

**VARIABILITY STUDIES FOR YIELD AND BLAST
RESISTANCE IN SEGREGATING POPULATION
OF FINGER MILLET (*Eleusine coracana* (L.) Gaertn)**

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DEPARTMENT OF GENETICS AND PLANT BREEDING

UNIVERSITY OF AGRICULTURAL SCIENCES

BANGALORE-65

2014

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Thesis submitted to the

UNIVERSITY OF AGRICULTURAL SCIENCES, BANGALORE

in partial fulfilment of the requirements

for the award of the degree of

MASTER OF SCIENCE (Agriculture)

in

GENETICS AND PLANT BREEDING

BANGALORE

AUGUST, 2014

*Dedicated to
My beloved
Parents...*



**DEPARTMENT OF GENETICS AND PLANT BREEDING
UNIVERSITY OF AGRICULTURAL SCIENCES
GKVK, BANGALORE- 560 065**

CERTIFICATE

This is to certify that the thesis entitled “**VARIABILITY STUDIES FOR YIELD AND BLAST RESISTANCE IN SEGREGATING POPULATION OF FINGER MILLET (*Eleusine coracana* (L.) Gaertn)**” submitted by **Mr. SUNILGOUDA SHANKARAGOUDA PATIL, I.D. No. PALB 2233** for the award of degree of **MASTER OF SCIENCE (Agriculture)** in **GENETICS AND PLANT BREEDING** to the University of Agricultural Sciences, GKVK, Bangalore is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any other degree, diploma, associateship, fellowship or any other similar titles.

**Bangalore
August, 2014**

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ACKNOWLEDGEMENT

*I avail this opportunity to express my heartfelt gratitude to **Dr. C. R. Ravishankar** Professor and Scheme Head (small millets) ZARS, V.C. Farm, Mandya and chairman of my Advisory Committee for his inspiring guidance, encouragement, keen interest and personal concern which helped me in a great deal for the successful completion of my Research.*

*I am extremely grateful to members of my Advisory Committee, **Dr. Jayarame Gowda**, Principle scientist, AICRP on chick Pea, UAS, GKVK, Bangalore. **Dr. P. Ravishankar**, Geneticist, Project coordinating unit, (Small Millet), ZARS, UAS, GKVK, Bangalore. and **Dr. A. Nagaraja**, Pathologist, Project coordinating unit (Small Millet), ZARS, UAS, GKVK, Bangalore for their valuable suggestions, encouragement and critical comments during the course of this study.*

*I wish to express my thanks to The Staffs of genetics and plant breeding Department **Dr. R. S. Kulkarni**, **Dr. Shailaja Hittalmani**, **Dr. D. L. Savithramma**, **Dr. E. Gangappa**, **Dr. Mohan Rao**, **Dr. Ramesh**, **Dr. J. Shanthala** and **Dr. R. Nandini** for their constant support during my voyage.*

*I would like to thank, **Dr. Ryindra**, Pathologist, ZARS, V. C. Farm, Mandya. for his invaluable help and guidelines during blast disease analysis and interpretation*

*I am highly indebted to **Dr. B. Nandini** and **Manjappa** for their constructive suggestions, encouragement and help throughout my master's degree programme.*

*I thank all my friends and classmates **Vivekananda**, **Chandrakant**, **Sanjeev**, **Umesh**, **Sunil, L.**, **Pattan**, **Ambi**, **Naganagouda**, **Jagadish**, **Sunil, M.**, **Lokesh**, **Murali**, **Madusudan**, **Gauthami**, **Ashwini**, **Shabi**, **Bharani**, **Hyndavi**, **Roopa**, **Spandana** and **Varsha** for their friendship, love, help and care and for making the two year study in Bangalore, enjoyable and memorable.*

*I also like to convey my sincere thanks to the senior field assistant **Mr. Harikrishna, ZARS**, V.C. Farm, Mandya and all the workers especially **Santhosh** and **Naveen** for their care and help during my research period.*

*Lastly, I would like to thank each and every **faculty members** of Project Coordination Cell, AICSMIP, ZARS, V.C. Farm, Mandya for their constant help during the course of my study.*

I wish to thank all those hearts who helped me in one or the other way during my course of my study and research.

.....Any omission in this brief acknowledgement does not mean lack of gratitude.

Bangalore

August, 2014

(Sunilgouda Shankaragouda Patil)

Variability studies for yield and blast resistance in segregating population of finger millet (*Eleusine coracana* (L.) Gaertn)

Sunilgouda Shankaragouda Patil

Abstract

Four F₂ population of finger millet crosses viz., PR 202 X GE 1409 (cross I), PR 202 X IE 2712 (cross II), GPU 28 X IE 2712 (cross III) and Indaf 5 X GE 1462 (cross IV) involving six parents were studied in order to understand the variability for yield and yield attributes and blast disease reaction caused by *Magnaporthe grisea* during *kharif* 2013 at ZARS, V. C. Form, Mandya and to identify the best segregants in terms of yield and blast resistance. High PCV and GCV values were observed for characters like productive tillers, weight of main ear and grain yield per plant. Plant height, fingers on main ear, weight of main ear registered high broad sense heritability. Phenotypic correlation studies revealed strong positive association of weight of main ear with the component traits. Path analysis revealed potent role of weight of main ear followed by 1000 seed weight to make up the grain yield and contribute maximum than any other character. Blast scoring showed that, cross IV, I and cross II recorded much of the segregants showing highly resistant and resistant reaction. In all the crosses superior segregants in terms of both yielding ability and blast resistance were identified for advanced generation study and to select for their credibility in terms of yield and blast resistance.

August, 2014

(C. R. Ravishankar)

Major Advisor

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ರಾಗಿಯ ವರ್ಗೀಕರಣಗೊಂಡ ಸಮುದಾಯದಲ್ಲಿ ಇಳುವರಿ ಮತ್ತು ಬೆಂಕಿ ರೋಗ

ನಿರೋಧಕತೆಯ ವೈವಿಧ್ಯತೆಯ ಅಧ್ಯಯನ

ಪ್ರಬಂಧದ ಸಾರಾಂಶ

ಪ್ರಸ್ತುತ ಅಧ್ಯಯನದಲ್ಲಿ ಎಫ್‌೨ ಸಂತತಿಯ ರಾಗಿ ಸಂಕರಗಳಾದ ಪಿ. ಆರ್-೨೦೨ X ಜಿ. ಇ. ೧೪೦೯ (ಸಂಕರ-೧), ಪಿ. ಆರ್-೨೦೨ X ಐ. ಇ. ೨೭೧೨ (ಸಂಕರ-೨), ಜಿ. ಪಿ. ಯು.-೨೮ X ಐ. ಇ. ೨೭೧೨ (ಸಂಕರ-೩) ಮತ್ತು ಇಂಡಾಫ್-೫ X ಜಿ. ಇ. ೧೪೬೨ (ಸಂಕರ-೪) ಜೊತೆಗೆ ಆರು ಮೂಲತಳಿಗಳ ಇಳುವರಿ ಮತ್ತು ಇಳುವರಿಗೆ ಪೂರಕವಾದ ಗುಣಗಳ ವೈವಿಧ್ಯತೆಯನ್ನು ಅಧ್ಯಯನ ಮಾಡಲಾಯಿತು. ಇದರ ಜೊತೆಗೆ ಬೆಂಕಿರೋಗ ನಿರೋಧಕ ತಳಿಗಳಿಗಾಗಿ ೨೦೧೩ರ ಮುಂಗಾರಿನಲ್ಲಿ ವಲಯ ಕೃಷಿ ಸಂಶೋಧನಾ ಕೇಂದ್ರ ವಿ. ಸಿ. ಫಾರಂ, ಮಂಡ್ಯದಲ್ಲಿ ಸಂಶೋಧನೆ ನಡೆಸಲಾಯಿತು.

ಈ ಸಂಶೋಧನೆಯ ಫಲಿತಾಂಶ ಸೂಚಿಸಿದ್ದೇನೆಂದರೆ, ಪ್ರತಿ ಗಿಡಕ್ಕೆ ಫಲವತ್ತಾದ ತೆಂಡೆಗಳ ಸಂಖ್ಯೆ ಮತ್ತು ಮುಖ್ಯ ತೆನೆಯ ತೂಕದ ಪಿ. ಸಿ. ವಿ. ಮತ್ತು ಜಿ. ಸಿ. ವಿ. ಹೆಚ್ಚಾಗಿತ್ತು. ಗಿಡದ ಎತ್ತರ, ಮುಖ್ಯ ತೆನೆಯ ಇಳುವರಿ ಸಂಖ್ಯೆ ಮತ್ತು ಮುಖ್ಯ ತೆನೆಯ ತೂಕ ವಿಶಾಲ ಅನುವಂಶೀಯತೆಯನ್ನು ಹೊಂದಿತ್ತು. ಪ್ರಕಟಣಾ ಪರಸ್ಪರ ಸಂಬಂಧದಿಂದ ತಿಳಿದುಬಂದುದೇನೆಂದರೆ ಮುಖ್ಯ ತೆನೆಯ ತೂಕ ಉಳಿದೆಲ್ಲಾ ಗುಣಗಳೊಂದಿಗೆ ಸಕಾರಾತ್ಮಕ ಪರಿಣಾಮ ಬೀರಿತ್ತು. ಪಾಲ್ ಅನಾಲಿಸಿಸಿನಿಂದ ತಿಳಿದುಬಂದುದೇನೆಂದರೆ ಮುಖ್ಯ ತೆನೆಯ ತೂಕ ಮತ್ತು ೧೦೦೦ ಕಾಳುಗಳ ತೂಕ ಇಳುವರಿಗೆ ದನಾತ್ಮಕ ನೇರ ಪರಿಣಾಮವನ್ನು ಬೀರಿತ್ತು. ಬೆಂಕಿರೋಗದ ಅಧ್ಯಯನದಿಂದ ತಿಳಿದುಬಂದಿದ್ದೇನೆಂದರೆ, ಸಂಕರ-೪, ಸಂಕರ-೧ ಮತ್ತು ಸಂಕರ-೨ ಅತೀ ಹೆಚ್ಚಿನ ಸಂಖ್ಯೆಯಲ್ಲಿ ರೋಗ ನಿರೋಧಕ ತಳಿಗಳನ್ನು ಹೊಂದಿದ್ದವು. ಅಧ್ಯಯನ ನಡೆಸಿದ ನಾಲ್ಕು ಸಂಕರಗಳಿಂದ ಹೆಚ್ಚಿನ ಇಳುವರಿ ಹೊಂದಿದ ಮತ್ತು ಬೆಂಕಿರೋಗ ನಿರೋಧಕ ಗಿಡಗಳನ್ನು ಗುರುತಿಸಿ ಮುಂದಿನ ಸಂತತಿ ಅಧ್ಯಯನಕ್ಕೆ ಉಪಯೋಗಿಸಲಾಯಿತು.

ಆಗಸ್ಟ್, ೨೦೧೪

ಅನುವಂಶೀಯತೆ ಮತ್ತು ಸಸ್ಯತಳಿ ಅಭಿವೃದ್ಧಿ ವಿಭಾಗ,

ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾನಿಲಯ

ಜಿಕೆವಿಕೆ, ಬೆಂಗಳೂರು - ೫೬೦ ೦೬೫

(ಡಾ|| ಸಿ. ಆರ್. ರವಿಶಂಕರ್)

ಮುಖ್ಯ ಸಲಹೆಗಾರರು

“CORRELATION STUDIES IN F₂ POPULATION OF FINGER MILLET (*Eleusine coracana* (L.) GAERTN.)”

SUNILGOUDA, S. P.

DEPARTMENT OF GENETICS AND PLANT BREEDING, GKVK, UAS BENGALURU – 560 065



Introduction

- Finger millet (*Eleusine coracana* (L.) Gaertn.) is an important food crop in Africa and South Asia.
- It is a hardy crop that can be grown in diverse environments.
- It has dual importance as a source of food grain and straw.
- Finger millet is a C₄ plant belongs to the family Poaceae.
- Grain yield being a quantitative character, is resultant of various contributing characters
- Therefore it is desirable to study the association of different characters among themselves and with the grain yield of crop.

Objective

- Association analysis of yield and its attributing characters.

Materials and methods

- The present investigation was carried out during *kharif* 2013 at Zonal Agricultural Research Station (ZARS), V.C.Farm, Mandya.
- Experimental material is comprised of F₂ population of two crosses of finger millet viz., GPU 28 X IE 2712 and Indaf-5 X GE 1462.
- F₂ Seeds of two finger millet crosses were sown in nursery bed and 21 days old healthy seedlings were transplanted to the main field.
- Yield and yield attributing characters were recorded from randomly selected F₂ plants from both the crosses.
- Phenotypic correlation coefficient analysis was carried out by using SPSS 16.0



Fig.1 Field view of I-5 X GE 1462 F₂ cross

RESULTS

(GPU-28 X IE 2712) F₂ population

- In this cross grain yield per plant exhibited significant positive association with test weight (0.480), weight of main ear (0.433), days to 50% flowering (0.407), number of productive tillers (0.271) and finger width of main ear (0.115).
- Days to fifty per cent flowering is significantly positively correlated with the test weight (0.304), weight of main ear (0.275) and productive tillers (0.172)
- Productive tillers per plant is significantly positively associated with test weight (0.198).
- Weight of main ear is positively associated with the test weight (0.216).

(Indaf-5 X GE 1462) F₂ population

- Grain yield is significantly positively associated with weight of main ear (0.769), number of fingers (0.699), number of productive tillers (0.498) and test weight (0.316).
- Days to fifty per cent flowering is significantly positively associated with productive tillers (0.530) but negatively associated with number of fingers (-0.306) and ear head weight (-0.288).
- Plant height is positively related with the number of productive tillers (0.169), which is in turn positively associated with the number of fingers (0.509), weight of main ear (0.496) and 1000 seed weight (0.313), all these three traits are in turn positively associated with the test weight.

Discussion

- Days to 50% flowering registered strong significant positive association with grain yield and other yield attributing characters in cross I, as a result these trait can be taken into account during selection for improving total grain yield.
- Because of significant positive association of productive tillers and finger number with the grain yield and their favorable intrinsic interaction with other yield attributing characters, these traits are also use full in improvement of yield.
- Finger length and width are exhibited negative association with most of the yield attributing characters in general. Thus these traits cannot be considered as a used full trait in improvement of grain yield
- Weight of main ear and test weight are exhibiting strong significant positive association with trait of interest. Hence these traits are preferred for improvement of grain yield.



Fig. 2 Field view of GPU-28 X IE 2712 F₂ cross

Table 1. Estimation of phenotypic correlation coefficient in two F₂ crosses of finger millet

	F ₂ Cross	PHT	PTN	FN	FL	FW	EW	TW	YLD
DF	Cross I	0.046	0.172**	-0.049	0.048	0.104	0.275**	0.304**	0.407**
	Cross II	0.142*	0.012	0.044	0.010	-0.027	0.034	-0.013	-0.126*
PHT	Cross I		0.090	-0.072	-0.097	0.110	0.014	0.020	0.037
	Cross II		0.169**	-0.024	-0.009	0.061	0.105*	-0.025	0.107*
PTN	Cross I			-0.047	-0.056	0.102	0.107*	0.198**	0.271**
	Cross II			0.509**	-0.033	-0.028	0.496**	0.313**	0.498**
FN	Cross I				-0.010	-0.085	-0.019	0.087	0.026
	Cross II				-0.059	0.016	0.768**	0.461**	0.199*
FL	Cross I					-0.300**	0.022	0.039	-0.044
	Cross II					0.002	-0.024	-0.050	-0.017
FW	Cross I						0.065	0.076	0.115*
	Cross II						-0.003	-0.061	0.017
EW	Cross I							0.216**	0.433**
	Cross II							0.444**	0.769**
TW	Cross I								0.480**
	Cross II								0.316**

Abbreviations:

- DF - Days to 50% flowering
- PHT - Plant height
- PTN - Number of productive tillers
- FN - Finger number per main ear
- FL - Finger length of main ear
- FW - Finger width of main ear
- EW - Weight of main ear
- TW - 1000 Seed weight / test weight
- YLD - Grain yield per plant

Cross 1- GPU-28 X IE-2712

Cross 2- Indaf-5 X GE-1462



Fig.3 Field view of I-5

Summary

- Correlation studies in general exhibited strong significant positive association of grain yield with weight of main ear, 1000 seed weight and total tillers per plant. Finger number and plant height exhibited moderate positive association with grain yield. However, its association with finger length and finger width of main ear was of very low magnitude.

ADVISORY COMMITTEE

- Dr. C. R. Ravishankar. } Chairperson
- Dr. Jayaramgowda. }
- Dr. P. Ravishankar. } Members
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I INTRODUCTION

Finger millet (*Eleusine coracana* (L.) Gaertn.) is an important food crop in Africa and South Asia. It is a hardy crop that can be grown in diverse environments from almost at sea level in South India to high lands of Himalayas. It has dual importance as a source of food grain as well as straw. In India it is popularly known as ragi and is grown in an area of 1.6 million ha with annual production of 2.1 million tones and with productivity of 1.3 tones ha⁻¹ (www.indiastat.com 2013). While over 50 per cent of the crop area in India is in Karnataka (0.9 million ha) with of productivity (1.9 tones ha⁻¹) which is higher than Indian average (www.indiastat.com 2013). Finger millet provides staple food for a large section of farming community in many parts of India. The major finger millet growing states are Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Odisha, Jharkhand, Chhattisgarh and Uttarakhand.

Finger millet (*Eleusine coracana* (L.) Gaertn) subspecies *coracana* belongs to family Poaceae/ Graminae. The cultivated *E. coracana* is a tetraploid (2n = 36); has morphological similarities to both *Eleusine indica* (L.) Gaertn (2n = 18) and *Eleusine africana* (O.) Byrne (2n = 36). The native of finger millet is presumed to be high altitudes of central Africa, and the crop moved to Indian subcontinent in around 3000 BC. The long history of cultivation in Indian subcontinent under diverse agro ecological conditions with natural and human selection has resulted in large diversity in the crop. India is often considered as secondary center of diversity for finger millet.

Finger millet is nutritious with good quality protein, rich in minerals, dietary fibers, phytochemicals and vitamins. It is the richest source of calcium providing 8 – 10 times more than that of rice or wheat. Finger millet carbohydrate has unique property of slower digestibility and regarded as food for long sustenance. It has dual importance as a source of food grain as well as straw. This crop is especially valuable as it contains the amino acid methionine, which is lacking in the diets of hundreds of millions of the poor who live on starchy staples such as polished rice or maize meal. Finger millet flour is used to prepare cakes, puddings or porridge. The grain is made into a fermented drink (or beer) in Nepal, Arunachal Pradesh and in many parts of Africa. The straw from finger millet is used as animal fodder.

Excellent grain storage quality in finger millet (Iyengar *et al.*, 1945) is attributed to polyphenol content, (Chetan and Malleshi, 2007) which makes finger millet an ideal crop for famine reserves. Finger millet stover (dried residue after the harvest of grains) is the major dry matter source for both draft and milch animals in India where mixed crop-livestock system is the predominant type of farming practice.

Even with advantages like good nutritional quality and long storability of grains, finger millet is not exempted from biotic and abiotic stresses. This creates imbalance in food economy of poor and marginal farmers along with instability to overall production. The major factors reducing the grain yield in finger millet are moisture stress and specific diseases.

Along with the marginal cropping situation, in recent years heavy incidence of fungal and other diseases on this crop has led to significant yield losses. Among the fungal diseases, blast caused by *Magnaporthe grisea* ranks first, which affects all the aerial parts at all stages of crop growth, causing heavy yield loss under favorable environment conditions for disease development.

