days to maturity (0.16).

### 4.3.2 Heritability percentage (b.s.)

The heritabilities (b.s.) obtained in the present investigation were of high magnitude for all the characters. The heritability (b.s.) estimates varied from 60.10 (number of fingers per head) to 98.67 per cent (finger length). Very high heritability (b.s.) was recorded for finger length (98.67 %) followed by plant height (97.27 %), days to maturity (96.93 %), days to 50% flowering (96.49 %), number of productive tillers per plant (94.04 %), dry biomass (93.70 %) and 1000-grain weight (92.04 %). These were followed by grain yield per plant (84.82 %), harvest index (83.74 %) and number of total tillers per plant (80.36 %), showing high heritability. Lowest heritability among the traits was recorded for number of fingers per head (60.10).

### 4.3.3 Genetic advance

The highest magnitude of genetic advance was observed for the character plant height (29.72) followed by days to maturity (23.88), dry biomass (21.31) and days to 50 per cent flowering (19.34). The lowest genetic advance was exhibited by 1000-grain weight (0.90), followed by number of fingers per head (1.77). The other characters had genetic advance between 3.58 (number of productive tillers per plant) and 10.45 (harvest index). The characters days to 50 per cent flowering, days to maturity and plant height recorded high genetic advance accompanied by high heritability estimates.

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### 4.3.4 Genetic advance as per cent of mean

The expected genetic advance varied between 21.56 and 98.71 per cent. Genetic advance as a per cent of mean was highest in number of productive tillers per plant (98.71) followed by finger length (67.04) and number of total tillers per plant (52.84). Whereas, the characters days to 50 per cent flowering (23.92) and maturity (21.56), and number of fingers per head (26.51) had lowest genetic advance as per cent of mean.



**Table 4.3. Parameters of genetic variability in 50 genotypes of finger millet**

Sr. No.	Characters	Parameters						
		Range	General mean	GCV	PCV	Heritability % (b.s)	Genetic advance	G.A. as a percentage of mean
1	Days to 50% flowering	53.67-92.67	80.86	11.82	12.03	96.49	19.34	23.92
2	Days to maturity	85.67-125.33	110.75	10.63	10.79	96.93	23.88	21.56
3	Plant height (cm)	64.08-121.57	91.15	16.05	16.27	97.27	29.72	32.61
4	Total tillers / plant (No.)	4.07-16.60	6.86	28.61	31.92	80.36	3.62	52.84
5	Productive tillers / plant (No.)	1.07-12.40	3.63	49.41	50.95	94.04	3.58	98.71
6	Fingers / head (No.)	5.07-9.47	6.69	16.60	21.41	60.10	1.77	26.51
7	Finger length (cm)	3.16-13.46	6.59	32.76	32.98	98.67	4.41	67.04
8	1000-grain weight (g)	1.50-3.58	2.41	18.96	19.76	92.04	0.90	37.47
9	Dry biomass (g)	52.67-96.42	69.50	15.37	15.88	93.70	21.31	30.66
10	Harvest index (%)	20.33-42.00	30.61	18.11	19.79	83.74	10.45	34.14
11	Grain yield / plant (g)	7.47-23.71	12.82	19.45	21.12	84.82	4.73	36.91

GCV = Genotypic coefficient of variation

PCV = Phenotypic coefficient of variation

#### **4.4 Correlations**

The Table 4.4 represents the correlation coefficients between the characters at both genotypic as well as phenotypic levels. As the genetic correlations are important from breeding point of view, only these are described below.

##### **4.4.1 Association between grain yield and its components**

The grain yield per plant showed highly significant positive association with number of total tillers per plant (0.806), number of productive tillers per plant (0.954), dry biomass (0.541) and harvest index (0.466). The traits 1000-grain weight (0.149) and number of fingers per head (0.049) showed positive but non-significant association. The character plant height showed significantly negative association (-0.322) while, days to 50 percent flowering (-0.053) and maturity (-0.054) showed negative but non-significant association with grain yield per plant.

##### **4.4.2 Inter relationships between yield components**

Days to 50 per cent flowering was significantly and positively correlated with days to maturity (0.907), plant height (0.535), finger length (0.375) and dry biomass (0.336), whereas, with the character, number of total tillers per plant it showed non significant positive association. It showed non significant negative correlation with number of productive tillers per plant (-0.118), number of fingers per head (0.132), 1000-grain weight (-0.033) and harvest index (-0.101).

Days to maturity was significantly and positively correlated with plant height (0.449) and finger length (0.410). It had non-significant and negative association with most of the characters except for dry biomass where its association was positive.

**Table 4.4. Genotypic (above diagonal) and phenotypic (below diagonal) correlations of 11 characters in finger millet**

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	Total tillers / plant (No.)	Productive tillers / plant (No.)	Fingers / head (No.)	Finger length (cm)	1000 – grain weight (g)	Dry biomass (g)	Harvest index (%)	Grain yield / plant (g)
Days to 50% flowering	<b>1.000</b>	0.907**	0.535**	0.055	-0.118	-0.132	0.375**	-0.033	0.336*	-0.101	-0.053
Days to maturity	0.872**	<b>1.000</b>	0.449**	-0.048	-0.156	-0.066	0.410**	-0.114	0.254	-0.037	-0.054
Plant height (cm)	0.520**	0.429**	<b>1.000</b>	-0.118	-0.324*	-0.213	0.391**	0.062	-0.078	0.229	-0.322**
Total tillers / plant (No.)	0.044	-0.045	-0.116	<b>1.000</b>	0.883**	-0.030	-0.055	0.171	0.618**	0.403**	0.806**
Productive tillers / plant (No.)	-0.115	-0.154	-0.306	0.797**	<b>1.000</b>	-0.015	-0.176	0.250	0.548**	0.411**	0.954**
Fingers / head (No.)	-0.099	-0.052	-0.154	0.007	-0.018	<b>1.000</b>	-0.148	0.040	0.173	-0.073	0.049
Finger length (cm)	0.366**	0.402**	0.383**	-0.051	-0.169	-0.117	<b>1.000</b>	-0.244	0.011	0.077	-0.095
1000-grain weight (g)	-0.023	-0.116	0.064	0.151	0.234	0.024	-0.230	<b>1.000</b>	0.013	-0.033	0.149
Dry biomass (g)	0.318*	0.243	-0.078	0.549**	0.0512	0.120	0.011	0.007	<b>1.000</b>	0.147	0.541**
Harvest index (%)	-0.098	-0.041	-0.200	0.347*	0.374**	-0.070	-0.075	-0.011	0.128	<b>1.000</b>	0.466**
Grain yield / plant (g)	-0.054	-0.046	-0.300*	0.656**	0.845**	0.024	-0.088	0.122	0.493**	0.382**	<b>1.000</b>

\*, \*\* Significance at 5 and 1 per cent of probability, respectively

The trait plant height was significantly and negatively correlated with number of productive tillers per plant (-0.324). It was significantly and positively correlated with finger length (0.391). It had non-significant negative correlation with other characters except 1000-grain weight and harvest index.

Number of total tillers per plant was significantly and positively correlated with dry biomass (0.618), harvest index (0.403) and grain yield per plant (0.806). It was positively and non-significantly associated with 1000-grain weight. However, it showed negative association with other characters.

The trait, number of productive tillers per plant was significantly and positively correlated with dry biomass (0.548), harvest index (0.411) and grain yield per plant (0.954). It was positively and non-significantly associated with 1000-grain weight. However, it showed negative association with other characters.

Number of fingers per head showed positive and non-significant association with 1000-grain weight (0.040) and dry biomass (0.173). However, it was negatively associated with rest of the characters.

Finger length was non-significantly and positively correlated with dry biomass (0.011) and harvest index (0.077).

It was observed that 1000-grain weight had non-significant negative correlation with days to 50 per cent flowering, days to maturity, finger length and harvest index. It showed non-significant and positive association with plant height (0.062), number of total tillers per plant (0.171), number of productive tillers per plant (0.250) and dry biomass (0.013).

Dry biomass was significantly and positively associated with days to 50 per cent flowering (0.336), number of total tillers per plant (0.618) and number of productive tillers per plant (0.548), whereas, it showed

non-significant positive association with other characters except plant height.

It was observed that harvest index had significant and positive association with number of total tillers per plant (0.403) and number of productive tillers per plant (0.411). It was non-significantly and positively correlated with plant height (0.229), finger length (0.077) and dry biomass (0.147). It showed non-significant and negative association with days to 50 per cent flowering and maturity, number of fingers per head and 1000-grain weight.

#### **4.5 Path coefficient analysis**

The direct and indirect contributions of each character as revealed by path analysis are presented in Table 4.5. The genotypic correlation coefficients only are considered for path analysis.

##### **4.5.1 Direct effects**

In the present investigation it was found that number of productive tillers per plant recorded the highest positive direct effect (1.233) on yield and was also significantly and positively correlated with it. The other characters days to 50 per cent flowering (0.089) and maturity (0.024), plant height (0.014), number of fingers per head (0.096), finger length (0.041) and harvest index (0.091) produced positive direct effect of low magnitude. However, the traits *viz.*, number of total tillers per plant (-0.286), 1000-grain weight (-0.097) and dry biomass (-0.022) had negative direct effect on grain yield. Number of total tillers per plant, dry biomass and harvest index had significant and positive association with grain yield.

