GENETIC VARIABILITY FOR MICRONUTRIENTS IN LOCAL LANDRACES OF RICE (*Oryza sativa* L.) GROWN UNDER AEROBIC CONDITION

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DEPARTMENT OF GENETICS AND PLANT BREEDING
UNIVERSITY OF AGRICULTURAL SCIENCES
GKVK, BENGALURU-65

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University of Agricultural Sciences, Bengaluru
in partial fulfillment of the requirements
for the award of the degree of

Master of Science (Agriculture)

in

GENETICS AND PLANT BREEDING

BENGALURU **JULY, 2018**

Affectionately Dedicated to
My Beloved Parents,
Brothers, Sisters,
Guide and Farmers

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

CERTIFICATE

This is to certify that the thesis entitled **"GENETIC VARIABILITY FOR MICRONUTRIENTS IN LOCAL LANDRACES OF RICE (*Oryza Sativa* L.) GROWN UNDER AEROBIC CONDITION"** submitted by **Ms. TRAN THI THAO NHU**, ID No. **PALB 6256** in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (AGRICULTURE) IN GENETICS AND PLANT BREEDING** to the University of Agricultural Sciences, Bengaluru is a record of *bonafide* research work carried out by her during the period of her study in this University under my guidance and supervision and no part of the thesis has been submitted for the award of any other degree, diploma, associateship, fellowship or any other similar titles.

BENGALURU
JULY, 2018

SHAILAJA HITTALMANI
(Major advisor)

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Bengaluru
July, 2018 *(TRAN THI THAO NHU)*

GENETIC VARIABILITY FOR MICRONUTRIENTS IN LOCAL LANDRACES OF RICE (*Oryza Sativa* L.) GROWN UNDER AEROBIC CONDITION

TRAN THI THAO NHU

ABSTRACT

Local landraces were evaluated for grain nutrients like protein, zinc, and iron content. Plant growth and yield attributing characters were also studied during *kharif* 2017 under aerobic condition. High phenotypic and genotypic coefficient of variation (PCV and GCV) was observed for grain yield per plant and moderate for the remaining traits. Heritability was high for most of the traits observed while moderate for harvest index and grain yield^{-1}. Genetic advance was high for majority of yield and its attributing traits and moderate for plant height, days to maturity and flag leaf length. Genetic advance as mean was high for grain yield per plant. Highly significant positive correlation was observed for grain yield plant^{-1} with plant height, total number of tillers, spikelet fertility, flag leaf length and test weight. Significant negative correlation was observed between zinc content and grain yield plant^{-1}. The phenotypic path-coefficient analysis indicated high, positive direct effect of total number of tillers, grain length, test weight and harvest index on grain yield plant^{-1}. Grain protein content had low direct effect on grain yield plant^{-1}. Genotypes, Marabatta, Jeerige Batta, Neerguli, Mugadh Sughanda, Kesarnellu contained high grain protein (13.63- 13.97 %) and zinc (30.17ppm) content compared to yield checks like MAS 946-1 and MAS26, but less than nutrient checks HP1, and HP9. Naga Batta had iron content of 15.72ppm which was comparable to check HP7 (15.21ppm). Among the superior nutrient landraces, Neerguli (25.42g), Jeerige Batta (22.16g), DBN (21.34g), Kesarnellu (20.31g) and Doddiga (20.03g) had high grain yield plant^{-1}.

July, 2018 (**SHAILAJA HITTALMANI**)
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ಅರೆ ನೀರಾವರಿ ಪದ್ಧತಿಯಲ್ಲಿ ಬೆಳೆದ ಭತ್ತದ ಸ್ಥಳೀಯ ಪ್ರಾದೇಶಿಕ ತಳಿಗಳಲ್ಲಿ ಸೂಕ್ಷ್ಮ ಪೋಷಕಾಂಶಗಳ ವೈವಿಧ್ಯತೆಯ ಬಗ್ಗೆ ಅಧ್ಯಯನ

ತ್ರಾನ್ ಥಿ ಥಾನ್ ನ್ಯು

ಪ್ರಬಂಧ ಸಾರಾಂಶ

ಭತ್ತದ ಸ್ಥಳೀಯ ಪ್ರಾದೇಶಿಕ ತಳಿಗಳಲ್ಲಿ ಸಸಾರಜನಕ, ಸತು ಮತ್ತ ಕಬ್ಬಿಣ ಅಂಶಗಳಂತಹ ಧಾನ್ಯ ಪೋಷಕಾಂಶಗಳನ್ನು ಹೋಲಿಸಲು ಮತ್ತು ಬೆಳವಣಿಗೆ ಹಾಗೂ ಧಾನ್ಯದ ಇಳುವರಿಗೆ ಸಹಕರಿಸುವ ಗುಣಲಕ್ಷಣಗಳನ್ನು ಮೌಲ್ಯಮಾಪನ ಮಾಡಲು ಮುಂಗಾರು–೨೦೧೭ ರಲ್ಲಿ ಅರೆ ನೀರಾವರಿ ಪದ್ಧತಿಯಲ್ಲಿ ಅಧ್ಯಯನ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಇದರಲ್ಲಿ, ಹೆಚ್ಚಿನ ಪಿಸಿವಿ ಮತ್ತು ಜಿಸಿವಿಗಳು ಧಾನ್ಯದ ಇಳುವರಿಯಲ್ಲಿ ಆದರೆ ಉಳಿದ ಗುಣಲಕ್ಷಣಗಳಲ್ಲಿ ಮಧ್ಯಮ ಮಟ್ಟದಲ್ಲಿರುವುದು ಕಂಡುಬಂದಿದ್ದು, ಪರಿಸರದ ಕಡಿಮೆ ಪ್ರಭಾವವನ್ನು ಸೂಚಿಸುತ್ತದೆ. ಹೆಚ್ಚಿನ ಗುಣಲಕ್ಷಣಗಳಿಗೆ ಅನುವಂಶೀಕತೆ ಹೆಚ್ಚಾಗಿದ್ದು ಆದರೆ ಸುಗ್ಗಿ ಸೂಚ್ಯಂಕ ಮತ್ತು ಧಾನ್ಯ ಇಳುವರಿಗೆ ಮಧ್ಯಮವಾಗಿದೆ. ಅನುವಂಶೀಕ ಮುನ್ನಡೆಯು, ಇಳುವರಿ ಹಾಗೂ ಇಳುವರಿಗೆ ಸಹಕರಿಸುವ ಗುಣಲಕ್ಷಣಗಳಲ್ಲಿ ಹೆಚ್ಚಾಗಿದ್ದು ಮತ್ತು ಸಸ್ಯದ ಎತ್ತರ, ಪಕ್ವತೆಯ ದಿನಗಳು ಮತ್ತು ಧ್ವಜದ ಎಲೆಯ ಉದ್ದಗಳಿಗೆ ಮಧ್ಯಮವಾಗಿದೆ. ಹಾಗೆಯೇ, ಪ್ರತಿ ಸಸ್ಯದ ಧಾನ್ಯ ಇಳುವರಿಯಲ್ಲಿ ಶೇಕಡಾ ಸರಾಸರಿ ಅನುವಂಶೀಕ ಮುನ್ನಡೆಯು ಹೆಚ್ಚಾಗಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಸಸ್ಯ ಎತ್ತರ, ಒಟ್ಟು ಕವಲುಗಳು, ಹೂ ತೆನೆಯ ಎಸಳಿನ ಫಲವತ್ತತೆ, ಧ್ವಜದ ಎಲೆಯ ಉದ್ದ ಮತ್ತು ಪರೀಕ್ಷಾ ತೂಕಗಳು, ಪ್ರತಿ ಸಸ್ಯದ ಧಾನ್ಯ ಇಳುವರಿಗಾಗಿ ಹೆಚ್ಚಿನ ಮಹತ್ವದ ಧನಾತ್ಮಕ ಪರಸ್ಪರ ನೇರ ಸಂಬಂಧವನ್ನು ಗಮನಿಸಲಾಯಿತು. ಸತುವಿನ ಅಂಶವು ಧಾನ್ಯದ ಇಳುವರಿಯೊಂದಿಗೆ ಮಹತ್ವದ ಸಕಾರಾತ್ಮಕ ಸಂಬಂಧವನ್ನು ಹೊಂದಿದೆ. ಹಾಗೆಯೇ, ಭೌತಿಕ ಪಥ–ಗುಣಾಂಕ ವಿಶ್ಲೇಷಣೆಯು, ಒಟ್ಟು ಕವಲುಗಳು, ಧಾನ್ಯದ ಉದ್ದ, ಪರೀಕ್ಷಾ ತೂಕ ಮತ್ತು ಸುಗ್ಗಿ ಸೂಚ್ಯಂಕಗಳಲ್ಲಿ ಹೆಚ್ಚಿನ ಧನಾತ್ಮಕ ನೇರ ಪರಿಣಾಮವನ್ನು ಸೂಚಿಸಿದೆ. ಧಾನ್ಯದ ಸಸಾರಜನಕ ಅಂಶವು, ಪ್ರತಿ ಸಸ್ಯದ ಧಾನ್ಯ ಇಳುವರಿ ಮೇಲೆ ಕಡಿಮೆ ಪರಿಣಾಮ ಬೀರಿತು. ಸಸಾರಜನಕ (೧೩.೬೩–೧೫.೯೫%) ಮತ್ತು ಸತು (೩೦.೧೭ ಪಿಪಿಎಮ್) ಗಳ ಪ್ರಮಾಣವು ಸ್ಥಳೀಯ ಪ್ರಾದೇಶಿಕ ತಳಿಗಳಾದ ಮರಭತ್ತ, ಜೀರಿಗೆಭತ್ತ, ನೀರ್‌ಗೋಳಿ, ಮುಗದ್‌ಸುಗಂಧ ಮತ್ತು ಕೇಸರನೆಲ್ಲುಗಳಲ್ಲಿ, ಇಳುವರಿ ತಪಾಸಣೆಗಳಾದ ಎಮ್‌ಎಎಸ್–೯೪೬–೧ ಮತ್ತು ಎಮ್‌ಎಎಸ್–೨೬ ತಳಿಗಳಿಗಿಂತ ಹೆಚ್ಚಿನ ಪ್ರಮಾಣ ಮತ್ತು ಪೋಷಕಾಂಶ ಅಂಶಗಳ ತಪಾಸಣೆ ತಳಿಗಳಾದ ಪೌಷ್ಟಿಕ–೧ (ಸತು) ಮತ್ತು ಪೌಷ್ಟಿಕ–೯ (ಸಸಾರಜನಕ) ಗಳಿಗಿಂತ ಕಡಿಮೆ ಪ್ರಮಾಣದಲ್ಲಿರುವುದು ಕಂಡುಬಂದಿದೆ. ನಾಗಭಟ್ಟ ಸ್ಥಳೀಯ ಪ್ರಾದೇಶಿಕ ತಳಿಯಲ್ಲಿನ ಕಬ್ಬಿಣದ (೧೫.೭೨ ಪಿಪಿಎಮ್) ಅಂಶವು, ಕಬ್ಬಿಣ ತಪಾಸಣೆ ತಳಿಯಾದ ಪೌಷ್ಟಿಕ–೭ (೧೫.೨೧ ಪಿಪಿಎಮ್) ಗಿಂತ ಹೆಚ್ಚಾಗಿದೆ. ಹೆಚ್ಚಿನ ಇಳುವರಿ ಪ್ರಾದೇಶಿಕ ತಳಿಗಳಲ್ಲಿ, ನೀರ್‌ಗೋಳಿ (೨೫.೪೨ ಗ್ರಾಂ), ಜೀರಿಗೆ ಭತ್ತ (೨೨.೧೬ ಗ್ರಾಂ), ಡಿಬಿಎನ್ (೨೧.೩೪ ಗ್ರಾಂ), ಕೇಸರನೆಲ್ಲು (೨೦.೩೧ ಗ್ರಾಂ) ಮತ್ತು ದೊಡ್ಡಿಗ (೨೦.೦೩ ಗ್ರಾಂ) ಪ್ರಾದೇಶಿಕ ತಳಿಗಳು ಹೆಚ್ಚಿನ ಪ್ರತಿ ಸಸ್ಯದ ಧಾನ್ಯ ಇಳುವರಿಯನ್ನು ಹೊಂದಿವೆ.

ಜುಲೈ, ೨೦೧೮

(ಶೈಲಜ ಹಿತ್ತಲಮನಿ)
ಪ್ರಧಾನ ಸಲಹೆಗಾರರು

ಅನುವಂಶೀಯ ಮತ್ತು ಸಸ್ಯ ತಳಿಅಭಿವೃದ್ಧಿ ಶಾಸ್ತ್ರ ವಿಭಾಗ
ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾನಿಲಯ, ಜಿಕೆವಿಕೆ, ಬೆಂಗಳೂರು–೬೫

Genetic variability for grain yield and grain quality characters in local land races of rice (*Oryza sativa* L.) grown under aerobic condition*

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Introduction

- Rice (*Oryza sativa*) is the world's most important staple food crop and more than two-third of the world's population depends on rice for their energy requirement.
- About 7.5 % of total rice production come from irrigated lowlands.
- Protein and micronutrients play an important role in human diet. Deficiency causes severe malnutrition and diseases. Protein content in rice varies from 6-8 % in grains. Most rice varieties developed are mainly for high grain yield with protein content of 7 to 8 % and low in Fe and Zn content.
- Productivity can be enhanced through better utilization of available germplasm resources while identifying nature and magnitude of gene action involved in the inheritance of yield and its attributes and there by genetically enhancing the potentiality of the germplasm resources. Along with product improvement, quality traits help to secure the nutritional requirement.
- The availability of genetically diverse germplasm is the basic need for the progress in plant breeding. Choice of parents for hybridization is one of the important considerations for creating new variability.

Objective

1. **To assess genetic variability for grain yield and grain quality characters among local land races of rice.**

Material and methods

- 50 local land races and five checks (MAS 946-1, MAS 26, HP1, HP7 and HP9) were evaluated in RCBD design with two replications at the experimental plots of the Department of Genetics and Plant Breeding at 'K' block, UAS, GKVK, Bengaluru, during *Kharif*-2017. Each genotype was grown in 2 rows with 10 plants per row. The spacing followed was 0.2m between plants within a row and 0.25m between rows.
- Observations were recorded on whole plant, panicle and grain characters such as plant height, days to maturity, number of tillers, number of productive tillers, seed fertility(%), flag leaf length (cm), panicle length (cm), grain length (mm), grain breadth (mm), grain length per breadth ratio, test weight (g), grain yield per plant (g).
- Variability for all the traits were assessed using diversity analysis (Mahalanobis, 1928).

Statistical analysis

- Genetic variability of 55 local land races was analyzed using Mahalanobis D^2 analysis.
- Variability parameters like mean, range, phenotypic coefficients of variation (PCV) , genetic coefficients of variation (GCV), heritability broad sense and genetic advancement as percentage of mean (GAM) were also calculated.

Fig 1: Field plant pictures of local land races of rice

Results

- Among the local land races, range of variation for plant height was from 66.60 cm to 155.60 cm, high heritability of 97.50% was recorded for this trait, range of days to maturity was form 135.00 to 169.00 days, number of productive tiller range form 11.00 to 24.60, the range of maximum grain length was 10.3 mm and the minimum was 6.2 mm, the grain breadth varied from 2.20 to 2.75 mm.
- Higher estimates (>15%) of GCV and PCV were observed for biomass per plant height, length/breadth ratio and grain yield per plant (Table 2). GCV and PCV estimates were moderate (<15%) for days to 50% flowering, days to maturity, productive tillers, panicle length, grain length and grain breadth.

Table 1: Comparative ANOVA for growth, yield and grain attributing of 55 local land races of rice

Source of variation	Degrees of freedom	Mean sum of squares									
		Days to 50% flowering	Plant height (cm)	Days to maturity	Productive tillers/plant	Seed fertility (%)	Panicle length (cm)	Grain length (mm)	Grain breadth (mm)	Length/ Breadth ratio	Grain yield plant¹ (g)
Replication	1	4.01	77.88	8.18	0.35	63.5	0.27	0.01	0.003	0	16.71
Genotypes	54	98.67***	121.62***	142.8***	15.19***	71.99***	8.37***	1.01***	0.293***	0.48***	47.08***
Error	54	2.38	34.95	13.39	2.06	12.3	1.42	0.001	0.001	0.002	17.32

Table 2: Descriptive statistics and genetic parameters for growth, yield, grain of 55 local land races of rice

Sl. No.	Characters	Mean	Range		ECV	GCV	PCV	h^2 (%)	GAM (%)
			Min	Max					
1	Days to 50% flowering	103.49	87.00	117.00	1.48	9.30	9.41	98.80	18.91
2	Plant height (cm)	117.58	66.60	155.60	5.03	14.90	15.73	97.50	29.09
3	Days to maturity	156.56	135.00	169.00	2.36	6.52	6.93	88.40	12.62
4	Productive tillers/plant	16.60	11.00	24.60	8.64	15.44	17.69	76.10	27.74
5	Seed fertility (%)	79.58	63.27	93.76	4.41	6.87	8.16	70.8	11.90
6	Panicle length (cm)	22.79	16.52	32.50	5.23	8.18	9.71	71.00	14.19
7	Grain length (mm)	8.32	6.20	10.30	0.37	8.54	8.54	99.80	17.57
8	Grain breadth (mm)	3.03	2.20	3.75	1.15	12.61	12.66	99.20	25.87
9	Length/Breadth ratio	2.80	2.17	4.37	1.64	17.48	17.56	99.10	35.86
10	Grain yield plant¹ (g)	17.95	5.82	34.6	23.18	21.48	31.60	46.20	30.09

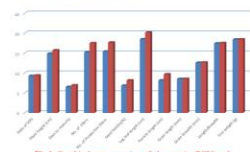

Fig 1. Graphical representation of phenotypic (PCV) and genetic (GCV) coefficients of variation

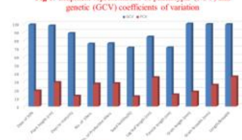

Fig 2. Graphical representation of heritability (h^2) and genetic advancement as percentage of mean (GAM)

Fig 3: Variation in grain of local land race of rice genotypes.
1: Bilidoddi 2: MAS 946-1 3: Doddiga 4: Dadda Mullare 5: Gud Batta 6: Gidda Rajakamala 7: Karihasali 8: Sanna Mullu

Discussion

- ANOVA showed highly significant differences among the genotypes for all the growth, grain and yield attributing characters indicating presence of wide range of variability in the local land races of rice
- The length and breadth of a rice grain are important attributes that determine the class of the rice. There are three main classes of rice, based on grain length: short, medium and long. The ratio of the length and the width is used internationally to describe the shape and class of the variety.
- GCV and PCV were comparable indicating lower influence of environment on the phenotypic expression.
- Higher h^2 (BS) coupled with GAM suggested that the traits can be improved through selection.