Despite its significant direct and indirect contribution to the dietary system of millions of people, still much is expected in varietal improvement, compared to other parallel crops. In India, especially in Karnataka and Tamil Nadu, rapid strides have been made in finger millet breeding programme in the recent past.

In order to maintain progressive curve, persistent effort is required by plant breeders with appropriate breeding programme concentrating on yield improvement along with resistance to biotic and abiotic stresses.

In any plant breeding programme, availability of large genetic variability in the crop species is the first step to select better performing types among the divergent groups. If vast amount of variability present, attempts can be made to improve the trait of interest by enforcing selection. Variability generally exists in germplasm collection and when this is exploited to a maximum extent by way of selection, additional variability can be created by crossing best available varieties.

The ultimate expression of yield in crop plants is usually dependent upon the action and interaction of a number of important characters. This is due to the fact that in the integrated plant structure, most of the characters are interrelated with one another and often a change in one is likely to influence the other, so that the net gain obtained by selection of one may be counterbalanced or even negated by a simultaneous change in the other.

Correlation, therefore, is helpful in determining the component characters of a complex trait, like yield. With more variables in correlation studies, indirect associations become more complex and important; consequently, a correlation study coupled with a path analysis is more effective tool in the study of yield attributing characters.

However, the correlation between the grain yield and its component characters are often misleading, since it is affected by the inter relationships existing between the component traits. Further evaluation of relative influence of various characters is therefore necessary. Path coefficient analysis developed by Wright (1921) is useful in partitioning the correlation coefficient values into direct and indirect effects, so that the differential contribution of each component characters to the grain yield could be assessed. In addition, path analysis also helps to elucidate the intrinsic nature of observed association and imparts confidence in the selection scheme adopted for a given situation. Integration of information on genetic variability, correlation, path analysis of different component characters of grain yield and their application in selection will be helpful in obtaining better results.

With this background, the present study was undertaken in F₂ segregating population of four crosses of finger millet with the following objectives.

- To assess the genetic variability in F₂ segregating population for yield and yield attributes
- To study correlation and path analysis in F₂ segregating population
- To evaluate F₂ segregating population for blast resistance

II REVIEW OF LITERATURE

Review of earlier reports relating to the present investigation in finger millet is brought under following headings

- 2.1 To assess the genetic variability in F₂ segregating population for yield and yield attributes
- 2.2 To study correlation and path analysis in F₂ segregating population
- 2.3 To evaluate F₂ segregating population for blast resistance

2.1 To assess genetic variability

The process of selection is more important in any crop improvement and this progress depends on the existence of genetic variability for yield and yield contributing characters and their heritability. Heritability in conjunction with genetic advance has a greater role to play in determining the effectiveness of selection of a character. Therefore, the present study was conducted to assess genetic variability, heritability and genetic advance among the four F₂ populations

Johanson (1909) attributed the variation in a segregating population to both heritable and non-heritable factors, while the variation within pure lines was attributed to environmental factors, which was later confirmed by East (1916).

The genetic variance was separated from total variance using the estimates of environmental variance based on non-segregating generation (Power, 1942). The genotypic variation was further partitioned into additive and non-additive variances, whereas non-additive variance includes both dominance and epistasis.

Johnson *et al.* (1955) outlined the method of estimating phenotypic and genotypic variances from ANOVA table. Heritability in broad sense is the ratio between the genotypic variance and phenotypic variance (Lush, 1945). Since the genotypic variance includes non additive variances, which is not transmitted from generation to generation, the estimation of broad sense heritability along with the genetic gain was reported to be more useful instead of depending upon heritability alone (Johnson *et al.*, 1955).

The available literature in respect of genetic variability, heritability and genetic advance in ragi has been reviewed and presented below.

Patnaik (1968) in a study involving 54 lines of ragi, observed maximum phenotypic coefficient of variation (PCV) for grain yield followed by number of productive tillers per plant, seed density and number of fingers per ear head while the genotypic coefficient of variation (GCV) was the highest for yield per plant, followed by plant height, 1000 seed weight, seed density and length of the fingers. However, both GCV and PCV were low for heading date. Heritability estimates revealed the highest values for heading date, seed size, finger length, while, rest of the characters exhibited lower values.

Kempanna and Thirumalachar (1968) in a study of 18 ragi genotypes collected from various ragi growing states, found significant difference among the entries in respect of tiller number and grain yield per plant. A comparative view of GCV, PCV, heritability and genetic advance indicated high heritability and genetic advance for grain yield, while tiller number per plant was highly susceptible to the influence of the environment.

In a study involving 14 varieties of ragi from different states, Narasimha Rao and Pardhasardhi (1968a) observed high GCV and PCV for plant height, while tiller number, number of leaves and grain yield registered very low values. Plant height and peduncle length exhibited the maximum heritability whereas, panicle width and tiller number recorded lower values. Expected genetic advance was maximum for grain yield and panicle weight whereas, panicle length has exhibited lower values for this parameter.

Genetic investigations (Chaudhari and Acharya, 1969) in 48 varieties of Indian ragi collections has revealed higher values of GCV and PCV with respect to plant height, number of productive tillers, length of main ear and grain and straw yield. Heritability and genetic advance exhibited a wide range of variation for different characters. However, genetic advance was the highest for straw yield.

Kempanna and Govindu, (1969a and b) reported considerable amount of variability with respect to plant height, days to maturity, structure and composition of ears and the grain color in a study involving Indian and African collections of ragi.

In a study of variability of different small millet genotypes, Walia *et al.* (1970) reported the highest variability with respect to number of fingers, while it was moderate for days to 50 per cent flowering.

Plant height topped with regard to PCV and GCV, while grain yield and tiller number registered very low values, in a study involving 22 varieties of ragi by Kempanna *et al.* (1971). However, the maximum heritability was observed for plant height followed by days to heading. Grain yield exhibited moderate heritability and high genetic advance whereas, tiller number exhibited the least heritability and genetic advance.

Dhagat *et al.* (1972) observed high GCV, heritability and expected genetic advance for grain weight of main ear followed by length of the main ear, days to maturity and number of productive tillers in a study comprising of 20 varieties of ragi from different parts of India.

In another study in finger millet, Mahudeswaran and Murugesan (1973) observed high GCV for number of productive tillers and grain yield. However, plant height registered high heritability and genetic advance.

Setty *et al.* (1974), in a study of variability pattern of grain yield and its components among 81 genotypes of ragi, observed high GCV for grain yield. On the other hand, finger length, tiller number, plant height have shown lower GCV values.

Heritability has higher for grain yield, plant height, number of leaves and finger length whereas, moderate values were reported for number of fingers and tiller numbers

In a study of morphological and genetic variability for quantitative traits of 33 selected varieties of ragi, Goud and Lakshmi (1977) reported wide range of PCV and GCV for most of the yield components. However, only plant height and number of fingers per ear had high heritability. Tiller number though exhibited moderate heritability, registered maximum predicted genetic gain.

In an inheritance study of the inter varietal crosses of ragi, high PCV and GCV values for number of productive tillers was reported in both F₂ and F₃ generations (Shanthappa, 1979). Moderate to high heritability was observed for number of productive tillers, harvest index, straw yield, grain yield and plant height. Among these characters, plant height, grain yield and straw yield had high genetic gain, while it was moderate for productive tillers.

Agalodia *et al.* (1979) while studying different genotypes of ragi reported less genotypic variance than the environmental variance for plant height and number of tillers. However, genotypic variability was high for ear length, moderate for number of productive tillers and low for plant height and grain yield. Broad sense heritability estimates exhibited higher value for all the characters except plant height. However, the genetic gain was the maximum for number of fingers per ear followed by grain yield and productive tillers and low for plant height.

Maximum variability was observed for plant height followed by days to 50 per cent flowering, straw yield and ear weight per plant in a study involving 40 entries of ragi by Sarvaiya *et al.* (1982). However, the values were moderate for grain yield and low for other characters. Grain yield per plant and ear weight per plant recorded high GCV coupled with high heritability and large magnitude of predicted genetic advance.

The PCV values were observed to be higher for effective tillers followed by grain yield in a study involving 480 indigenous lines of ragi (Mishra *et al.*, 1980b). On the other hand, GCV values were higher for grain yield followed by effective tillers.

In a study involving F₂ population, Shankar (1982) reported high GCV values for number of fingers per ear, grain yield, ear weight and straw yield per plant. Heritability estimates and genetic advance were high for fingers per ear, grain yield, plant height and days to maturity.

In another investigation with 27 genetic stocks of ragi, grain yield exhibited high GCV values. However, GCV values were moderate for number of fingers per ear and ear length, while it was low for plant height (Joshi and Mehra, 1989). Further, the estimates of heritability and genetic advance were high for grain yield, moderate for fingers per ear followed by ear length. However, plant height registered moderate heritability with low genetic advance.

In genetic variability studies involving 34 indigenous varieties of ragi from Sikkim and 12 varieties from AICRP, Goswami and Asthana (1984), reported high GCV for grain yield followed by length of finger, finger number in main ear, plant height, days to 50 per cent flowering and days to maturity. Among the traits, grain yield, finger length, days to 50 per cent flowering and days to maturity recorded high heritability.

Grain yield and productive tillers exhibited high PCV values whereas, GCV was high for finger number, 1000 grain weight and grain yield in a study comprising of F₄ populations of three crosses by (Prabhakar and Prasad, 1984). Grain yield exhibited high heritability with high genetic advance whereas, heritability was the highest for 1000 seed weight followed by plant height.

Mehta *et al.* (1985) in an evaluation study of 30 populations of ragi from various agro-climatic regions, reported moderate values of variability for plant height, days to 50 per cent flowering, days to maturity and grain yield. Whereas, high GCV value was recorded for number of tillers per plant, while heritability estimates were high for all the characters studied.

Harinarayan *et al.* (1989) examined diversity in 770 accessions of Maharashtra, 560 of Sikkim and 183 of Malawi. The Malawi collections were tall, late maturing, high tillering with long fingers, while sikkim genotypes had more finger number and finger width. The Maharashtra entries showed maximum variability for grain yield per plant, finger number per ear, finger width, basal tillers and days to maturity indicating the potentiality of Maharashtra material.

Tyagi and Koranne (1989) evaluated 29 genotypes of ragi and reported considerable variability for fingers per ear, productive tillers and grain yield. High heritability and genetic advance were observed for grain yield, fingers per ear, plant height and productive tillers.

Grain yield exhibited high GCV value coupled with high heritability and genetic advance in a study involving 23 genotypes of ragi (Verma, 1989). On the other hand, productive tillers, plant height, ear length and days to 50 per cent flowering exhibited moderate broad sense heritability and low genetic advance.

High heritability coupled with high genetic advance were recorded for days to 50 per cent flowering followed by days to maturity, plant height, ear weight, harvest index and biomass yield (Naik, 1991) in 120 Indian and 105 African accessions of ragi. However, tillers per plant and fingers per ear exhibited moderate heritability with low genetic gain.

Days to heading exhibited the maximum heritability whereas, productive tillers recorded the least value in a study involving various ragi genotypes by Devkota and Mohapatra (1991). However, the predicted genetic gain was low for productive tillers, but moderate for grain yield.

Venkatesh Bhat (1991), in an evaluation of early segregating generations of two inter varietal crosses of ragi for variability, reported higher values of GCV and PCV for productive tillers, ear weight and grain yield, moderate values for fingers per ear and ear length and lower values for plant height. However, ear weight, fingers per ear and ear length exhibited higher broad sense heritability values whereas, plant height and harvest index exhibited moderate values.

Wide range of variability was observed with respect to days to 50 per cent flowering, days to maturity, plant height, productive tillers, ear length, fingers per ear and grain yield in a study of ragi germplasm involving 978 African and Indian collections (Purushotham Rao, 1992).

Cauvery (1993), in a study involving 192 finger millet germplasm, observed high GCV coupled with moderate heritability and high genetic advance for grain yield and productive tillers. The GCV was moderate for harvest index and low for days to 50 per cent flowering, days to maturity and plant height. However, days to 50 per cent flowering and days to maturity were characterized by high heritability and moderate to low genetic advance.

Moderate to higher values of PCV, GCV, heritability and genetic advance were reported by Ramaswamy *et al.* (1994) for plant height, productive tillers and days to 50 per cent flowering in a study involving diverse genotypes of finger millet.

Ravikumar and Seetharam (1994) in a study involving F₂ populations of four crosses of ragi, observed moderate to high GCV for productive tillers, fingers per ear and very high values of grain yield. The estimates of PCV were low for plant height and days to 50 per cent flowering. However, these traits along with grain yield registered high heritability coupled with high genetic gain.

Genetic investigations with 46 finger millet land races of Bihar revealed high heritability coupled with high genetic advance for plant height, ear length and days to 50 per cent flowering. However, productive tillers and fingers per ear had lower value for these two parameters (Haider *et al.*, 1995).

In another genetic investigation involving African germplasms of finger millet, Malali Gowda (1996) reported low magnitude of GCV than PCV values for all the characters studied. However, high heritability coupled with moderate genetic advance was recorded for number of fingers per ear and total tillers per plant. Whereas, grain yield, productive tillers and ear length exhibited moderate heritability and genetic advance.

Byre Gowda (1997) working with two ragi crosses involving white and brown genotypes observed narrow differences between PCV and GCV for grain yield, while productive tillers and fingers per ear exhibited wide differences indicating high magnitude of environmental effect on these traits. However, grain yield exhibited high heritability and high genetic gain whereas, productive tillers registered moderate

heritability and high genetic gain while, fingers per ear manifested moderate heritability with low genetic advance.

Debelo (1998), working with F₂ and F₃ generation of finger millet observed higher PCV and GCV for grain yield and productive tillers and high broad sense heritability for days to 50 per cent flowering, days to maturity and plant height and also observed higher genetic advance for plant height.

Mohan Prem Anand (2003) in a study comprising of F₂ population of ragi observed high GCV, heritability and expected genetic advance for grain weight of main ear followed by length of the main ear and number of productive tillers.

Balwant Kumar *et al.* (2006) evaluated thirty genotypes of ragi for quantitative characters. The analysis of variances showed significant differences among the genotypes for most of the characters. The medium-maturing genotypes, HR-374, PR-202, KM-246 and ZAH-1, were superior for grain yield. Wide differences between genotypic and phenotypic coefficients of variation were recorded for length of main axis and number of basal tillers per plant, followed by straw yield per plot. The traits days to 50% flowering, days to maturity and grain yield per plant showed high heritability along with moderate to low genetic advance.

Bedis *et al.* (2006a) observed high PCV and GCV for plant height, productive tillers per plant and days to fifty per cent flowering with high values of heritability and genetic advance as a per cent of mean.

Bezaweletaw *et al.* (2006) noticed significant variation in phenotypic and genotypic coefficients of variations and high heritability, coupled with high genetic advance for finger width and length for all the 66 finger millet accessions evaluated.

Sonnad *et al.* (2007) reported high estimate of PCV for straw yield per plant (22.48%), moderate estimates of PCV for traits like number of productive tillers per plant (14.36%), ear head length (10.06%), finger length (12.72%), test weight (15.57%), ear weight per plant (15.14%) and grain yield per plant (16.32%). Also recorded high GCV for straw yield per plant (20.80%), moderate GCV for number of productive tillers per plant (13.65%), finger length (12.59%), test weight (14.46%), ear weight per plant (13.73%) and grain yield per plant (14.49%). Whereas, low estimates of GCV were recorded for characters like days to maturity (6.32%), days to 50 per cent flowering (7.96%), plant height (8.40%), number of tillers per plant (8.67%) and finger number per ear (7.12%).

Sumathi *et al.* (2007) reported low GCV and PCV for plant height and days to fifty per cent of flowering whereas moderate values for productive tillers, grain yield per plant and finger length coupled with high heritability and genetic advance expressed as per cent of mean.

Anonymous (2008) In a study involving nineteen white seeded finger millet genotypes and three checks observed moderate GCV for number of productive tillers per plant, finger length, test weight, ear weight per plant and grain yield per plant. Whereas, low estimates of GCV were exhibited by characters like days to maturity, days to 50 per cent flowering, plant height, number of tillers per plant, ear head length and finger number per ear. Heritability values for all the characters were found to be high and high genetic advance as per cent of mean was noticed for number of productive tillers per plant, grain yield per plant, test weight, ear weight per plant and finger length. The traits ear head length, number of tiller per plant, plant height, days to 50 per cent flowering, days to maturity and finger number per ear were recorded moderate genetic advance.

Krishnappa *et al.* (2009) estimated components of genotypic variability through analysis of half-sib and full-sib progeny family variances of working germplasams. The results revealed involvement of both additive and dominance genetic variation with a preponderance of the latter in the expression of time to 50 per cent flowering and plant height while only dominance genetic variation was operative in the expression of number of tillers per plant, number of fingers per ear and grain weight per plant.

Nandini *et al.* (2010b) had conducted a study in F₂ population of four crosses of finger millet to quantify the variability created along with heritability and genetic advances for yield and important yield attributing characters. In general, moderate to high broad sense heritability was observed for days to fifty per cent flowering, finger length, 1000 seed weight, whereas high broad sense heritability was observed for plant height, total tillers per plant and number of productive tillers per plant. A very high genetic advance was observed for total tillers per plant, productive tillers per plant, finger number per main ear, finger length and weight of main ear. Moderate to low genetic advance was observed for plant height, days to fifty per cent flowering and 1000 seed weight.

In F₂ population derived from interspecific cross between *Eleusine coracana* and *Eleusine africana*, Ratnakar *et al.* (2010) observed high PCV and GCV values for grain yield per plant and finger width whereas low for plant height and days to 50 per cent flowering and low to moderate for all the other characters. And observed high broad sense heritability accompanied with high genetic advance for plant height, finger length, test weight and grain yield per plant.

Priyadharshini *et al.* (2011) noticed greater phenotypic coefficients of variability than genotypic coefficients of variability for all the traits studied and high heritability along with high genetic advance had been reported for plant height, number of productive tillers per plant, and number of fingers per ear head in all the twenty one hybrids along with seven parents of finger millet evaluated

Ganapathy *et al.* (2011) reported higher PCV and GCV for productive tillers per plant and moderate for the traits such as days to 50 per cent flowering, plant height, finger number per ear, finger length and grain yield per plant. And also reported, high heritability coupled with high genetic advance observed in days to 50 per cent flowering,

plant height, productive tillers per plant, finger numbers per ear, finger length and seed yield per plant.

Analysis of variability in one hundred and forty four finger millet landraces by Dagnachew Lule *et al.* (2012), indicated that phenotypic coefficient of variation was higher than the corresponding genotypic and genotype by environment coefficient of variations for all traits. Also reported higher heritability coupled with higher genetic advance for ear weight, finger length, thousand grain weights and grain yield per plant.

2.2 Correlation and path analysis in F₂ population

2.2.1 Correlation studies in F₂ population

The ultimate expression of yield in crop plants is usually dependent upon the action and interaction of a number of important characters. This is due to the fact that in the integrated plant structure, most of the characters are interrelated with one another and often a change in one is likely to influence the other, so that the net gain obtained by selection of one may be counterbalanced or even negated by a simultaneous change in the other. Correlation, therefore, is helpful in determining the component characters of a complex trait, like yield.

In a study involving 15 distinct varieties of ragi in Karnataka, Mahadevappa and Ponnaiya (1965) reported significant association of number of productive tillers, number of fingers per ear and straw weight per plant with grain yield per plant.