**Table 4.5. Direct (diagonal) and indirect path effects of different characters towards yield in finger millet**

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	Total tillers / plant (No.)	Productive tillers / plant (No.)	Fingers / head (No.)	Finger length (cm)	1000 – grain weight (g)	Dry biomass (g)	Harvest index (%)	Grain yield / plant (g)
Days to 50% flowering	<b>0.089</b>	0.022	0.008	-0.016	-0.146	-0.013	0.012	0.003	-0.007	-0.009	-0.053
Days to maturity	0.081	<b>0.024</b>	0.006	0.013	-0.192	-0.006	0.017	0.011	-0.006	-0.003	-0.054
Plant height (cm)	0.048	0.011	<b>0.014</b>	0.034	-0.399	-0.020	0.016	-0.006	0.002	-0.021	-0.322**
Total tillers / plant (No.)	0.005	-0.001	-0.002	<b>-0.286</b>	1.089	-0.003	-0.002	-0.017	-0.014	0.037	0.806**
Productive tillers / plant (No.)	-0.011	-0.004	-0.005	-0.252	<b>1.233</b>	-0.001	-0.007	-0.025	-0.012	0.037	0.954**
Fingers / head (No.)	-0.012	-0.002	-0.003	0.008	-0.018	<b>0.096</b>	-0.006	-0.0044	-0.004	-0.007	0.049
Finger length (cm)	0.034	0.009	0.006	0.016	-0.218	-0.014	<b>0.041</b>	0.024	-0.000	0.007	-0.095
10000-grain weight (g)	-0.003	-0.003	0.001	-0.049	0.308	0.004	-0.010	<b>-0.097</b>	-0.000	-0.003	0.146
Dry biomass (g)	0.030	0.006	-0.001	-0.177	0.676	0.017	0.000	-0.001	<b>-0.022</b>	0.013	0.541**
Harvest index (%)	-0.009	-0.001	-0.003	-0.115	0.507	-0.007	0.003	0.003	-0.003	<b>0.091</b>	0.466**

Residual effect = 0.218

\*, \*\* denotes significance at 5 and 1 per cent of probability, respectively

#### 4.5.2 Indirect effects

Days to 50 per cent flowering and maturity had non significant and negative correlation with grain yield; they also had very low indirect effect *via* other characters in positive direction. They contributed negatively, mainly through number of productive tillers per plant.

Plant height was negatively and significantly correlated with grain yield per plant (-0.322), however, it had positive indirect effect *via* days to 50 per cent flowering (0.048), and maturity (0.011), number of total tillers per plant (0.034) and finger length (0.016).

Number of total tillers per plant had significant and positive correlation with the grain yield per plant (0.806) and appeared to be contributing indirectly *via* number of productive tillers per plant (1.088) and harvest index (0.037).

Number of productive tillers per plant had positive and significant association with grain yield (0.954) and contributed indirectly through harvest index (0.037).

Number of fingers per head was positively and non significantly correlated with grain yield per plant (0.049) and contributed indirectly *via* number of total tillers per plant (0.008).

Finger length had non-significant and negative association with grain yield per plant (-0.095), however, it had contributed indirectly through days to 50 per cent flowering (0.036) and maturity (0.009), plant height (0.006), number of total tillers per plant (0.016), 1000-grain weight (0.024) and harvest index (0.007).

1000-grain weight had positive and non significant association with grain yield per plant (0.149) and positive indirect effect through number of productive tillers per plant (0.308) and number of fingers per head (0.004).

Dry biomass was positively and significantly correlated with grain yield per plant (0.541) and contributed indirectly through days to 50 per cent flowering (0.030) and maturity (0.006), number of productive tillers per plant (0.676), number of fingers per head (0.017) and harvest index (0.013).

Harvest index had positive and significant correlation with grain yield per plant (0.466) and contributed indirectly through number of productive tillers per plant (0.507), finger length (0.003) and 1000-grain weight (0.003).

#### **4.6 Divergence ( $D^2$ ) analysis**

Genetic divergence in 50 genotypes was measured following Mahalanobis (1936)  $D^2$  statistic. The  $D^2$  values corresponding to the pair of comparison between the genotypes studied ranged between 178.58 and 12378.53.

##### **4.6.1 Cluster formation**

The cluster formation was done by following Tocher's methods as described by Rao (1952). The 50 genotypes were grouped into 7 clusters. Cluster I with 35 genotypes emerged as the largest cluster. The cluster II was with 6 genotypes, cluster III with 3 genotypes, cluster IV and V with 2 genotypes each. Clusters VI and VII were mono-genotypic indicating wide diversity from the rest and also from each other (Table 4.6).

##### **4.6.2 Intra and Inter cluster distance**

The intra and inter cluster  $D^2$  and  $D$  values were worked out using divergence analysis. The mean  $D^2$  values of cluster elements were used as measurers of intra and inter cluster distances. They are presented in Table 4.7.

**Table 4.6. Distribution of 50 genotypes of finger millet into different clusters**

<b>Cluster number</b>	<b>Number of genotypes included</b>	<b>Genotypes</b>
I	35	GE-995 (3), GE-1116 (4), GE-1235 (5), GE-1799 (10), GE-2022(12), GE-2147 (14), GE-2644 (16), GE-2912 (17), GE-3200 (18), GE-3314 (19), GE-3322 (20), GE-3434 (21), GE-3443 (22), GE-3474 (23), GE-4440 (24), GE-4708 (25), GE-4731 (26), GE-4754 (27), GE-4799 (28), GE-4839 (29), GE-4840 (30), GE-4846 (31), GE-4849 (32), GE-4862 (33), GE-4866 (34), GE-4872 (35), GE-5194 (38), GE-5257 (39), GE-5388 (40), GE-5628 (41), GE-5652 (42), GE-5702 (43), GE-5889 (44), GE-5908 (45), GE-5936 (46)
II	6	GE-435 (1), GE-978 (2), GE-1247 (6), GE-1317 (7), GE-1603 (8), GE-5949 (47)
III	3	GE-1639 (9), GE-1834 (11), GE-2222 (15)
IV	2	GE-2027 (13), GE-4941 (36)
V	2	GE-6012 (49), GE-6029 (50)
VI	1	GE-5005 (37)
VII	1	GE-6004 (48)

Figures in bracket indicate the serial number assigned to the genotypes

Maximum intra cluster distance was observed for cluster I ( $D^2 = 481.48$ ) followed by cluster II (402.28), cluster IV (257.84), cluster III (183.30) and cluster V (178.58). Cluster IV and VII being monogenotypic, showed no intra cluster distance.

The maximum inter-cluster distance was observed between cluster VI and VII ( $D^2 = 12378.53$ ) followed by IV and VII, II and VII, V and VII, III and VII. The minimum inter-cluster distance was observed between cluster II and III (811.24).

The cluster I showed maximum inter-cluster distance with cluster VII ( $D^2 = 8614$ ) which was followed by cluster V ( $D^2 = 1359.94$ ). It had minimum inter-cluster distance with cluster III ( $D^2 = 897.03$ ) which was followed by cluster II, IV and VI.

Cluster II showed maximum inter cluster distance with cluster VII ( $D^2 = 10608.08$ ) followed by cluster VI and cluster V. The minimum inter cluster distance was recorded with cluster III followed by cluster IV and cluster I. Cluster III was most distant from cluster VII (6218.63) followed by cluster VI and cluster IV. It was closer to cluster V (718.86).

Cluster IV showed the maximum distance from cluster VII (10864.74) followed by cluster V and cluster III, whereas, it had minimum  $D^2$  value with cluster II (87.19) followed by cluster I and cluster VI.

Cluster V was closer to cluster III (718.86) and was most distant from cluster VII (3890.25), followed by cluster VI (3579.99), IV (2515.53), cluster II (2151.42) and cluster I (1359.94).

Cluster VI recorded maximum distance from cluster VII (12378.53) followed by cluster V (3579.99). It was closest to cluster IV (943.66).

Cluster VII was most distantly placed away from cluster VI (12378.53) followed by cluster IV (10864.74) and cluster II (10608.08).

**Table 4.7. Average intra and inter-cluster  $D^2$  and  $D$  values in seven clusters of 50 genotypes in finger millet**

Clusters	I	II	III	IV	V	VI	VII
I	481.48 (21.94)	907.75 (30.13)	897.03 (29.95)	932.53 (30.54)	1359.94 (36.88)	1279.65 (35.77)	8614 (92.81)
II		402.28 (20.06)	811.24 (28.48)	874.19 (29.57)	2151.42 (46.38)	2270.07 (47.65)	10608.08 (102.99)
III			183.30 (13.54)	1344.08 (136.66)	718.86 (26.81)	2933.33 (54.16)	6218.63 (78.86)
IV				178.58 (13.36)	2515.53 (50.16)	943.66 (30.72)	10864.74 (104.23)
V					257.84 (16.06)	3579.99 (59.83)	3890.25 (62.37)
VI						0	12378.53 (111.26)
VII							0

## **4.7 Cluster means**

The mean performance of clusters for 11 characters is presented in Table 4.8.