Summary

- There was significant genetic variability for all the quality characters studied, it gave scope for selection of suitable local land race as parents in crossing program.
- Higher heritability broad sense coupled with GAM suggested that the traits can be improved through selection for desired local land races.

Advisory Committee

Chairperson: Dr. Shailaja Hittalmani

Members :
Dr. Ramakrishna Parama
Dr. A Mohan Rao
Dr. Banu Deshpande

* Part of MSc (Agri) thesis, to be submitted to the University of Agricultural Sciences, Bengaluru; Presented in P G Science Week held during 28th - 31st May, 2018

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I. INTRODUCTION

Rice (*Oryza sativa* L.) is the staple cereal crop, which serves as a major carbohydrate source for more than half of the world population. In Asia, the daily intake of rice is very high and it is consumed three times a day to meet their calorie need. Since rice is low in protein and other micronutrients, malnutrition problem is widely prevalent in rice eating population. More than three billion people are affected by protein and micronutrient malnutrition. In addition, iron deficiency anemia is also a most common nutritional disorder found across the world in more than two billion people, mainly in developing countries where rice is a staple food. The recommended dietary allowance (RDA) have estimated that individuals between 25 and 50 years of age require 10–15 mg of iron and 12-15 mg of zinc per day, which is not met by many individuals (FAO/WHO, 2000). As a result, micronutrients deficiencies severely affect all age groups and populations, especially the children and woman of poor families. Hence, identification of genotypes with high protein, iron and zinc content is the need of the hour.

Developed countries are managing deficiency by adopting fortification programs, but some programs are not feasible in poor countries. Therefore, an alternative and less expensive strategy is to modify the nutritional quality of the major cereals consumed by the people. To improve the nutritional values of rice, research programs should be reoriented to develop high yielding cultivars with high nutrient content either by selective breeding or by genetic modification (Gearing, 2015). As the quantity of rice is consumed more in diet, the enhancement of grain protein is vital in nutrients balance. In addition, the quality of rice is also an important character to determine the economic value in the export market and consumer acceptance (Pingali *et al*., 1997).

Breeding in rice is mainly focused on grain yield rather than the nutritional enhancement to feed the large rice eating population. An increase in protein content would result in substantial increase in protein intake by a large number of consumers provided the quality of protein is not impaired (Rahman and Bahl, 1986). Hence, enhancement of total protein in rice is of immense importance for nutritional security.

Moreover, rice landraces could be of potential use as some of the landraces are known to contain high protein and other micronutrients.

Landraces harbour a great genetic potential for rice improvement (Kayode *et al.*, 2008). Unlike high yielding varieties, whose variability is limited due to homozygosity, landraces are maintained by farmers and endowed with tremendous genetic variability, as they are not subjected to subtle selection over a long period of time. This support in the adaptation of landraces to wide agro-ecological niches and they also have unmatched quality traits and medicinal properties. Landraces are precious genetic resources because they contain rich variability of agronomical important complex quantitative traits, which have not been widely utilized or incorporated into modern varieties. Thus assessing genetic variability for growth, yield and grain quality characters among the local landraces is an important step before starting crop breeding program to incorporate trait of interest.

Considering the above factors, the present investigation was carried out with the following objectives:

1. To assess genetic variability for growth and yield characters among local landraces.

2. To identify of local rice genotypes with variation for zinc, iron and grain protein content.

II. REVIEW OF LITERATURE

More than 50 % of the global population consumes rice as a staple food. Poor people in developing countries solely eat rice and they are rarely accessible to nutrient rich food sources to supplement rice. In fact, it supplies 23 *per cent* of global per capita energy and 16 *per cent* of protein. The consumption of rice is declining in developing countries because of its own limitation viz., low protein, fat and micronutrients especially Iron and Zinc. Thus, micronutrient malnutrition, so called hidden hunger has a serious impact on the human and plant nutrition. In this chapter available literature pertaining to the present investigation has been reviewed and presented under the following headings.

2.1. Importance of local landraces.

2.2. Aerobic cultivation.

2.2. Importance of Protein, Zinc and Iron.

2.3. Genetic variation for traits in local landraces.

2.4. Genetic variability for grain nutrients.

2.1. Importance of local landraces.

Local landrace is a local variety of a domesticated plant species which has developed largely by natural processes, by cultural environment and adaptation to the natural in which it lives. The landraces have particular traits, such as their adaptability to local conditions and constraints, which are not easily to found in the formal varieties. Local landraces are also known as traditional cultivars, local populations or farmer varieties, it provided a valuable resource for plant breeding as well as for the preservation of genetic diversity (Hanamaratti *et al.*, 2008). They are precious genetic resources, because they contain the huge genetic variability which can be used to complement and broaden the gene pool of advanced genotypes. The extent of genetic diversity in a crop population depends on recombination, mutation, selection and random genetic drift. Mutation and recombination bring new variations to a population, whereas selection and genetic drift remove some alleles, often from agronomically important lines. The use of adapted rice landraces, as the primary source of variation into which desired characters present in modern cultivars are introgressed may be an effective strategy for producing cultivars adapted to difficult production environments. The demand for productivity and homogeneity in crops has resulted in a limited number of standard, high-yielding varieties and a loss of heterogeneous traditional local varieties (landraces), a process known as genetic erosion. Landraces and older crop varieties preserve much of this lost diversity and comprise the genetic resources for breeding new crop varieties to cope with environmental and demographic changes (Esquinas-Alacazar, 2005). Rice landraces, maintained through traditional farming practices, possess high genetic diversity and specific traits such as disease resistance, environmental constraint tolerance and nutritional quality which are often used in crop improvement. Furthermore, landraces are adapted to local agro-environmental conditions which contributes to yield stability and hence, they continue playing an important role in traditional and subsistence farming. Thus, landraces of rice play a very important role in the local food security and sustainable development of agriculture (Rajesh *et al.*, 2010).

Landraces harbor a great genetic potential for rice improvement (Kobayashi *et al.*, 2006). Therefore, landraces of distinct genetic structure are a good promise for the future rice crop improvement. Landraces of rice played a very important role in the local food security and sustainable development of agriculture, in addition to their significance as genetic resource for rice genetic improvement (Tang *et al.*, 2002). They have provided “adaptability genes” for specific environmental conditions. Incorporation of such adaptability genes from landraces only could ensure optimum grain yield for the specific regions. Thus to maintain crop diversity for crop improvement program collection, characterization and conservation of traditional landraces is vital. Landraces are also important genetic resources for resistance to pest diseases and abiotic stresses, which have not been widely utilized or incorporated into modern varieties.

In tropical Asian countries such as India, few of the traditional native landraces are still under cultivation by resource poor farmers who practice subsistence farming (Ram *et al.*, 2007).

Although less productive, these landraces have shown excellent adaptation to local conditions and they are known to harbour great genetic potential for rice improvement, particularly for stress tolerance and quality (Huang *et al*., 2010).

Rice (*Oryza sativa* L.) landraces play a pivotal role in rural food, especially in hill and mountain areas where modern technologies are not commonplace. Local landraces are adapted to specific niches, where they out-compete modern varieties. Landraces such as Basmati and Sathi are culturally important, being used during feasts and festivals. These examples demonstrate the importance of local landraces in food security and the local economy. In situ conservation and participatory plant breeding are important for production of site-specific varieties that meet the requirements of local farming communities. However, loss of rice diversity continues. To redress this situation, immediate action needs to be taken towards conserving valuable landraces on-farm.

Rice landraces, maintained through traditional farming practices, possess high genetic diversity and specific traits such as disease resistance, environmental constraint tolerance and nutritional quality which are often used in crop improvement (Camacho-Villa *et al*., 2005). In tropical Asian countries such as India, few of the traditional native landraces are still under cultivation by resource poor farmers who practice subsistence farming. Although less productive, these landraces have shown excellent adaptation to local conditions and they are known to harbour great genetic potential for rice improvement, particularly for stress tolerance and quality (Huang *et al*., 2010). Therefore, there is a need to characterize available landraces has become important in modern day crop improvement.

2.2. Aerobic cultivation.

In the water scarce situation of present day, it has become necessary to adopt a system of cultivation which is profitable, feasible and results in no yield compensation.

Yagi *et al*. (1997) proposed that methane gas emission can be mitigated by better water management, organic matter management, soil amendments *etc*. Alteration in water management promoting midseason aeration is one of the promising strategies.

Scarcity of water necessitates the development of promising varieties of rice that can be cultivated successfully in non-flooded and non-saturated soil under supplemented irrigatio

n. The varieties have to be tested for their yield potentials and water use. Aerobic rice holds a promise for farmers who do not possess enough water to grow flooded lowland rice (Bouman *et al.*, 2005). HD502 and HD297, aerobic rice varieties were found suitable for water scarce environment (Xiaoguang *et al.*, 2004).

Haradari and Hittalmani (2017) reported that alternately submerged and non-submerged rice can reduce water consumption up to 15% on shallow groundwater fields without affecting the yield.

Six rice genotypes (*Oryza sativa* L.) showed lower zinc uptakes, biomass production, grain yield and zinc-harvest index under aerobic condition in calcareous soils. Aerobic rice systems may increase zinc deficiency problems in calcareous soils (Gao *et al*., 2009).

Germplasm screening is the initial step for a breeding program to raise grain Zn concentration, and to achieve breeding objectives there should be a wide genetic variation in grain Zn concentration. Substantial genetic variation of Zn concentration in brown rice (13.5–58.4 mg kg^{-1}) has been reported in a large collection of rice germplasm at the International Rice Research Institute (IRRI), with an average of 25.4 mg Zn kg^{-1} (Boonchuay *et al*., 2013). The world's first Zn enriched rice variety was released in 2013 by the Bangladesh Rice Research Institute (BRRI dhan- 62), which is claimed to contain 20–22 mg Zn kg^{-1} for brown rice. Nonetheless this is well short of the target of 30 mg Zn kg^{-1} set by the HarvestPlus program. Zn biofortification can be improved by drawing on under-utilized genetic materials.

Rice is cultivated in several diverse ecosystems namely, upland, rain fed lowland, flood prone and irrigated conditions. The variations and deviations in climatic factors brought water unavailability to rice cultivation which led to reduction in the production and productivity. To keep up the rice production during the water shortage regime, alternate cultivation methods of rice is essential and necessary. One of such alternative option is cultivation of rice under aerobic condition (Kahani and Hittalmani, 2015a).

Aerobic rice could be successfully cultivated with 600 to 700 mm of total water in summer and entirely on rainfall in wet season (Shailaja Hittalmani, 2007a, 2007b)). New varieties specially bred for this situation are most suitable for such cultivation to achieved high yields (Shailaja Hittalmani, 2008). Varieties suitable for this type of cultivation also possess ability to withstand intermittent drought spells with minimum yield loss with maximum potential of 6 tons per hectare. Irrigation is given at an interval of 5 days up to 25 days; 5-7 days once up to 50 days and during grain filling stage irrigation is provided once in 3 days. Aerobic cultivation with suitable varieties saves about 50-60 *per cent* of irrigation water. It is also reported that amount of methane emitted under aerobic situation is very low and contributes to lowering of greenhouse gas emission (Shailaja Hittalmani, 2007b; Anon, 2008).

New aerobic rice varieties MAS 946-1 and MAS 26 were bred and were released in 2007 and 2008 respectively at Marker Assisted Selection Laboratory, Department of Genetics and Plant Breeding for South Eastern Dry Zone of Karnataka following farmer participatory breeding and selection. The varieties which are the progenies of the cross between upland and lowland cross have the high yielding traits from lowland rice and stress tolerant character of the upland line and maintain rapid growth in soils with moisture content at field capacity or below. They have good root systems, plant stand and vigour and tolerate brief water stress at both vegetative and reproductive stages. They mature in 115 to 120 days duration and yields 5.5 tons of grain and 6 tons of fodder yields per ha (Gandhi *et al.*, 2012).

2.3. Importance of Protein, Zinc and Iron.

Micronutrients deficiency is a global problem contributing to world’s malnutrition. This in turn leads to high rate of women and children mortality (Anon., 1996). Mineral deficiencies in human populations are one of the greatest health concerns given that half the current population of the world is affected by some sort of mineral deficiency (Pfeiffer and Mcclafferty, 2007).

In addition to protein, micronutrients play an important role in human nutrition. Iron deficiency is the most common nutritional disorder in the world as anaemia was found across the world in more than two billion people, mainly in developing countries. The daily dietary protein requirement of normal Indian man and women is 55 – 60 mg (Gopalan *et al.*, 2014). The RDA of iron and zinc for man is 17 mg and 12 mg respectively and for women it is 21 mg and 10 mg respectively. As a result, micronutrients deficiencies severely affect all age groups and populations, especially the children and woman of poor families.

Protein energy malnutrition affects 25% of children where their dietary intake is mainly on rice and staple crops have low levels of essential amino acids (FAO, 2010). Therefore, attempts to improve the nutritional value of rice have been concentrated on protein content and other nutritional quality. Rice grain supplies about 40% of the protein to human through diet in developing countries and lysine about 3.8 % which is one of the essential amino acids.

The chemical composition of rice is influenced to some extent by genetic and environmental factor. The major carbohydrate of rice is starch (72- 75 %). The protein content ranges from 10.9 – 13.8 % which is slightly lower than that of wheat. The protein of husked and polished rice have a lower biological value but a higher digestibility. The nutritive value of rice proteins is of high order, being superior to that of wheat and other cereal proteins. They are deficient in lysine and threonine. Polished rice is poor in calcium and iron (Manay and Shadaksharaswamy, 2005).

The micronutrients Iron, Zinc, and Copper are essential for plants, humans and animals that consume plants. Increasing the micronutrient density of staple crops or bio fortification will greatly improve human nutrition on a global scale and translocate micronutrients through the plant to the developing seeds and potential strategies for developing bio fortified crops (Waters and Sankaran, 2011).

More than 60 *per cent* of the world population suffers from iron deficiency, and over 30 *per cent* of the global population has zinc deficiency. A multipronged strategy towards enhancing mineral content of cereal grains should involve increased uptake of minerals from soil, enhanced partitioning towards grain and improved sequestration in the edible tissues of grain. (Rawat *et al.,* 2013).

Zinc is the second most abundant transition metal in living organisms (after iron), and has important characteristics. Zn is a strong Lewis acid with high binding affinity to soft (sulphide ligands) and hard (amino, carboxylate, and hydroxyl ligands) bases. Zn occurs in a single oxidation state (Zn^{2+}) and does not catalyze free radical formation. Its most common coordination geometry is tetrahedral, which generally represents the optimal Zn complexes in protein cavities as Zn fingers and enzymes (Broadley *et al.*, 2007).

Zinc play a key role in plants with enzymes and proteins involved in carbohydrate metabolism, protein synthesis, gene expression, auxin (growth regulator) metabolism, pollen formation, maintenance of biological membranes, protection against photo oxidative damage and heat stress, and resistance to infection by certain pathogens.

The zinc deficiency has serious wide-ranging health consequences and is thought to be one of the most prevalent micronutrient deficiencies in the world. However, reliable indicators or biomarkers to assess zinc status are not available at present. Indirect indicators such as the prevalence of stunting or anemia, iron deficiency, as well as more direct indicators such as plasma zinc concentrations are being used at present to estimate the prevalence of zinc deficiency in populations. Zinc deficiency among children is four times more prevalent than iron deficiency and 2.3 times more than stunting prevalence (Wieringa *et al.,* 2015).

Iron is an essential micronutrient for almost all living organisms including bacteria, yeast, plants, and animals. Iron deficiency is a major micronutrient deficiency affecting an estimated 30 *per cent* of the global population and causing around 0.8 million deaths annually (World Health Organization, 2002).

Iron is an essential micronutrient for all plant species and its deficiency severely impairs plant growth and development. In humans, iron is needed to support the daily synthesis of the 200 billion red blood cells derived from reticulocytes, which synthesize massive quantities of haemoglobin. Despite its abundance in mineral soils, it is often not readily available to plants, especially under neutral to alkaline conditions. Plants, like other organisms, require Fe as an essential micronutrient. It is needed for numerous functions such as mitochondrial electron transport, hemi biosynthesis and function, Fe-sulfur (Fe-S) cluster synthesis, chlorophyll biosynthesis, and photosynthetic electron transport (Bashir *et al*., 2013).