Significant positive correlation of grain yield with number of leaves on main tiller, finger number and negative association with panicle length was reported by Narasimha Rao and Pardhasardhi (1968b) at both genotypic and phenotypic levels in a study involving 14 ragi varieties differing widely for many characters. However, finger number was negatively correlated with plant height and number of leaves on main tiller.

Patnaik (1968) observed positive correlation of heading date and plant height with grain yield in a study involving 54 lines of ragi. The association of number of fingers and length of fingers with grain yield was moderately positive, while for tiller number it was low. However, the association of tiller number with other yield attributes like number of fingers and seed size was negative.

Higher values of genotypic correlations than phenotypic correlations were observed between all characters studied by Chaudhari and Acharya (1969). Positive association was found between plant height and the productive tillers, ear length and the straw yield. However, seed yield was positively correlated with plant height, productive tillers and straw yield, while its relationship was negative with days to heading.

Dhagat *et al.* (1972) observed significant negative correlation of plant height with grain yield of the main ear in a study involving 20 promising divergent lines of ragi belonging to different maturity groups and ear types.

Grain weight registered high positive genotypic correlation with straw yield and number of tillers whereas, it exhibited antagonistic interaction with number of fingers per panicle and length of fingers in a study involving 20 varieties of ragi by Appaduari *et al.* (1977). Strong negative correlation was also observed between finger length and straw yield.

In another study by Goud and Lakshmi (1977), grain yield of ragi exhibited positive correlation with plant height, fingers per ear and ear weight.

Ranganathan *et al.* (1977) reported strong positive association of productive tillers with grain yield in a study involving diverse genotypes of ragi whereas, the association between plant height and grain yield was not significant.

Correlation studies in 16 varieties of ragi by Chaugale *et al.* (1982) revealed positive association of grain yield with harvest index and biological yield. However, no significant correlation was observed between biological yield and harvest index. Further, harvest index did not exhibit any significant associations with days to maturity, ear length and fingers per ear.

Sarvaiya *et al.* (1983) reported strong correlation of grain yield with plant height and number of productive tillers.

In another study involving F₃ generation of three crosses of ragi, Prabhakar and Prasad (1983) observed strong significant positive correlation of productive tillers with grain yield in all the three crosses. Further, the inter correlations between productive tillers and 1000 grain weight was consistent and positive in all the three crosses studied.

Positive association of grain yield with productive tillers, fingers per ear, harvest index and total dry matter was revealed in a study involving 40 elite cultivars of ragi by Dinesh Kumar (1986).

Sundaram *et al.* (1986) in a study involving 14 genotypes of ragi representing various agro climatic regions, revealed high positive association of grain yield with total dry matter production and 1000 seed weight.

In another study comprising of F₂ and F₃ populations of two crosses of ragi, Shanthakumar (1988) observed high, significant and positive association of grain yield with productive tillers, fingers per ear, ear length and ear weight.

Grain yield exhibited positive correlation with plant height, productive tillers, fingers per ear and ear length in a study involving finger millet collections from Maharashtra, Sikkim and Madras (Harinarayana *et al.*, 1989).

Basavaraja (1990) reported highly significant and positive association of grain yield with ear weight, productive tillers and harvest index in F₂ generations of two crosses. However, harvest index exhibited negative correlation with grain yield in F₃

generation. Inter correlations among the characters like ear weight, productive tillers and harvest index were consistently high in all the three crosses.

Positive and highly significant association of grain yield with ear weight and productive tillers and significant positive association with ear length, plant height and fingers per ear were reported by Venkatesh Bhat (1991) in F₂ and F₃ generations of ragi crosses.

Agronomic traits such as days to fifty per cent flowering, days to maturity, number of productive tillers, plant height and ear length were associated positively with grain yield in a study involving 978 accessions of ragi by Purushotham Rao (1992).

Cauvery (1993) reported high, significant and positive correlation of grain yield with productive tillers and harvest index at both genotypic and phenotypic levels.

Plant height registered high positive association with ear length and number of leaves in a study involving 46 ragi collections from Bihar (Haider *et al.*, 1993).

Ravikumar and Seetharam (1993) reported significant positive association of grain yield with plant height, productive tillers and fingers per ear in segregating populations of ragi.

Significant and positive association of grain yield with number of productive tillers, plant height, days to fifty per cent flowering, fingers per ear and ear length in F₂ and F₃ populations of three inter varietal crosses was reported by Kishan Reddy (1994).

Girish Kumar (1995) observed high significant positive association of harvest index with grain yield in a study involving 14 genotypes of ragi. However, plant height and productive tillers exhibited positive but weak association with grain yield.

Negative association of grain yield with ear length was reported by Haider *et al.* (1995). However, association of grain yield with biological yield, harvest index and fingers per ear was positive and significant.

Lal chuni *et al.* (1996) Reported that for all the 40 genotypes grain yield per plant was positively associated with the characters such as finger length, fingers per ear and tillers per plant. Whereas days to 50 per cent flowering exhibited negative association.

In another study involving 14 genotypes of ragi under rainfed conditions, Mahto *et al.* (1996) observed high and positive significant association of seed yield per plant with plant height and number of tillers.

Malali Gowda (1996) observed high, significant and positive association of grain yield with plant height, number of productive tillers and fingers per ear and days to fifty per cent flowering.

In a comprehensive and exhaustive study involving 4000 finger millet germplasm, Ramakrishna *et al.* (1996) reported positive association of grain yield with plant height, productive tillers, fingers per ear and ear length.

Grain yield exhibited strong positive association with productive tillers and fingers on main ear in a study involving 18 promising cultivars of ragi (Ravindran *et al.*, 1996).

Byre Gowda (1997) reported low positive association of grain yield with plant height, ear length, productive tillers and fingers per ear.

In another study comprising of F₂ generations of four crosses of ragi, Marimuthu (1997) noticed positive association of grain yield with ear weight followed by number of productive tillers, fingers per ear, ear length, plant height and days to fifty per cent flowering.

Sharathbabu (2005) in a study comprising 19 genotypes of finger millet observed that at both genotypic and phenotypic levels, grain yield per plant exhibited highly significant positive association with finger number per ear and ear weight per plant. While, other traits did not exhibit significant association with grain yield per plant.

The results from a study with 50 finger millet genotypes by Ananthraju and Meenakshiganesan (2005) indicated a positive and significant genotypic correlation of grain yield with number of productive tillers and culm thickness.

Correlation study in thirty seven diverse genotypes of finger millet was carried out by Bedis *et al.* (2006b). The positive correlation of plant height, main ear length and number of fingers per ear with grain yield and among themselves for these characters was observed, suggesting that these are the major yield contributing traits in finger millet.

Bezawelelaw *et al.* (2006) reported that grain yield per plant associated positively with productive tillers and 1,000-grain weight, while strongest negative association was reported between 1,000-grain weight and finger number

Correlation analysis in 20 genotypes of finger millet by John (2006) revealed that total dry matter production showed positive and highly significant association with test weight. Grain yield showed positive and highly significant correlation with test weight, total dry matter production and harvest index.

Days to maturity, number of productive tillers per plant, number of fingers per ear, main ear length and harvest index registered significant and positive association with grain yield. A non-significant association was observed for grain yield with days to 50 per cent flowering and dry matter production as reported by John (2007) in finger millet.

In a study involving 451 accessions of finger millet, Jayarame Gowda *et al.* (2007) reported significant positive association of culm thickness, number of productive tillers, days to maturity and days to 50 per cent flowering on grain yield.

The research conducted by Nandini *et al.*, (2010a) in F₂ generation of the seven crosses of finger millet revealed that grain yield had strong positive correlation with weight of main ear, 1000 seed weight and total tillers per plant, and also reported moderate positive correlation between productive tillers and plant height.

Ratnakar *et al.* (2010) noticed highly significant positive association of grain yield per plant with finger width and test weight in F₂ population derived from interspecific cross between *Eleusine coracana* and *E. africana*.

Priyadharshini *et al.* (2011) reported positive correlation of grain yield with number of productive tillers and finger length for all the twenty one hybrids along with seven parents of finger millet evaluated.

Ganapathy *et al.* (2011) noticed that productive tillers per plant and finger length are significantly positively correlated with grain yield.

From correlation studies, Das *et al.* (2013) observed that grain yield per plant had exhibited significant positive association with total number of basal tillers per plant, productive tillers per plant, total fingers on the main ear, finger length and finger width in forty eight genotypes of finger millet.

Suryanarayana *et al.* (2014), in a study involving 35 genotypes of finger millet, reported positive and significant inter relationship of seed yield plant⁻¹ with days to maturity, plant height and days to 50 per cent flowering suggesting that these are the major yield contributing traits.

2.2.2 Path coefficient analysis in F₂ population

Knowledge of interrelationship between yield and its components is essential for efficient selection of desirable segregants in plant breeding. Unlike the correlation coefficient values which measure the extent of relationship, path coefficients measure the magnitude of direct and indirect effects of characters on complex dependent character like yield and thus enable the breeders to judge the best about the important component characters during selection.

A brief review of literature pertaining to path analysis studies in finger millet is presented below.

Tillers per plant exhibited maximum influence on the plant yield followed by length of the fingers (Mahudeswaran, 1968).

Chaudhari and Acharya (1969) observed maximum direct effect of grain yield of the main ear on total grain yield per plant whereas, number of fingers in the main ear had low direct effect.

The potent role of plant height, grain weight of the main ear and days to maturity to make up the yield to the maximum by their direct positive effect, was revealed by Dhagat *et al.* (1973).

In another study, Mahudeswaran and Murugesan (1973) noticed high direct effect of both the tiller number and plant height on grain yield.

Prabhakar and Prasad (1983) noticed the potent role of productive tillers, which exhibited positive direct effect on the grain yield in F₃ generations of all the three crosses studied. But in F₄, plant height and ear length contributed more towards the yield while other characters registered high direct negative effect on grain yield.

Dinesh kumar (1986) reported high positive direct effect of productive tillers and fingers per ear on grain yield.

In another study, Shanthakumar (1988) noticed maximum direct effect of ear weight on grain yield followed by ear length, fingers per ear, plant height and productive tillers.

Basavaraja (1990) in a study involving segregating populations of two ragi crosses observed high positive direct effect of ear weight followed by harvest index on grain yield. However, ear length exhibited direct effect on grain yield in opposite direction.

In a study involving different African and Indian collections, Naik (1991) reported maximum positive direct effect of ear weight and productive tillers on grain yield. Similar results had been reported by Purushotham Rao (1992).

High positive direct effect of ear weight on grain yield was observed by Venkatesh Bhat (1991). However, other characters exhibited very low direct effect on yield whereas, straw weight exerted its influence through high indirect effect.

Ravikumar and Seetharam (1993) reported very high positive direct effect of productive tillers on grain yield.

Productive tillers and plant height exhibited positive direct effect on grain yield whereas, days to 50 per cent flowering had high negative indirect effect through productive tillers (Kishan Reddy, 1994).

Girish Kumar (1995) observed maximum positive direct effect of plant height and very high negative direct effect of productive tillers on grain yield.

Haider *et al.* (1995) reported that plant height, effective tillers per plant and day's to maturity had direct positive effect on harvesting index.

Chunilal *et al.* (1996) reported high positive direct effect of productive tillers, plant height, ear length and fingers per ear on grain yield. Higher positive direct effect of productive tillers and plant height on grain yield was reported by Malali gowda (1996).

Ravindran *et al.* (1996) observed high direct effect of productive tillers per plant and number of fingers on main ear on grain yield, whereas, plant height registered negative indirect effect.

Mahto *et al.* (1996) reported that number of tillers per plant and days to maturity had high positive direct effect on grain yield.

Byre Gowda (1997) observed high effect of productive tillers and fingers per ear on grain yield. High direct effect of ear weight, number of productive tillers and ear length on grain yield was reported by Marimuthu (1997)

Satish (2003) observed high effect of ear weight per plant, straw yield per plant and flag leaf length on grain yield.

Anantharaju and Meenakshiganesan (2005) in a study comprising 50 genotypes of finger millet reported that number of productive tillers had a high positive direct effect whereas culm thickness and number of leaves had moderate direct effects on grain yield. Finger length had high indirect effects on grain yield through the number of leaves and days to fifty per cent flowering.

In a study of F₂ generation of three crosses of finger millet, Mohan Prem Anand *et al.* (2005) revealed high direct positive effect of biomass on grain yield along with ear weight and number of fingers per plant.

Nandini *et al.* (2010a) observed positive direct effect of weight of main ear and 1000 seed weight on grain yield of main ear in F₂ generation of the seven crosses of finger millet (*Eleusine coracana* Gaertn.).

In a study involving eighty-eight finger millet (*Eleusine coracana* (L.) Gaertn) genotypes, Andualem Wolie and Tadesse Dessalegn (2011) reported phenotypic path analysis of finger length, number of fingers per ear, and number of ears per plant exhibited positive direct effects on grain yield, while plant height and days to heading exhibited negative direct effects. And genotypic path analysis revealed that number of tillers per plant, and finger length exerted positive direct effects on grain yield.

Dagnachew Lule *et al.* (2012), while working with one hundred and forty four finger millet landraces reported that, higher and positive direct effect of productive tiller per plant and thousand grain weight and the positive direct effect of finger length, finger number, ear weight and number of grain per spikelet on grain yield

Path analysis in forty eight genotypes of finger millet conducted by Das (2013) revealed that maximum positive direct effect on grain yield per plant was exhibited by productive tillers per plant followed by finger length and finger width. Therefore, it is emphasized to lay attention on traits like productive tillers per plant followed by finger length and finger width.

Suryanarayana *et al.* (2014), in a study involving 35 genotypes of finger millet, reported positive direct effect of days to maturity, plant height, days to 50 per cent flowering followed by main ear length and fingers ear⁻¹ on grain yield per plant.

2.3 Blast disease studies

Even though, finger millet is known to be one of the hardiest crops, it is affected by good number of diseases such as blast, foot rot, smut and streak and mottling viruses. Among these, blast caused by the fungus *Pyricularia grisea* Sacc. is the most devastating disease affecting different aerial parts of the plant at all stages of its growth starting from seedling to grain formation. Yield loss due to blast may be around 28 per cent, but under favorable conditions it may go higher to 80-90 per cent. In spite of a great deal of research on the pathogen and the disease, blast still remains a serious constraint to finger millet production in areas with conducive environments where susceptible cultivars are grown. Since finger millet is predominantly grown as rainfed crop by small farmers, the disease management by chemical means is found to be economically unaffordable. Hence, it would be useful for the disease to be managed with the inherent capacity of the plant. Growing resistant varieties is not only economical for minimizing the losses caused by the disease, but it is also an environment friendly method.

Symptoms

Pathogen infects all stages of crop from seedling to post flowering. Small brown circular to elongated spots appear on leaves, which coalesces and develop into large, elongated or spindle shaped spots with yellowish margins and grayish centers. Later, the center become grey or whitish under humid conditions and an olive grey outgrowth of fungal spores develop at the center of the spots. The infection during the heading stage occurs on the neck region resulting in not only blackening of the area but also weakening of tissues and consequent breaking of the ears. Similar infections occur at the basal part of the panicle branches including the fingers. Ear head affected at the neck region become chaffy and if there is any grain set at all, they are poorly filled or shriveled. When infection occurs at the base of the fingers, they fail to develop further, though the rest of the ears might grow normally (Arasumallaiah, 1989).

The severity of the blast disease depends on the climatic conditions. The fungus is known to prefer low temperature (< 20° C) with high humidity, heavy rainfall and low light for out breaks (Viswanath and Channamma, 1988).

According to Jain *et al.* (1994), moderate temperature of between 20° C with more than 80 per cent mean atmospheric relative humidity during reproduction period of ragi favours the disease development.

Pathogen

The blast causing organisms *Pyricularia spp* (imperfect stage, Sexual stage: *Magnaporthe*) belongs to the class: Deuteromycetes, order: Moniliales and family: Moniliaceae. The blast fungus has marked pathogenic variability, infects different species of family Poaceae. According to Paul (1980) the two most common and morphologically similar species are *Pyricularia oryzae* and *P. grisea*.

Review of literature with respect to source of resistance and breeding for resistance against blast disease of finger millet is presented below.

Govindu and Shivanandappa (1972) in a study of blast reactions to world collections of ragi reported moderate resistance in African entries followed by Madhya Pradesh, Tamil Nadu, Sikkim, Kerala and Mysore entries. However, Bihar, collections registered least resistance, whereas, Gujarat collections exhibited highest susceptibility.

Serious efforts were made during early 1980's to identify the sources of resistance by screening large number of germplasm at Bangalore. Viswanath *et al.* (1986a) screened 941 germplasm accessions and identified 30 entries resistant to finger blast, 28 entries resistant to neck blast and 18 entries to leaf blast.

Viswanath *et al.* (1986b) identified IE 1012, HPBIE 11-1, MR-3, MR-2 and MR-1 ragi cultivars as resistant in descending order for both neck and finger blast.

In evaluation of 316 accessions over four seasons (Ravikumar *et al.*, 1990) reported resistant nature of seven ragi genotypes *viz.*, GE 75, GE 669, GE 866, GE 1309, GE 1407 and GE 1409 to both neck and finger blast across different environments.

At small millet coordinating unit, University of Agricultural Sciences, Bangalore, an elaborate programme was drawn up in a phased manner for evaluating 4000 accessions for ragi blast by growing each year, a representative collections of about 1000 accessions. The disease incidence ranged from 0 to 80.4 per cent and 0 to 99.0 per cent for neck and finger blast respectively. However, 286 entries were free from both neck and finger blasts which exhibited high level of resistance (Ramakrishna *et al.*, 1996).

Somashekara *et al.* (1991), while evaluating 25 finger millet cultivars for their reaction to blast, observed complete immunity of IE 1012 for neck and finger blast, while none of the cultivars were found resistant to leaf blast. Further, they observed poor correlation between leaf blast and neck blast.

Nagaraja and Mantur (2007), evaluated 64-75 finger millet germplasm entries at the Zonal Agricultural Research Station, UAS, Bangalore, Karnataka for their reaction to natural epiphytotics of blast for four consecutive years. From this study, they had noticed 1 and 12 entries showing free from both neck and finger blast (*Magnaporthe grisea*) incidence and some 28, 23, 33 and 16 entries showing resistant for both neck and finger blast. However, they also noticed entries GE 5183, 5203, 5205, 5209, 5212, 5215, 5218, 5227 and 5230 showing consistent resistance reaction.

Bijender Kumar and Kumar, (2009), conducted Study on small millet genotypes that present in mid-western Himalayas to identify resistant cultivars against important endemic diseases. Results revealed that nine finger millet genotypes viz; VL 234, SANJI 1, PRM 9802, VL 328, VL 333, ED 201- 5A, VR 708, SANJI 1 and VL 324 were completely free from neck and finger blast disease.

Out of the 17 long duration entries of finger millet screened along with local check at seven centers, Anonymous (2012), had noticed only one entry PR 10-26 was promising against blast with less than 10 per cent disease incidence.

Kiran Babu *et al.* (2012) evaluated core collection consisting of 622 accessions for neck and finger blast resistance. Among the core collection evaluated they could identify 402 accessions showing resistance reaction to neck blast, 436 for finger blast resistance and 372 accessions showed combined resistance to both the diseases and they have recorded 1–5 scale for neck blast and severity percentage for finger blast. A significant strong positive correlation ($r = 0.85$, $P < 0.0001$) was also found between neck blast and finger blast ratings.