### **4.7.1 Days to 50 percent flowering**

Cluster II (60.87 days) flowered earliest among the clusters, which was followed by cluster III (66.67 days) and cluster IV (68.50 days). However, cluster V and VI flowered late (88.00 days) followed by cluster I (84.32 days) and cluster VII (77.33 days).

### **4.7.2 Days to maturity**

Cluster IV was the earliest to mature (96.17 days) followed by cluster III (96.67 days). Cluster VI (118.33 days), cluster V (114.83 days) and cluster I (114.66 days) were comparatively late in maturity.

### **4.7.3 Plant height (cm)**

This character showed wide range of variability between clusters from 71.86 (cluster V) to 118.02 cm (cluster VI). The highest cluster mean was recorded in cluster VI followed by cluster I, cluster VII, cluster II and cluster III, while, the genotypes grouped into cluster V (71.86 cm) and cluster IV (74.72 cm) were dwarf than others.

### **4.7.4 Total tillers per plant (No.)**

The cluster mean for this character varied between 5.14 (cluster II) and 16.60 (cluster VII). The cluster VII showed maximum number of total tillers per plant followed by cluster V. The lowest cluster mean for this character was recorded in cluster II (5.14).

### **4.7.5 Productive tillers per plant (No.)**

Cluster VII recorded the highest cluster mean (12.14), while cluster VI showed the least value (2.33). The other cluster means ranged between 2.50 (cluster IV) and 6.33 (cluster V).

**Table 4.8. Mean performance of clusters for 11 characters in finger millet**

<b>Characters</b>	<b>Days to 50% flowering</b>	<b>Days to maturity</b>	<b>Plant height (cm)</b>	<b>Total tillers / plant (No.)</b>	<b>Productive tillers / plant (No.)</b>	<b>Fingers / head (No.)</b>	<b>Finger length (cm)</b>	<b>1000-grain weight (g)</b>	<b>Dry biomass (g)</b>	<b>Harvest index (%)</b>	<b>Grain yield / plant (g)</b>
	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>
<b>I</b>	84.32	114.66	96.20	6.71	3.34	6.52	6.87	2.38	68.82	30.97	12.50
<b>II</b>	60.89	98.39	77.98	5.14	2.99	7.10	4.11	2.45	63.62	26.22	11.56
<b>III</b>	66.67	96.67	77.68	7.76	4.69	8.04	4.28	2.85	71.39	29.89	13.45
<b>IV</b>	68.50	96.17	74.72	5.87	2.50	6.57	10.50	1.92	67.67	32.67	12.18
<b>V</b>	88.00	114.83	71.86	10.27	6.33	6.50	5.35	2.25	89.64	32.00	16.80
<b>VI</b>	88.00	118.33	118.02	5.40	2.33	5.93	13.46	2.23	59.47	28.00	12.21
<b>VII</b>	77.33	103.67	78.53	16.60	12.140	7.47	6.26	3.58	96.42	42.00	23.71

#### **4.7.6 Fingers per head (No.)**

Cluster mean for this trait ranged between 5.93 and 8.04 fingers per head. The highest cluster mean value was observed for cluster III followed by cluster VII (7.47) and cluster II (7.10), whereas minimum cluster mean was observed in cluster VI (5.93).

#### **4.7.7 Finger length (cm)**

Very high range of variability in cluster means (4.11 to 13.46 cm) was observed for this character. The maximum cluster mean was observed for cluster VI (13.46 cm) followed by cluster IV (10.50 cm). The minimum cluster mean was observed for cluster II (4.11 cm).

#### **4.7.8 1000-grain weight (g)**

The cluster means for this characters was maximum for cluster VII (3.58 g) followed by cluster III (2.85 g). The lowest cluster mean was estimated for cluster IV (1.92 g).

#### **4.7.9 Dry biomass (g)**

Range of variation was high for this character and varied from 59.47 to 96.42 g. The highest cluster mean was recorded for cluster VII which was followed by cluster V (89.64 g) and cluster III (71.39 g). The least cluster mean was observed for cluster VI (59.47g).

#### **4.7.10 Harvest index (%)**

The cluster VII recorded highest cluster mean (42.00%) for harvest index followed by cluster IV (32.67%), cluster III (32.00%), cluster I (30.97%) and cluster III (29.89%). The least cluster mean was observed for cluster II (26.22%) followed by cluster VI (28.00%).

#### **4.7.11 Grain yield per plant (g)**

Considerable variability for grain yield per plant was observed among the clusters. Cluster VII showed highest cluster mean (23.71 g) followed by cluster V (16.80 g), cluster III (13.45 g) and cluster I (12.50 g) whereas, cluster II (11.56 g) recorded the lowest value.

#### 4.8 Per cent contribution of various characters to divergence

Out of the eleven characters studied for genetic divergence 1000-grain weight (31.51%) contributed highest for divergence, which was followed by plant height, finger length, harvest index and number of fingers per head (Table 4.9).

**Table 4.9. Contribution of various characters to divergence**

Sr. No.	Characters	No. of times appeared 1 <sup>st</sup> ranking	% contribution
1	Days to 50% flowering	25	2.041
2	Days to maturity	71	5.796
3	Plant height (cm)	230	18.776
4	Total tillers / plant (No.)	0	0.000
5	Productive tillers / plant (No.)	44	3.592
6	Fingers / head (No.)	116	9.469
7	Finger length (cm)	159	12.980
8	1000-grain weight (g)	386	31.510
9	Dry biomass (g)	51	4.163
10	Harvest index (%)	140	11.429
11	Grain yield / plant (g)	3	0.245
	Total	1225	100.00

#### 4.9 Morphological character variation in finger millet

The morphological character variation was recorded on all 50 genotypes for five qualitative characters and is presented in Table 4.10.

**Table 4.10. Performance of 50 genotypes of finger millet for five qualitative characters**

<b>Sr. No.</b>	<b>Genotype</b>	<b>Stem pigmentation</b>	<b>Foliage colour</b>	<b>Natural incidence of pest and diseases</b>	<b>Finger arrangement</b>	<b>Grain colour</b>
1	GE-435	0	1	1	3	2
2	GE-978	0	1	1	3	3
3	GE-995	0	2	1	4	2
4	GE-1116	0	1	3	1	2
5	GE-1235	+	1	1	1	4
6	GE-1247	0	1	1	3	2
7	GE-1317	+	3	1	1	2
8	GE-1603	0	1	7	3	4
9	GE-1639	0	2	1	4	4
10	GE-1799	0	1	7	3	2
11	GE-1834	+	1	3	1	4
12	GE-2022	0	3	1	4	3
13	GE-2027	0	1	3	2	3
14	GE-2147	0	1	1	4	3
15	GE-2222	0	1	1	4	2
16	GE-2644	0	1	1	5	2
17	GE-2912	+	3	5	1	3
18	GE-3200	0	1	1	1	1
19	GE-3314	+	1	1	1	1

<b>Sr. No.</b>	<b>Genotype</b>	<b>Stem pigmentation</b>	<b>Foliage colour</b>	<b>Natural incidence of pest and diseases</b>	<b>Finger arrangement</b>	<b>Grain colour</b>
20	GE-3322	+	1	1	3	2
21	GE-3434	0	1	5	3	3
22	GE-3443	0	1	1	1	2
23	GE-3474	0	1	1	3	1
24	GE-4440	0	2	1	5	2
25	GE-4708	0	1	1	3	1
26	GE-4731	0	3	1	3	1
27	GE-4754	0	1	1	1	2
28	GE-4799	0	1	1	1	3
29	GE-4839	0	1	1	3	1
30	GE-4840	+	1	1	4	1
31	GE-4846	0	1	1	4	1
32	GE-4849	0	1	1	3	1
33	GE-4862	0	1	5	1	1
34	GE-4866	0	1	1	4	1
35	GE-4872	0	1	3	1	2
36	GE-4941	0	1	1	2	4
37	GE-5005	0	1	1	2	1
38	GE-5194	0	3	5	3	4
39	GE-5257	0	1	1	1	2
40	GE-5388	0	2	1	1	2
41	GE-5628	0	1	1	3	1

Sr. No.	Genotype	Stem pigmentation	Foliage colour	Natural incidence of pest and diseases	Finger arrangement	Grain colour
42	GE-5652	0	1	3	5	2
43	GE-5701	0	1	3	5	1
44	GE-5889	0	1	1	1	2
45	GE-5908	0	2	1	1	2
46	GE-5936	+	1	3	1	2
47	GE-5949	0	1	1	5	2
48	GE-6004	0	1	1	5	2
49	GE-6012	0	1	1	5	2
50	GE-6029	0	1	1	5	2

Scale:

**Stem pigmentation:**

0 = Non pigmented 1 = Pigmented

**Foliage colour:**

1 = Dark green 2 = Green 3 = Yellowish green

**Natural incidence of pest and diseases:**

1 = Extremely low susceptibility 3 = Low susceptibility 5 = Medium susceptibility 7 = High susceptibility