Commercially, white rice is preferred by rice industries and farmers because the oil-rich aleurone layer renders brown rice prone to rancidity during long storage. However, the aleurone layer and the embryo are the major Fe sinks in brown rice, and more than 70 *per cent* of micronutrients are removed during the polishing process (Sellappan *et al.*, 2009).

2.4. Genetic variation for traits in local landraces.

Thirty-seven rice genotypes were evaluated for their variability with regards to yield and yield components. Estimates of heritability and genetic advance in percent of mean were also obtained for the above traits (Ajmera *et al.*, 2017). All the characters under study except days to fifty percent flowering exhibited high heritability coupled with high genetic advance as per cent of mean, which indicated that these traits were controlled by additive type of gene action in the inheritance of these characters. These characters can be further improved by following simple selection procedure. The high estimates of heritability coupled with low genetic advance as percent of mean for days to 50 *per cent* flowering indicated the presence of non-additive gene effects, in addition to influence of environment to some extent, hence its response to selection would be poor.

The estimates of genotypic coefficient of variation (GCV) for days to maturity, plant height and grain breadth were moderately phenotypic coefficient of variation (PCV) for days for 50 *per cent* flowering, days to maturity, panicle length and grain breadth and low PCV for grain length and test weight was reported by Abebe *et al*., 2017. Further, moderate heritability and genetic advance was reported for grain yield.

Significant positive association of biological yield and panicle weight with grain yield was reported by Thakur *et al*. (2000). Positive correlation of grain yield with single panicle weight, number of grains per panicle and number of primary rachis. A significant and positive association of plant height with panicle length at both genotypic as well as phenotypic level was observed. Nagabhushan (2003) reported significant and positive association of grain yield with number of tillers and negatively and significant correlation of plant height with number of tillers per plant.

Madhusudhan (2001) reported low GCV for days to 50 *per cent* flowering, grain length and grain breadth. Low PCV was observed for days to 50 *per cent* flowering, days to maturity and grain length; whereas, moderate PCV was noticed for panicle length and grain breadth. Low heritability was observed for productive tillers per plant, grain length and grain breadth.

Several national and international projects are addressing Zn biofortification of edible crops. The target Zn concentrations set by the Harvest Plus program are 28μg g^{-1} dry matter (DM) in polished rice, 38 mg kg^{-1} DM in wheat grain, 38 mg kg^{-1} DM in maize, 66 mg kg^{-1} DM in pearl millet, 56 mg kg^{-1} DM in beans, 34 mg kg^{-1} DM in cassava roots, and 70 mg kg^{-1} DM in roots of sweet potatoes (Bouis and Welch, 2010). These target concentrations are considered to be conservative, and have been exceeded in breeding lines of rice, wheat, and maize (White and Brodley, 2011).

Zeng *et al.* (2005) showed that the genetic diversity index is greater for Japonica accessions when compared to Indica accessions in a study conducted using 653 brown rice germplasm accessions.

Classification of rice genotypes using various grain characters viz., length, shape, 1000 grain weight, profile value (width) and hulled grain characters like shape, colour and vitreous characters has been made by Bhattacharya *et al.* (1982).

Chauhan *et al*. (1987) observed significant differences among different varieties of rice for all physical characters and suggested the use of grain size and weight as major identifying traits.

Naidu *et al*. (1986) classified 20 rice varieties into slender, medium and bold classes based on grain length to breadth ratio.

Sarma *et al*. (2004) reported that length to breadth ratio in rice varieties ranged from 3.1 to 4.2. A greater variation in length to breadth ratio from 2.7 to 4.1 which was found useful in classifying 25 rice varieties. Grouped 85 rice varieties based on colour of hulled grain, vitreous characters, length, shape, profile value (width), 100-grain weight, presence or absence of pearl spot and shape of the pearl spot. Classification of rice varieties using grain characters such as kernel length, breadth, length to breadth ratio, grain thickness, area and volume.

Chauhan (1996) evaluated 29 upland rice cultivars for variation in physical traits and found that the range of variability was moderate for kernel length (4.20 mm to 6.64 mm) and breadth (1.94 mm to 2.56 mm), but it was high for length to breadth ratio (1.89 to 3.15) and 1000 grain weight (19.6 g to 29.6 g) which suggested that such characters must be used precautiously for grouping rice cultivars.

2.5. Genetic variability for grain nutrient.

Rice has been rightly considered as the queen among cereals for its nutritional quality and higher digestibility. Minerals present in rice like zinc, manganese, iron and copper play an important role in body regulatory functions other than cadmium and lead. A definite difference exists between varieties of brown and white rice in vitamins, minerals, and fiber and fat contents. Seeds contain chemical substances that are stored as food reserves to accommodate germination. The major storage substance in seeds is carbohydrate, which is a common food reserve. Protein comprise valuable food storage component and great majority of seed protein is metabolically inactive and serve merely as food reserves for the growing embryo during germination.

Anjum *et al*. (2007) studied the protein and mineral content in four coarse rice varieties namely Irri-6, Irri-9, Sarshar and DR-83. The highest protein content was observed in the rice cultivar Sarshar (8.80%) followed by Irri 6 (8.77%). The mineral contents like Iron, zinc, manganese, copper ranged from 1.57 to 1.94 mg/100g, 1.44 to 2.97 mg/100g, 1.57 to 2.33 mg/100g and 0.58 to 0.92 mg/100g among different varieties. They concluded that the rice varieties Sarshar and Irri-6 must be given more attention by the rice breeders to use in their hybridization programs as these varieties exhibit more proteins and minerals which are required to maintain normal body metabolism.

Banerjee and Chandel (2011) assessed the protein content in 258 milled rice grains. The protein content among the rice landraces ranged from 4.91to12.08 % with the mean of 6.63 %. Fifty-two were found with < 6.0% protein, two hundred two landraces were found to possess protein levels between 6.0 to 9.0% whereas, four lines were with >9.0% of grain protein. Further, Pramila *et al*. (2011) also estimated the Zn and Fe content in 12 rice genotypes. The entry MAS 946-1 recorded significantly higher soluble seed proteins (5.86%), Zn (88.65 mg/kg) and significantly higher soluble sugar was recorded in MAS 946 (18.29%) whereas, Fe content was high (131.30 mg/kg) in PB 26.

Vanitha *et al*. (2015) evaluated sixty rice genotypes for zinc deficiency tolerance and yield traits under aerobic condition, and found nine rice genotypes with increased yield and suitable for zinc deficiency tolerance under aerobic cultivation. Genetic parameters estimated showed that the highest genetic and phenotypic coefficients of variations were observed for zinc score, plot yield, plant harvest index and vegetative vigour. Also, high heritability accompanied by high genetic advance as per cent of mean was observed for zinc score, plant height, plant harvest index, 100 grain weight and plot yield. Based on these results, authors concluded that selection for any one of the above characters would bring in simultaneous improvement of other characters and ultimately improving the grain yield.

Susanto *et al*. (2017) compared the Zn content of 22 rice genotypes, developed at IRRI and ICRR, in an experiment in the Cirebon district of West Java (Indonesia). Yield and grain Zn content (using an XRF machine) were measured. Five lines had similar grain Zn content to the check variety Ciherang (23.4 ppm), ranging from 19.0 to 24.8 ppm. On the other hand, seven lines had higher grain Zn content (ranging from 30.0 to 34.2 ppm) compared to Ciherang, and five of these lines had comparable yield to Ciherang. The selected lines had acceptable agronomic traits, hence providing a foundation for future improvement in the dual goals of increasing the yield and nutritional value of rice.

Zn content in rice grains varies from variety to variety and has been reported from many scientists. Qui *et al.* (1995) reported a higher variability in mineral contents in some rice cultivars and the level of Fe content varied from 15.41 mg kg^{-1} to 162.37 mg kg^{-1} and Zn content ranged from 23.92 mg kg^{-1} to 145.78 mg kg^{-1}.

Wang *et al.* (1997) reported that average Zn content in grains was 3.34 mg per 100 g and varied between 0.79 mg/100 g and 5.89 mg/100 g in 57 rice genotypes. Highest grain Zn content and lowest grain Zn content were reported in Ganjay Roozy, a variety grown at Indian Agricultural Research Institute (IARI) and Long, a Chinese fragrant rice respectively.

Genotypic variation for micronutrient accumulation in grain have been reported in staple crops such as rice (Gregorio *et al*., 1999; Zhang *et al*., 2004), wheat (Ortiz-Monasterio and Graham, 2000; Balint *et al*., 2001) and maize (Arnold and Bauman, 1976; Banziger and Long, 2000) and bean (Moraghan and Grafton, 1999).

Graham *et al.* (2000) screened 1000 rice genotypes in International Rice Research Institute (IRRI) and reported that concentration of grain Zn was varied from 15.3 to 58.4 ppm and grain Fe concentration was varied from 6.3 to 24.4 ppm. High Fe and high Zn content has been linked to aromatic varieties such as Jasmine and Basmathi.

Gregorio and Htut, (2003) reported that study the genetics of trace mineral accumulation in the grain is essential to determine the best selection techniques for use in breeding. High grain zinc and iron traits need to be combined with improved agronomic traits like grain number etc. This is demonstrated with the development of aromatic variety (IR68144-3B-2-2-3) that has a high concentration of grain Iron, about 21 mg/kg in brown rice which is about 80% more Iron than IR64, a widely grown commercial variety.

IR68144-3B-2-2-3, a hybrid developed by IRRI by cross between a high yielding variety (IR72) and a tall, traditional variety from India (Zawa Bonday) was reported by Bouis., 2001 as an elite line also has good grain quality, high yielding having 21 ppm of grain Fe and 34 ppm of grain Zn.

Large genetic variation for grain Zn content in rice germplasm accessions has been reported. This variation can be exploited in breeding programs to enhance Zn content in grains (Welch and Graham, 2004).

Plant breeding is the most reliable, sustainable and cost-effective approach among all strategies for improvement of grain Zinc content in rice (Marschner, 2008).

Martínez *et al*. (2010) were reported 11,400 rice samples collected in local stores and supermarkets in Colombia, Bolivia, Nicaragua and the Dominican Republic were evaluated for Fe and Zn content during 2006 - 2009 in brown and milled rice samples and 2 – 3 ppm for Fe and 16 – 17 ppm for Zn in milled rice, whereas values for brown rice were 10 – 11 ppm for Fe and 20 – 25 ppm for Zn.

Nagarthna *et al.* (2010) reported the presence of wide genetic variation for grain Zn content in rice with a variability ranging between 84 to 5.00 mg/ 100 g dry weight.

In the study conducted using 25 rice genotypes by Singh *et al.* (2010), grain Zn was varying from 30 to 64 ppm. Among all genotypes, Dular was showing highest grain Zn content whereas, Selection New 2 was having lowest grain Zn content.

Fe and Zn of traditional rice genotypes were significantly higher than those of improved cultivars (Anandan *et al.,* 2011).

Moyano *et al.* (2016) investigated associations of increased grain Fe and Zn concentrations with agro-morphological traits of backcross twice second filial (BC_2F_2)

transgenic progeny carrying *OsNAS1* or *OsNAS2* overexpression constructs under *indica/japonica* and *japonica/japonica* genetic backgrounds.

Higher iron content trait is expressed in all rice environments tested such as dry season in normal and saline soils, in acid and neutral soils were reported by Graham *et al*., 1999. Genotype generally varied much more with grain iron content, than with environment and genotype x environment interactions.

Liu (1998) reported higher variability in mineral contents like Zn, Fe, Mn, and P in black rice than almost white rice genotypes.

Nagabhushan (2003) reported positive significant association of grain yield with the number of tillers and negative significant correlation coefficient of plant height with number of tillers per plant.

Martinez *et al*. (2006) was given nine genotypes of rice were evaluated for zinc and iron content in rice grain at IRRI, found a range of 8.8 to 21.0 ppm, 14.0 to 40.0 ppm for iron, and zinc respectively.

Total variability of a trait is divided into genotypic variability and phenotypic variability. The estimate of variability suggests the variation in heritable portion of a trait that could be transferred from parent to offspring in response to selection (Hallauer and Carena, 2009; Lakshmana *et al*., 2009).

The Fe and Zn contents in grains of traditional rice genotypes were significantly higher than those of improved cultivars (Anandan *et al*., 2011). On the primary of grain zinc content, rice genotypes could be grouped into three categories, high (greater than 25 ppm), moderate (14 ppm – 24 ppm) and low (less than 14 ppm).

Thakur *et al*. (2000) reported significant positive association of biological yield panicle weight, number of grains per panicle and number of primary rachis with grain yield.

There are several defined classes of rice; based on the physical appearance, cooking properties and the aroma of the cooked rice. Therefore, quality evaluation programs should go hand-in-hand with breeding programs for higher grain yield per plant. Grain size, its uniformity and test weight determine the class of the rice. Head rice yield, colour (whiteness and translucence), chalkiness, the opaque area in the rice grain and cracks are the traits that decide the physical property of grain.

Amylose content, gelatinization temperature, texture of cooked rice flavour and aroma decides the cooking and eating characteristics of rice. Amylose content is important because firmness and stickiness are two properties of cooked rice that influence consumer preference and use of different classes of rice. Fragrant rice contains particular compounds that give the rice flavour which is produced by volatile compounds, many of which are volatilised during cooking to produce an aroma.

Breeding in rice is mainly focused on grain yield rather than the nutritional enhancement to feed the large rice eating population. As rice is a major source of food protein in Asia and other countries where the daily intake of rice is high, its value as a protein source is enhanced by its high lysine content compared to other cereal grains. However, the main limitation of rice as a protein source is its less protein content (6 to 8 *per cent*). As such protein deficiency is predominant in rice consuming population. An increase in protein content would result in substantial increase in protein intake by a large number of consumers provided the quality of protein is not impaired. Hence, enhancement of total protein in rice is of immense importance for nutritional security. Identification for high protein source in rice is difficult. In this connection use of DNA markers linked to protein could help in screening large number of germplasm.

Correlation coefficient analysis helps to determine the nature and degree of relationship between any two measurable characters. But measure of correlation does not consider dependence of one variable over the other.

Direct contribution of each component to the yield and the indirect effects it has through its association with other components cannot be differentiated from mere correlation studies. But this can be studied using path coefficient analysis and high phenotypic and genotypic coefficient of variation for number of tillers per plant, grain yield per plant, total biomass per plant, harvest index. It was first developed and described by Wright (1921).

Zhang *et al*. (2005) showed that improvement of micronutrient contents could be accomplished by making selection through grain characteristics in the black rice. It was found that selection of narrow and small grain tends to increase Zn, Mn and P contents; long grain tends to increase Fe and Mn contents, short grain tends to raise Zn and P contents.

Kumar *et al*. (2001) showed significant positive correlation between grain Fe and Zn contents for sorghum lines indicating that either genetic factor for Fe and Zn contents are linked, or physiological mechanisms were interconnected for Fe and Zn uptake/translocation in the grains. On the other hand, they found that grain Fe and Zn contents showed significant negative correlation with grain yield but genetic enhancement for grain Fe and Zn contents does not have yield penalty.

The high genetic correlations between grain characteristics and some mineral element contents can be used to conduct indirect selection of a grain characteristic for mineral element content in a breeding program (Bekele *et al*., 2013).

According to Nagesh *et al*. (2012) grain length, number of productive tillers per plant, number of grains per panicle, test-weight had highest positive direct effect towards grain yield while L/B ratio, grain breadth and days to 50 *per cent* flowering had highest negative direct effect for grain yield. Other traits like days to maturity, plant height, panicle length, tillers per plant and grain zinc content had moderate to low direct effects on grain yield. Among indirect effects, grain breadth had highest indirect effect via length to breadth ratio.

Nagesh *et al*. (2012) observed that grain yield was positively correlated with number of productive tiller per plant, test weight and number of grains per panicle. A positive correlation between iron and zinc content was observed while there is no correlation between grain iron and zinc content with grain yield. According to them path analysis revealed the highest direct effect of test weight on grain yield followed by number of productive tillers per plant and iron content.

III. MATERIAL AND METHODS

EXPERIMENT-I:

To assess variability for grain characters among local rice genotypes.

3.1. Experimental materials

The material for this study consisted of 55 local landraces of rice, collected from different agro-ecological regions of Karnataka and are maintained in the Department of Genetics and Plant Breeding, UAS, Bangalore (Table 1). These landraces were evaluated for genetic variability parameters for grain yield and its component traits during *kharif*-2017 at the experimental plots of the Department of Genetics and Plant Breeding, 'K' block, UAS, GKVK, Bengaluru (Plate 1).

Table 1: List of 55 local landraces and checks used for the study

Sl. No.	Landraces	Sl. No.	Landraces	Sl. No.	Landraces	Sl. No	Landraces
1	Alibulla	16	Gowri Sanna	31	Karidoddi	46	Mattalaga
2	Alugidda	17	Gidda Rajakamala	32	Rajmudi-1	47	Mugadhsughanda
3	Anthrasali	18	Gud Batta	33	Kesarnellu	48	Sannakki Batta
4	DBN	19	Halu Gidda	34	Kirwana	49	Neermullare
5	Biliakki	20	Howne Kattu	35	Marabatta	50	Sanna Mullu
6	Biliakki-1	21	Jaddu Batta	36	Neergoli	**Checks**	
7	Bilidoddi Marthayala	22	Jeerige Batta	37	Malligae	51	MAS 946-1
8	Rajmudi	23	Kadullite	38	Mysore Malligae	52	MAS 26
9	Bilidoddi	24	Kaduvelpe	39	Putta Batta	53	HP 1
10	Budda	25	Kalajeera	40	Raj Bhog	54	HP 7
11	Coimbatore Sanna	26	Kalu Mottaga	41	Naga Batta	55	HP 9
12	Dodda Batta	27	Karihasali	42	Navasali		
13	Dodda Mullare	28	Kari Kondaga	43	Sampigae Batta-1		
14	Dodda Mullare-1	29	Kanakasali	44	Sampigae Batta-2		
15	Doddiga	30	Karijaddu	45	Sanesali		

3.2. Methods

3.2.1. Experimental layout

The 50 landraces and 5 checks (MAS 946-1, MAS 26, HP1, HP7 and HP9) were sown in Randomized Complete Block Design with two replications. The spacing of 25cm between rows and 20cm between plants was followed.