Kiran Babu *et al.* (2013) evaluated mini core collection of 80 finger millet germplasm accessions for blast resistance both in the field and greenhouse and found that sixty six of the 80 accessions showing combined resistance to leaf, neck and finger blast in two seasons (2009 and 2010) of field screening whereas they found fifty-eight of the 80 accessions showing resistant to leaf blast in the greenhouse screen as well.

Losses due to blast

Mc Rae (1922) first reported an epiphytotic form of blast on finger millet, causing grain losses upto 50 per cent. Later Venkatarayan (1947) estimated yield loss of 80 to 90 per cent due to blast under favorable conditions.

Working on the nature of losses due to neck blast on yield components, Rath and Mishra (1975) reported significant loss of 40 to 44 per cent in grain number per panicle, 4 to 10 per cent increase in spikelet sterility and 7 to 25 per cent reduction in spikelets per panicle due to blast disease in finger millet

Rao (1990) reported loss of grain in ragi due to blast disease, which ranged from 3.7 to 5.4 per cent. In another field experiment, one per cent increase in infection in neck and finger blast resulted in corresponding increase of 0.32 and 0.084 per cent loss in yield. However, in farmers field general grain loss was to a tune of 6.75 per cent to 87.5 per cent (Rao and Hegde, 1987).

Madhukeshwar *et al.* (2004) evaluated the different regions of finger millet accessions and observed the less association between leaf blast and neck blast.

Lenne *et al.* (2007) reported that 30 per cent loss in grain yield due to infestation of blast. So appropriate management practices are required.

III MATERIAL AND METHODS

The present investigation was carried out during *kharif* 2013 at Zonal Agricultural Research Station, V. C. Farm, Mandya. This represents southern dry zone (zone-VI) of Karnataka which is located at an altitude of 716 m above MSL and at 12°32' N latitude and 76°53' E longitude. The details of materials equipped in this study, method of recording observations on yield and its attributing characters and the statistical techniques adopted for the analysis of the data are briefly reported in the following paragraphs.

3.1 Experimental material

The experimental material for the present investigation comprised of F₂ population derived from four crosses of finger millet *viz.*, PR 202 X GE 1409, PR 202 X IE 2712, GPU-28 X IE2 712 and Indaf 5 X GE 1462 obtained from Ragi breeder, All India Coordinated Small Millets Improvement Project (AICSMIP), Zonal Agricultural Research Station (ZARS), V. C. Farm, Mandya.

3.1.1 Indaf 5

It is a cultivated variety derived from the cross “Cauvery X IE 929”. Characterized by erect plant habit with 100-110 cm height, compact and incurved ears, ear head is green and fist type, mature at 110-115 days and moderately susceptible for blast. Recommended for both *kharif* and summer season.

3.1.2 IE-2712

It is a germplasm received from (AICSMIP), (ZARS), V. C. Farm, Mandya. Characterized by erect plant habit with 90-100 cm plant height and long finger length, green ear head and is a long duration variety, mature in 120-125 days is resistance to neck and finger blast disease.

3.1.3 GE-1409

It is a germplasm collection from (AICSMIP), (ZARS), V. C. Farm, Mandya, characterized by erect plant habit with 110-120 cm plant height, long finger length, purple ear head and it is long duration variety, mature in 120-122 days and has tolerance to neck and finger blast disease.

3.1.4 GPU-28

It is a variety derived from the cross “Indaf 5 X (Indaf 9 X IE 1012)” characterized by decumbent growth habit with green ear head and it is of medium duration variety. Mature in 110-115 days and in Karnataka, it is recommended for zone 4, 5, 6, and 7.

3.1.5 PR 202

It is a pure line selection from Meltachodi ragi of Araku valley in Vishakapatnam with medium duration, tolerant to drought, but highly blast susceptible and recommended for *kharif*, *rabi* and summer.

3.1.6 GE 1462

It is a germplasm accession with open and long spike, very early maturing and resistant to blast disease.

3.2 Experimental layout

The F₂ population of all four crosses and their parents were evaluated in the experiment conducted during *kharif* 2013 and the details are presented below;

3.2.1 Evaluation of F₂ population of four crosses

The F₂ seeds of all four crosses and their parents were first sown in nursery, after 21 days, around 600 healthy seedlings from each of the crosses were transplanted to the main field under irrigated condition during *kharif* 2013 with single seedling per hill at a spacing of 22.5 cm between rows and 10 cm between plants within the row. Crop was raised as per the recommended package of practice

3.3 Recording of observation

A total of 350 plants from each of the crosses tagged excluding the border plants in each rows. Observations were recorded on grain yield and its attributing character as well as blast disease reaction.

Methods adapted to record observation for each character and blast disease are presented below

3.3.1 Days to 50 per cent of flowering

Days to 50 per cent flowering was taken from sowing date to the stage where ears have emerged from 50 per cent of main tillers.

3.3.2 Plant Height (cm)

The height of the plant was measured from base of main tiller to the tip of the panicle at the time of harvest and expressed in centimeter and mean was computed

3.3.3 Productive tillers per plant

Number of basal tillers bearing the mature ears was counted from each of tagged plant.

3.3.4 Number of fingers per ear

The number of fingers on main ear of each tagged plant was counted and averaged per plant.

3.3.5 Finger length of main ear (cm)

The length of a randomly selected finger (except thumb finger) in main ear head from its base to tip was measured and expressed in centimeter.

3.3.5 Finger width of main ear (cm)

The width of a randomly selected finger (except thumb finger) in main ear head was measured and expressed in centimeter.

3.3.7 Weight of main ear (g)

Weight of main ear head of each tagged plant after harvesting was taken and expressed in grams.

3.3.8 1000 seed weight (g)

With the help of seed counter, weight of 1000 randomly selected seeds was recorded and expressed in grams.

3.3.9 Total grain yield per plant (g)

Weight of total grain yield of all tagged plants was recorded and expressed in grams.

3.3.10 Blast disease scoring

Both the finger and neck blast were scored under natural epiphytotic conditions.

3.3.10.1 Neck blast

The number of tillers infected with blast disease at the neck region and the total number of productive tillers in each plant was counted and the percentage of neck blast was computed by using following formula

$$\text{Neck Blast (\%)} = \frac{\text{No. of tillers with neck blast per plant}}{\text{Total No. of productive tillers per plant}} \times 100$$

3.3.10.2 Finger blast

The number of affected fingers among all the ear heads of productive tillers were counted and expressed in percentage. Both finger and neck blasts per cent were converted to standard scale according to the per cent diseases incidence as given below (Arasumallaiah, 1989).

Disease incidence (%)	Score	Disease reaction
0 to 1	1	Highly resistant
1.1 to 5	2	Resistant
5.1 to 10	3	Moderately resistant
10.1 to 20	4	Moderately susceptible
>20.1	5	Susceptible

3.4 Statistical analysis

The mean and variance of randomly selected plants in each cross and their parents were computed for all the traits mentioned above (except blast scoring) and they were used for the statistical analysis.

3.4.1 Estimation of phenotypic and genotypic variances

The phenotypic and genotypic variances for each of the nine characters were computed as per the method suggested by Weber and Moorthy (1952) for F₂ population.

i) Phenotypic variance (V_{pF₂}) = total observed variance

ii) Genotypic variance (V_{gF₂}) = V_{pF₂} - V_e

$$V_e = \frac{V_{p1} + V_{p2}}{2}$$

Where,

V_e = Environmental variance

V_{p1} = Phenotypic variance of parent 1 of that particular cross.

V_{p2} = Phenotypic variance of parent 2 of that particular cross.

3.4.2 Estimation of genotypic and phenotypic coefficients of variability

The coefficients of variability both at phenotypic and genotypic levels for all the eleven characters were computed by applying the following formula as suggested by Burton and De Vane (1953).

i) Genotypic coefficient of variability (GCV)

$$GCV = \frac{\text{Genotypic Standard deviation}}{\bar{X}} \times 100$$

ii) Phenotypic coefficient of variability (PCV)

$$PCV = \frac{\text{Phenotypic Standard deviation}}{\bar{X}} \times 100$$

Where, \bar{X} = Grand mean of the character

3.4.3 Heritability (Broad sense)

Heritability estimates in broad sense were computed as per the formula suggested by Johnson *et al.* (1955).

$$h^2 \text{ (broad sense)} = \frac{V_{gF_2}}{V_{pF_2}}$$

Where,

h^2 = Heritability (Broad sense)

V_{gF_2} = Genotypic variance of F_2 population

V_{pF_2} = Phenotypic variance of F_2 population

3.4.4 Genetic advance (GA)

The extent of genetic advance expected through selection for each of the characters was computed as per the formula suggested by Johnson *et al.* (1955).

$$GA = h^2 p k$$

Where,

h^2 = Heritability (broad sense)

p = Phenotypic standard deviation

k = Selection differential which is equal to 2.06 at 5 per cent selection intensity respectively (Lush, 1945).

Further GA as percentage of mean was calculated as $(GA/\text{mean}) \times 100$ for each character for all four crosses in F_2 population.

3.4.5 Estimation of correlation coefficient

Phenotypic and genotypic correlation coefficients were worked out for all possible combination of characters using the following formula given by Al-Jibouri *et al.* (1958) for F_2 population.

(i) Phenotypic correlation coefficient

$$r_{xy} = \frac{CoV_{xy}}{(\sqrt{Var_x}) \times (\sqrt{Var_y})}$$

Where,

r_{xy} = Phenotypic correlation coefficient between the characters x and y

CoV_{xy} = Phenotypic covariance between characters x and y

Var_x = Phenotypic variance of the character x

Var_y = Phenotypic variance of the character y

The significance of correlation coefficient values were tested for referring to the table r values at $n-2$ degrees of freedom as per Snedecor and Cochran, (1967), where n is the number of pairs of observations.

3.4.6 Path coefficient analysis

Path coefficient analysis was carried out as suggested by Wright (1921) and illustrated by Dewey and Lu (1959) in F_2 populations. Standard path coefficients, which are standardized partial regression coefficients, were obtained by solving the following sets of 'P' simultaneous equation by "DOOLITTLE TECHNIQUE" using SPAR-1 computer programme as described below.

$$\begin{aligned}
 P_{01} + P_{01r12} + \dots + P_{opr1p} &= r_{01} \\
 P_{01r12} + P_{02} + \dots + P_{opr2p} &= r_{01} \\
 \cdot & \cdot \cdot \cdot \cdot \cdot \cdot \\
 \cdot & \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \\
 \cdot & \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \\
 \cdot & \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \\
 P_{01r1p} + P_{0r2p} + \dots + P_{op} &= r_{0p}
 \end{aligned}$$

Where, $P_{01}, P_{02}, \dots, P_{0p}$ are the direct path coefficients of the variables, 1, 2, ..., p on the dependent variable 0, $r_{12}, r_{13}, \dots, r_{1p}, \dots, r_{p(p-1)}$ are possible correlation coefficients between various independent variables and $r_{01}, r_{02}, \dots, r_{0p}$ are the correlations between dependent and independent variables.

The indirect effect of i^{th} variable via j^{th} variable is obtained as $P_{0j} r_{ij}$. The contribution of remaining unknown factors was measured as residual factor (r_{ox}), which was calculated as given below.

$$r_{ox} = \sqrt{1 - (P_{01}^2 + 2P_{01}P_{02}r_{12} + 2P_{01}P_{03}r_{13} + \dots + P_{02}^2 + 2P_{02}P_{03}r_{13} + \dots + P_{0p}^2)}$$

IV EXPERIMENTAL RESULTS

The results of the investigation are presented under the following headings.

- 4.1 To assess mean and variability parameters in F₂ segregating population for yield and yield attributes.
- 4.2 Correlation coefficient studies in F₂ segregating population.
- 4.3 Path analysis in F₂ segregating population.
- 4.4 Screening for blast disease

4.1 To assess mean and variability parameters in F₂ segregating population for yield and yield attributes

Mean, range, variability parameters *viz.*, phenotypic variance, genotypic variance, PCV, GCV, broad sense heritability and genetic advance expressed as per cent of mean with respect to all nine characters recorded on 350 plants in each of the four F₂ crosses were presented from table 1-4 and briefly outlined below.

4.1.1 Mean and variability parameters in F₂ population of cross I (PR 202 X GE 1409)

4.1.1.1 Days to fifty per cent flowering

Days to fifty per cent of flowering varied between 60 to 87 days with a mean of 65 days, indicating moderate range of variability. The values of PCV (5.50) and GCV (4.57) were recorded low. Broad sense heritability registered moderately high value (68.93) coupled with moderately low genetic advance (5.39) expressed as per cent of mean (Table 1).

4.1.1.2 Plant height (cm)

Plant height varied between 55 to 117 cm with mean a value of 91.33 cm. The PCV (10.53) and GCV (9.81) estimates were moderate. Broad sense heritability was high (86.89) but genetic advance (16.38) expressed as per cent of mean was quite low.

4.1.1.3 Productive tillers per plant

Productive tillers per plant varied from 1 to 8 with a mean value 2.65. This wide range of variability was further confirmed by higher values of PCV (47.14) and GCV (38.31). However broad sense heritability was moderately high (66.05) with high genetic advance (42.37) expressed as per cent of mean.

4.1.1.4 Finger number of main ear

Finger number ranged from 3 to 14 on main ear, with a mean value of 7.42 indicating considerable amount of variability. Further PCV (28.05) and GCV (24.65) were moderate. Estimate of broad sense heritability was high (77.26) whereas, genetic advance expressed as per cent of mean (34.49) was also moderately high.

Table 1: Estimates of mean and variability parameters for nine quantitative traits in F₂ population of the cross I (PR 202 X GE 1409)**n= 350**

Character	Range		Mean \pm SEM	Phenotypic variance	Genotypic variance	PCV (%)	GCV (%)	Heritability (broad sense) (%)	GAM
	Min.	Max.							
Days to 50 per cent flowering	60	79	65 \pm 0.2	12.82	8.84	5.50	4.57	68.93	5.39
Plant height (cm)	55	117	91.33 \pm 0.55	92.52	80.40	10.53	9.81	86.89	16.38
Productive tillers/plant	1	8	2.65 \pm 0.07	1.56	1.03	47.14	38.31	66.05	42.37
Finger number/main ear	3	14	7.39 \pm 0.12	4.30	3.32	28.05	24.65	77.26	34.49
Finger length (cm)	2.5	10	5.86 \pm 0.07	1.76	0.96	22.67	16.80	54.88	14.07
Finger width (cm)	1	1.9	1.11 \pm 0.008	0.02	0.012	13.22	10.06	57.62	9.06
Weight of main ear (g)	2	17	6.93 \pm 0.14	6.43	4.57	36.59	30.86	71.13	38.14
1000 seed weight (g)	1.99	3.59	2.60 \pm 0.01	0.104	0.06	12.44	9.51	58.43	8.75
Grain yield /plant (g)	3.7	32.13	14.56 \pm 0.31	28.93	22.94	36.94	32.90	79.31	47.87

4.1.1.5 Finger length of main ear (cm)

Length of the finger ranged between 2.5 to 10.0 cm with the mean value of 5.86 cm. The PCV (22.67) and GCV (16.80) registered moderate values. Broad sense heritability (54.88) was moderately high coupled with moderate genetic advance (14.07) expressed as per cent of mean.

4.1.1.6 Finger width of main ear (cm)

Width of the finger ranged from 1 to 1.9 cm with the mean value of 1.11 cm. The PCV (13.2) and GCV (10.06) registered moderate values. Broad sense heritability (57.62) was moderately high coupled with low genetic advance (9.06) expressed as per cent of mean.

4.1.1.7 Weight of main ear (g)

Weight of main ear varied from 2 to 17 g with the mean value of 6.93 g. Estimates of PCV (36.59) and GCV (30.86) were moderately high, which resulted in moderately higher value of broad sense heritability (71.13) coupled with higher value of genetic advance (38.14) expressed as per cent of mean.

4.1.1.8 1000 seed weight (g)

The value of 1000 seed weight varied from 1.99 to 3.59 g, with the mean of 2.60 g. The PCV (12.44) and GCV (9.51) values were moderately low, combined with moderate broad sense heritability (58.43) and genetic advance (8.75) expressed as per cent of mean.

4.1.1.9 Grain yield per plant (g)

Grain yield per plant showed a wide range from 3.70 to 32.13g with a mean value of 14.56g. This trait exhibited high PCV (36.94) and GCV (32.9) values. The estimates of both broad sense heritability (79.31) and genetic advance (47.87) expressed as per cent of mean were high.

4.1.2 Mean and variability parameters in F₂ population of cross II (PR 202 X IE 2712)

4.1.2.1 Days to fifty per cent flowering

Days to fifty per cent of flowering varied between 53 to 78 days with a mean of 65.45 days, indicating moderate range of variability. The values of PCV (7.56) and GCV (6.76) were recorded as low. Broad sense heritability registered high value (80.09) coupled with moderate genetic advance (9.99) expressed as per cent of mean (Table 2).

4.1.2.2 Plant height (cm)

Plant height varied between 70 to 121 cm with the mean value of, 91.11 cm indicating low variation for this trait, which was further confirmed by low value of both PCV (11.70) and GCV (9.94). Broad sense heritability was moderately high (72.08) coupled with moderate genetic advance (12.53) expressed as per cent of mean.

Table 2: Estimates of mean and variability parameters for nine quantitative traits in F₂ population of the cross II (PR 202 X IE 2712)

n= 350

Character	Range		Mean \pm SEM	Phenotypic variance	Genotypic variance	PCV (%)	GCV (%)	Heritability (broad sense) (%)	GAM
	Min.	Max.							
Days to 50 per cent flowering	53	78	65.45 \pm 0.61	24.50	19.62	7.56	6.76	80.09	9.99
Plant height (cm)	70	121	91.11 \pm 0.28	113.82	82.04	11.70	9.94	72.08	12.53
Productive tillers/plant	1	6	2.78 \pm 0.07	1.56	0.86	44.82	33.41	55.55	28.49
Finger number/main ear	2	15	8.21 \pm 0.14	5.58	5.02	30.31	28.92	91.04	51.51
Finger length (cm)	2	10	6.46 \pm 0.09	2.57	1.9	24.81	21.36	74.10	28.07
Finger width (cm)	1	1.9	1.07 \pm 0.008	0.021	0.012	13.47	10.15	56.83	8.96
Weight of main ear (g)	2	20	7.81 \pm 0.18	10.19	7.74	40.83	35.59	75.96	48.53
1000 seed weight (g)	1.7	3.74	2.84 \pm 0.02	0.15	0.96	13.9	10.90	61.53	10.87
Grain yield /plant (g)	2.8	42.38	38.1 \pm 0.35	29.56	28.99	39.56	34.97	78.13	49.76

4.1.2.3 Productive tillers per plant

Productive tillers per plant varied from 1 to 6 with mean value 2.78. This wide range of variability was further confirmed by higher values of PCV (44.82) and GCV (33.41). However, broad sense heritability was moderately high (55.55) with moderate genetic advance (28.49) expressed as per cent of mean.

4.1.2.4 Finger number on main ear

Finger number varied from 3 to 15 on main ear, with the mean value of 8.21 indicating considerable high amount of variability. Further PCV (30.31) and GCV (28.92) were moderate. Estimate of broad sense heritability was high (91.04) whereas, genetic advance expressed as per cent of mean (51.75) was moderate.

4.1.2.5 Finger length of main ear (cm)

Length of the finger varied between 2.0 to 10.0 cm with the mean value of 6.46 cm. The PCV (24.81) and GCV (21.36) registered moderate values. This was further reflected in moderately high value of broad sense heritability (74.10) coupled with moderate genetic advance (28.07) expressed as per cent of mean.