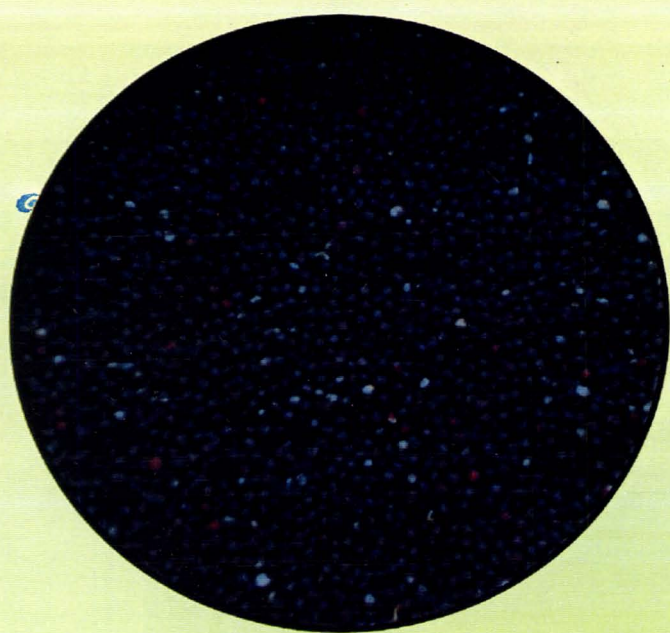
**Finger arrangement:**

1 = Droopy 2 = Open 3 = Semi-compact 4 = Compact 5 = Fist like

**Grain colour:**

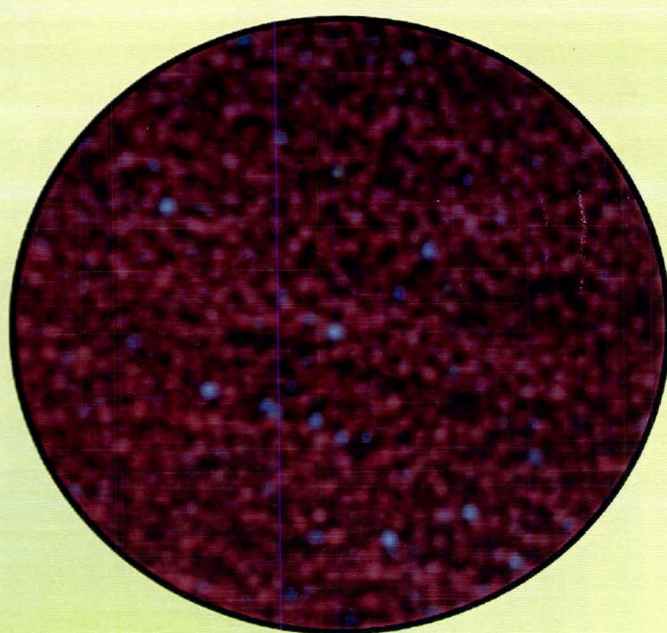
1 = White 2 = Light brown 3 = Copper brown 4 = Purple brown

## PLATE II



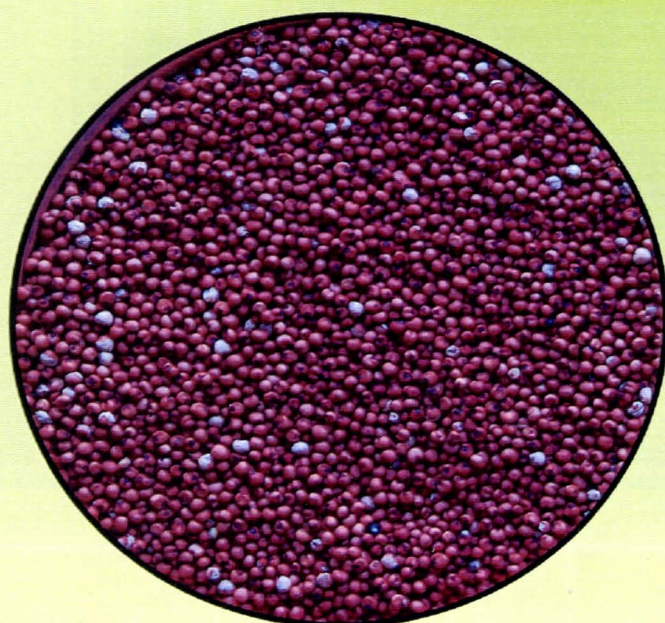
**Purple Brown**

**GE 4866**



**Copper Brown**

**GE 5628**



**White**

**GE 4840**



**Light Brown**

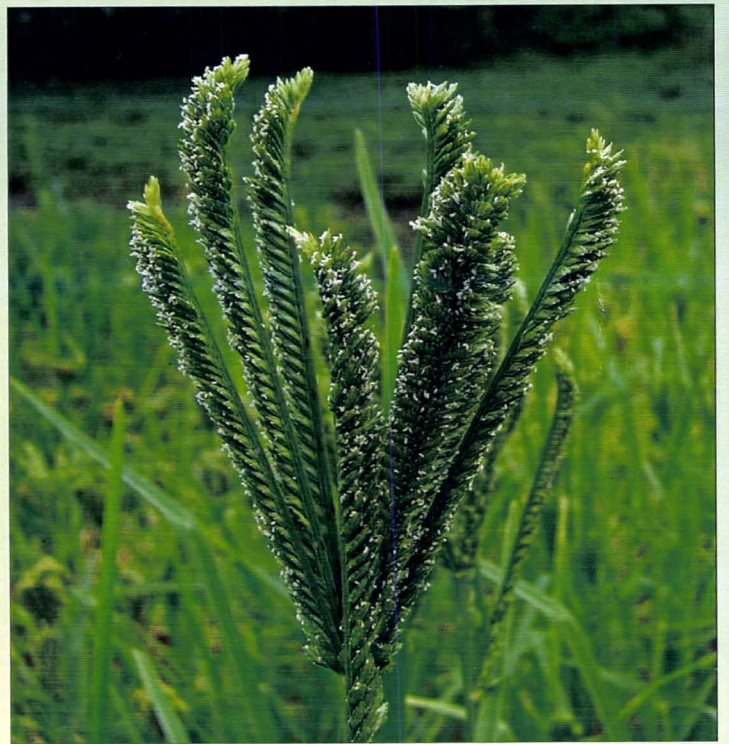
**GE 1116**

**Variation for Seed Colour in Finger Millet**

# PLATE I



**Fist Like**  
**GE 2644**



**Open**  
**GE 4941**



**Droopy**  
**GE 5889**



**Semi-compact**  
**GE 5628**

**Variation for Finger arrangement in Finger Millet**

#### 4.9.1 Stem pigmentation

Most of the genotypes were non pigmented. The genotypes GE-1235, GE-1317, GE-1834, GE-2912, GE-3314, GE-3322, GE-4840 and GE-5936 showed pigmentation.

#### 4.9.2 Foliage colour

Foliage colour was observed to be dark green in most of the genotypes except in few genotypes like GE-995, GE-1639, GE-4440, GE-5388 and GE-5908 where it was found to be green in colour. In genotypes GE-1317, GE-2022, GE-2912, GE-4731 and GE-5194 yellowish green foliage colour was observed.

#### 4.9.3 Natural incidence of pests and diseases

The genotypes GE-1603 and GE-1799 were found to be highly susceptible to pests viz., stem borer (*Sesamia inferens*) and white borer (*Saluria inficita*) when compared to other genotypes which showed extremely low susceptibility. The genotypes GE-3434, GE-4862, GE-5194 showed medium susceptibility to sucking pests viz., plant lice (*Schizaphis graminum*) and mealy bug (*Brevennia rehi*). The genotypes GE-116, GE-1834, GE-2027, GE-5652 showed low susceptibility to diseases viz., blast (*Pyricularia fungi*) and seedling blight (*Cochliobolus noduloeus*) whereas the other genotypes have showed extremely low susceptibility.

#### 4.9.4 Finger arrangement

The genotypes GE-2027, GE-4941 and GE-5005 had open finger arrangement whereas the genotypes GE-2644, GE-4440, GE-5652, GE-5702, GE-5949, GE-6004, GE-6012 and GE-6029 had fist like finger arrangement. The other genotypes were observed to have droopy and semi-compact type of finger arrangement.

#### 4.9.5 Grain colour

Out of 50 genotypes 23 had light brown coloured grain and 14 genotypes had white coloured grain. The genotypes GE-978, GE-2022, GE-2027, GE-2147, GE-2912, GE-3434 and GE-4799 had copper-brown coloured seed. Whereas the genotypes GE-1235, GE-1603, GE-1639, GE-1834, GE-4941 and GE-5194 had purple-brown coloured seed.

Chapter Opener Page

# DISCUSSION

## **5. DISCUSSION**

The extent of genetic variability available in a crop is prerequisite for its improvement, due to the fact that the efficiency of selection depends mainly on it. Genotypic and phenotypic coefficients of variation measure the extent of variability present in a population for a particular character. Heritability is an index of transmissibility of a character from parents to their offspring. The concept of heritability is important in determining whether the phenotypic differences among the individuals are genetically or the result of environmental factors. Genetic advance on the other hand measures the expected gain from the selection applied in a population. Heritability along with genetic advance gives the best picture of the efficiency of selection. Likewise, the correlations provide the interrelationships among the quantitative characters which facilitates the choice of suitable parents for the improvement in the crop, whereas path analysis helps in understanding the direct and indirect effects of various characters towards the yield. The genetic divergence enables the evaluation of genotypes without actual crossing and grouping the genetic material into few clusters in a significant pattern.