3.2.2. Recording of phenotypic observations

Observations were recorded from each plant and means of the five plants for each trait was used for statistical analyses. The characters observed are as shown below.

3.2.2.1. Date of sowing

The date of sowing of the seed material in the field was recorded which is a reference for further observations.

3.2.2.2. Days to 50 *per cent* flowering

This is total number of days taken by each genotype from sowing to opening of 50 *per cent* flower of the plants.

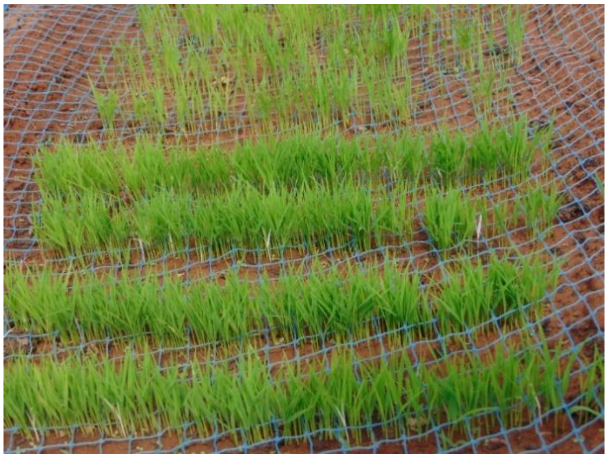
3.2.2.3. Plant height at 60 days after sowing (cm)

The height of the plant was taken from the base of the plant to the tip of the main panicle and expressed in centimeter at 60 days after sowing.

3.2.2.4. Plant height at 90 days after sowing (cm)

The height of the plant was taken from the base of the plant to the tip of the main panicle and expressed in centimeter at 90 days after sowing

3.2.2.5. Number of tillers per plant at maturity



a: Nursery grown

b: Grown under aerobic condition

d: Days to Maturity

c: Days to fifty per cent flowering

Plate 1. A field view of local landraces of rice grown under aerobic condition during *kharif* 2017 (a: Nursery grown; b: Grown under aerobic condition; c: Days to fifty per cent flowering; d: Days to Maturity)

The total number of tillers from each plant including both productive and non-productive tillers were counted and recorded at the time of harvest.

3.2.2.6. Number of productive tillers per plant

Among total number of tillers per plant the number of productive tillers were counted and recorded.

3.2.3 Panicle traits

3.2.3.1. Panicle Length (cm)

Total length of panicle from its ciliate ring to the tip, excluding awns, if any, was measured and recorded in centimeter.

3.2.3.2. Number of spikelets per panicle

Number of filled spikelets and chaffy grain per panicle was averaged to calculate per cent spikelets fertility.

3.2.4. Grain quality traits

3.2.4.1 Grain Length (mm)

The length of ten grains randomly selected was measured using digital vernier callipers to record grain length.

3.2.4.2. Grain Breadth (mm)

The average breadth of ten grains randomly selected was measured using digital verniear callipers, recorded as grain breadth.

3.2.4.3. Grain L: B ratio

The mean values of ten grains used to measure the length and breadth was used to estimate the Length to breadth ratio.

3.2.5. Yield traits

3.2.5.1. Test weight (g)

Weight of 1000 randomly selected grains was recorded and expressed in grams as test weight.

3.2.5.2 Harvest index (%)

The ratio between the grain yield per plant and biomass of the plant was recorded as harvest index.

3.2.5.3. Grain yield per plant (g)

Total weight of single plant filled grains were taken in grams and recorded after harvest.

3.3. Statistical analysis

3.3.1 Analysis of variance (ANOVA)

The mean values for all the characters of 50 local landraces as well as check entries were computed and used for statistical analysis. The variance for various traits was estimated following ANOVA as per randomized complete block design (RCBD) as outlined by Panse and Sukhathme (1984). Analysis was done using "Windostat" computer programme. The level of significance was tested at 5% and 1% using F – stest. The model of ANOVA used is presented Table 2.

Table 2 : ANOVA table for randomized complete block design

Source of variation	**Degrees of freedom**	**Sum of Square**	**Mean sum of squares**	**F-ratio**
Replications	(r- 1)	rSS		
Genotypes	(g- 1)	gSS	gSS -------- = 2MS (g- 1)	gMS ------- EMS
Error	(s- 1)(g- 1)	SSE	ESS ----------- = EMS (r-1) (g-1)	
Total	(rg- 1)	TSS		

Where,

r = Number of Replications

g = Number of Genotypes

The significance was tested by referring to the table given by Fisher (1932). Standard error of mean (SEm), critical difference (CD) and coefficient of variation (CV) were worked out using appropriate formula comparing means of the genotypes.

3.3.2. Estimation of genetic variability parameters

Phenotypic and genotypic components of variance were estimated by using the formula given by Cochran and Cox (1957).

Genotypic variance ($\sigma^2 g$) = MSS due to genotypes – MSS due to error/No. of blocks.

Phenotypic variance ($\sigma^2 p$) = Genotypic variance ($\sigma^2 g$) + MSS due to error.

3.3.3 Coefficient of variability

The coefficient of variability both at phenotypic and genotypic levels for all the characters were computed by applying the formula as suggested by Burton and Devane (1953).

3.3.4. Phenotypic and genotypic coefficient of variance (PCV and GCV)

Both phenotypic and genotypic coefficient of variability for traits were estimated using the formulae of Burton and Devane (1953).

$$PCV = \frac{P}{X} x100$$

$$GCV = \frac{G}{X} x100$$

Where,

P = Phenotypic standard deviation

G = Genotypic standard deviation

X = Grand mean of character

PCV = Phenotypic coefficient of variation

GCV = Genotypic coefficient of variation

PCV and GCV were classified and follows Sivasubramanian *et al.* (1973).

0 – 10 %: Low; 10.1 – 20 %: Moderate; > 20 %: High.

3.3.5. Heritability in Broad sense (h^2)

Broad sense heritability for all the characters was calculated as per the method outlined by Lush (1949).

$$h^2 \text{ (BS)} = \frac{\sigma^2_g}{\sigma^2_p} \text{ X } 100$$

Where,

h^2 (BS) = Heritability percentage

$\sigma^2 g$ = Genotypic variance

$\sigma^2 p$ = Phenotypic variance

Heritability percentage was categorized as follows (Sivasubramanian *et al*, 1973).

0 – 30 %: Low; 30.1 – 60 %: Moderate, > 60 %: High.

3.3.6. Genetic advance as per mean (GAM)

Genetic advance was calculated as per the method outlined by Johnson *et al.* (1955).

$$GA = h^2 \, x \, K \, x \, \sigma_p$$

Where,

h^2 = heritability estimate

K = selection differential which is equal to 2.06 at 5% intensity of selection.

σ_p= phenotypic standard deviation

Further the genetic advance as per cent of mean was computed by using the following formula:

$$GAM = \frac{GA}{\bar{X}} \times 100$$

Where,

GA $\bar{X}$ = Genetic advance and

= Treatment mean for the character.

The GA as per cent mean was classified as given below.

0 – 10 %: Low; 10.1 – 20 %: Moderate; > 20 %: High.

3.3.7. Correlation studies

3.3.7.1. Phenotypic correlations

Phenotypic coefficients of correlation between various characters were obtained as suggested by Burton and Devane (1953).

$$r_P \ x,y = \frac{P_X . P_Y}{\sqrt{V_{P_X} V_{P_Y}}}$$

Where,

Px Py	: Phenotypic co-variance of x and y.
Vpx	: Phenotypic variance of x.
Vpy	: Phenotypic variance of y.
rp(x,y)	: phenotypic correlation co-efficient of x and y.

The calculated value of ‘r’ was compared with table ‘r’ value from Fisher and Yates with n - 2 degree of freedom at 5% and 1% level of significance, where n refers to number of pairs of observations.

3.3.7.2 Path co-efficient analysis

Path coefficient analysis was carried out following the method (Dewey and Lu, 1959)

$$P_{01} + P_{02}\, r_{12} + \cdots\cdots + P_{0P}\, r_{1P} = r_{01}$$
$$P_{01} + P_{12}\, r_{02} + \cdots\cdots + P_{0P}\, r_{2P} = r_{02}$$
$$\downarrow$$
$$P_{01} + r_{1P} + P_{02}\, r_{2P} \cdots\cdots + P_{0P} = r_{0P}$$

Where P_{01}, P_{02}, --------- P_{0P} are the direct effects of variables 1, 2, ---------- p on the dependent variable 0 and r_{12}, r_{13}, --------- r_{1P} --------- $r_{P(P-1)}$ are the possible correlation co-efficients between various independent variables and r_{01}, r_{02}, r_{03} --------- r_{0P} are the correlations between dependent and independent variables. The indirect effect of the i^{th} variable *via* j^{th} variable is attained as (P_{oj} x r_{ij}). The contribution of remaining unknown factor is measured as the residual factor, which is calculated and given below.

P^2ox = 1- [P^2_{01} + 2P_{01} P_{02} r_{12} + 2 P_{01} P_{03} r_{13} + --------- + P^2_{02} + 2P_{02} P_{03} r_{13} + --------- + P^2_{0P}]

Residual factor = $(P^2_{ox})^{½}$.

3.3.8 Test of normality

3.3.8.1 Normal distribution

The normal distribution function is determined by the following formula:

$$f(x) = 1/\left[\ 2*\pi\ ^{1/2} * \sigma\ \right] * e**\ -1/2*\ x-\mu\ /\sigma^2\ \ -\infty to \infty$$

Where,

'μ' is the mean

'σ' is the standard deviation

'e' is Euler's constant (2.71)

'π' is the constant Pi (3.14)

3.3.8.2 Skewness

Skewness is a measure of the extent to which the distribution of the respective variable is skewed to the left (negative value) or right (positive value), relative to the standard normal distribution (for which the skewness is 0). Genetic expectations of skewness reveal the nature of genetic control of the traits (Fisher *et al.*, 1932). The adjusted mean values of each genotype for quantitative traits were used to estimate coefficient of skewness using "STATITICA" software program. The skewness is calculated with the formula:

$$Skewness = n * M_3 / \left[\; n-1 \; * \; n-2 \; * \sigma^3 \right]$$

Where,

'M_3' is equal to S (Xi – mean X) **3

'N' is the valid number of cases

'σ^3' is the standard deviation (sigma) raise to the third power.

3.3.8.3 Kurtosis

Kurtosis is a measure of how "wide" or skinny ("flat" or "peaked") the distribution is for the respective variable, relative to the standard normal distribution (for which the kurtosis is equal to 3). Kurtosis indicates the relative number of genes controlling the traits (Robson, 1956). The adjusted mean values of each genotype (line) for quantitative traits were used to estimate coefficient of kurtosis using "STATITICA" software program. The kurtosis is calculated with the formula:

$$Kurtosis = \left[n * \; n+1 \; * M_4 - 3 * M_2 * M_2 \; \; n+1 \; \right] / \left[\; n+1 \; * \; n+2 \; * \; n+3 \; * \sigma^4 \right]$$

Where,

'Mj' is equal to S (Xj – mean X)**j

‘N’ is the valid number of cases

‘σ^4’ is the standard deviation (sigma) raise to the fourth power

EXPERIMENT-II:

Identification of local rice genotypes with high Zinc, Iron and grain protein content Near infrared reflectance spectroscopy (NIR system, Broker, Denmark) system was used for the estimation of crude protein, Iron and zinc content. NIR is a fast and non-destructive technique that provides multi-constituent estimates. It works on the principle of detection and measurement of chemical composition of biological materials was based on vibrational responses of chemical bonds to NIR radiations.

IV. RESULTS AND DISCUSSION

Rice is the primary source of energy for billions of people in developing countries, yet the commonly consumed polished grain contains insufficient levels of key protein and micronutrients such as zinc and iron to meet daily dietary requirements. As a result, protein and micronutrient deficiencies afflict billions of people throughout that world.

In Asia, rice serves as the major source of energy, protein, thiamine, riboflavin, niacin, iron (Fe) and calcium (Ca) in the diet. Polished rice does not contain minerals adequately. It has limited contents of Fe and Zn, as losses of minerals, particularly of Fe, during milling. Biofortification of mineral micronutrients in food crops for the benefit of human nutrition the potential biotechnological applications that arise from the research on mineral uptake, transport and metabolism in plants (Guerinot and Salt, 2001).

Traits like number of productive tillers, number of primary and secondary branches and grain number majorly contribute to grain yield, grain weight, grain number shows large amount of variation (Yu *et al*., 2017). Improvement of grain yield per plant can be achieved through breeding of the traits that are positively associated with it.

The experimental results obtained from the present investigation has been presented below under the following sub headings.

4.1. To assess variability for growth and yield characters among local landraces of rice.

4.1.1. Analysis of variance

4.1.2. Mean performance of genotypes, variability, heritability and genetic advance

4.1.3. Cluster analysis

4.1.4. Correlation studies and path-coefficient analysis

4.2. To identify of local rice genotypes with high zinc, iron and grain protein content.

4.1.1. Identification of local genotypes for variation in protein content.

4.1.2. Identification of local genotypes for variation in zinc content.

4.1.3. Identification of local genotypes for variation in iron content.

4.1. To assess variability for growth and yield characters among local landraces of rice.

4.1.1 Analysis of variance

Creation and utilization of genetic variability is important factors for crop improvement. Thus, variability generated is a prerequisite for any breeding programme aimed at improving the yield and other characters.

The mean sum of squares for 14 morphological traits among fifty-five local landraces in *kharif*-2017 under aerobic conditions are presented in Table 3. It is evident from the table that highly significant differences among the genotypes were observed for all the characters ($P < 0.05$) (Table 3). The results showed that there is a presence of acceptable amount of variability among the local landraces. This behavior was responsible for the wide range of variability among the genotypes. This gives a scope for rice breeders to improve these traits through selection and hybridization to improve the desired traits (Ndukauba *et al.*, 2015).

4.1.2. Mean performance of genotypes, variability, heritability and genetic advance

The frequency distribution for all the growth and yield attributing traits was found normally distributed except for L/B ratio in the present study (Fig. 1, 2, 3 & 4). The mean performance, variability parameters of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), broad sense heritability (h^2), genetic advance (GA) and genetic advance as per cent of mean (GAM) of 14 characters in local landraces grown during *kharif*-2017 under aerobic conditions are presented in Table 4; Fig. 5&6; Appendix I.

Table 3: ANOVA for growth and yield attributing characters in local landraces of rice

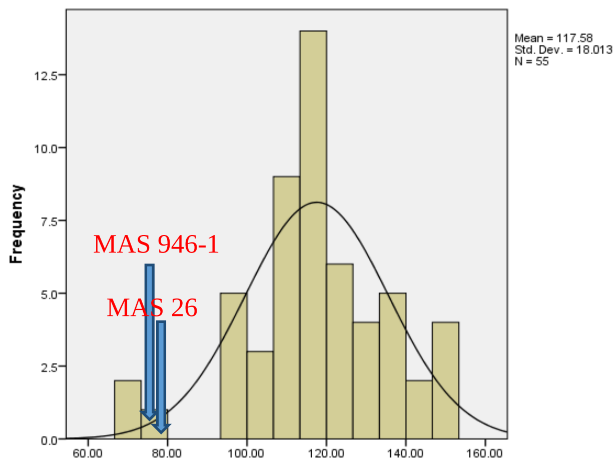
Source of variation	Degrees of freedom	Mean sum of squares						
		Plant height (cm)	Days to 50% flowering	Days to maturity	Total No. Tiller	Productive Tillers plant[1]	Spikelet fertility (%)	Flag leaf length (cm)
Replication	1	4.01	77.88	8.18	1.73	0.35	63.5	1.14
Genotypes	54	98.67***	1121.62***	142.8***	17.06***	15.19***	71.99*	78.25***
Error	54	2.38	34.95	13.39	2.37	2.06	12.3	6.81
C.V		5.03	1.48	2.36	8.67	8.64	4.41	8.09
C.D. 5%		11.85	3.09	7.48	3.09	2.88	7.03	5.23
C.D. 1%		15.78	4.12	9.96	4.11	3.83	9.37	6.97

* Significance at 5%, ** Significance at 1%, ***Significance at 0.01%

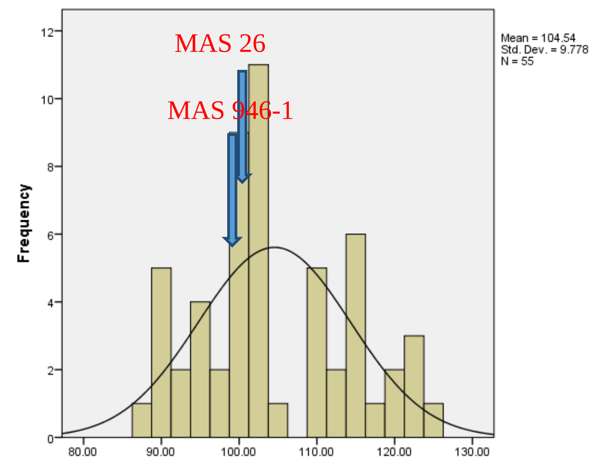
Table 3: Continued…

Source of variation	Degrees of freedom	Mean sum of squares						
		Panicle length (cm)	Grain length (mm)	Grain breadth (mm)	L/B ratio	Test weight(g)	Harvest index	Grain yield plant^{1} (g)
Replication	1	0.27	0.01	0.003	0	12.25	0.025	16.71
Genotypes	54	8.37***	1.01**	0.293***	0.48***	40.47 ***	0.015 **	47.08***
Error	54	1.42	0.001	0.001	0.002	0.078	0.007	17.32
C.V		5.23	0.37	1.15	1.64	1.14	15.29	23.18
C.D. 5%		2.39	0.06	0.07	0.09	0.56	0.17	8.34
C.D. 1%		3.18	0.08	0.09	0.12	0.74	0.22	11.11

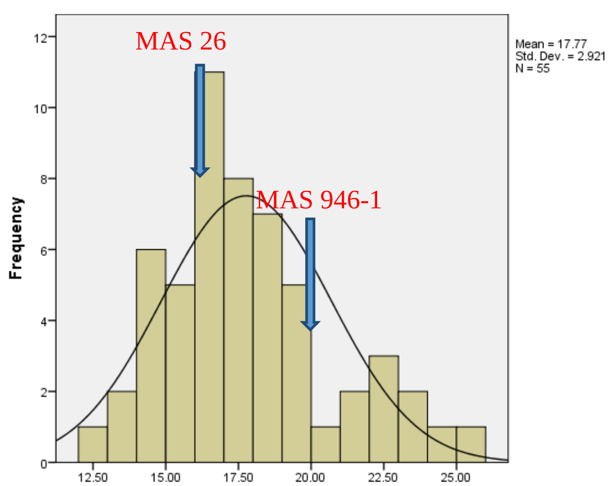
* Significance at 5%, ** Significance at 1%, ***Significance at 0.01%.