4.1.2.6 Finger width of main ear (cm)

Width of the finger varied between 1 to 1.9 cm with the mean value of 1.07 cm. The PCV (13.47) and GCV (10.15) registered moderate values. Whereas broad sense heritability (56.83) registered high value coupled with moderate genetic advance (8.96) expressed as per cent of mean.

4.1.2.7 Weight of main ear (g)

Weight of main ear varied between 2.0 to 20 g with the mean value of 7.81 g. Estimates of PCV (40.83) and GCV (35.59) were moderately high, which resulted in higher value of broad sense heritability (75.96) and higher value of genetic advance (48.53) expressed as per cent of mean.

4.1.2.8 1000 seed weight (g)

The value of 1000 seed weight ranged between 1.70 to 3.74 g, with mean value of 2.84 g. The PCV (13.9) and GCV (10.96) values were moderate. However, broad sense heritability (62.02) was quite high with moderate genetic advance (10.84) expressed as per cent of mean.

4.1.2.9 Grain yield per plant (g)

Yield of main ear varied between 2.1 to 42.38 g with a mean value of 38.1 g. This trait exhibited high PCV (39.56) and GCV (34.97) value indicating presence of high variability for this trait. The estimate of both broad sense heritability (78.15) and genetic advance (49.76) expressed as per cent of mean were high.

4.1.3 Mean and variability parameters in F₂ population of cross III (GPU-28 X IE 2712)

4.1.3.1 Days to fifty per cent flowering

Days to fifty per cent of flowering varied between 59 to 86 days with a mean of 71.86 days, indicating moderate range of variability. The values of PCV (7.87) and GCV (6.75) were low. Broad sense heritability registered high value (74.99) coupled with moderate genetic advance (9.04) expressed as per cent of mean (Table 3).

4.1.3.2 Plant height (cm)

Plant height ranged between 61 to 120 cm with the mean value of 90.98 cm indicating moderate range of variation for this trait which further confirmed by moderate value of both PCV (10.96) and GCV (7.68). However broad sense heritability was moderate (49.1) coupled with low (5.44) genetic advance expressed as per cent of mean

4.1.3.3 Productive tillers per plant

Productive tillers ranged between 1 to 6 with the mean value of 3.19 indicating moderate range of variation which was further confirmed by moderate value of both PCV (35.65) and GCV (22.29). However broad sense heritability was moderate (39.10) coupled with low (11.23) genetic advance expressed as per cent of mean

4.1.3.4 Finger number on main ear

Finger number varied from 2 to 15 on main ear, with a mean value of 7.61 indicating considerable amount of variability. Further PCV (24.65) and GCV (21.32) were moderate. Estimate of broad sense heritability was higher (74.82) whereas, genetic advance expressed as per cent of mean (28.43) was moderate.

4.1.3.5 Finger length of main ear (cm)

Length of the finger varied between 3 to 12 cm with the mean value of 6.67 cm. The PCV (21.33) and GCV (16.15) registered moderate values. This was further reflected in high value of broad sense heritability (57.34) and high genetic advance (14.45) expressed as per cent of mean.

4.1.3.6 Finger width of main ear (cm)

Width of the finger ranged from 0.9 to 1.9 cm with a mean value of 1.07 This moderate range of variation was further confirmed by low PCV (14.42) and GCV (12.41) values. But this trait exhibited high broad sense heritability (72.61) with moderate (16.32) genetic advance as per cent of mean

4.1.3.7 Weight of main ear (g)

Weight of main ear varied between 2 to 17 g with the mean value of 7.64 g. Estimates of PCV (34.65) and GCV (25.97) were moderately high, which resulted in higher value of broad sense heritability (56.17) and considerable value of genetic advance (22.52) expressed as per cent of mean.

Table 3: Estimates of mean and variability parameters for nine quantitative traits in F₂ population of the cross III (GPU-28 X IE 2712)

n= 350

Character	Range		Mean \pm SEM	Phenotypic variance	Genotypic variance	PCV (%)	GCV (%)	Heritability (broad sense) (%)	GAM
	Min.	Max.							
Days to 50 per cent flowering	59	86	71.86 \pm 0.57	31.46	23.6	7.87	6.75	74.99	9.04
Plant height (cm)	61	120	90.98 \pm 0.32	99.60	48.92	10.96	7.68	49.1	5.44
Productive tillers/plant	1	6	3.19 \pm 0.06	1.29	0.51	35.65	22.29	39.10	11.23
Finger number/main ear	2	15	7.61 \pm 0.10	3.52	2.64	24.65	21.32	74.82	28.43
Finger length (cm)	3	12	6.67 \pm 0.08	2.03	1.17	21.33	16.15	57.34	14.45
Finger width (cm)	0.9	1.9	1.07 \pm 0.01	0.02	0.02	14.42	12.41	72.61	16.32
Weight of main ear (g)	2	17	7.64 \pm 0.15	7.02	3.95	34.65	25.97	56.17	22.52
1000 seed weight (g)	1.23	3.87	2.64 \pm 0.02	0.17	0.11	15.83	12.25	59.89	11.70
Grain yield /plant (g)	2.5	46.64	16.36 \pm 0.38	44.78	31.87	40.9	34.51	71.19	42.70

4.1.3.8 1000 seed weight (g)

The value of 1000 seed weight varied from 1.23 to 3.87 g, with a mean value of 2.64 g this indicated the moderate variation. The PCV (15.83) and GCV (12.25) values were also moderate. However, broad sense heritability (59.89) was high coupled with moderate genetic advance (11.10) expressed as per cent of mean.

4.1.3.9 Grain yield per plant (g)

Grain yield per plant showed wide range from 2.5 to 46.64 g with a mean value of 16.36 g. This trait exhibited high PCV (40.9) and GCV (34.5) values indicating the presence of high variability for this trait. The estimates of both broad sense heritability (71.19) and genetic advance (42.73) expressed as per cent of mean were also high.

4.1.4 Mean and variability parameters in F₂ population of cross IV (Indaf 5 X GE 1462)

4.1.4.1 Days to fifty per cent flowering

Days to fifty per cent of flowering varied between 62 to 81 days with a mean of 71.46 days, indicating moderate range of variability. This was further confirmed by low values of PCV (4.80) and GCV (3.64). Broad sense heritability registered moderate value (57.62) coupled with moderately low genetic advance (3.28) expressed as per cent of mean (Table 4).

4.1.4.2 Plant height (cm)

Plant height varied from 69 to 120 cm with mean value of 90.96 cm. The PCV (10.80) and GCV (9.11) estimates were moderate. Broad sense heritability was high (71.25) coupled with moderate genetic advance (11.29) expressed as per cent of mean.

4.1.4.3 Productive tillers per plant

Productive tillers per plant ranged from 1 to 13 with a mean value 4.45. This wide range of variability was further confirmed by higher values of PCV (49.03) and GCV (41.26). However broad sense heritability was moderately high (70.82) with high genetic advance (50.66) expressed as per cent of mean.

4.1.4.4 Finger number of main ear

Finger number ranged from 4 to 14 on main ear, with the mean value of 6.44 indicating considerable amount of variability. Further PCV (29.04) and GCV (18.75) were moderate. Estimate of broad sense heritability was also moderate (41.66) coupled with moderate genetic advance expressed as per cent of mean (10.38).

4.1.4.5 Finger length of main ear (cm)

Length of the finger varied between 1.9 to 13 cm with the mean value of 8.56 cm. PCV (17.23) and GCV (13.60) registered moderate values. Broad sense heritability (62.33) was moderately high coupled with moderate genetic advance (13.79) expressed as per cent of mean.

Table 4: Estimates of mean and variability parameters for nine quantitative traits in F₂ population of the cross IV (Indaf 5 X GE 1462)

n= 350

Character	Range		Mean ± SEM	Phenotypic variance	Genotypic variance	PCV (%)	GCV (%)	Heritability (broad sense) (%)	GAM
	Min.	Max.							
Days to 50 per cent flowering	62	81	71.46 ± 0.19	11.76	6.78	4.80	3.63	57.62	3.23
Plant height (cm)	69	120	90.96 ± 0.58	96.53	68.78	10.80	9.11	71.25	11.29
Productive tillers/plant	1	13	4.45 ± 0.07	4.77	3.38	49.03	41.26	70.82	50.66
Finger number/main ear	4	14	6.44 ± 0.1	3.49	1.4	29.04	18.75	41.66	10.38
Finger length (cm)	1.9	13	8.56 ± 0.08	2.17	1.34	17.23	13.60	62.21	13.79
Finger width (cm)	1	1.5	1.09 ± 0.02	0.025	0.013	14.53	10.57	52.23	8.16
Weight of main ear (g)	3.24	14.34	7.72 ± 0.12	4.80	3.10	28.35	22.78	64.58	24.36
1000 seed weight (g)	1.34	3.94	2.78 ± 0.02	0.19	0.12	15.70	12.82	66.68	14.38
Grain yield /plant (g)	5.85	31.94	12.60 ± 0.23	16.03	25.32	31.77	27.52	75.03	36.86

4.1.4.6 Finger width of main ear (cm)

Width of the finger varied between 1 to 1.5 cm with the mean value of 1.10 cm. The PCV (14.53) and GCV (10.50) registered moderate values. Broad sense heritability (52.23) was moderately high coupled with high genetic advance (8.16) expressed as per cent of mean.

4.1.4.7 Weight of main ear (g)

Weight of main ear ranged between 3.24 to 14.34 g with the mean value of 7.72 g. Estimates of PCV (28.35) and GCV (22.78) were moderately high, which resulted in moderately higher value of broad sense heritability (64.58) and higher value of genetic advance (24.36) expressed as per cent of mean.

4.1.4.8 1000 seed weight (g)

The value of 1000 seed weight ranged between 1.34 to 3.94 g, with a mean value of 2.72 g. The PCV (15.70) and GCV (12.82) values were moderately low, combined with moderately high broad sense heritability (66.68) with moderate genetic advance (14.38) expressed as per cent of mean.

4.1.4.9 Grain yield per plant

Grain yield per plant varied between 5.85 to 31.94 g with a mean value of 12.60 g. This trait exhibited high PCV (31.77) and GCV (27.52) values. The estimates of both broad sense heritability (75.03) and genetic advance (36.86) expressed as per cent of mean were high.

4.2 Correlation coefficient studies in F₂ segregating population.

Phenotypic correlations among all the characters recorded from 350 plants from each of the four F₂ crosses were estimated and the same have been presented in table 5.

4.2.1 Phenotypic correlations in F₂ population of cross I (PR-202 X IE 2712)

4.2.1.1 Association between grain yield and its component characters

Grain yield per plant exhibited significant positive correlation with 1000 seed weight (0.457), weight of main ear (0.641), finger length (0.181), number of fingers per main ear (0.133), total number of productive tillers per plant (0.170) and with plant height (0.327).

4.2.1.2 Association among yield attributing character

Plant height exhibited positive association with number of productive tillers (0.129), weight of main ear (0.194) and 1000 seed weight (0.202).

Finger number on main ear exhibited strong positive association with weight of main ear (0.172) and 1000 seed weight (0.206). Finger length of main ear exhibited strong negative association with finger width of main ear (0.249), whereas it exhibited

Table 5: Phenotypic correlation coefficients in F₂ populations of four crosses of Finger millet

		X2	X3	X4	X5	X6	X7	X8	X9
X1	Cross I	-0.014	-0.040	0.032	0.055	-0.060	-0.082	0.113	0.003
	Cross II	0.142*	0.012	0.044	0.010	-0.027	0.034	-0.013	-0.083
	Cross III	0.046	0.172**	-0.049	0.048	0.104	0.275**	0.304**	0.407**
	Cross IV	-0.011	-0.160**	-0.306**	-0.072	-0.028	-0.288**	-0.077	-0.356**
X2	Cross I		0.129*	0.072	0.051	-0.039	0.194**	0.202**	0.327**
	Cross II		0.095	-0.038	0.131*	-0.043	0.010	0.055	0.151**
	Cross III		0.090	-0.072	-0.097	0.110	0.014	0.020	0.037
	Cross IV		0.169**	-0.024	-0.009	0.061	0.105	-0.025	0.307**
X3	Cross I			-0.018	-0.032	-0.034	0.102	0.013	0.034
	Cross II			0.112	0.204**	-0.141*	0.060	0.088	-0.051
	Cross III			-0.047	-0.056	0.102	0.107	0.198**	0.271**
	Cross IV			0.509**	-0.033	-0.028	0.496**	0.313**	0.498**
X4	Cross I				0.103	-0.068	0.172**	0.206**	0.133*
	Cross II				0.235**	-0.206**	0.127*	-0.001	0.232**
	Cross III				-0.010	-0.085	-0.019	0.087	0.026
	Cross IV				-0.059	0.016	0.768**	0.461**	0.699**
X5	Cross I					-0.249**	0.141*	0.092	0.181**
	Cross II					-0.476**	0.155**	0.147*	0.145*
	Cross III					-0.300**	0.022	0.039	-0.044
	Cross IV					0.002	-0.024	-0.050	-0.017
X6	Cross I						0.001	-0.035	-0.087
	Cross II						-0.126*	-0.072	-0.176**
	Cross III						0.065	0.076	0.115*
	Cross IV						-0.003	-0.061	0.017
X7	Cross I							0.407**	0.641**
	Cross II							0.064	0.329**
	Cross III							0.216**	0.433**
	Cross IV							0.444**	0.769**
X8	Cross I								0.457**
	Cross II								0.148*
	Cross III								0.480**
	Cross IV								0.316**

*Significant at 5% probability level

** Significant at 1% probability level

X1 – Days to 50 per cent flowering

X2 - Plant height (cm)

X3 -Productive tillers/plant

Cross I - PR 202 X GE 1409

Cross II - PR 202 X IE 2712

Cross III - GPU - 28 X IE 2712

Cross IV - Indaf 5 X GE 1462

X4- Finger number/main ear

X5- Finger length (cm)

X6 – Finger width (cm)

X7 - Weight of main ear (g)

X8 - 1000 seed weight (g)

X9 - Grain yield /plant (g)

positive association with weight of main ear (0.141) and in turn weight of main ear is highly positively correlated with 1000 seed weight (0.407).

4.2.2 Phenotypic correlations in F₂ population of cross II (PR 202 X IE 2712)

4.2.2.1 Association between grain yield and its component characters

Grain yield per plant is having significant positive association with 1000 seed weight (0.148), weight of main ear (0.329), finger length of main ear (0.145) and number of fingers per main ear (0.232). But this trait was significantly negatively associated with finger width of main ear (-0.176) and days to 50 per cent flowering (-0.151).

4.2.2.2 Association among yield attributing characters

Days to 50 per cent flowering registered significant negative correlation with the plant height (-0.142) whereas, plant height intern exhibited positive significant association with the finger length of main ear (0.131).

Number of productive tillers per plant having significant positive association with finger length of main ear (0.204) and significant negative association with finger width of main ear (-0.141). Number of fingers per main ear registered significant positive association with finger length (0.235) and weight of main ear (0.127) whereas, it is having significant negative association with finger width of main ear (-0.206).

Finger length of main ear is significantly positively associated with weight of main ear (0.155) and 1000 seed weight (0.147) but it is significantly negatively associated with finger width of main ear (-0.476). Finger width of main ear is intern significantly negatively correlated with weight of main ear (-0.126).

4.2.3 Phenotypic correlations in F₂ population of cross III (GPU-28 x IE 2712)

4.2.3.1 Association between grain yield and its component characters

Grain yield per plant is having significant positive association with 1000 seed weight (0.480), weight of main ear (0.433), finger width of main ear (0.115), number of productive tillers (0.271) and days to 50 per cent flowering (0.407).

4.2.3.2 Association among yield attributing characters

Days to 50 per cent flowering registered significant positive correlation with the productive tillers (0.172), weight of main ear (0.275) and 1000 seed weight (0.304)

Productive tillers per plant having significant positive association with 1000 seed weight (0.198). Finger length is having significant negative correlation with finger width of main ear (-0.300) and weight of main ear is having positive significant association with the 1000 seed weight (0.216).

4.2.4 Phenotypic correlations in F₂ population of cross IV (Indaf 5 X GE 1462)

4.2.4.1 Association between grain yield and its component characters

Grain yield per plant is having positive significant association with 1000 seed weight (0.316), weight of main ear (0.769), number of fingers per main ear (0.699), number of productive tillers (0.498) and plant height (0.307) whereas, it is negatively correlated with days to 50 per cent flowering (-0.356).

4.2.4.2 Association among yield attributing characters

Days to fifty per cent flowering is having a significant positive association with productive tillers (0.530) but it is significantly negatively associated with number of fingers (-0.306) and weight of main ear (-0.288).

Plant height is having a significant and positive relation with the number of productive tillers (0.169) intern productive tillers per plant is having significant and positive association with the number of fingers (0.509), weight of main ear (0.496) and 1000 seed weight (0.313).

Number of fingers per main ear is having a positive association with the weight of main ear (0.776) and 1000 seed weight (0.461) whereas weight of main ear is positively associated with 1000 seed weight (0.444).

4.3 Path analysis in F₂ segregating population

All the characters recorded on 350 plants in each of the four F₂ crosses were selected for phenotypic path analysis to reveal the differential direct and indirect effects of all these component characters with grain yield of main ear and the result of the same are presented from table 6 to 9 and explained below.

4.3.1 Phenotypic path analysis in F₂ population of cross I (PR 202 X GE 1409)

4.3.1.1 Days to fifty per cent flowering Vs. grain yield per plant

Direct contribution of this trait to grain yield per plant is positive and low in magnitude (0.0176), whereas its indirect effect through 1000 seed weight (0.0020) is also positive and low in magnitude but through weight of main finger (-0.0014) and finger width of main ear (-0.0011) indirect effects are low but in negative magnitude (Table 6).

4.3.1.2 Plant height Vs. grain yield per plant

Direct contribution of this trait to grain yield per plant was high and positive in magnitude (0.1865), whereas its indirect effects through 1000 seed weight (0.0377), weight of main ear (0.0363), productive tillers per plant (0.0241) and finger number (0.0135) were low and positive in magnitude.

4.3.1.3 Productive tillers per plant Vs. grain yield per plant

Direct contribution of productive tillers to grain yield per plant is low and in negative magnitude (-0.0458), whereas its indirect effects through the finger width

Table 6: Estimates of direct (diagonal leading) and indirect effects of different quantitative traits on seed yield in F₂ population of cross I (PR 202 X GE 1409)

n = 350

	X₁	X₂	X₃	X₄	X₅	X₆	X₇	X₈	'r' value
X ₁	0.0176	-0.0002	-0.0007	0.0006	0.0010	-0.0011	-0.0014	0.0020	0.0031
X ₂	-0.0026	0.1865	0.0241	0.0135	0.0095	-0.0072	0.0363	0.0377	0.3267
X ₃	0.0018	-0.0059	-0.0458	0.0008	0.0015	0.0016	-0.0047	-0.0006	0.0339
X ₄	-0.0008	-0.0017	0.0004	-0.0241	-0.0025	0.0016	-0.0041	-0.0050	0.1330
X ₅	0.0035	0.0033	-0.0021	0.0066	0.0643	-0.0160	0.0090	0.0059	0.1806
X ₆	0.0036	0.0023	0.0020	0.0040	0.0147	-0.0593	-0.0001	0.0021	-0.0870
X ₇	-0.0428	0.1018	0.0532	0.0900	0.0736	0.0005	0.5235	0.2131	0.6406
X ₈	0.0228	0.0408	0.0026	0.0416	0.0185	-0.0071	0.0821	0.2018	0.4570

Residual effect = 0.2101

The main diagonal values (bold) are direct effects

X₁ - Days to 50 per cent flowering

X₄ - Finger number/main ear

X₇ - Weight of main ear (g)

X₂ - Plant height (cm)

X₅ - Finger length (cm)

X₈ - 1000 seed weight (g)

X₃ - Productive tillers/plant

X₆ - Finger width (cm)

r - Correlation with grain yield

(0.0016), finger length (0.0015), and plant height (0.0018) were low and positive in magnitude but with days to 50 per cent flowering (-0.0059) and weight of main ear (-0.0047), it is low and in negative magnitude

4.3.1.4 Finger number per main ear Vs. grain yield per plant

Finger number per main ear exhibited direct and negative (-0.0241) association with grain yield per plant whereas, its indirect contribution through weight of main ear (-0.0041), finger length (-0.0025) and plant height (-0.0017) was also negative and in low magnitude, but with finger width it was (0.0016) low and in positive magnitude.