The results obtained on variability, correlations, path analysis and genetic divergence among 50 genotypes of finger millet are discussed under the following sub-heads.

- 5.1 Genetic variability
- 5.2 Genotypic and phenotypic coefficient of variation
- 5.3 Heritability and genetic advance
- 5.4 Correlations
- 5.5 Path analysis
- 5.6 Genetic divergence

## 4. EXPERIMENTAL RESULTS

The present experiment “Path analysis and genetic diversity in finger millet (*Eleusine coracana* Gaertn L.)” was undertaken to study the genetic variability, correlations, path analysis and genetic divergence in finger millet during *Kharif*, 2006 at the Farm of Botany Section, College of Agriculture, Pune. The observations were recorded on eleven yield and yield contributing characters and the results obtained are presented below.

### 4.1 Analysis of variance

The analysis of variance (Table 4.1) revealed significant differences among genotypes, showing variations for all the eleven characters under study.

### 4.2 Mean performance

The mean values of 50 genotypes for eleven characters studied are presented in Table 4.2

#### 4.2.1 Days to 50 per cent flowering

The variation for days to 50 per cent flowering ranged between 53.67 and 92.67 days. The population mean for this character was 80.86 days. The genotype GE-5949 was the earliest to flower (53.67 days) followed by GE-2027 (63.00 days), GE-435 and GE-2222 (63.67 days). The genotype GE-1116 was late for 50 per cent flowering (92.67 days) followed by GE-4862, GE-487 and GE-5257 (91.00 days). Twenty five out of fifty genotypes flowered significantly earlier than the population mean.

#### 4.2.2 Days to maturity

Twenty four genotypes showed significantly early maturity when compared with the population mean of 110.75 days. The variation for this character ranged between 85.67 to 125.33 days. The genotypes GE-5949

## 5.1 Genetic variability

In the present investigation, genotype GE-6004 was identified as a potent and the best genotype as it exhibited high *per se* performance for yield and other five yield contributing characters *viz.*, number of total tillers, number of productive tillers, 1000-grain weight, dry biomass and harvest index. GE-6012, GE-4440 and GE-2222, were also identified as potent genotypes next to GE-6004.

Wide range of variation was observed for all the characters studied. Highly significant differences were observed among 50 genotypes for days to 50 per cent flowering which ranged from 53.67 (GE-5949) to 91 days (GE-4862, GE-4872 and GE-5257). The genotype GE-5949 flowered in less than 55 days indicating their earliness in flowering behaviour. Haider and Mahto (1995) have also reported the good amount of variability for earliness.

The days to maturity varied between 85.67 (GE-5949) and 125.33 days (GE-4846). The genotypes GE-5949, GE-2027, GE-2222 and GE-1603 matured very early suggesting use of such early maturing types in breeding programmes. Setty *et al.* (1974), Sarvaiya *et al.* (1982), Goswami and Asthana (1984), Chaugule *et al.* (1982) reported the significant differences for days to maturity.

The appreciable amount of variation was observed for plant height, which ranged between 64.08 (GE-1247) and 121.57 cm (GE-4708). The genotypes GE-4708, GE-5005 (118.02) and GE-2644 (117.14) recorded highest plant height. Dhagat *et al.* (1972), Setty *et al.* (1974) Shanthappa (1978) and Sarviya *et al.* (1982) have also reported good amount of variability for plant height.

The variability for number of total tillers per plant ranged between 4.07 (GE-1247) and 16.60 (GE-6004). The genotypes GE-6029 (11.27),

GE-3200 (9.33) and GE-6012 (9.27) recorded more number of total tillers per plant.

The genotypes GE-6004 (12.40) produced the highest number of productive tillers per plant followed by genotypes GE-6012 (6.87), GE-2022 (6.00). Setty *et al.* (1974), Hussaini *et al.* (1977), Shanthappa (1978) and Devkota and Mohapatra (1991) also reported significant difference for productive tillers.

Average fingers per head showed significant differences and ranged between 5.07 (GE-2022) and 9.47 (GE-1639). The genotypes GE-1639 (9.47), GE-5936 (9.27), GE-435 (9.13) and GE-5889 (9.07) showed more than nine fingers per head. Goud and Lakshmi (1977), Hussaini *et al.* (1977), Gontia *et al.* (1992) and Haider and Mahto (1995) showed significant differences for average fingers per head.

Significant differences were observed for finger length. It ranged between 3.16 (GE-1247) and 13.46 cm (GE-5005). Chaugule *et al.* (1982), Goswami and Asthana (1984) and Ayyangar *et al.* (1993) reported similar results for this character. The genotypes GE-4941 (10.84), GE-4731 (10.24) and GE-2027 (10.17) showed high finger length.

The variability for 1000-grain weight ranged between 1.50 (GE-4872) and 3.58g (GE-6004). The genotypes GE-6004, GE- 4799 (3.48), GE-5702 (3.23) and GE-1639 (3.19) recorded highest 1000-grain weight and produced bold sized grains. Setty *et al.* (1974), Hussaini *et al.* (1977), Goud and Lakshmi (1977), Shanthappa (1978), Gontia *et al.* (1992) and Haider and Mahto (1995) have reported significant differences for test weight.

The genotypes GE-6004 (96.42), GE-6029 (95.25) and GE-5652 (87.62) produced highest dry biomass. The variability for this character

ranged between 52.67 (GE-1235) and 96.42 g (GE-6004) and showed significant differences among the genotypes.

Harvest index showed the wide range of variation and the variability for this character ranged between 42.00 (GE-6004) and 20.33 per cent (GE-4799). The genotypes GE-6004, GE-4440 (41.67) and GE-5936 (40) recorded the highest harvest index.

The highly significant differences were observed for grain yield per plant. The variation for this characters ranged between 7.47 (GE-4799) and 28.71g (GE-6004). The genotypes GE- 5702 (17.37), GE- 6012 (17.23), GE-4440 (16.60), GE-6029 (16.37), GE-2222 (15.75), GE- 2022 (15.64) and GE-995 (15.52) showed more than 15.00 g grain yield per plant. Setty *et al.* (1974), Goud and Lakshmi (1977), Hussaini *et al.*(1977), Chaugule *et al.* (1982), Goswami and Asthana (1984) and Gontia *et al.* (1992) observed high variability for grain yield per plant.

## **5.2 Genotypic and phenotypic coefficient of variation**

The genetic variability in different quantitative characters is measured from the genotypic coefficient of variation (Fisher, 1930). The magnitude of phenotypic coefficient of variation was high as compared to genotypic coefficient of variation. This was due to the fact that addition of the environmental variance would naturally increase the magnitude of the total variance. The results obtained by Tyagi and Koranne (1989) and Verma (1989) were similar to present findings.

The genotypic and phenotypic coefficients of variation were high for the characters productive tillers per plant, finger length, number of total tillers per plant and grain yield per plant. In the present investigation the characters number of total tillers per plant, number of productive tillers per plant, finger length, grain yield and 1000-grain weight recorded high genotypic coefficient of variation indicating good scope for their

improvement through selection. Similar results were reported by Narasimha Rao and Parthosarathi (1968), Dhagat *et al.* (1972), Swaminath (1978), Mishra *et al.* (1980), Goswami and Asthana (1984) and Thakur and Saini (1995).

The magnitudes of GCV and PCV were low for days to 50 per cent flowering and days to maturity. These results are in conformity with those reported by Appadurai *et al.* (1977), Goud and Lakshmi (1977), Kulkarni (1980) and Mishra *et al.* (1980).

In the present studies, grain yield per plant, productive tillers per plant and test weight, showed high magnitude of genotypic and phenotypic coefficients of variation. Similar results were reported by Bendale *et al.* (2002). The earlier findings of Narasimha Rao and Parthosarathi (1968), Swaminath (1978), Kulkarni (1980), Mishra *et al.* (1980), Abraham *et al.* (1989), Thakur and Saini (1995), Bandyopadhyay (1998) for grain yield per plant, productive tillers per plant and test weight were similar to those observed in the present investigation.

The difference between magnitude of phenotypic and genotypic coefficient of variation was maximum for number of fingers per head, grain yield per plant, number of total tillers per plant and number of productive tillers per plant, indicating the role of environment in the expression of these characters. Similar results were reported earlier by Mishra *et al.* (1980), Abraham *et al.* (1989) and Thakur and Saini (1995). For the characters *viz.*, days to 50 per cent flowering, days to maturity, plant height and finger length, the magnitudinal differences between phenotypic and genotypic coefficients of variation were minimum, indicating greater role of genotype than environment in the expression of these characters.

### 5.3 Heritability (b.s.) and genetic advance

High heritability estimates indicate the effectiveness of selection based on phenotypic performance, but does not necessarily mean a high genetic gain for that particular trait. The character with high genetic gain may be attributed to the additive gene effects (Panse, 1957), which can easily be improved by simple selection. On the other hand, high heritability and low genetic advance may be attributed to non-additive gene action and such characters may be improved by hybridization.

Burton (1952) had suggested that genotypic coefficient of variation together with heritability would furnish most reliable information on the amount of genetic advance to be expected for selection.