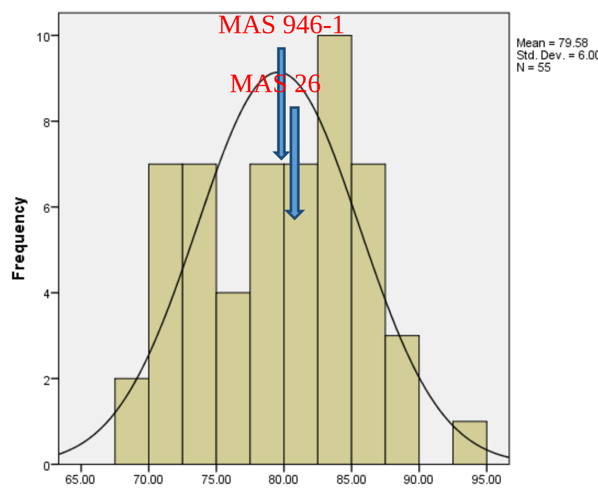
Plant height (cm)



Days to 50% flowering



Total No. Tiller



Spikelet fertility (%)

Fig 1: Frequency distribution of response of growth and yield characters in local landraces of rice for plant height, days to 50 % flowering, total number of tiller, spikelet fertility

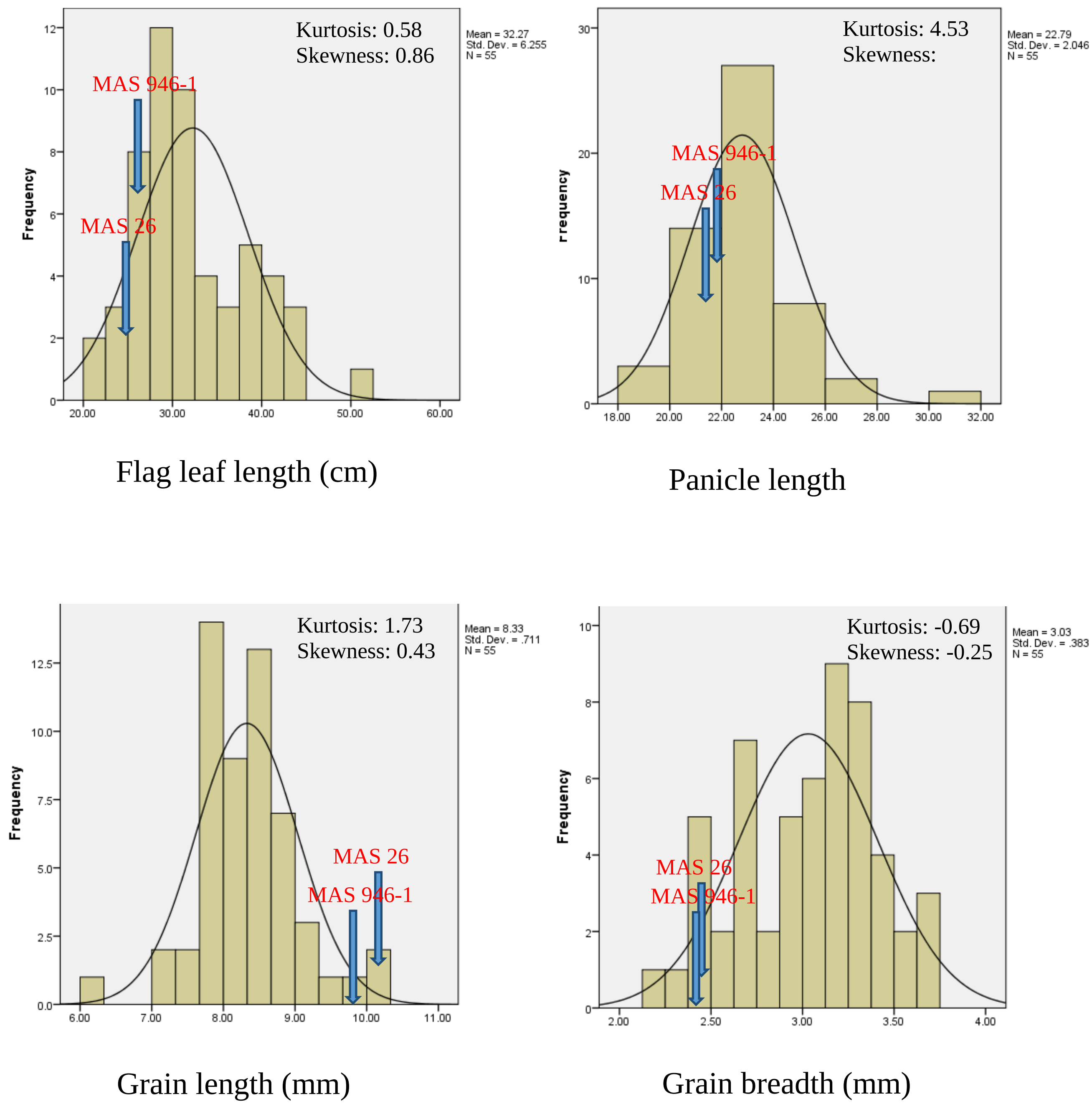


Fig 2: Frequency distribution of response of growth and yield characters in local landraces of rice for flag leaf length, panicle length, grain length, grain breadth

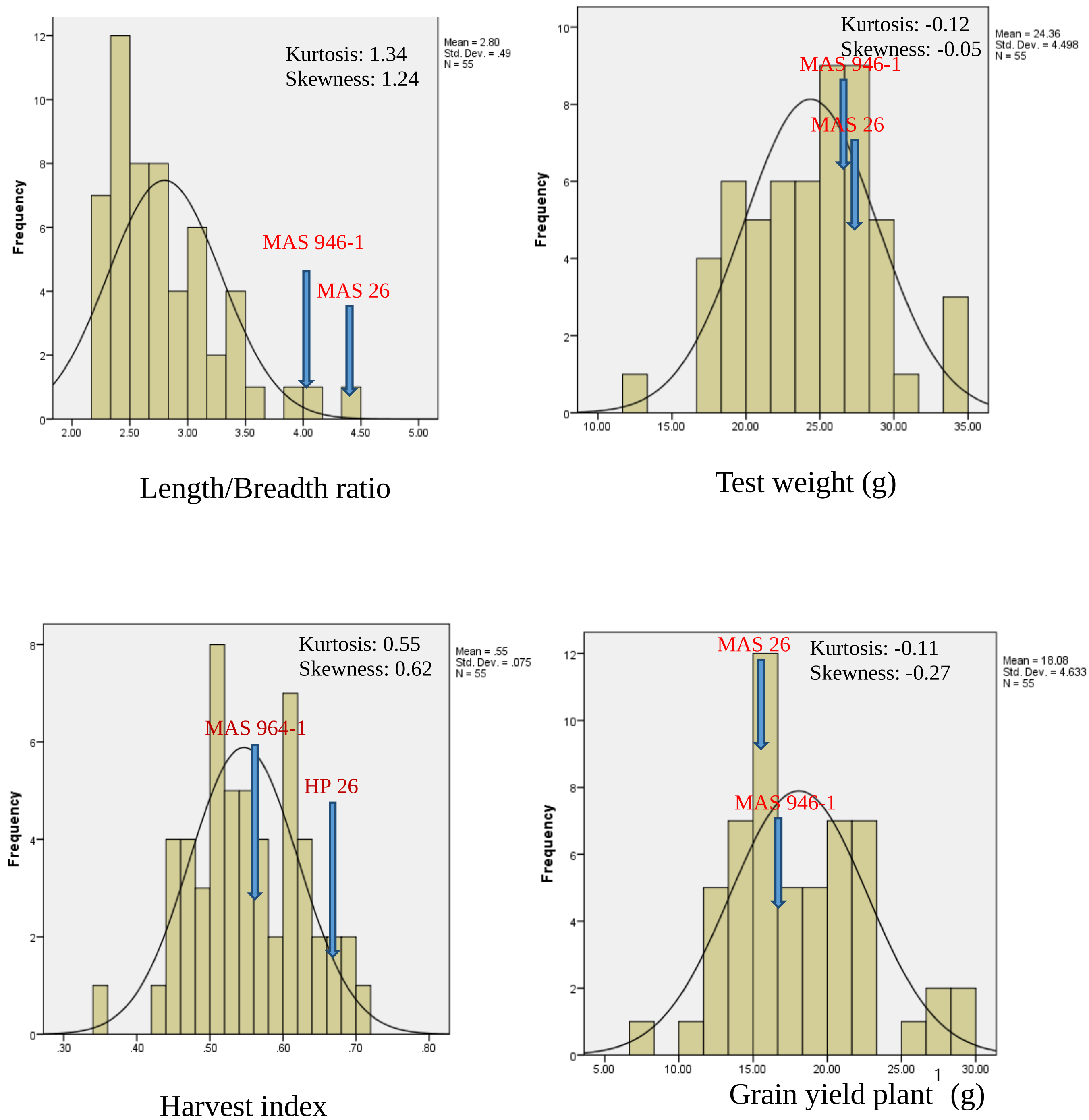


Fig 3: Frequency distribution of response of growth and yield characters in local landraces of rice for L/B ratio, test weight, harvest index, grain yield plant^{-1}

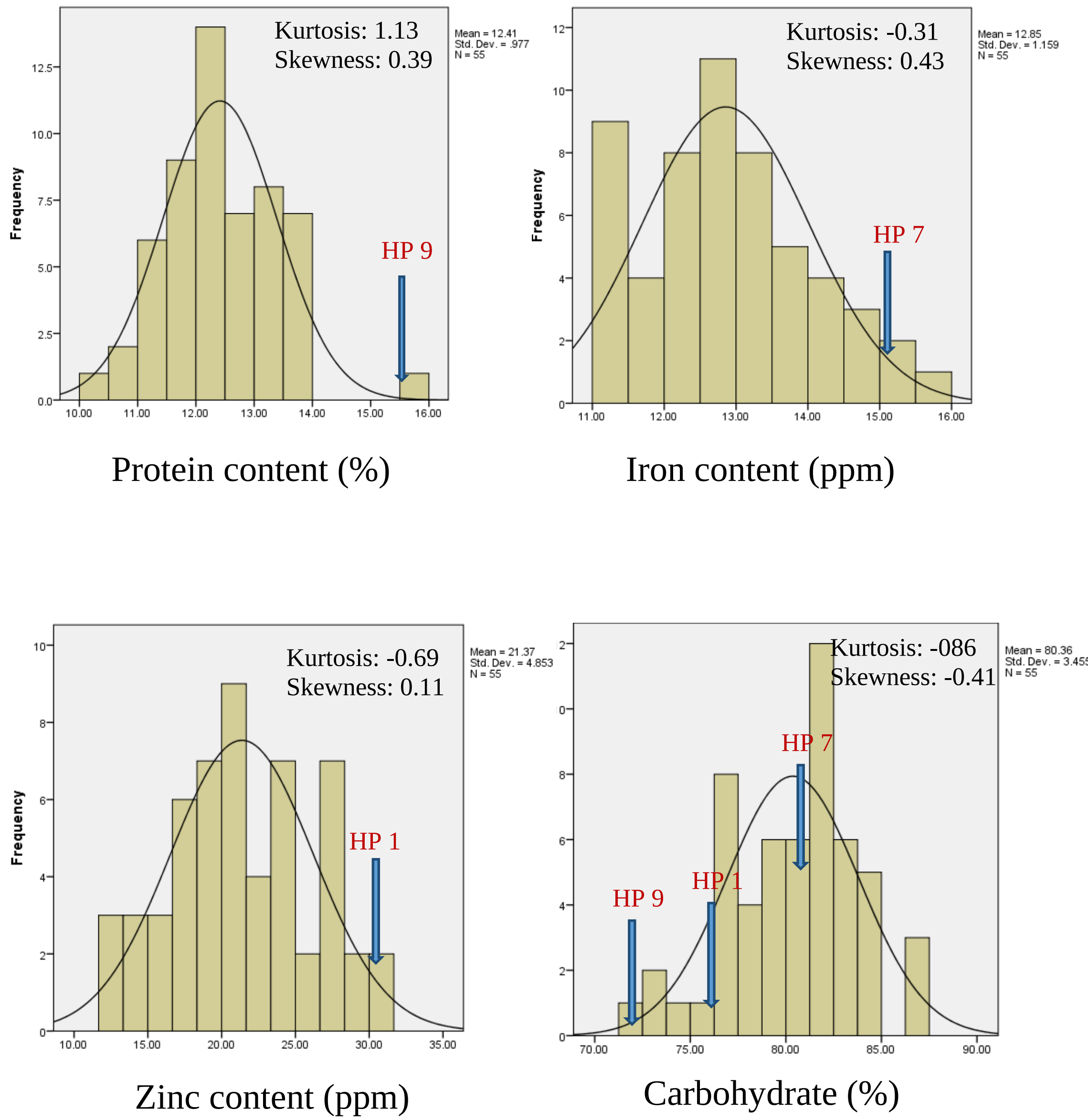


Fig 4: Frequency distribution of response of growth and yield characters in local landraces of rice for protein, iron, zinc and carbohydrate content

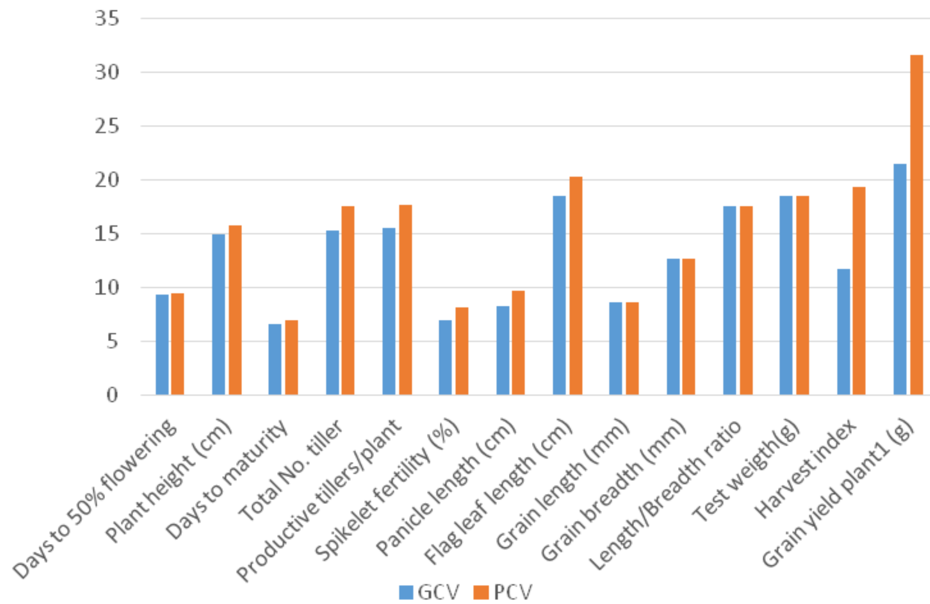


Fig 5. Graphical representation of phenotypic (PCV) and genetic (GCV) coefficients of variation

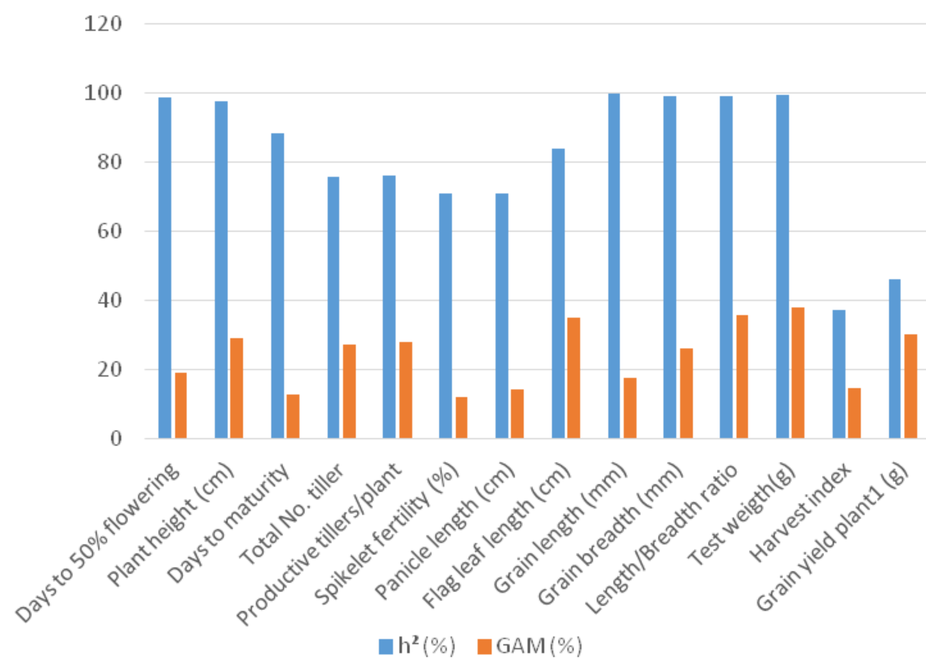


Fig 6. Graphical representation of heritability (h2) and genetic advancement as percentage of mean (GAM)

4.1.2.1. Plant height at maturity (cm)

Plant height ranged from 66.6 cm (HP9) to 155.6 cm (Kanakasali) among the local landraces with an average of 117.58 cm. Moderate phenotypic coefficient of variation (PVC) and genotypic coefficient of variation (GCV) of 15.73 % and 14.9 %, high heritability of 97.5 % and high genetic advance as *per cent* mean (GAM) of 29.09 % was observed in local landraces.