4.3.1.5 Finger length of main ear Vs. grain yield per plant

Direct contribution of this trait to the grain yield per plant was low and positive (0.0643). Its indirect contribution through finger width of main finger (-0.0160) and number of productive tillers (-0.0021) was low and negative but with remaining traits it is low and in positive magnitude.

4.3.1.6 Finger width of main ear Vs. grain yield per plant

Its direct contribution to the grain yield per plant was low and negative (-0.0593) and its indirect contribution through remaining traits was low and in positive magnitude except with weight of main ear where it was negligible and negative in magnitude.

4.3.1.7 Weight of main ear Vs. grain yield per plant:

Direct contribution of this trait to the grain yield was high and positive in magnitude (0.5235) whereas its indirect contribution through 1000 seed weight (0.2131) and plant height (0.1018) was also high and positive in magnitude and its indirect contribution with remaining traits was in low positive magnitude.

4.3.1.8 1000 seed weight Vs. grain yield per plant:

Direct contribution of this trait to the grain yield was positive in magnitude (0.2018) whereas its indirect contribution through weight of main ear (0.0821), finger number (0.0416), plant height (0.0408) and days to 50 per cent flowering (0.0228) were high and with positive magnitude but contribution through other traits was negligible.

4.3.2 Phenotypic path analysis in F₂ population of cross II (PR 202 X IE 2712)

4.3.2.1 Days to fifty per cent flowering Vs. grain yield per plant:

Days to 50 per cent flowering is having a negative and high direct effect (-0.1405) on grain yield per plant. Its indirect effect through plant height (-0.0199), finger number (-0.0184), and number of productive tillers (-0.0134) was low and with negative magnitude. Indirect effect through the other traits were negligible (Table 7).

Table 7: Estimates of direct (diagonal leading) and indirect effects of different quantitative traits on seed yield in F₂ population of cross II (PR 202 X IE 2712).

n = 350

	X₁	X₂	X₃	X₄	X₅	X₆	X₇	X₈	'r' value
X ₁	-0.1405	-0.0199	-0.0134	0.0054	-0.0184	0.0060	-0.0013	-0.0075	-0.0834
X ₂	-0.0117	-0.0826	0.0000	-0.0036	-0.0008	0.0022	-0.0028	0.0010	-0.1509
X ₃	-0.0103	0.0000	-0.1080	-0.0121	-0.0220	0.0152	-0.0064	-0.0100	-0.0514
X ₄	-0.0067	0.0077	0.0196	0.1758	0.0413	-0.0362	0.0224	0.0005	0.2316
X ₅	0.0042	0.0003	0.0066	0.0076	0.0324	-0.0154	0.0050	0.0047	0.1451
X ₆	0.0044	0.0027	0.0144	0.0211	0.0488	-0.1024	0.0130	0.0072	-0.1764
X ₇	0.0028	0.0099	0.0173	0.0370	0.0449	-0.0367	0.2905	0.0199	0.3291
X ₈	0.0069	-0.0016	0.0120	0.0004	0.0189	-0.0090	0.0088	0.1292	0.1450

Residual effect = 0.1043.

The main diagonal values (bold) are direct effects

X₁ – Days to 50 per cent flowering
 X₂ - Plant height (cm)
 X₃ – Productive tillers/plant

X₄ - Finger number/main ear
 X₅ - Finger length (cm)
 X₆ - Finger width (cm)

X₇ - Weight of main ear (g)
 X₈ - 1000 seed weight (g)
 r – Correlation with grain yield

4.3.2.2 Plant height Vs. grain yield per plant

Direct contribution of this trait to the grain yield was low and negative in magnitude (-0.0826) whereas its indirect contribution through other traits was negligible except through the plant height (-0.0117) where it has low but in negative magnitude.

4.3.2.3 Productive tillers Vs. grain yield per plant

Direct contribution of this trait to the grain yield was in negative magnitude (-0.1080) where as its indirect contribution through finger length (-0.0220), number of fingers (-0.0121), plant height (-0.0103), and 1000 seed weight (-0.0100) were low but in negative magnitude. Indirect effect through the width of finger (0.0152) was in positive magnitude.

4.3.2.4 Finger number Vs. grain yield per plant

Finger number (0.1758) had positive and high direct effect on grain yield, whereas its indirect effect through finger length (0.0413), weight of main ear (0.0224), and number of productive tillers (0.0196) were positive but through the finger width (-0.0362) it was in negative magnitude.

4.3.2.5 Finger length of main ear Vs. grain yield per plant

Direct contribution of this trait to the grain yield was in positive magnitude (0.0324) whereas, its indirect contribution through remaining traits were negligible but in positive magnitude except through the finger width (-0.0154), where it was negative in magnitude.

4.3.2.6 Finger width of main ear Vs. grain yield per plant

Positive association of this trait with grain yield is due to high indirect positive effect through finger length (0.0488), finger width (0.0211) and number of productive tillers (0.0144) but its direct effect is in negative magnitude (-0.1024).

4.3.2.7 Weight of main ear Vs. grain yield per plant

Direct effect of this trait to the grain yield was high and positive in magnitude (0.2905), whereas, indirect effect of this trait through the finger length (0.0449), finger number (0.0370), 1000 seed weight (0.0199) and number of productive tillers (0.0173) is positive in magnitude. But through the width of the finger (-0.0367) it was in negative magnitude.

4.3.2.8 1000 seed weight Vs. grain yield per plant

Direct effect of this trait to the grain yield was high and positive in magnitude (0.1292), whereas, indirect effect of this trait through the finger length was low and in positive magnitude (0.0189), but through other traits contribution was negligible.

4.3.3 Phenotypic path analysis in F₂ population of cross III (GPU-28 X IE 2712)

4.3.3.1 Days to fifty per cent flowering Vs. grain yield per plant

Direct effect of this trait to the grain yield is low and negative in magnitude (-0.0024), whereas, indirect effect of this trait through the other traits was negligible in magnitude (Table 8).

4.3.3.2 Plant height Vs. grain yield per plant

Direct contribution of this trait to the grain yield was high and positive in magnitude (0.2032) and its indirect contribution through 1000 seed weight (0.0618), weight of main ear (0.0560), finger width (0.0176) and number of productive tillers (0.0350) were also positive in magnitude whereas through finger number (-0.0099) it registered negligible and negative magnitude.

4.3.3.3 Productive tillers Vs. grain yield per plant

Productive tillers (0.1338) had high direct positive effect on grain yield and indirect contribution of this trait through 1000 seed weight (0.0265), weight of main ear (0.0143), finger width (0.0133), plant height (0.0230) and days to 50 per cent flowering (0.0121) were also positive in magnitude.

4.3.3.4 Finger number Vs. grain yield per plant

Finger number (0.0181) had positive and direct effect on grain yield, whereas its indirect effect through 1000 seed weight (0.0016) was very low but in positive magnitude however, through other traits contribution was negligible.

4.3.3.5 Finger length of main ear Vs. grain yield per plant

Direct contribution of this trait to the grain yield was in negative magnitude (-0.0490) where as its indirect contribution through finger width (0.0185), days to 50 per cent flowering (0.0048) and number of productive tillers (0.0027) were low but in positive magnitude.

4.3.3.6 Finger width of main ear Vs. grain yield per plant

Positive association of this trait with grain yield is due to its high direct positive effect (0.0437) and positive but low indirect effect through remaining traits except with finger length where it registered negative magnitude (-0.0165).

4.3.3.7 Weight of main ear Vs. grain yield per plant

Direct effect of this trait to the grain yield was high and positive in magnitude (0.2926) and its indirect effect through the plant height (0.0806), 1000 seed weight (0.0631) and number of productive tillers (0.0314) were also positive in magnitude, whereas through other traits its effect was negligible.

Table 8: Estimate of direct (diagonal leading) and indirect effects of different quantitative traits on seed yield in F₂ population of cross III (GPU-28 X IE 2712)

n = 350

	X₁	X₂	X₃	X₄	X₅	X₆	X₇	X₈	'r' value
X ₁	-0.0024	-0.0001	-0.0002	0.0002	0.0002	- 0.0002	-0.0001	0.0000	0.4068
X ₂	0.0094	0.2032	0.0350	-0.0099	0.0097	0.0176	0.0560	0.0618	0.0370
X ₃	0.0121	0.0230	0.1338	-0.0063	-0.0075	0.0133	0.0143	0.0265	0.2708
X ₄	-0.0013	-0.0009	-0.0008	0.0181	-0.0002	0.0001	-0.0003	0.0016	0.0259
X ₅	0.0048	-0.0023	0.0027	0.0005	-0.0490	0.0185	-0.0011	-0.0019	-0.0441
X ₆	0.0039	0.0038	0.0043	0.0002	-0.0165	0.0437	0.0014	0.0022	0.1190
X ₇	0.0042	0.0806	0.0314	-0.0055	0.0064	0.0097	0.2926	0.0631	0.4334
X ₈	0.0064	0.0995	0.0647	0.0286	0.0127	0.0163	0.0705	0.3271	0.4803

Residual effect = 0.1802

The main diagonal values (bold) are direct effects

X₁ – Days to 50 per cent flowering
 X₂ - Plant height (cm)
 X₃ – Productive tillers/plant

X₄ - Finger number/main ear
 X₅ - Finger length (cm)
 X₆ - Finger width (cm)

X₇ - Weight of main ear (g)
 X₈ - 1000 seed weight (g)
 r – Correlation with grain yield

4.3.3.8 1000 seed weight Vs. grain yield per plant

Positive association of this trait with grain yield is due to its high direct positive effect (0.3271) and positive indirect effect through plant height (0.0995), weight of main ear (0.0705) and number of productive tillers (0.0647).

4.3.4 Phenotypic path analysis in F₂ population of cross IV (Indaf 5 X GE 1462)

4.3.4.1 Days to fifty per cent flowering Vs. grain yield per plant:

Strong negative association of this trait with grain yield is due to its strong direct negative effect (-0.1263) whereas, its indirect effect through finger number (0.0387), weight of main ear (0.0364) and number of productive tillers (0.0202) were in positive magnitude (Table 9).

4.3.4.2 Plant height Vs. grain yield per plant:

Direct contribution of this trait to the grain yield was high and positive in magnitude (0.2696) and its indirect contribution through number of productive tillers (0.0455), weight of main ear (0.0284) and finger width (0.0165) were also positive in magnitude whereas through other traits its effects were negligible.

4.3.4.3 Number of productive tillers Vs. grain yield per plant

Number of productive tillers (0.0527) had positive and direct effect on grain yield, whereas its indirect effect through number of finger (0.0268), 1000 seed weight (0.0165) and weight of main ear (0.0261) was low but in positive magnitude however, contribution through other traits was negligible.

4.3.4.4 Finger number Vs. grain yield per plant

Direct contribution of this trait to the grain yield was high and positive in magnitude (0.3044) whereas, its indirect contribution through weight of main ear (0.2337), number of productive tillers (0.1551), 1000 seed weight (0.1404) and finger width (0.0511) were positive in magnitude whereas, through finger length (- 0.0179), it was negative in magnitude.

4.3.4.5 Finger length of main ear Vs. grain yield per plant

Strong negative association of this trait with grain yield is due to its negligible negative indirect effect through most of the traits, whereas its direct effect on grain yield was (0.0078) positive in magnitude.

4.3.4.6 Finger width of main ear Vs. grain yield per plant

Strong negative association of this trait with grain yield was due to its low but negative direct effect (-0.0496) and low negative indirect effect through finger number (-0.0083) and plant height (-0.0030).

Table 9: Estimate of direct (diagonal leading) and indirect effects of different quantitative traits on seed yield in F₂ population of cross IV (Indaf 5 X GE 1462)

n = 350

	X₁	X₂	X₃	X₄	X₅	X₆	X₇	X₈	'r' value
X ₁	-0.1263	0.0014	0.0202	0.0387	0.0092	0.0036	0.0364	0.0097	-0.3564
X ₂	-0.0029	0.2696	0.0455	-0.0065	-0.0024	0.0165	0.0284	-0.0740	0.3067
X ₃	-0.0084	0.0089	0.0527	0.0268	- 0.0017	- 0.0015	0.0261	0.0165	0.4977
X ₄	-0.0932	-0.0074	0.1551	0.3044	- 0.0179	0.0511	0.2337	0.1404	0.6991
X ₅	-0.0006	-0.0001	-0.0003	-0.0005	0.0078	0.0000	- 0.0002	-0.0004	-0.0170
X ₆	0.0014	-0.0030	0.0014	-0.0083	-0.0001	-0.0496	0.0001	0.0030	0.0172
X ₇	-0.1241	0.0454	0.2138	0.3309	- 0.0104	- 0.0012	0.4310	0.1915	0.7687
X ₈	-0.0023	- 0.0081	0.0092	0.0136	- 0.0015	-0.0018	0.0131	0.0296	0.3163

Residual effect = 0.1802

The main diagonal values (bold) are direct effects

X₁ – Days to 50 per cent flowering
 X₂ - Plant height (cm)
 X₃ – Productive tillers/plant

X₄ - Finger number/main ear
 X₅ - Finger length (cm)
 X₆ - Finger width (cm)

X₇ - Weight of main ear (g)
 X₈ - 1000 seed weight (g)
 r – Correlation with grain yield

4.3.4.7 Weight of main ear Vs. grain yield per plant

Direct effect of this trait to the grain yield was high and positive in magnitude (0.4310) and its indirect effect through the 1000 seed weight (0.1915), finger number (0.3309), number of productive tillers (0.2138) and plant height (0.0454) were also positive in magnitude, whereas through other traits its effect was negligible.

4.3.4.8 1000 seed weight Vs. grain yield per plant

Direct effect of this trait to the grain yield was positive in magnitude (0.0296) and its indirect effect through the weight of main ear (0.0131) and finger number (0.0136) were also positive in magnitude, whereas through other traits indirect effect was negligible.

4.4 Screening for blast disease

350 plants from each of the four F₂ populations were evaluated for neck and finger blast under natural epiphytotic conditions. The disease incidence was recorded in terms of percentage and converted to standard disease score index and the results of the same are presented below and meteorological data of the crop period is presented in appendix I.

4.4.1 Neck Blast

The results showed that, neck blast disease was evaluated for both parents and F₂ populations. Parents *viz.* Indaf-5, GPU-28, IE 2712 and GE 1462 (89.67, 82.48, 87.42 and 98.0 respectively) showed resistance reaction to neck blast whereas GE 1409 showed moderate resistance reaction to neck blast and PR 202 showed moderate susceptibility reaction to neck blast (Table 10). In case of F₂ segregating populations, majority of the segregants from cross IV (56.09) exhibited highly resistance reaction whereas majority of the segregants from cross I and cross II (65.34 and 76.42 respectively) exhibited resistance reaction and cross III (70.09) showed moderate resistance reaction to neck blast whereas cross II (10.40), IV (9.05) and cross I (8.44) showed moderate susceptibility reaction to neck blast (Table 11). Segregants showing susceptible reaction to neck blast were recorded only from cross II

4.4.2 Finger Blast

Both parents and segregating materials were evaluated for finger and neck blast diseases. The results showed that parent GPU-28 (89.13) exhibited highly resistance reaction and IE 2712 (93.5), GE1462 (89.13) and Indaf 5 (76.37) recorded resistance reaction whereas GE 1409 (95.34) recorded moderate resistance reaction but PR 202 (91.32) exhibited moderate susceptibility (Table 10). In case of F₂ segregating populations, the maximum segregants from cross IV (64.46) registered highly resistance reaction and cross II (73.77) registered resistance reaction whereas cross III (69.35) and cross I (69.22) exhibited moderate resistance reaction but cross IV (11.07), cross I (7.34) and cross III (6.89) exhibited moderate susceptibility. Segregants showing susceptible reaction to finger blast were recorded only from cross II (1.64) (Table 11).

Table 10: Per cent distribution of finger and neck blast disease reaction in parents of finger millet

Blast score	Disease reaction	Indaf 5		GPU-28		GE 1409		IE 2712		PR 202		GE 1462	
		FB	NB	FB	NB	FB	NB	FB	NB	FB	NB	FB	NB
1	HR	8.57	-	90.45	2.17	4.66	2.13	-	12.58	-	-	10.87	2.0
2	R	76.37	89.67	-	82.48	-	5.85	93.5	87.42	-	-	89.13	98.0
3	MR	15.06	5.36	9.55	15.35	95.34	92.02	6.5	-	8.68	-	-	-
4	MS	-	4.97	-	-	-	-	-	-	91.32	11.03	-	-
5	S	-	-	-	-	-	-	-	-	-	-	-	-

HR- Highly resistant
R- Resistant
MR- Moderately resistant
MS- Moderately susceptible
S- Susceptible
FB- Finger blast
NB- Neck blast

Table 11: Per cent distribution of finger and neck blast disease reaction in four crosses of finger millet

Blast score	Disease reaction	Cross I		Cross II		Cross III		Cross IV	
		FB	NB	FB	NB	FB	NB	FB	NB
1	HR	5.98	4.55	7.38	2.80	14.46	6.57	65.46	60.09
2	R	69.22	65.34	73.77	76.42	9.30	19.58	17.12	14.49
3	MR	17.46	18.45	12.92	10.38	69.35	70.09	6.35	16.37
4	MS	7.34	8.44	4.30	10.40	6.89	3.76	11.07	9.05
5	S	-	3.22	1.64	-	-	-	-	-

Cross I PR 202 X GE 1409

Cross II PR 202 X IE 2712

Cross III GPU-28 X IE 2712

Cross IV Indaf 5 X GE 1462

HR Highly resistant

R Resistant

MR Moderately resistant

MS Moderately susceptible

S Susceptible

FB Finger blast

NB Neck blast

4.5 Identification of desirable transgressive segregants

All the plants in the F₂ population of four crosses exceeding the respective parental means in the desirable direction were counted and expressed in terms of percentage of favorable segregants and the results of the same are presented in table 12.

In general, desirable transgressive segregants were higher in cross I (total rank: 22) followed by cross IV (total rank: 40),

Within in the cross I, weight of main ear (50.66 %) has more favorable segregants followed by grain yield per plant (47.64%) and plant height (43.23 %) whereas, it is in the order of weight of main ear (44.33 %), grain yield per plant (42.00 %), plant height (41.37 %) followed by finger width (34.16 %), finger length (32.00 %) and 1000 seed weight (30.92 %) in cross II. Cross III registered the highest frequency of favorable segregants for plant height (39.13 %) followed by grain yield per plant (38.47 %), weight of main ear (38.00 %), finger width (34.66 %) and 1000 seed weight (31.66 %) whereas it is in the order of 1000 seed weight (56.24 %), grain yield per plant (38.33 %), weight of main ear (36.66 %) followed by finger number (34.56 %) and number of productive tillers (33.23 %) in cross IV.