In the present studies, all the characters recorded high estimates of heritability (b.s.). Finger length (98.67) showed highest heritability estimates followed by plant height, days to maturity and days to 50 per cent flowering (Table 4.3), indicating that these characters were less influenced by the environment and selection for these traits would result in desirable improvement. Similar results were reported by Dhagat *et al.* (1972), Jana (1973), Sarvaiya *et al.* (1982), Abraham *et al.* (1989), Tyagi and Koranne (1989), Verma (1989), Ravikumar and Seetharam (1994) and Thakur and Saini (1995) for days to 50 per cent flowering, Patnaik and Jana (1973), Sarvaiya *et al.* (1986), Shankar (1986), Ravikumar and Seetharam (1994) and Thakur and Saini (1995) for days to maturity and plant height.

Heritability was comparatively medium range for average fingers per head (60.10 per cent), indicating the role of environment on the expression of this character. Similar results were reported by Patnaik (1968) and Setty *et al.* (1974).

Johnson *et al.* (1955) observed that the genetic gain will be low when there is non-additive gene action whereas, the genetic advance

would be high when there is additive gene action. In the present investigation, days to 50 per cent flowering, days to maturity, plant height and finger length had high heritability with high genetic advance indicating the likelihood of presence of additive gene action for these characters and simple selection in the segregating generations would be effective for improving these characters. While the characters, number of fingers per head and number of total tillers per plant showed presence of non-additive gene effects, implying that hybridization will be the best way to improve these characters. Similar results were reported by Patnaik and Jana (1973) and Agalodia *et al.* (1979).

#### **5.4 Correlations**

A wide range of variation in quantitative characters provide the basis for selection in plant breeding programmes where, the information on inter relationships among such quantitative traits facilitates the choice of suitable breeding method to be applied and selecting the parents for improving the crop.

The genotypic and phenotypic correlations indicate the extent of relationship between two variable characters under study. Of the two measures, genotypic correlation coefficient provides a close measure of association between characters and gives an indication of characters which may be useful for overall improvement in the crop. They may also help to identify characters that have little or no importance in the selection programme. In any event, they provide basic information useful to the breeder (Johnson *et al.*, 1955). The phenotypic correlations also help in formulating the selection index useful for crop improvement through simultaneous selection.

In the present investigation four traits *viz.*, number of productive tillers per plant, number of total tillers per plant, dry biomass and harvest

index showed highly significant positive correlations with grain yield per plant both at genotypic and phenotypic level. Mahudeswaran and Murugesan (1973), Ranganathan (1977), Prabhu ((1980), Chaugule *et al.* (1982), Reddy *et al.* (1994), Singh *et al.* (1995) and Ravindran *et al.* (1996) have reported the similar results in finger millet. However, plant height exhibited significantly negative association with grain yield. The other traits, days to 50 per cent flowering and maturity and finger length also showed negative but non significant association with grain yield.

The interrelationship among the characters revealed that the traits days to 50 per cent flowering and maturity were strongly related with each other in positive direction (0.907). It was followed by strong association between number of total tillers per plant and number of productive tillers, number of total tillers and dry biomass and number of productive tillers and dry biomass. Similar results were also reported by Reddy *et al.* (1994).

### **5.5 Path coefficient analysis**

Path analysis is one of the efficient ways to understand the direct and indirect effects of different component characters on yield. In the present investigation path analysis was worked out by following Dewey and Lu (1959) to find out the magnitude and direction of direct and indirect effects of various yield and yield contributing characters. Direct effect of any character on yield gives an idea about how reliable selection can be made for a particular character to bring improvement in the yield. If the correlation between a causal factor and the direct effect is more or less of equal magnitude, it explains the true relationship between the characters and direct selection through these traits will be effective. However, if the final correlation coefficient is positive and the direct

effect is negative or negligible then the indirect causal factors are to be considered simultaneously for selection.

Days to 50 per cent flowering and maturity though had non significant and negative correlation with grain yield, they were observed to be contributing indirectly through plant height, finger length and 1000-grain weight.

The character number of productive tillers per plant recorded highest positive magnitude of direct effect on grain yield and its association with grain yield was also highly significant and positive indicating the true and perfect association between productive tillers and grain yield. Mahudeswaran and Murugesan (1973), Appadurai *et al.* (1977) and Singh *et al.* (1995) have reported the similar results in finger millet. The dependency of characters could be considered while selecting high yielding genotypes in *ragi*.

Number of fingers per head was positively and non-significantly correlated with grain yield per plant (0.049), however, it was found to be contributing through number of tillers per plant

Finger length had negative and non significant correlation with grain yield per plant (-0.095), however, its indirect effect through test weight was positive but of low magnitude. Upadhyaya *et al.* (2006) reported that this character could be given least priority in future genotype evolution of finger millet.

The characters days to 50 per cent flowering, days to maturity, fingers per head and harvest index had direct positive effect but of less magnitude. Similar results were obtained by Bedis *et al.* (2006).

The character 1000-grain weight and dry biomass though had negative direct effect showed positive association with grain yield, mainly through the trait productive tillers.

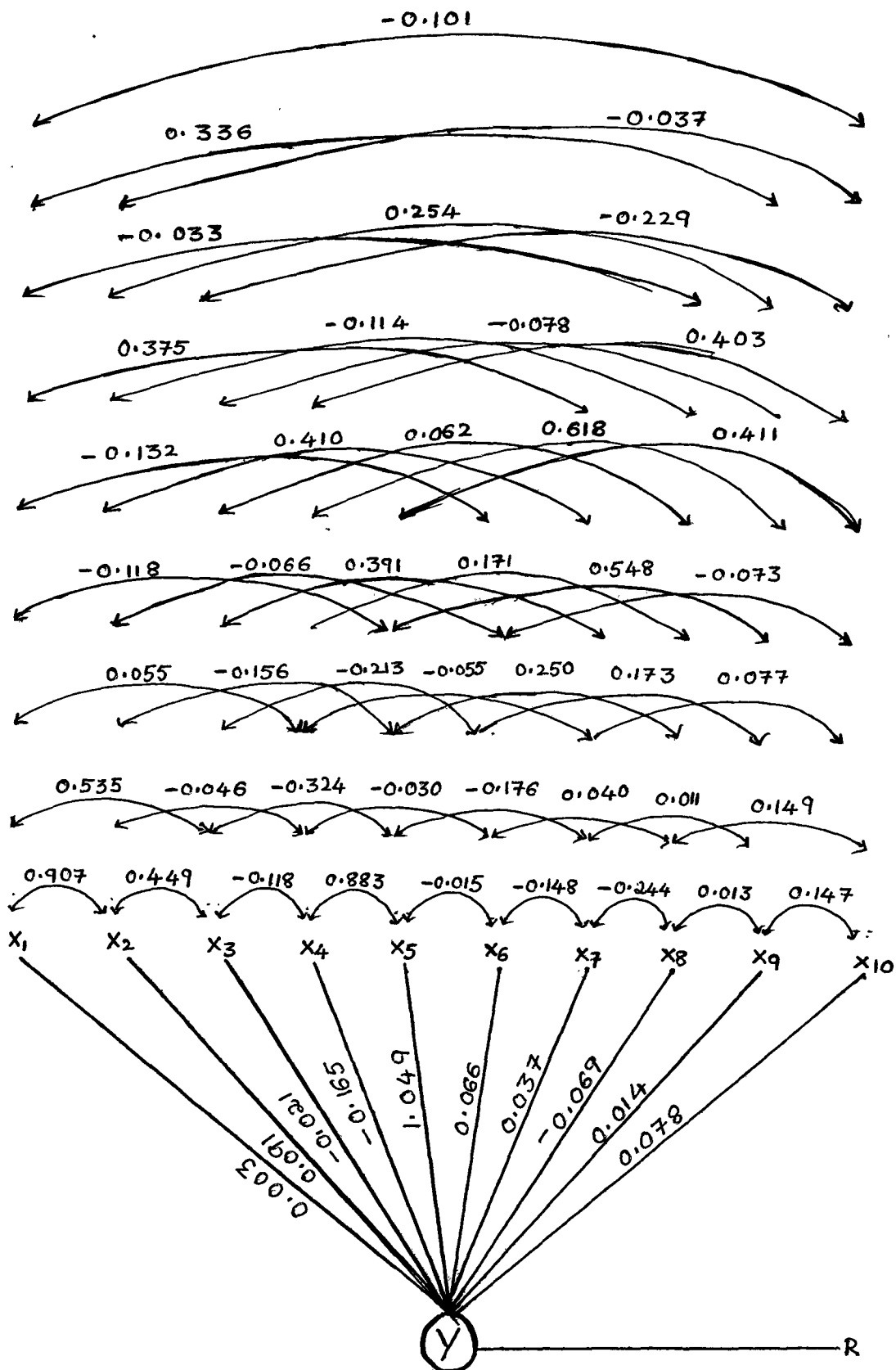


Fig:5.1 Path diagram showing nature of causal system Of variables with their coefficients for the path analysis in finger millet (*Eleusine coracana* Gaertn)

X<sub>1</sub> = Days to 50% flowering (No.)  
 X<sub>2</sub> = Days to maturity (No.)  
 X<sub>3</sub> = Plant height (cm)  
 X<sub>4</sub> = Total number of tillers  
 X<sub>5</sub> = No. of productive tillers

X<sub>6</sub> = Number of fingers per head  
 X<sub>7</sub> = Finger length (cm)  
 X<sub>8</sub> = 1000-seed weight (g)  
 X<sub>9</sub> = Dry biomass (g)  
 X<sub>10</sub> = Harvest index (%)  
 Y = Yield (g)

## 5.6 Genetic divergence

The important objective in obtaining biometrical measurements is to understand the possibilities of classifying different groups of individual genotypes. It is the most important and difficult task in initiation of hybridization programme for selecting genotypes with high *per se* performance among them. From the genetic variability estimates, it should be possible to identify desirable genotypes but unless we have sound knowledge about divergence between them, it is difficult to expect any extraordinary results from their progeny.