4.1.2.2. Days to 50 *per cent* flowering (DFF):

Among the genotypes, range of variation for days to 50 *per cent* flowering was from 87 days (Coimbatore Sanna) to 117 days (Gowri Sanna) with an average of 103 days. Low PCV of 9.41 %, low GCV of 9.30 %, high broad sense heritability of 98.8 % and GAM of 18.91 % respectively was recorded for days to 50 *per cent* flowering.

4.1.2.3. Days to maturity (DTM):

An average value of 157 days with a range of 135 (Coimbatore Sanna, Doddiga) to 169 (Kadullite) days was recorded. Low PCV of 6.93%, low GCV of 6.52 %, high heritability of 88.4 % and moderate GAM of 12.62 % was recorded in these genotypes for this trait.

4.1.2.4. Number of tillers per plant (NTP)

Total number of tillers per plant ranged from 12.2 tillers in Dodda Batta to 26.2 tillers in Karijaddu with an average of 17.7 Moderate PCV of 17.54 %, moderate GCV of 15.25 %, high heritability of 75.6 % and high GAM of 27.31 % was recorded for this trait.

4.1.2.5. Number of productive tillers (NPT):

An average of 16.6 productive tillers was observed with a range of 11 (Dodda Batta) to 24.6 (Karijaddu). Moderate PCV of 17.69 % and GCV of 15.44 %, high heritability of 76.1 % and a high GAM of 27.74 % was recorded for this trait in local landraces.

4.1.2.6. Spikelet fertility (%)

Spikelet fertility *per cent* ranged from 63.27 % in Kari Kondaga to 93.76 % in Bilidoddi with an average of 78.52 %. Low PCV of 8.16 %, low GCV of 6.87 %, high heritability of 70.80 % and moderate GAM of 11.90 % was recorded for this trait.

4.1.2.7. Flag leaf length (cm)

Flag leaf length among genotypes ranged from 22.15 cm (Biliakki) cm to 51.85 cm (Jeerige Batta) with average of 36.98 cm. High PCV of 20.21 % and moderate GCV of 18.52 %, high heritability of 84.00 % and a high GAM of 34.97 % was recorded for this trait.

4.1.2.8. Panicle length (PL)

Average value for panicle length recorded was 24.51 cm with a range of 16.52 cm (Kalajeera) to 32.50 cm (Gidda Rajakamala). Low PCV of 9.71 %, low GCV of 8.18 %, high heritability of 71.00 % and moderate GAM of 14.19 % was recorded for this trait.

4.1.2.9. Grain length (mm)

Grain length ranged from 6.20 mm (Dodda Mullare) to 10.30 mm (Anthrasali) with an average of 8.25mm. Low PCV of 8.54 %, low GCV of 8.54 %, high heritability of 99.8 % and moderate GAM of 17.57 % was recorded for this trait (Fig. 7,8 & 9).

4.1.2.10. Grain breadth (mm)

Grain breadth ranged from 2.20 mm (Rajmudi) to 3.75 mm (Jaddu Batta) with an average of 2.98 mm. Moderate PCV of 12.66 %, moderate GCV of 12.61 %, high heritability of 99.20 % and high GAM of 25.87 % was recorded for this trait (Fig. 7,8 & 9).

4.1.2.11. Grain length and breadth ratio

Grain length to breadth ratio among local landraces ranged between 2.17 (Kirwana) and 4.37 (Anthrasali) manifesting an average of 3.01. Moderate PCV of 17.56 %, moderate GCV of 17.48 %, high heritability of 99.10 % and high GAM of 35.86 % was recorded for this trait.

Table 4: Estimation of genetic parameters for growth and yield attributing characters in local landraces of rice

Sl. No.	Characters	Mean	Range		Variances			Coefficient of Variation (%)		h^2 (%)	GA (%)	GAM (%)
			Min	Max	σ^2e	σ^2g	σ^2p	GCV	PCV			
1	**Days to 50% flowering**	103.49	87.00	117.00	34.95	94.41	96.79	9.30	9.41	98.80	34.20	18.91
2	**Plant height (cm)**	117.58	66.60	155.60	2.38	307.00	341.94	14.90	15.73	97.50	19.77	29.09
3	**Days to maturity**	156.56	135.00	169.00	13.92	106.46	120.39	6.52	6.93	88.40	19.99	12.62
4	**Total No. Tiller**	17.77	12.20	26.20	2.37	7.34	9.72	15.25	17.54	75.60	4.85	27.31
5	**Productive tillers/plant**	16.60	11.00	24.60	2.06	6.57	8.63	15.44	17.69	76.10	4.61	27.74
6	**Spikelet fertility (%)**	79.58	63.27	93.76	12.31	29.85	42.15	6.87	8.16	70.80	9.47	11.90
7	**Panicle length (cm)**	22.79	16.52	32.50	1.42	3.47	4.89	8.18	9.71	71.00	3.24	14.19
8	**Flag leaf length (cm)**	32.27	22.15	51.85	6.81	35.72	42.53	18.52	20.21	84.00	11.28	34.97
9	**Grain length (mm)**	8.32	6.20	10.30	0.00	0.51	0.51	8.54	8.54	99.80	1.46	17.57
10	**Grain breadth (mm)**	3.03	2.20	3.75	0.00	0.15	0.15	12.61	12.66	99.20	0.78	25.87
11	**Length/Breadth ratio**	2.80	2.17	4.37	0.00	0.24	0.24	17.48	17.56	99.10	1.00	35.86
12	**Test weight(g)**	24.36	12.60	34.90	0.08	20.20	20.27	18.45	18.48	99.60	9.24	37.93
13	**Harvest index**	0.55	0.29	0.74	0.01	0.00	0.01	11.72	19.27	37.00	0.08	14.68
14	**Grain yield plant^1 (g)**	17.95	5.82	33.34	17.32	14.88	32.20	21.48	31.60	46.20	5.40	30.09

σ^2e = Environmental variance; σ^2g = Genotypic variance; σ^2p = Phenotypic variance; PCV = Phenotypic coefficient of variation; GCV = Genotypic coefficient of variation; h^2 (BS) = Heritability percentage; GA = Genetic advance; GAM = Genetic advance as per mean

4.1.2.12. Test weight (g)

Test weight among of local landraces ranged from 12.60g (Kadullite) to maximum 34.9g (Jaddu Batta) with an average of 23.75g. Moderate PCV of 18.48 %, moderate GCV of 18.45 %, high heritability of 99.60 % and high GAM of 37.93 % was recorded for this trait.

4.1.2.13. Harvest index

Harvest index ranged from 0.29 (Kari Kondaga) to 0.74 (Navasali) with an average of 0.52. Moderate PCV of 19.27 %, moderate GCV of 11.72 %, moderate heritability of 37.00 % and moderate GAM of 14.68 % was recorded for this trait.

4.1.2.14. Grain yield per plant (GY/P):

Average value of grain yield per plant recorded was 20.21g/plant with a range of 5.82g/plant (Kari Kondaga) to 33.34g/plant (Kalu Mottaga). High PCV of 31.60 %, high GCV of 21.28%, moderate heritability of 46.20% and high GAM of 30.09 % was recorded for this trait.

Genotypic coefficient of variation measures the range of variability in crop and also enables to compare the amount of variability present in different characters. The PCV estimates were higher than GCV for all the characters studied among the fifty-five local landraces, indicated that the substantial influence of environment in the expression of these characters. Similar findings were observed by Fathelrahman *et al.* (2015), high PCV was observed for stem diameter and high GCV was observed for grain yield. Heritability gives the information on the magnitude of inheritance of characters, while genetic advance is helpful in formulating suitable selection procedures.

High heritability coupled with high expected genetic advance as per mean indicated the effectiveness of selection for plant height, total number of tillers, productive tillers per plant, flag leaf length, grain breadth, L/B ratio and test weigh. Similar reports were observed by Mall *et al*. (2005), Karim *et al*. (2007) and Ganapathy *et al*. (2007).

Fig 7: Variation in grain size in selected local landraces of rice (Doddiga, Jeerige Batta, Marabatta, Neergoli, Mugadsushanda, kesarmellu)

Fig 8: Variation in grain size in selected local landraces of rice (DBN, Malligae, Naga batta, Sampigae Batta)

Fig 9: Variation in grain size of checks in local landrace of rice (MAS 946-1, MAS 26. HP1. HP7, HP9)

Moderate heritability coupled with moderate genetic advance as per mean was observed for days to 50 *per cent* flowering, days to maturity, spikelet fertility, panicle length, grain length, harvest index and grain yield per plant. The traits such as plant height, productive tillers per plant, L/B ratio and test weight with high genotypic variance, high heritability coupled with high expected genetic gain would be responsive to selection.

High heritability along with high genetic advance is an important factor for predicting the resultant effect for selecting the best individuals. Heritability and genetic advance are important selection parameters. The estimation of genetic advance is more useful as a selection tool when considered jointly with heritability estimates.

In contrast, the low heritability means that the selection will be relatively less effective, because the appearance of phenotypic variance of plants is more influenced by environmental factors. Breeding for traits with low heritability is difficult because low heritability means that the phenotype is not highly correlated with the genotype. In other words, the contribution of the environmental conditions is relatively high in such traits. The most important function of the heritability in the genetic study of quantitative characters is its predictive role to indicate the reliability of the phenotypic value as a guide to breeding value (Satheeshkumar and Saravanan, 2012).

The study of frequency distribution of quantitative traits using skewness and kurtosis give information about nature of gene action (Fisher *et al*., 1932) and number of genes controlling the traits (Robson, 1956), respectively. The frequency distribution for all the growth and yield attributing traits was found normally distributed except for L/B ratio in the present study (Fig. 1, 2, 3 & 4).

The results of the skewness and kurtosis for all the 14 characters among local landraces are presented in Figure 2, 3 & 4. Positive skewness was observed for total number of tillers, number productive tillers, panicle plant, flag leaf length, grain length, L/B ratio, grain yield per plant. Kurtosis the distribution curves for all the 14 characters in the local landraces were found to be platykurtic with a kurtosis value less than 3, except panicle length.

The skewness frequency distribution of a trait in general suggests that the trait is under the control of non-additive gene action and is influenced by environmental variables. The positive skewness is associated with complementary gene interactions and the negative skewness is associated with duplicate (additive x additive) gene interactions. The genes controlling the trait with skewed distribution tend to be predominantly dominant irrespective of whether they have increasing or decreasing effect on the trait.

The kurtosis is positive in the presence of gene interactions and it is negative or close to zero in the absence of gene interaction (Choo and Reinbergs, 1982; Kotch *et al*., 1992).

4.1.3. Cluster analysis

Analysis of variance showed significant differences for all the 14 characters studied among the local landraces of rice. Based on D^2 value, 50 genotypes were grouped into 8 clusters (Table 5). Maximum number of genotypes (12 genotypes) were grouped in cluster VI and cluster VIII. Cluster I consists of 11 genotypes. Cluster II and cluster V had five genotypes each, cluster IV had four genotypes, cluster II consists of two genotypes while cluster VII had only one genotypes.

The results of cluster mean (Table 6) showed that cluster III had highest mean value for days of 50 *per cent* flowering (145.75), spikelet fertility (84.51), panicle length (48.21), flag leaf length (25.30), grain breadth (3.73) and test weight (34.03), while lowest mean value for plant height (91.5). Cluster I and cluster II had genotypes with high plant height but short for panicle length and flag leaf length. Cluster IV had genotypes with highest mean value for iron content (13.79) and lowest test weight (17.25). Cluster V had genotypes with highest plant height (107.6), days to maturity (159.8) and lowest for flag leaf length (21.77). Cluster VI had genotypes with highest mean value for protein content (15.30). Cluster VII had genotypes with highest harvest index (0.69) and grain yield per plant (29.01) and clusters VIII with genotypes had highest mean value for zinc content (27.89).

Cluster analysis helps in grouping of genotypes sharing similar characters in different clusters and to identify genetically diverse as well as desirable genotypes. On the whole composition of the clustering pattern showed that genotypes collected from the same places of origin were distributed in different clusters. Similar findings of non-correspondence of geographic origin with genetic diversity were also reported by Shanmugasundaram *et al.* (2000).

There was none of the clusters contained genotypes with all the desirable traits which could be directly selected and utilized. All the maximum and minimum clusters mean values were distributed in relatively distant clusters. However, cluster III recorded desirable mean value for days to 50 *per cent* flowering, spikelet fertility percentage, panicle length, grain breadth and grain yield. Bose and Pradhan (2005) were also reported similar results for studying the divergence in deep water rice genotypes, thereby underlining the fact that the hybridization between genotypes of different clusters is necessary for the development of desirable genotypes. Based on the per se performance of genotypes among different clusters, they may be directly selected or may be used as potential parents in hybridization programme.

Table 5: Clustering pattern of 55 local landraces of rice

Cluster	Number of landraces	Name of genotypes
I	11	Alugidda, Biliakki, Rajmudi, Dodda Batta, Halu Gidda, Kalajeera, Karidoddi, Rajmudi-1, Raj Bhog, Mattalaga, Mugadhsughanda
II	3	Anthrasali, Sampigae Batta-1, Sampigae Batta-2
III	2	Jaddu Batta, Sanesali
IV	4	Bilidoddi Marthayala, Dodda Mullare, Kadullite, Karihasali
V	5	Biliakki-1, Howne Kattu, Kaduvelpe, Karijaddu, Putta Batta
VI	12	DBN, Bilidoddi, Budda, Coimbatore Sanna, Gidda Rajakamala, Gud Batta, Kalu Mottaga, Kari Kondaga, kesarnellu, Marabatta, Neergoli, Navasali
VII	1	Kirwana
VIII	12	Alibulla, Dodda Mullare-1, Doddiga, Gowri Sanna, Jeerige Batta, Kanakasali, Malligae, Mysore Malligae, Naga Batta, Sannakki Batta, Neermullare, Sanna Mullu

Table 6: Cluster means for growth and yield attributing characters in local landraces of rice

SL No.	Characters	Cluster								F	Sig.
		1	2	3	4	5	6	7	8		
1	**Days to 50% flowering**	111.25	102.46	145.75	112.2	126.42	118	127.3	123.43	58.74	0.00
2	**Plant height (cm)**	104.75	104.4	91.5	103.88	107.6	102.13	93	104.04	15.67	0.00
3	**Days to maturity**	157	157.9	142.75	157.13	159.8	155.13	160	157.42	12.61	0.00
4	**Total No. tiller**	18.03	17.07	14.6	17.43	19.31	17.77	14.3	18.06	2.76	0.02
5	**Productive tillers/plant**	16.83	16.03	13.6	16.35	18.11	16.59	13.3	16.83	3.09	0.01
6	**Spikelet fertility (%)**	78.09	81.24	84.51	81.99	79.09	80.66	83.45	77.8	7.01	0.00
7	**Panicle length (cm)**	29.95	26.89	48.21	33.04	30.76	33.91	37.71	32.82	18.13	0.00
8	**Flag leaf length (cm)**	22.41	22.41	25.3	23.2	21.77	23.25	22.63	22.83	1.72	0.13
9	**Grain length (mm)**	8.38	9.82	9.05	7.07	7.85	7.95	8.13	8.53	1.56	0.17
10	**Grain breadth (mm)**	2.63	2.73	3.73	2.89	3.11	3.35	3.73	3.14	5.50	0.00
11	**Length/Breadth ratio**	3.21	3.68	2.43	2.45	2.53	2.38	2.18	2.72	5.08	0.00
12	**Test weight(g)**	20.05	27.48	34.03	17.25	22.87	27.28	33.75	25.76	3.56	0.00
13	**Harvest index**	0.52	0.55	0.65	0.65	0.53	0.54	0.69	0.53	7.80	0.00
14	**Protein (%)**	13.65	13.07	13.02	12.36	13.12	15.30	12.14	12.10	5.17	0.00
15	**Iron (ppm)**	13.65	12.55	13.00	13.79	13.56	11.99	12.29	12.52	4.59	0.01
16	**Zinc (ppm)**	21.50	22.30	22.23	26.81	27.54	17.04	19.22	27.89	5.43	0.00
17	**Grain yield plant^{1} (g)**	15.73	16.36	22.82	18.24	16.07	19.79	29.01	18.34	7.09	0.00

4.1.4. Correlation studies and path-coefficient analysis

4.1.4.1. Correlation

An attempt was made to understand the phenotypic correlation coefficients of different characters in local landraces grown under aerobic condition during *kharif*-2017 to determine the nature of association. The results of the correlation analysis among local landraces were present in Table 7; Fig. 10 &11.