With respect to finger blast score, cross III registered the highest value (74.89 %) followed by cross II (70.35 %), cross I (67.56 %) and cross IV (67.37 %). With respect to neck blast again cross III registered the highest value (86.46 %) than cross I (78.45 %) followed by cross IV (78.38 %) and cross II (76.36 %).

Table 12: Percentage distribution of desirable segregants in respect of ten traits in F₂ populations of four crosses of finger millet

Sl.	Characters	Cross I (PR 202 X GE 1409)		Cross II (PR 202 X IE 2712)		Cross III (GPU-28 X IE 2712)		Cross IV (Indaf 5 X GE 1462)	
		Frequency (%)	Rank	Frequency (%)	Rank	Frequency (%)	Rank	Frequency (%)	Rank
v1	Days to 50 per cent flowering	22.66	1	16.66	2	9.67	4	13.62	3
2	Plant height (cm)	43.23	1	41.37	2	39.13	3	9.87	4
3	Productive tillers/plant	19.24	2	12.63	3	10.33	4	33.23	1
4	Finger number/main ear	29.31	2	23.66	3	13.30	4	34.56	1
5	Finger length (cm)	31.25	2	32.00	1	29.32	3	23.66	4
6	Finger width (cm)	28.33	3	34.16	2	34.66	1	20.46	4
7	Weight of main ear (g)	50.66	1	44.33	2	38.00	3	36.66	4
8	1000 seed weight (g)	37.33	2	30.92	4	31.66	3	56.24	1
9	Grain yield /plant (g)	47.64	1	42.00	2	38.47	3	38.33	4
10	Blast disease score								
	a) Finger blast	67.56	3	70.35	2	74.89	1	67.37	4
	b) Neck blast	78.45	2	76.36	4	86.46	1	78.38	3
	Total rank		20		27		34		33
	Average rank		1.8		2.4		3.09		3.0
	Overall rank		1		2		4		3

Ranks are given based on across the characters.

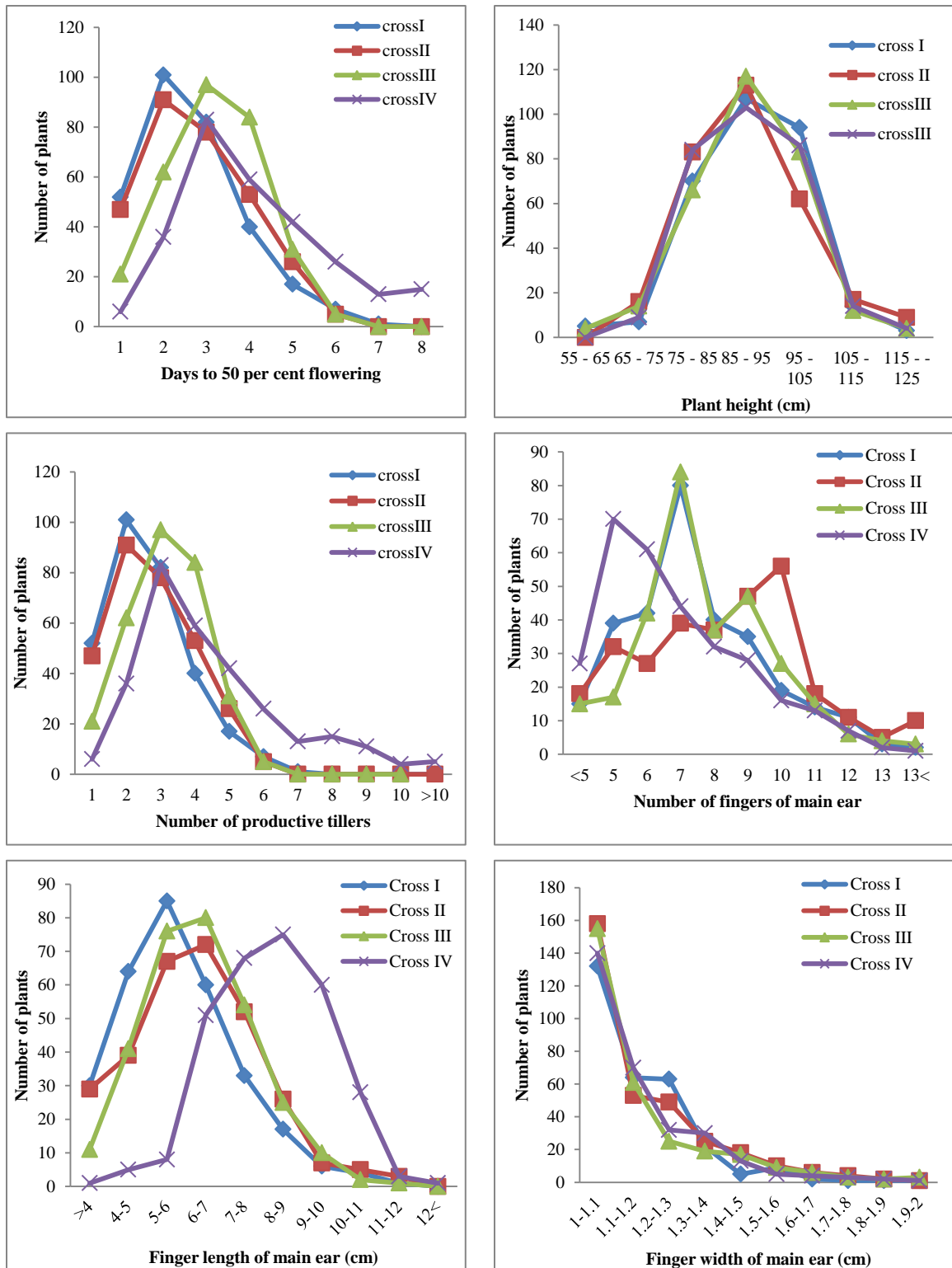


Figure 1a: Frequency distribution graph showing the pattern of segregation of different characters in F₂ population of cross I (PR202 X GE 1409), cross II (PR 202 X IE 2712), cross III (GPU 28 X IE 2712) and cross IV (Indaf 5 X GE 1462).

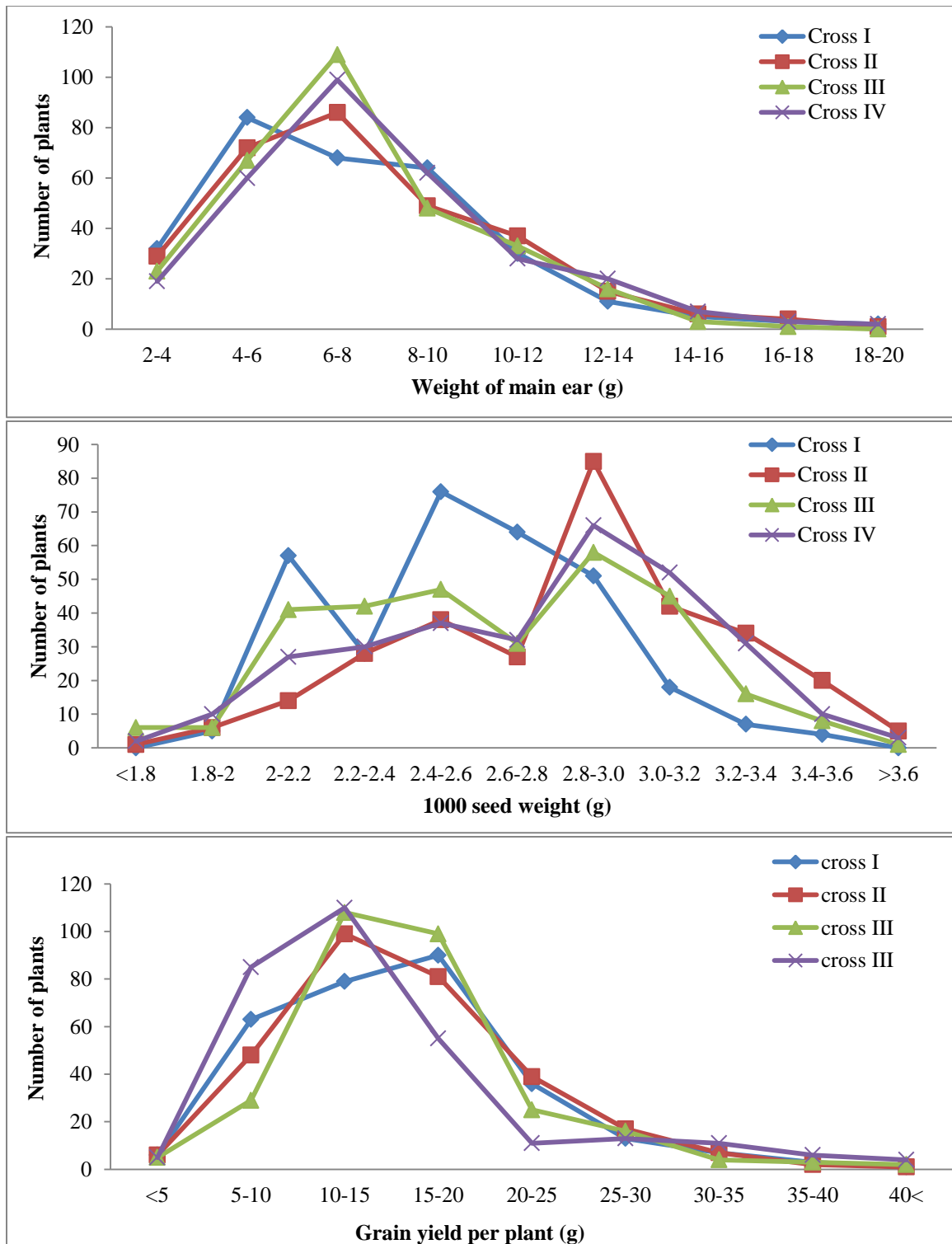


Figure 1b: Frequency distribution graph showing the pattern of segregation of different characters in F₂ populations of cross I (PR202 X GE 1409), cross II (PR 202 X IE 2712), cross III (GPU 28 X IE 2712) and cross IV (Indaf 5 X GE 1462)

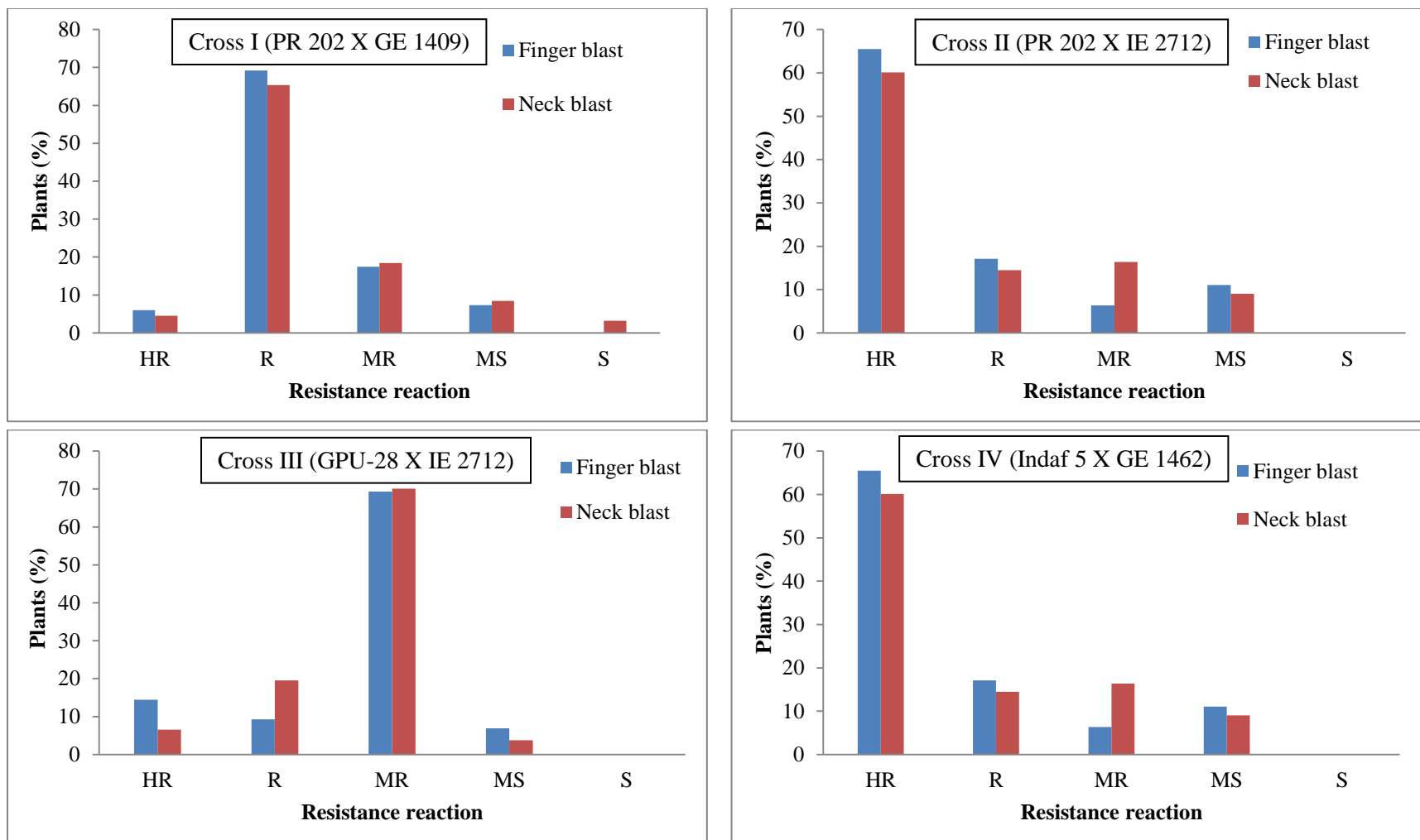


Figure 2: Graph showing the pattern of distribution of resistance reaction for finger and neck blast in F₂ populations of cross I (PR202 X GE 1409), cross II (PR 202 X IE 2712), cross III (GPU 28 X IE 2712) and cross IV (Indaf 5 X GE 1462). HR- Highly resistance, R- Resistance, MR- Medium resistance, MS- Medium susceptibility and S- Susceptibility



Figure 3a: Field view of cross I (PR 202 X GE 1409)



Figure 3b: Field view of cross II (PR 202 X IE 2712)



Figure 3c: Field view of cross III (GPU-28 X IE 2712)



Figure 3d: Field view of cross IV (Indaf 5 X GE 1462)

V DISCUSSION

Knowledge of genetic advance that is expected by applying selection pressure to a segregating population is useful in designing effective breeding programme. The evaluation of segregating progenies helps in estimation of various genetic and non-genetic components of variance. The study of variability provides an opportunity for selecting the desirable genotypes. Heritability is a fraction of variance in phenotypic expression that arises from genetic effect. The nature of selection units and sampling errors also influence greatly the magnitude of heritability estimates. The heritability estimates in segregating generation helps to know genetic variance, genotype environment interaction and progress to be expected from selection. The most misleading estimate of phenotypic variance for yield under natural conditions would have been obtained from a single test, resulting in the confounding of the interaction variance with progeny variance. The estimates of genetic advance may be biased upward if phenotypic variance contains a fraction of whatever genetic variance due to non-genetic effects (dominance or epistasis) if present.

The potential progress expected in accomplishing the objectives demands knowledge of interrelationships among various traits and component characters contributing to yield, which helps the breeder in the simultaneous improvement of several characters in the selection programme. Character association may vary with environmental conditions. Association of economically important yield components of quantitative nature, which is statistically determined by correlation coefficient, is quite useful as basis of selection.

Path coefficient analysis is used to partition the association among characters into direct and indirect effects and measures the relative importance of the causal factors involved. It is simply a standardized partial regression coefficient and as such measures the direct influence of one variable upon another. The characters associated can be considered together as criteria for selection by plant breeders to identify traits that are useful as selection criteria to improve the crop yield.

The present investigation was designed to study the F_2 population of four crosses of finger millet developed at AICSMIP, Zonal Agricultural Research Station, V. C. Farm, Mandya for variability studies, association of nine quantitative characters with yield and the direct and indirect effects of important yield component characters on grain yield. It also aims in selecting best segregants with high yielding ability along with least blast score. The result obtained in the present investigation and conclusion drawn thereof has been discussed under the following headings.

- 5.1 To assess mean and variability parameters in F_2 segregating populations for yield and yield attributes.
- 5.2 Correlation studies in F_2 segregating population
- 5.3 Path analysis in F_2 segregating population

5.4 Screening for blast resistance.

5.5 Identification of desirable transgressive segregants

5.1 To assess mean and variability parameters in F₂ segregating populations for yield and yield attributes

The range of variability was high for all the characters studied except for days to fifty per cent flowering, finger length and finger width of main ear which exhibited low to moderate amount of variability across all the four crosses (Table, 1, 2, 3 and 4) This indicates high scope for improvement of the highly variable characters, which were created by segregation and recombination whereas, it may not be equally effective for a character, which exhibited narrow range of variability.

In all the four crosses, the phenotypic coefficient of variance (PCV) values were quite higher than a genotypic coefficient of variance (GCV) for all the characters studied. This is in agreement with results reported by Priyadharshini *et al.* (2011). Differences between PCV and GCV are also considerably high, which indicated the substantial influence of environment in the expression of these traits and the same result was observed by Mohan Prem Anand (2003).

Days to fifty per cent flowering registered low value of GCV and PCV in all the crosses mainly in cross I and cross IV this result is in agreement with the reports of Chunilal *et al.* (1996) and Malali Gowda (1996). Heritability in broad sense for this trait was moderate in cross I and cross IV whereas, cross II and cross III showed high heritability coupled with high genetic advance expressed as percent of mean. This result is in conformity with Dagnachew Lule *et al.*, (2012). This indicates its role in the criteria of selection.

Plant height exhibited moderately high values of GCV and PCV in cross I and cross I. This was in conformity with the reports of Chaudhari and Acharya (1969) and Prabhakar and Prasad (1984) who reported moderate variability for this trait while Narasimha Rao and Pardhasardhi (1968b) and Bedis *et al.* (2006) reported high variability for this trait. On the contrary cross III and cross IV recorded low variability for this trait. This was in conformity with the reports of Patnaik, (1968), Setty *et al.* (1974), Appadurai *et al.* (1977), Goswami and Asthana (1984), Venkatesh Bhat (1974), and Ravikumar and Seetharam (1994) and Sumathi *et al.* (2007). Difference between the GCV and PCV was low, which indicates high genetic determination for this trait as a result, the heritability in broad sense for this trait was high in all the crosses except in cross III. Computed genetic advance as per cent of mean, which was based on broad sense heritability combined with favorable genetic advance exhibited by this trait indicates its prominent role in selection of desirable segregants.

Productive tillers per plant registered moderate to high level of variability for PCV and GCV. Difference between PCV and GCV were moderate to wide in all the four crosses, which indicates the major effect of environment on this character. Broad sense heritability as comparatively moderate to high, while genetic advance expressed as per

cent of mean was high in all the crosses except in cross III, where it was registered moderate. These values are in agreement with results reported by Shanthappa (1979), Prabhakar and Prasad (1984), Venkatesh Bhat (1991), Ravikumar and Seetharam (1994), Ramaswamy *et al.* (1994), Krishan Reddy (1994), and Byre Gowda (1997), where they have reported moderate to high phenotypic and genotypic variability, heritability and genetic advance for this trait in segregating generation. Reliability can be placed on this important trait for selection of segregants owing to its high broad sense heritability coupled with high genetic advance.