$D^2$  statistic, a concept developed by Mahalanobis (1936) is an important tool to plant breeders. It is useful in quantifying the degree of divergence between biological population at genotypic level and to assess the relative contribution of different components to the total divergence at both intra and inter cluster levels. Rao (1952) suggested the application of this technique for the assessment of genetic diversity in plant breeding.

### 5.6.1 Cluster formation, intra and inter cluster distances and mean performance

The cluster formation i.e. intra and inter-cluster divergence provides a basis for selecting genetically diverse parents belonging to different clusters. The crosses between strains of widely separated cluster with high inter-cluster diversity appear to be very effective. It is assumed that the statistical distance ( $D$ ) is the index of genetic diversity.

In the present investigation, clustering of genotypes following the Tocher's method as described by Rao (1952) lead to formation of seven clusters indicating high amount of divergence among the genotypes. The distribution of genotypes into different clusters is presented in Table 4.6. The cluster I was the largest with 35 genotypes followed by cluster II and cluster III containing 6 genotypes and 3 genotypes, respectively, cluster

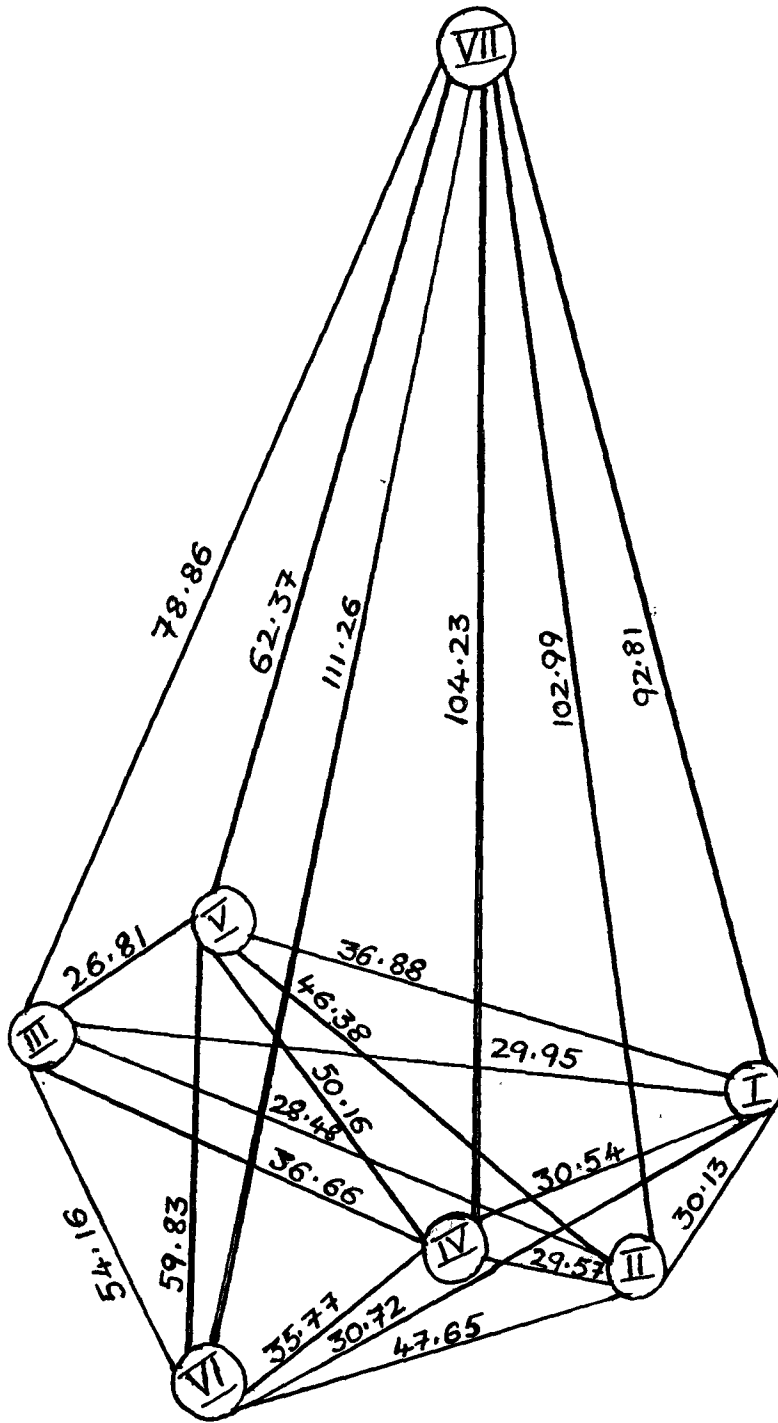
IV and cluster V with 2 genotypes each whereas, cluster VI and VII was monogenotypic. These genotypes had wide variation from the rest as well as from each other. The cluster with single genotype may have different genetic architecture from the others.

It was observed that the maximum intra-cluster distance was found in cluster I ( $D^2 = 481.48$ ), which was followed by cluster II and cluster IV (Table 4.7) whereas, the minimum intra-cluster distance was shown by cluster V (178.58), indicating that the strains of these clusters resemble one another genetically and might have evolved from common gene pool. In the present study, the cluster VI and cluster VII was monogenotypic, therefore, no intra-cluster distance.

The maximum inter-cluster distance was observed between cluster VI and VII (12378.53) followed by cluster IV and cluster VII (10864.74), cluster II and cluster VII (10608.08), cluster I and cluster VII (8614.00), cluster III and cluster VII (6218.63), cluster V and VII (3890.25) and cluster V and VI (3579.99) indicating wide divergence among the clusters. This also suggested that the genetic architecture of the genotypes in one cluster differs entirely from those included in other clusters.

The minimum inter-cluster distance was observed between cluster II and cluster III (811.24). The lower D values between these cluster suggested that the genetic constitution of these genotypes in one cluster were in close proximity with the genotypes in other cluster of the pair.

Based on mean performance of the clusters for eleven characters (Table 4.8) it was observed that the cluster VII recorded highest grain yield per plant (23.71 g) and was characterized by high productive tillers (12.14), 1000-grain weight (3.58 g) and harvest index (42.00 %) along with dry biomass (96.42 g) and number of fingers per head (7.47). Similar results were obtained by Patil (1982), Sheriff (1992), Reddy *et al.* (1993) and Jaylal and Haider (1994).



ot to scale-

g.5.2 A cluster diagram showing inter-relationships between seven clusters

The cluster I with maximum number of genotypes (35) was late for days to 50 per cent flowering and maturity likewise moderate productive tillers, number of fingers per head, finger length, 1000-grain weight and grain yield per plant (Table 4.8).

The cluster IV was early in maturity (96.67 days) with less test weight (1.92 g) and moderate grain yield (12.18 g). Cluster III showed highest number of fingers per head (8.04) and least finger length.

### **5.6.2 Relative contribution of characters towards genetic diversity**

The variance of cluster mean provides information on relative importance of yield and yield contributing characters. In present investigation, the character like 1000-grain weight (31.51%) has highest contribution towards genetic divergence. This was followed by plant height (18.78 %), finger length (12.98 %), harvest index (11.43 %) and number of fingers per head (9.47%). Patil (1982) and Jaylal and Haider (1994) reported similar results earlier. However, it was found that the grain yield per plant (0.25 %) and days to 50 per cent flowering (2.04 %) had minimum contribution towards genetic divergence.

### **5.6.3 Genetic divergence as a measure of choosing potent parents for crossing**

Diversity is the basic need of crop improvement programme. The success of any crossing programme involves selection of best parents having high expression for the economically important characters. Among the different approaches of selecting parents, selection based on diversity has its own significance, therefore, in the present study diversity among different genotypes was studied, which yielded valuable information that could be useful in suggesting potent parents for crossing. Bhatt (1970) has also advocated the use of multivariate analysis for the

selection of parents. According to him, crossing programme involving parental material selected on the basis of total genetic divergence of many economic characters may lead to greater improvement in yielding ability.

In the present study, 50 genotypes were grouped into seven clusters, based on the  $D^2$  values between different genotypes. Genotypes grouped into the same cluster presumably diverge very little from one another as regards the aggregate divergence of the characters measured. Thus, crossing of genotypes belonging to the same cluster is not expected to yield desirable segregate. Consequently, a crossing programme should be formulated such that the putative parents belong to different clusters.

Bhatt (1970) suggested that it would be logical to affect crosses between genotypes belonging to the cluster separated by high estimated statistical distances.