In the present study, grain yield per plant was positively correlated with plant height (0.029), total number of tillers (0.046), spikelet fertility (0.306), flag leaf length (0.318), test weight (0.339), harvest index (0.675), zinc content (0.034), but showed negative correlation with day to 50 *per cent* flowering (-0.34), day to maturity (-0.12) and protein content (-0.09).

In this study, plant height showed positive significant correlation with flag leaf length (0.34), panicle length (0.45), but showed negative significant correlation with total number of tillers (-0.32), number of productive tillers (-0.35) and L/B ratio (-0.46).

Days to 50 *per cent* flowering showed positive significant correlation with days to maturity (0.69), and showed negative significant correlation with total number of tillers (-0.21), number of productive tillers (-0.22), spikelet fertility (-0.33), flag leaf length (-0.49) and test weight (-0.36), and there was no significant correlation found between days to 50 *per cent* flowering with grain yield per plant.

Table 7: Phenotypical correlation coefficient for growth and yield attributing characters in local landraces of rice

	PH	DFF	DTM	TNT	NPT	SF	FLL	PL	GL	GB	L/B	TW	HI	Protein	Iron	Zinc	GY/P
PH	**1**																
DFF	0.123	**1**															
DTM	0.153	0.69***	**1**														
TNT	-0.32***	-0.21*	-0.27**	**1**													
NPT	-0.35***	-0.22*	-0.28**	0.99***	**1**												
SF	-0.15	-0.33***	-0.26**	-0.09	-0.10	**1**											
FLL	0.34***	-0.49***	-0.44***	0.02	-0.01	0.22*	**1**										
PL	0.45***	0.001	-0.12	-0.27**	-0.27**	-0.09	0.34***	**1**									
GL	-0.07	-0.06	0.00	-0.13	-0.13	-0.04	-0.10	0.12	**1**								
GB	0.51	-0.14	-0.11	-0.19	-0.19*	0.08	0.47***	0.36***	-0.12	**1**							
L/B	-0.46***	0.05	0.07	0.07	0.08	-0.07	-0.39***	-0.22*	0.64***	-0.83***	**1**						
TW	0.11	-0.36***	-0.29**	-0.10	-0.09	0.19*	0.34***	0.16	0.38***	0.59***	-0.23*	**1**					
HI	0.003	-0.18	-0.05	-0.12	-0.13	0.23*	0.16	-0.07	-0.05	0.09	-0.07	0.02	**1**				
Protein	-0.05	-0.05	-0.17	0.11	0.14	-0.14	0.02	-0.09	0.10	0.07	0.03	0.09	-0.23*	**1**			
Iron	0.36***	0.02	-0.03	0.05	0.04	-0.03	0.14	-0.01	-0.03	0.35***	-0.29**	0.28**	-0.17	0.35***	**1**		
Zinc	0.52***	0.08	0.18	-0.04	-0.05	-0.07	0.00	0.17	0.06	0.45***	-0.33***	0.24*	-0.07	0.18	0.61***	**1**	
GY/P	0.03*	-0.34*	-0.12*	0.05*	-0.06	0.31**	0.32**	-0.13	-0.05	0.280	-0.23	0.34**	0.68**	-0.09*	-0.04	0.03*	**1**

* Significance at 5%, ** Significance at 1%, ***Significance at 0.01%

DFF= Days to 50% flowering (days); PH= Plant height (cm); DTM= Days to maturity; TNT= Total numbers of tillers; NPT= Number of productive tillers; SF= Spikelet fertility (%); FLL= Flag leaf length (cm); PL= Panicle length (cm); GL= Grain length (mm); GB= Grain breadth (mm); L/B ratio = Length/Breadth ratio; TW= Test weight (g); GY/P= Grain Yield per Plant (g); HI= Harvest Index.

Days to maturity showed negative significant correlation with total number of tillers (-0.27), number of productive tillers (-0.28), spikelet fertility (-0.26), flag leaf length (-0.44) and test weight (-0.29). There was no significant correlation found between days to maturity with grain yield per plant. Similar research finding were reported by Kahani and Hittalmani, 2015b.

Total number of tillers showed positive significant correlation with number of productive tillers (0.99), but showed negative significant correlation with panicle length (-0.27) and there was significant correlation found between total number of tillers with grain yield per plant. Productive tillers showed negative significant correlation with panicle length (-0.27), grain breadth (-0.19) and no significant correlation with grain yield per plant. Similar positive correlation was reported for rice grain yield per plant with the number of productive tillers per plant by Sharma and Choubey, 1985; Dhanraj and Jagadish, 1987; Surek and Korkut, 1998.

Spikelet fertility showed positive significant correlation with flag leaf length (0.21), test weight (0.19) and harvest index (0.23) and there was significant correlation found between spikelet fertility with grain yield per plant.

Flag leaf length showed positive significant correlation with panicle length (0.34), grain breadth (0.47), test weight (0.34) and grain yield per plant (0.32), but showed negative significant correlation with L/B ratio (-0.39).

Panicle length showed positive significant correlation with grain breadth (0.36), but it showed negative significant correlation with L/B ratio (-0.22) there was no significant correlation found between panicle length with grain yield per plant.

Grain length showed positive significant correlation with L/B ratio (0.64) and test weight (0.38). Grain breadth showed positive significant correlation with test weight (0.60), but showed negative significant correlation with L/B ratio (-0.83). Test weight showed negative significant correlation with L/B ratio (-0.23) and there was significant correlation with grain yield per plant.

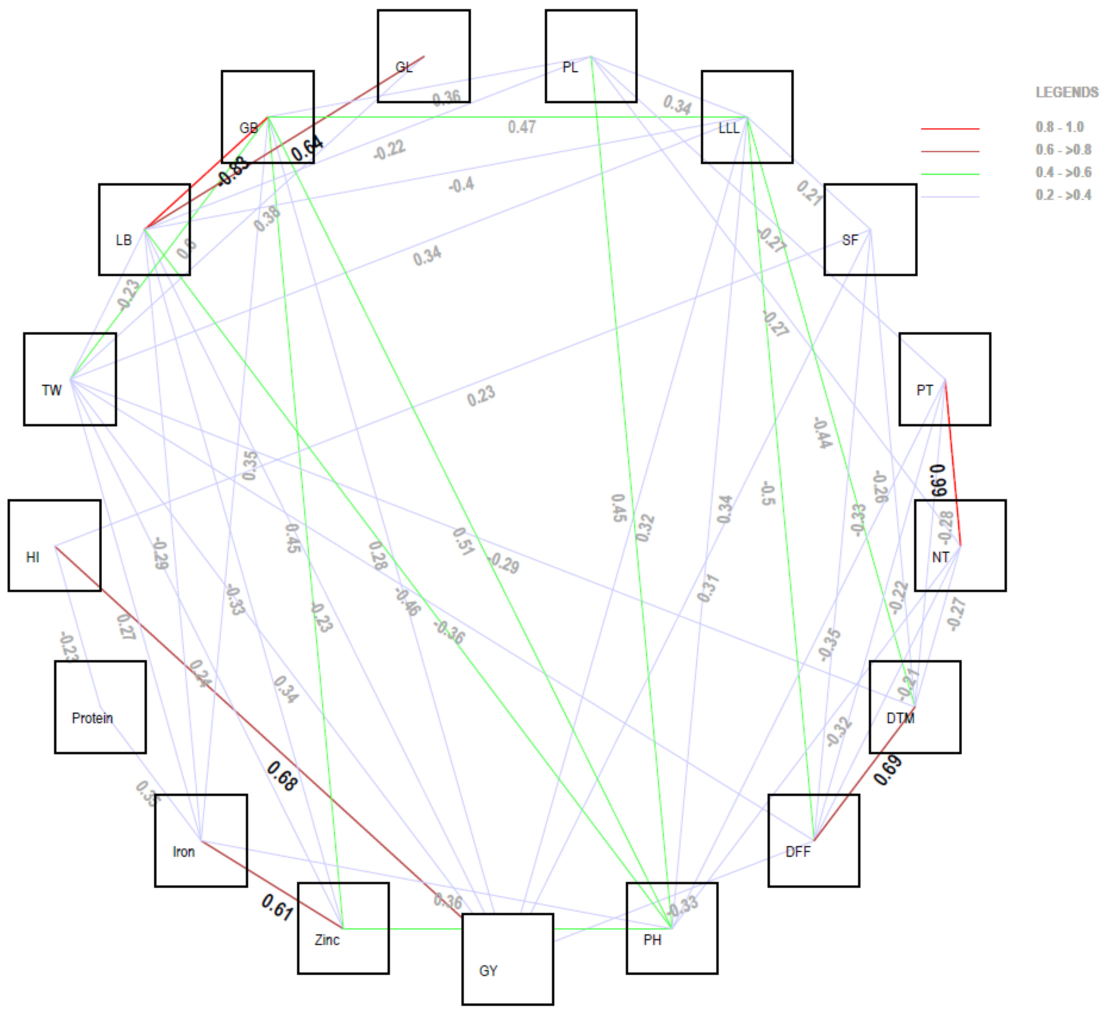


Fig 10: Phenotypical correlations of growth and yield attributing in local landraces of rice

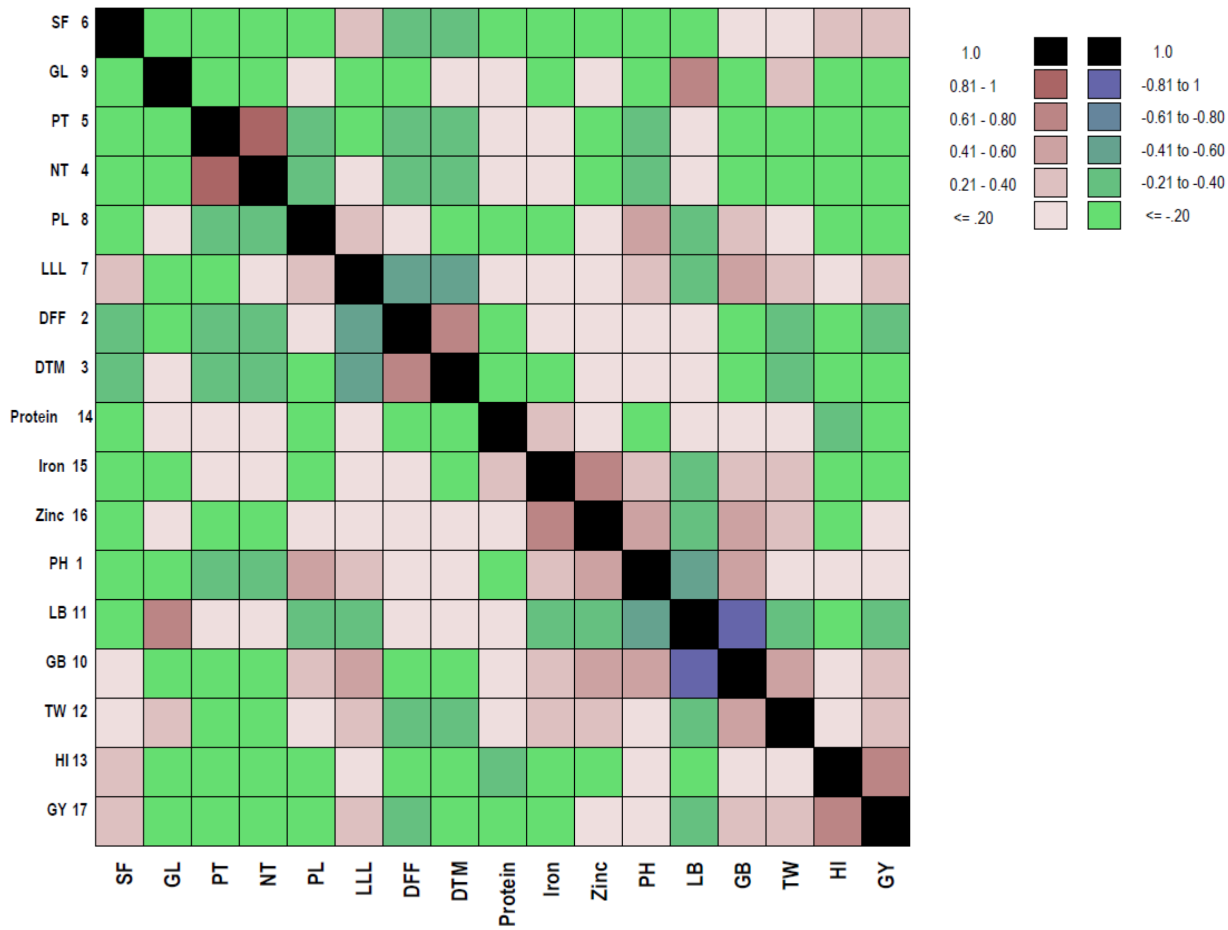


Fig 11: Shaded correlation matrix of growth and yield attributing in local landraces of rice

Grain protein content showed positive significant correlation with iron content (0.35), but showed negative significant correlation with harvest index (-0.23). Iron content showed positive significant correlation with zinc content (0.61), plant height (0.36), grain breadth (0.35), test weight (0.28), but showed negative significant correlation with L/B ratio (-0.29). Zinc content has positive effect on plant height (0.52), grain breadth (0.45), test weight (0.24), but showed significant negative effect on grain length and breadth ratio (-0.33).

Selection for specific character is known to result in correlated response in certain other characters. Generally, plant breeders make selection for one or two attributes at a time. Then it becomes important to know the effect on other characters. Development of genotypes with higher number of panicles, panicle length might help in improving yield (Nandan *et al.*, 2010). Improvement on seed yield per plant, the most important target character in most of the crops, can be achieved by direct selection through other easily observable characters. But, this needs a good understanding of association of different traits with grain yield per plant and their possible associations among themselves.

4.1.4.2. Path-coefficient analysis

The path-coefficient analysis was carried out to know the direct and indirect effects of growth and yield attribution characters on nutrients in grain, the results are presented in Table 8 and Fig 12 for *kharif*-2017 under aerobic conditions.

Harvest index (0.63) has highest positive significant direct effect for grain yield per plant followed by total number of tillers (0.44), test weight (0.44), grain length (0.29). Among the characters studied, L/B ratio (-0.91) had the highest negative direct effect towards grain yield per plant. Results on importance of direct effect of number of tillers per plant were reported by several researchers (Yadav and Bhushan, (2001); Madhavilatha *et al.*, (2005); Yogameenakshi and Vivekanandan, (2010). Grain length (0.76) had highest positive indirect effect via L/B ratio on grain yield. Grain length (-0.58) via L/B ratio had highest negative indirect effect on grain yield (Table 8).