Number of fingers on main ear exhibited moderate to high PCV and GCV values across all four crosses. Difference between PCV and GCV in all the four crosses was narrow, which indicates low magnitude of environmental influence on the expression of this trait. This was in accordance with earlier observation made by Setty *et al.* (1974) and Appadurai *et al.* (1977) who reported moderate values of variability for this trait but contradicts with the reports of Shanthakumar (1988), Byre Gowda (1997) and Debelo (1998) who reported high variability for this trait. The broad sense heritability for this trait was high in all four crosses. Genetic advance expressed as percentage of mean was also high in all the crosses studied except in cross IV where it was low to moderate. High values for this trait were earlier reported by Setty *et al.* (1974) and Appadurai *et al.* (1977). However Narsimha Rao and Pardhasardhi (1968b) reported moderate values for both broad sense heritability and genetic advance expressed as percentage of mean. Hence this trait can be used effectively for selection of desirable segregants owing to its high broad sense heritability combined with high genetic advance.

Finger length of main ear exhibited moderate PCV and GCV values in all the crosses studied but, wide difference between them were indicating the influence of environment on the expression of this trait in these crosses. This was in accordance with observations of Ganapathy *et al.* (2011). However broad sense heritability was low to moderate coupled with moderate genetic advance in all the crosses. These results of present study were in total agreement with earlier reports of Chaudhari and Acharya (1969), Setty *et al.* (1974) and Appadurai *et al.* (1977). However moderate to wider difference between the GCV and PCV values of this trait make itself less preferred for improvement of yield owing to its less genetic determination.

Finger width of main ear exhibited moderate to low PCV and GCV values for all the crosses under study. Difference between PCV and GCV was high for this trait which indicates the involvement of environment in its expression. However, broad sense heritability was moderate coupled with low genetic advance make itself less preferred for improvement of yield.

Weight of main ear exhibited moderately high to very high GCV and PCV in F₂ population of all the crosses. Wide difference is observed between PCV and GCV values indicating more environmental influence on expression of this trait. However, broad sense heritability was high coupled with high genetic advance in all four crosses. This can be attributed to the involvement of additive gene action in expression of this trait. The results of present study were in agreement with earlier reports of Venkatesh Bhat

(1991), Debelo (1998) and Mohan Prem Anand (2003). However, higher preference can be given to this trait in improvement of yield.

The 1000 seed weight exhibited low variability in terms of PCV and GCV in all crosses. In general there exists narrow range of difference between PCV and GCV, which reflects less influence of environment on the expression of this trait compared to other quantitative traits. However Prabhakar and Prasad (1984) noticed moderate to high variability for this character coupled with narrow difference between them. All the crosses registered moderate to high broad sense heritability coupled with low genetic advance. Same result was observed by Shanthappa (1979) and Nandini *et al.* (2010). Hence this trait can be used effectively for selection of desirable segregants

Grain yield per plant exhibited high variability in terms of both PCV and GCV in all the crosses studied. Wide difference observed between PCV and GCV values indicated more environmental influence on expression of this trait. However Chaudhari and Acharya (1969) have reported moderate values for both PCV and GCV. Broad sense heritability was moderate to high in all the crosses. However, genetic advance expressed as per cent of mean was high across all the crosses. Similar results were reported by Chaudhari and Acharya (1969) and Ratnakar *at el.* (2010) which they attributed to additive gene action. Thus present situation gives scope for further improvement of this trait.

5.2 Correlation studies in F₂ segregating population

Grain yield is the ultimate result of several complex characters, inheriting with one another and with the environment. Quite often component characters with yield are variably associated. Knowledge of association of different yield components with the yield and their interrelationships will help in improvement of yield through selection of components exhibiting strong favorable association.

Days to fifty per cent flowering registered strong and positive association with grain yield of main ear in cross III, earlier studies by Marimuthu (1997) confirm this. Whereas cross IV registered strong negative association, this is in agreement with the results reported by John (2007). Inter correlation with other trait shows the significant and positive correlation in cross III whereas, cross IV shows the strong and negative association. Because of its favorable associative nature with rest of the yield attributing characters, this trait can be taken into account during selection for improving total grain yield.

Plant height registered strong positive association with grain yield in all the crosses except in the cross IV. This result was strongly supported by earlier results by Patnaik, (1968), Chaudhari and Acharya (1969), Appadurai *et al.* (1977), Ranganathan *et al.* (1977), Sarvaiya *et al.* (1983), Harinarayana (1989), Krishana Reddy (1994) Ravikumar and Seetharam (1994), Malali Gowda (1996), Ramakrishana *et al.* (1996), Chunilal *et al.* (1996) Ravindran *et al.* (1996), Byre Gowda (1997) and Marimuthu (1997). With respect to phenotypic inter correlation of plant height with other traits it exhibited strong positive association with most of the traits such as, productive tillers per

plant, weight of main ear and 1000 seed weight. Thus positive association of plant height with many of the component characters make this trait favorable candidate for improvement of yield as well as characters to which it is strongly positively associated.

Productive tillers per plant exhibited strong positive association with grain yield per plant in two of the four cross i.e. cross III and cross IV. Thus confirms with earlier reports of Chaudhari and Acharya (1969), Appadurai *et al.* (1977), Ranganathan *et al.* (1977), Dinesh Kumar (1986), Shanthkumar (1988), Venkatesh Bhat (1991), Ravindran *et al.* (1996), Marimuthu (1997), Byre Gowda (1997) and Ganapathy *et al.* (2011). Productive tillers per plant exhibited positive association with most of the characters in general, However, Nandini *et al.* (2009) reported positive association of this trait with plant height and Ravikumar and Seetharam (1993) reported both positive and negative association of this trait with finger number and finger length on main ear in different crosses, which also partially agrees with results of present study. In general result suggested that productive tillers can be advantageously used as a criterion for selection to improve yield owing to its favorable intrinsic association with yield and other yield attributing traits.

Finger number on main ear exhibited positive association in all the crosses with grain yield per plant. This is in close agreement with the reports of Patnaik (1968), Chaudhari and Acharya (1969), Mishra *et al.* (1980), Krishana Reddy (1994), Haider *et al.* (1995), Ramakrishana *et al.*, (1996), Marimuthu (1997) and Debelo (1998), but contradicts with the observations of Appadurai *et al.* (1977) and Narsimha Rao and Pardhasardhi (1968b) and Das *et al.* (2013). Finger number per main ear exhibited positive but weak association with most of the characters in general, as a result this can also be considered as use full candidate in improvement of yield.

Finger length of main ear registered strong and positive association with grain yield of main ear in cross I but weak and positive association with cross II. This result is in agreement with the earlier reports of Patnaik (1968), Chaudhari and Acharya (1969), Mishra *et al.* (1980) Shantha kumar (1988), Venkatesh Bhat (1991), Purushotham Rao (1992), Ramakrshna *et al.* (1996), Byre Gowda (1997), Debelo (1998), Priyadharshini *et al.* (2011) and Ganapathy *et al.* (2011) who reported strong positive association of this trait with grain yield. Since this trait is weakly but negatively associated with most of the yield attributing characters, it was obvious that the finger length of main ear can't be considered as one of the selection criteria for improving the grain yield.

Finger width exhibited strong negative association with grain yield in cross II whereas, in cross III it exhibited positive and weak association with grain yield. This is in contradictory with the results reported by Shet *et al.* (2010) and Das *et al.* (2013) where they have reported positive association between finger width of main ear and grain yield. Finger width exhibited negative association with most of the yield attributing characters in general. Thus this trait cannot be considered as a usefull trait in improvement of grain yield

Weight of main ear exhibited strong and positive association with grain yield per plant for all crosses. This is in total agreement with the results reported by Dhagat *et al.* (1972). This trait exhibited high positive association with the 1000 seed weight in three of the four crosses. Favorable associative nature of this trait with the yield attributing trait makes this character preferable for improving grain yield.

The 1000 seed weight in majority of cases exhibited strong positive association with trait of interest i.e. total grain yield across all crosses. This result was supported by earlier works of Patnaik (1968), Mahudeswaran and Murugesan (1973), Appadurai *et al.* (1977), and Prabhakar and Prasad (1983). Hence, this trait is preferred for improvement of grain yield.

5.3 Path analysis in F₂ segregating population

The path analysis is a useful technique to understand more clearly the association among different variables as recorded by simple correlation values. It helps to partition the overall association of particular variables with dependent variable into direct and indirect effects. When the influence of a set of variables on the dependent variables is to be understood, it is possible with the help of path analysis to estimate the extent of direct contribution of particular variable and the extent of its indirect contribution through other variables in a set to the total influence it has on a dependent variable. While dealing with a more complex character like grain yield, it enables the breeder to specifically identify the important component trait of such a nature and differential emphasis can be laid on those characters for selection.

Days to 50 per cent flowering exerted moderately low positive direct effect on grain yield of main ear in cross I, moderately negative in cross II and cross IV and negative and negligible in cross II. These results were supported by Cauvery (1993), Marimuthu (1997), Malali Gowda (1996) and Nandini *et al.* (2009). However, its indirect effect through productive tillers per plant was high and positive in cross IV, whereas in cross I, II and III it was negative. This is in accordance with Kishan Reddy (1994) who reported, days to fifty per cent flowering had high negative indirect effect through productive tillers, weight of main ear and number finger on main ear. In cross IV, it exhibited high indirect effect. As this trait exhibited very low direct effect towards yield and high intrinsic association of this trait was due to indirect effect through other traits, which contributing indirectly towards grain yield as a result this phenomenon can be targeted for yield improvement rather than direct selection of this trait.

Plant height exhibited high positive direct effect on grain yield per plant in all crosses except cross II, where it has showed very low negative magnitude. Positive association of plant height with grain yield of main ear is attributed to its high indirect effect through 1000 seed weight followed by weight of main ear in cross I and cross III and also due to number of productive tillers and weight of main ear in cross IV. Shanthakumar (1988) reported moderate to high direct effect of plant height towards grain yield, and this is supported by Kishan Reddy (1994). Because of its positive direct effect towards grain yield, this trait can be considered selection criteria in improvement of yield.

Productive tillers exhibited moderate to high and positive direct effect on grain yield in cross I and cross II, whereas it is low to moderate negative effect in cross III and cross VI. This was in accordance with earlier reports of Chaudhari and Acharya (1969), Ravikumar and Seetharam (1993), Kishan Reddy (1994), Malali Gowda (1996) and Debelo (1998) for positive direct effect and Cauvery (1993) and Grish Kumar (1995) for negative direct effect of productive tillers on grain yield. Its positive association with grain yield of main ear was due to high indirect effect through 1000 seed weight and weight of main ear in cross III and cross IV. Thus the above results depicts the importance of productive tillers but not the exclusive choice as one of the important component for improvement of yield due to its poor contribution through direct effect.

Finger number per ear exerted high positive direct effect on grain yield in the entire crosses except cross I where it had shown low negative effect. This was in accordance with results reported by Shanthakumar (1988), Chunilal *et al.* (1996) and Byre Gowda (1997). Intrinsic association towards yield due to its indirect effect through weight of main ear, 1000 seed weight and productive tillers were observed positive in magnitude in cross IV. Interestingly, its indirect contribution through the other yield component is negligible in cross I and cross III. Thus this trait expresses itself through other yield attributing traits rather than itself to make up the yield and selection for those traits will be fruitful, when grain yield is our important character.

Finger length exhibited direct positive effect of moderate magnitude in cross I, II and in cross IV, whereas cross III shows negative and low magnitude. This was in accordance with Chaudhari and Acharya (1969), Mahudeswaran (1968), Marimuthu (1997) and ShanthaKumar (1988). Its indirect effect through the width of the finger was moderate and negative in cross I and cross II. However through the other characters the indirect contribution was negligible in cross I and cross IV. Thus the direct selection for this trait for the improvement of yield will not help for the breeder.

Finger width exhibited direct negative effect of moderate magnitude in all the crosses except in cross IV where it has shown direct positive effect towards grain yield. Its indirect effect through the other yield attributing characters was positive but with very low magnitude in all the crosses except in cross IV where it has negative indirect through plant height, finger number and finger length.

Weight of main ear exhibited high direct positive effect on grain yield per plant in all the crosses, and its indirect effect through other character was very low and positive/and negative magnitude. This result agrees with the earlier results of Dhagat *et al.* (1973), ShanthaKumar (1988), Basavaraja (1990), Naik (1991) and Marimuthu (1997). This indicates its immense importance in the selection programme for the improvement of yield.

Positive association of 1000 seed weight with grain yield attributed to its high direct positive effect in all cross. This was in accordance with the results reported by Nandini *et al.* (2009). Its indirect effect through weight of main ear, finger number days to 50 per cent flowering and plant height was high in cross I whereas, in cross II and

cross III indirect effect was low. Thus the direct selection for this trait for the improvement of yield helps for the breeder.

5.4 Screening for blast resistance

Blast disease caused by fungus *Magnaporthe grisea*, is one of the major factor that decreases the yielding ability of even an very good finger millet variety. In this present study F₂ segregants obtained by crossing high blast (neck and finger) resistance genotypes (GE 1409, GE 1462 and IE 2712) with cultivated high yielding varieties (Indaf 5, PR 202 and GPU 28) were scored for both finger and neck blast disease reactions.

Blast disease study revealed that more than 60 per cent of the segregants from cross IV registered highly resistance reaction for neck and finger blast. More than 65 per cent of the segregants from cross I and cross II registered resistance reaction for both neck and finger blast and nearly 70 per cent of segregants from cross III registered moderate resistance reaction for both neck and finger blast. However, the segregants exhibited variable reaction *viz.*, resistance, moderately resistant, moderately susceptible and susceptible reactions at variable frequency, where this can be attributed to segregation and recombination of the loci conditioning these traits. Majority of the segregants registered high resistant reaction, which may be attributed to the dominant gene action. This is in partial agreement with the results of Ravikumar (1988) who reported significant additive and dominant gene action for resistance, with later being predominant in control of neck blast whereas, for finger blast resistance, all the three type of gene action *viz.*, additive, dominance and their interactions were noticed. However, higher frequency of resistant reaction can also attributed to poor weather conditions *i.e.*, unfavorable for the proper development of disease prevailed during the flowering stage of the crop (Viswanath and Chennamma 1988 and Jain *et al.*, 1994).

5.5 Identification of desirable transgressive segregants

Recombination breeding is one of the important breeding method to incorporate the favorable quantitative and qualitative traits of both the parents in its progenies and selection in F₂ population where transgressive segregants occurs, which helps the breeder to pick out the favorable segregants.

In general, high frequencies of favorable segregants were identified in F₂ population of all the four crosses. However, among these crosses cross I registered highest percentage of favorable segregants for all the characters studied followed by cross II, IV and cross III which gives an idea about selection for favorable traits among these crosses.

Highest frequency of favorable transgressive segregants were found for 1000 seed weight in cross IV, weight of main ear in cross I whereas, grain yield per plant registered highest frequency of favorable transgressive segregants in cross I followed by II, III and IV. Cross III registered very low favorable transgressive segregants for days to fifty per cent flowering whereas cross IV registered lowest transgressive segregants for plant height. Within the cross I yield and yield attributing characters such as weight of main ear

and 1000 seed weight were registered favorable transgressive segregants, which indicates selection in this cross will helpful to improve these traits.

Within the cross II weight of main ear registered highest number of transgressive segregants followed by grain yield per plant, finger length and 1000 seed weight registered highest frequency of transgressive segregants. With respect to finger blast score, cross III registered highest value (74.89 per cent) followed by cross II (70.35 per cent), cross I (67.56 per cent) and cross IV (67.37 per cent). With respect to neck blast cross III registered highest value (86.46 per cent) followed by cross I (78.45 per cent), IV (78.38 per cent) and cross II (76.36 per cent).

Majority of the yield attributing traits like fingers on main ear, weight of main ear and 1000 seed weight along with grain yield per plant exhibited high magnitude of favorable segregants and can be attributed to segregation and recombination of the favorable loci from the parents.

Future line of work

Among all the crosses studied in this study, cross I (PR 202 X GE 1409) registered the highest number of transgressive segregants. So, transgressive segregants which are showing highly resistance and resistance reaction from this cross can be progressed to subsequent generations preferably in *kharif* seasons so as to screen desirable genotypes in terms of high yielding ability and blast resistance.

VI SUMMARY

The present investigation in F₂ population of four crosses of finger millet (PR 202 X GE 1409, PR 202 X IE 2712, GPU-28 X IE 2712 and Indaf 5 X GE1462) involving six parents was undertaken (i) to study the variability parameters, broad sense heritability and genetic advance for yield and its attributing traits: (ii) to study the character association of grain yield with its component traits and among themselves (iv) to estimate the direct and indirect effect of yield attributes which exhibit strong association with grain yield and (V) to identify superior segregants combining yield and blast disease resistance.

The F₂ population of all the four crosses chosen for the study were grown along with their parents at Zonal Agricultural Research Station, V.C. Farm, Mandya during *kharif* 2013. observations were recorded on 350 plants in each of the crosses in nine quantitative traits *viz.*, days to fifty per cent flowering, plant height, productive tillers per plant, finger number of main ear, finger length of main ear, finger width of main ear, weight of main ear, 1000 seed weight and grain yield per plant along with blast (finger and neck) disease scoring and the data were analyzed following standard statistical techniques except disease score.

In general, phenotypic coefficients of variation (PCV) were higher than genotypic coefficients of variation (GCV) for all the characters studied. High PCV and GCV values were obtained for characters like productive tillers, weight of main ear and grain yield per plant. Moderate values of these variability parameters were obtained for finger number, finger length of main ear, finger width of main ear and 1000 seed weight whereas, plant height and days to fifty per cent of flowering registered low value.

In general, plant height, fingers on main ear and grain yield per plant registered high broad sense heritability whereas, moderately high heritability was observed for weight of main ear, days to 50 per cent flowering and finger length of main ear. On the other hand, productive tillers per plant, 1000 seed weight and finger width registered relatively low value for this parameter.

Phenotypic correlation studies in general exhibited strong positive association of grain yield per plant with weight of main ear, 1000 seed weight and fingers on main ear. Finger number, plant height and Productive tillers exhibited moderate positive association with grain yield of main ear. However, its association with finger length and finger width of main ear was of very low in magnitude.

Phenotypic path coefficient analysis revealed high positive direct effect of weight of main ear, 1000 seed weight to the total grain yield per plant compared to other strongly associated yield attributing characters. Other traits like plant height and finger number on main ear registered moderate direct positive effect on grain yield. whereas, productive tillers per plant registered positive or negative direct or indirect effect on grain yield thus respectively increases or decreases the total intrinsic association towards yield. Finger length and finger width of main ear exhibited negligible positive direct and indirect

effect. Low residual effect of all the four crosses studied revealed the sufficiency of the characters selected to define the total grain yield.

Blast studies revealed the probable dominant gene action governing the disease resistance leading to high frequencies of favorable blast resistant segregants. In general, the cross I (PR 202 X GE 1409) registered high frequency of favorable transgressive segregants followed by II (PR 202 X GE 1409), IV (Indaf 5 X GE 1462) and cross III (GPU 28 X IE 2712) for all the characters studied.

In all the four crosses, superior segregants combining both for high yielding ability and blast resistance were identified in the F₂ populations, which can be advanced to further generations to study and select for their credibility.

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APPENDIX

Rainfall data of the year 2013 (Month wise)

Month	Total Rainfall (mm)
January	0.0
February	0.0
March	0.0
April	65.4
May	101.4
June	10.3
July	36.2
August	21.7
September	186.8
October	116.0
November	56.4
December	1.4