Arunachalam and Bandyopadhyay (1984) devised a method to delineate parental divergence into four divergence classes (DC). To take into account the variable magnitude of variation in parental divergence, the mean (M) and standard deviation (S) of the values of intra and inter cluster divergence (D) were calculated. They defined the divergence classes as follows.

$$DC1 = D \geq (M+S)$$

$$DC2 = D < (M + S) \text{ and } \geq M$$

$$DC3 = D \leq (M - S) \text{ and } < M$$

$$DC4 = D < (M - S)$$

Experiments by them (two in groundnut and one in rapeseed) showed that the chances for the occurrence of a high frequency of heterotic crosses with high values of heterosis were more, when the parents were chosen to have their divergence in the interval,  $M - S$  and  $M + S$ , compared to the crosses between parents, whose divergence fall outside this interval (i.e. those fall in DC1 and DC4).

In the present study, an attempt was made to classify the cluster combinations into four divergence classes, following the above procedure suggested by Arunachalam and Bandyopadhyay (1984). The statistical distance (D) given in Table 4.7 represents the index of genetic diversity among clusters. The mean of 21 inter cluster and five intra cluster distances (as two monogenotypic clusters had no intra cluster distances) was 46.58 and standard deviation was 28.54. The minimum (X) and maximum (Y) values among these distances were 13.36 and 111.26, respectively. Thus, the divergence classes are presented in Table 5.1

**Table 5.1 Distribution of different cluster combinations into four divergence classes based on D values between them**

	Y = 111.26
DC1	(I, VII), (II, VII), (III, VII), (IV, VII), (VI, VII)
	M + S = 75.12
DC2	(II, VI), (III, VI), (IV, V), (V, VI), (V, VII)
	M = 46.58
DC3	(I, II), (I, III), (I, IV), (I, V), (I, VI), (II, III) (II, IV), (II, V), (III, IV), (III, V), (IV, V)
	M - S = 18.04
DC4	X = 13.36

Grouping of the cluster pairs into the divergence classes is presented above. On the light of the above discussion, initial choice of the parents should be made from the cluster combinations falling in the divergence classes DC2 and DC3. For example cluster combinations (I, II) fall in the DC3, thus crosses of the genotypes grouped into cluster I can be formulated with the genotypes grouped into cluster II. However, while choosing among the genotypes of a cluster, the per se performance of genotypes for different traits such as yield, disease reaction, etc. should be taken into account so that desirable segregates would be obtained for hybridization.

Keeping in view all the above aspects the following genotypes deserve to be considered as potent parents for tentative breeding programme.

- (1) GE-6004 (2) GE-6012 (3) GE-4866 (4) GE-2222 (5) GE-1247  
(6) GE-2022 (7) GE-4731 (8) GE-4440 (9) GE-5949

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**SUMMARY AND  
CONCLUSION**

## 6. SUMMARY AND CONCLUSION

The present investigation “Path analysis and genetic diversity in Finger millet (*Eleusine coracana* Gaertn L.)” was undertaken to study the association between different characters, to measure the direct and indirect contribution of the component characters on yield, to group different genotypes into suitable cluster and to measure the genetic divergence among different genotypes of finger millet. 50 genotypes of finger millet collected from the project co-ordinator (Small millets), GKVK, Bangalore were evaluated during *Kharif*, 2006 in randomized block design with three replications. The observations were recorded on quantitative characters *viz.*, days to 50 per cent flowering, days to maturity, plant height (cm), number of total tillers per plant, number of productive tillers per plant, number of fingers per head, finger length (cm), 1000-grain weight (g), dry biomass (g), harvest index (%), grain yield per plant (g) and qualitative characters *viz.*, stem pigmentation, foliage colour, natural incidence of pests and diseases, finger arrangement and grain colour.

Among the 50 genotypes studied, GE-5949 for days to 50% flowering and days to maturity, GE-4708 for plant height, GE-6004 for number of total tillers and productive tillers per plant, GE-1639 for fingers per head, GE-5005 for finger length, GE-6004 for 1000-grain weight, dry biomass, harvest index and grain yield per plant have recorded high *per se* performance for various characters.

Significant treatment mean sum of squares for all the characters studied, revealed the presence of substantial amount of variability in the genotypes evaluated. The magnitudes of GCV and PCV were high for number of productive tillers per plant and finger length. However, lowest GCV and PCV were observed for days to maturity. High magnitudinal difference between PCV and GCV was found for fingers per head. High and very high heritability was observed for all the characters under study expect number of fingers per head. Plant height showed high broad sense

heritability with high genetic advance whereas, the character finger length showed high heritability with moderate genetic advance suggesting the role of additive gene effects for this character.

Grain yield per plant had positive and significant correlation with number of total tillers per plant, number of productive tillers per plant, dry biomass and harvest index. This indicated the dependency of these characters on each other.

The path analysis revealed that number of productive tillers per plant, number of fingers per head and harvest index exhibited high direct effect in the desirable direction and also confirmed their strong association with grain yield per plant, indicating the true and perfect relationship between them. It suggested that direct selection based on these characters would help in selecting the high yielding genotypes in finger millet.

In the present investigation  $D^2$  values for all possible pairs of 50 genotypes ranged between 178.58 and 12,378.53. All the 50 genotypes were grouped into seven clusters following Tocher's methods as described by Rao (1952). Cluster I was the largest with 35 genotypes followed by cluster II and cluster III with six and three genotypes, respectively. Cluster IV and cluster V had two genotypes each and cluster VI and cluster VII were monogenotypic.

The maximum intra cluster distance was observed for cluster I followed by cluster II and cluster IV, suggesting that genotypes present in these clusters might have different genetic architecture. The maximum inter cluster distance was observed between cluster VI and cluster VII ( $D^2 = 12378.53$ ) followed by the distance between cluster IV and cluster VII ( $D^2 = 10864.74$ ), indicating wide divergence among these clusters. The minimum inter cluster distance was observed between cluster II and cluster III ( $D^2 = 811.24$ ).

The variance of cluster means provided information that 1000-grain weight, plant height and finger length were the characters contributing maximum to the genetic divergence in the present study. The following

genotypes were suggested for tentative breeding programmes, based on divergence studies.

- |    |         |    |         |    |         |
|----|---------|----|---------|----|---------|
| 1) | GE-6004 | 2) | GE-6012 | 3) | GE-4866 |
| 4) | GE-2222 | 5) | GE-1247 | 6) | GE-2022 |
| 7) | GE-4731 | 8) | GE-4440 | 9) | GE-5949 |

### **Conclusion**

1. The grain yield per plant showed highly significant positive association with number of total tillers per plant, number of productive tillers per plant, dry biomass and harvest index.
2. The number of productive tillers per plant recorded the highest positive direct effect on yield whereas the other characters produced positive direct effect of low magnitude.
3. All the 50 genotypes are grouped into seven clusters and the maximum inter-cluster distance was observed between cluster VI and VII.
4. Among 50 genotypes studied, GE-6004 is the best genotype with highest *per se* performance for grain yield and other five quantitative characters *viz.*, number of total tillers per plant, number of productive tillers per plant, 1000-grain weight, dry biomass and harvest index.

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\* Originals are not seen.

Chapter Opener Page

**VITA**

## 8. VITA

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in  
AGRICULTURAL BOTANY  
(CYTOGENETICS AND PLANT BREEDING)

2007

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**Title of Thesis** : “Path analysis and genetic diversity in finger  
millet (*Eleusine coracana* Gaertn L.)”  
**Major Field** : Cytogenetics and Plant Breeding

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### BIOGRAPHICAL INFORMATION:

**PERSONAL** : Born on 18<sup>th</sup> August 1981 at Visakhapatnam,  
Andhra Pradesh. Daughter of Shri. Vanka  
Mallesu and Smt. Vanka Ramanamma.

**EDUCATIONAL** :

- Passed 10<sup>th</sup> board with first class from  
Suryodaya Public School, visakhapatnam,  
(A.P.) in 1996.
- Passed 12<sup>th</sup> board with first class from Mrs.  
A.V.N. College, visakhapatnam, (A.P.) in  
1998.
- Completed B.Sc. (Agri.) degree in 2005 from  
Acharya N.G. Ranga Agricultural University,  
Rajendranagar, Hyderabad, Andhra Pradesh  
with OGPA 8.32 on 10.00 scale.

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### **EXTRA CURRICULAR ACTIVITIES**

- Awarded fourth prize in the fifth National Youth Parliament competition held in the year 2001-02 by the Ministry of Parliamentary affairs and defence.
- Participated in the NSS National Integration Camp organized by Punjab Agricultural University, Ludhiana in November, 2003.
- Adjudged third place in Badminton in the 5<sup>th</sup> All India Inter Agricultural University sports and Games Meet 2003-2004 held at the University of Agricultural Sciences, Bangalore.
- Secured first place in Javelline throw continuously for two years at University level (ANGRAU).
- Secured first place in 4 x 100 m Relay continuously for two years at University level (ANGRAU).

- Secured runners in Volley ball at University level (ANGRAU).
- Participated in Cultural and Literary competitions at University and Inter University level and awarded prizes in singing competition.
- Represented M.P.K.V. University, Rahuri in Sports Meet held at Loni and awarded winners in badminton at College level.

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