Table 8: Path analysis for growth and yield attributing characters in local landraces of rice

	PH	DFF	DTM	TNT	NPT	SF	FLL	PL	GL	GB	L/B	TW	HI	Protein	Iron	Zinc
PH	**-0.0236**	-0.0029	-0.0036	0.0076	0.0082	0.0035	-0.0081	-0.0105	0.0016	-0.0119	0.0108	-0.0027	-0.0001	0.0012	-0.0085	-0.0123
DFF	-0.0177	**-0.1441**	-0.0996	0.0305	0.0317	0.0471	0.0715	-0.0001	0.0086	0.0195	-0.0065	0.0525	0.0263	0.0065	-0.0025	-0.0108
DTM	0.0304	0.1376	**0.1991**	-0.0541	-0.0553	-0.0517	-0.0884	-0.0233	0.0000	-0.0210	0.0136	-0.0578	-0.0103	-0.0337	-0.0049	0.0351
TNT	-0.1423	-0.0935	-0.1201	**0.4419**	0.4374	-0.0422	0.0065	-0.1204	-0.0581	-0.0826	0.0303	-0.0447	-0.0531	0.0496	0.0222	-0.0158
NPT	0.1502	0.0945	0.1192	-0.4249	**-0.4294**	0.0448	0.0023	0.1169	0.0574	0.0844	-0.0325	0.0416	0.0545	-0.0595	-0.0179	0.0197
SF	-0.0091	-0.0197	-0.0157	-0.0058	-0.0063	**0.0603**	0.0128	-0.0052	-0.0022	0.0048	-0.0040	0.0114	0.0137	-0.0087	-0.0016	-0.0042
FLL	0.0519	-0.0752	-0.0673	0.0022	-0.0008	0.0321	**0.1515**	0.0508	-0.0151	0.0708	-0.0599	0.0518	0.0248	0.0032	0.0205	0.0015
PL	-0.0533	-0.0001	0.0140	0.0326	0.0325	0.0103	-0.0401	**-0.1195**	-0.0140	-0.0428	0.0259	-0.0186	0.0078	0.0107	0.0013	-0.0197
GL	-0.0209	-0.0178	0.0000	-0.0394	-0.0401	-0.0109	-0.0299	0.0351	**0.2998**	-0.0356	0.1906	0.1145	-0.0140	0.0305	-0.0088	0.0181
GB	-0.3910	0.1047	0.0815	0.1442	0.1517	-0.0609	-0.3608	-0.2766	0.0917	**-0.7718**	0.6426	-0.4627	-0.0693	-0.0056	-0.2699	-0.3483
L/B	0.4147	-0.0407	-0.0619	-0.0622	-0.0687	0.0595	0.3586	0.1965	-0.5767	0.7552	**-0.9070**	0.2062	0.0623	-0.0298	0.2610	0.3019
TW	0.0500	-0.1613	-0.1287	-0.0448	-0.0430	0.0834	0.1516	0.0690	0.1693	0.2656	-0.1007	**0.4431**	0.0083	0.0413	0.1217	0.1070
HI	0.0018	-0.1148	-0.0324	-0.0754	-0.0798	0.1429	0.1029	-0.0408	-0.0293	0.0564	-0.0432	0.0118	**0.6283**	-0.1451	-0.1092	-0.0465
Protein	-0.0040	-0.0036	-0.0135	0.0090	0.0111	-0.0115	0.0017	-0.0071	0.0081	0.0006	0.0026	0.0075	-0.0185	**0.0799**	0.0283	0.0145
Iron	-0.0379	-0.0018	0.0026	-0.0053	-0.0044	0.0028	-0.0142	0.0011	0.0031	-0.0366	0.0301	-0.0288	0.0182	-0.0371	**-0.1047**	-0.0634
Zinc	0.0296	0.0042	0.0100	-0.0020	-0.0026	-0.0039	0.0006	0.0093	0.0034	0.0256	-0.0189	0.0137	-0.0042	0.0103	0.0343	**0.0567**
R^2	-0.0007	0.0482	-0.0232	-0.0203	0.0248	0.0184	0.0482	0.0149	-0.0157	-0.2164	0.2052	0.1501	0.4241	-0.0069	0.0041	0.0019

DFF= Days to 50% flowering (days); PH= Plant height (cm); DTM= Days to maturity; TNT= Total numbers of tillers; NPT= Number of productive tillers; SF= Spikelet fertility (%); FLL= Flag leaf length (cm); PL= Panicle length (cm); GL= Grain length (mm); GB= Grain breadth (mm); L/B ratio = Length/Breadth ratio; TW= Test weight (g); HI= Harvest Index; R^2= Partial R^2

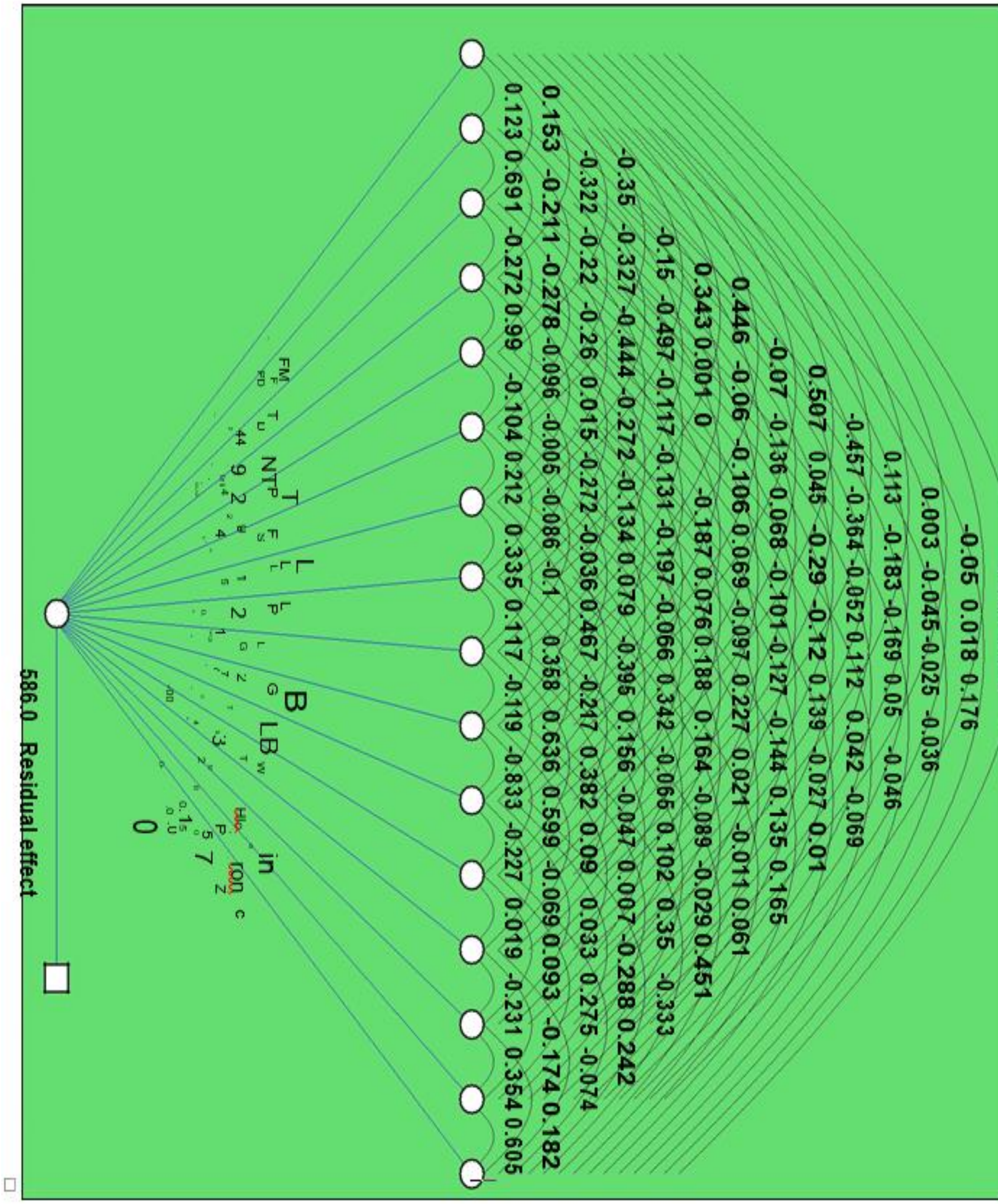


Fig 12: Phenotypical path diagram for growth and yield attributing in local landraces of rice

The relationship between grain yield and another trait may be negative or positive but it is the net result of direct effect of that particular trait and indirect effects via other traits. Hence, it is necessary to determine the path coefficients which partition the observed correlation into direct and indirect effects and also reveals the cause and effect relationship between grain yield and their related traits.

4.1. To identify of local rice landraces with high grain protein, zinc and iron content.

4.1.1. Identification of local landraces for variation in grain protein content.

Among the local landraces of rice, range of variation for rice protein content was observed from 10.36 % (Mattalaga) to 13.97 % (Marabatta) with an average value of 13.02 mg/kg^{-1} (Table 10). The check variety HP9 has recorded high protein content 15.67 % compared with another genotypes.

4.1.2. Identification of local landraces for variation in zinc content.

Zinc content in local landraces was ranged from 12.22 ppm (Biliakki) to 30.17 ppm (Neermullare) with an average value of 21.19 ppm (Table 11). The check variety HP1 has recorded high zinc content of 31.34 ppm compared to other local landraces of rice.

4.1.3. Identification of local landraces for variation in iron content.

Among the local landraces, range of variation for rice iron content was from 11. 03 ppm (Mattalaga) to 15.72 ppm (Naga Batta) with an average value of 13.38 ppm (Table 12). The check HP7 has recorded high iron content of 15.21 ppm compared with another genotypes from local landraces.

The performance of best genotypes having high grain protein coupled with high iron and zinc rich for selected agronomic traits were assessed (Table 13). Among the local landraces majority of them had lower protein (13.97 %) and zinc (30.17 ppm) content compared with check variety HP9 (15.67 % protein) and HP1 (31.34 ppm zinc), but this protein and zinc content was higher than high yielding check variety like MAS 26 (11.82 %

protein and 16.08 ppm zinc) and MAS 946-1 (11.92 % protein and 18.60 ppm zinc). Naga Batta has high iron content (15.72 ppm) compared to check HP7 (15.21 ppm). Nagesh *et al*. (2012) reported that grain Zn can act as selection criteria simultaneously to increase grain yield per plant, similar finding was also supported by Chakraborti *et al*., 2009, Bekele *et al*., 2013. Therefore, selection based on other traits such as plant height, number of productive tillers, test weight, would prove effective to enhance grain yield per plant and nutritional quality. These findings were supported by Anuradha *et al*. (2012).

Local landraces provided a valuable resource for plant breeding as well as for the preservation of genetic diversity. They are precious genetic resources, because they contain the huge genetic variability which can be used to complement and broaden the gene pool of advanced genotypes. The extent of genetic diversity in a crop population depends on recombination, mutation, selection and random genetic drift. Mutation and recombination bring new variations to a population, whereas selection and genetic drift remove some alleles, often from agronomically important lines. The use of adapted rice landraces, as the primary source of variation into which desired characters present in modern cultivars are introgressed may be an effective strategy for producing cultivars adapted to difficult production environments (Hanamaratti *et al*., 2008).

Table 9: Mean values of grain nutrient and grain yield parameters in local landraces of rice

SL. No	Landraces	Protein (%)	Zinc (ppm)	Iron (ppm)	Carbohydrate (%)	Moisture (%)	Grain yield plant^{1}
1	Alibulla	12.69	21.50	14.34	82.50	12.02	22.03
2	Alugidda	13.04	20.46	12.89	78.12	11.91	15.85
3	Anthrasali	13.03	20.60	13.08	76.31	12.19	21.57
4	DBN	13.30	27.54	14.16	76.74	12.60	21.34
5	Biliakki	13.05	28.31	14.67	76.88	11.54	19.50
6	Biliakki-1	12.52	12.22	11.45	79.65	12.16	16.60
7	Bilidoddi Marthayala	11.19	17.37	11.16	86.42	11.78	20.80
8	Rajmudi	11.85	17.13	11.35	77.48	11.74	19.40
9	Bilidoddi	11.72	20.17	11.56	82.31	12.27	21.95
10	Budda	12.25	23.61	13.36	83.29	11.98	27.29
11	Combatore Sanna	11.09	16.13	12.96	82.14	11.88	18.22
12	Dodda Batta	11.28	12.65	11.23	79.57	12.28	12.65
13	Dadda Mullare	11.31	15.49	12.02	78.39	12.06	11.69
14	Dadda Mullare-1	10.71	24.16	12.75	87.02	11.88	21.61
15	Doddiga	13.12	20.93	13.57	75.51	12.11	20.03
16	Gowri Sanna	12.22	22.34	13.30	80.37	12.06	15.52
17	Gidda Rajakamala	13.04	24.29	12.33	79.49	12.24	11.51
18	Gud Batta	12.10	29.34	12.77	81.58	12.13	19.07
19	Halu Gidda	12.41	27.05	13.51	86.49	12.31	14.56
20	Howne Kattu	12.09	28.26	14.51	77.38	12.01	13.66
21	Jaddu Batta	13.03	25.78	15.09	72.51	11.99	17.96
22	Jeerige Batta	13.75	20.70	12.31	81.95	11.42	22.16
23	Kadullite	11.95	23.78	12.56	78.26	11.93	17.70
24	Kaduvelpe	12.95	29.43	14.24	82.17	12.10	14.86
25	Kalajeera	12.46	13.46	11.27	80.39	11.99	16.95
26	Kalu Mottaga	12.11	23.47	12.80	84.95	12.03	22.73
27	Karihasali	11.00	13.09	11.36	82.49	11.87	15.53
28	Kari Kondaga	12.48	20.75	14.22	79.02	12.13	7.34

Table 9: Con'td…

SL. No	Landraces	Protein (%)	Zinc (ppm)	Iron (ppm)	Carbohydrate (%)	Moisture (%)	Grain yield plant ^{1}
29	Kanakasali	12.71	27.39	13.54	76.26	12.12	11.67
30	Karijaddu	12.36	20.10	13.02	80.19	12.00	15.24
31	Karidoddi	12.44	18.86	12.33	82.23	12.03	20.96
32	Rajmudi-1	12.94	19.28	12.44	73.39	12.07	15.10
33	Kesarnellu	13.63	23.63	13.62	82.16	12.35	20.31
34	Kirwana	11.23	22.98	13.11	84.89	12.20	29.01
35	Marabatta	13.97	22.06	13.47	79.71	11.93	13.88
36	Neergoli	13.66	21.13	11.83	84.13	11.78	25.42
37	Malligae	13.36	16.69	12.60	84.08	11.79	18.45
38	Mysore Malligae	12.25	21.87	12.18	82.49	12.17	23.26
39	Putta Batta	12.47	19.49	12.51	79.90	12.23	17.66
40	Raj Bhog	10.55	18.98	11.23	74.56	11.88	14.45
41	Naga Batta	13.56	25.25	15.72	82.11	12.21	13.04
42	Navasali	11.50	18.16	12.66	80.65	11.90	28.39
43	Sampigae Batta-1	13.63	19.46	13.50	77.19	11.89	12.39
44	Sampigae Batta-2	12.77	27.02	13.26	83.65	12.44	15.80
45	Sanesali	12.46	19.24	13.36	84.10	12.10	27.67
46	Mattalaga	10.36	14.12	11.03	83.37	12.08	15.44
47	Mugadhsughanda	13.64	18.20	11.90	80.17	11.73	16.34
48	Sannakki Batta	11.90	24.44	12.19	82.87	12.27	15.35
49	Neermullare	11.98	30.17	14.98	82.58	12.39	23.25
50	Sanna Mullu	11.59	27.98	12.47	81.38	12.34	18.75
				Checks			
51	MAS 946-1	12.08	18.60	11.82	77.86	11.91	16.50
52	MAS 26	11.66	16.08	11.03	80.61	12.39	15.70
53	HP 1	12.84	31.34	12.51	76.84	11.64	21.90
54	HP 7	11.73	17.90	15.21	81.35	11.71	14.04
55	HP 9	15.67	14.99	12.64	71.80	12.19	14.37

Table 10: Performance of top ten high grain protein local landraces compared with checks grown under aerobic condition

Sl.No.	Landraces	Protein (%)	Days to 50 % flowering	Plant height (cm)	Panicle length (cm)	Number of productive tillers	Test weight (g)	Grain length (mm)	Grain breadth (mm)	L/B ratio	Grain yield plant^{-1} (g)
1	Marabatta	13.97	114.50	110.70	23.10	16.30	25.35	7.93	3.37	2.36	13.88
2	Jeerige Batta	13.75	100.50	122.30	23.68	15.40	26.20	8.36	3.26	2.57	22.16
3	Neergoli	13.66	100.50	99.75	20.99	13.65	27.20	7.85	3.14	2.50	25.42
4	Mugadhsughanda	13.64	110.50	120.60	24.33	15.70	23.20	8.64	2.73	3.16	16.34
5	kesarnellu	13.63	110.00	118.40	22.94	16.10	26.10	7.99	3.32	2.41	20.31
6	Sampigae Batta-1	13.63	102.00	117.70	22.53	16.60	25.95	9.54	3.23	2.95	12.39
7	Naga Batta	13.56	114.00	119.30	21.08	15.80	26.05	8.15	3.03	2.69	13.04
8	Malligae	13.36	113.00	111.80	22.26	20.20	25.85	8.45	3.17	2.67	18.45
9	DBN	13.30	100.50	109.90	23.38	16.00	23.35	7.69	3.44	2.24	21.34
10	Doddiga	13.12	90.00	117.90	22.71	19.70	24.95	8.54	3.12	2.74	20.03
11	HP 9 (check)	15.67	90.00	67.40	18.80	24.40	19.80	7.82	2.47	3.17	14.37
12	MAS 26 (check)	11.03	102.00	72.60	20.73	15.45	26.25	10.26	2.35	4.37	15.70
13	MAS 946-1 (check)	11.82	103.50	74.30	21.73	20.70	27.75	9.84	2.38	4.14	16.50
Mean		13.56	105.55	114.84	22.70	16.55	25.42	8.31	3.18	2.63	18.34
Minimum		13.12	90.00	99.75	20.99	13.65	23.20	7.69	2.73	2.24	12.39
Maximum		13.97	114.50	122.30	24.33	20.20	27.20	9.54	3.44	3.16	25.42
Range		0.85	24.50	22.55	3.34	6.55	4.00	1.85	0.71	0.92	13.03
SE		0.08	2.54	2.15	0.33	0.62	0.40	0.17	0.06	0.09	1.37
Kurtosis		0.27	-0.37	1.51	-0.21	0.77	0.14	2.39	2.13	0.10	-1.02
Skewness		-0.35	-0.60	-1.26	-0.43	0.97	-0.88	1.33	-1.17	0.60	-0.01

Table 11: Performance of top ten high zinc content local landraces compared with checks grown under aerobic condition

Sl.No.	Landraces	Zinc (ppm)	Days to 50 % flowering	Plant height (cm)	Panicle length (cm)	Number of productive tillers	Test weight (g)	Grain length (mm)	Grain breadth (mm)	L/B ratio	Grain yield plant^{-1} (g)
1	Neermullare	30.17	102.50	111.60	22.01	21.20	27.00	8.35	3.04	2.75	23.25
2	Kaduvelpe	29.43	114.50	117.00	20.23	17.65	22.35	7.85	3.23	2.43	14.86
3	Gud Batta	29.34	100.50	136.67	19.98	15.00	28.14	8.15	3.35	2.43	19.07
4	Biliakki	28.31	121.50	152.00	21.75	15.60	22.10	7.84	3.13	2.50	19.50
5	Howne Kattu	28.26	103.50	116.10	22.31	17.70	24.95	7.97	3.04	2.63	13.66
6	Sanna Mullu	27.98	122.50	147.80	24.91	16.00	22.85	8.71	3.45	2.53	18.75
7	DBN	27.54	100.50	109.90	23.38	16.00	23.35	7.69	3.44	2.24	21.34
8	Kanakasali	27.39	100.50	148.30	24.12	16.60	23.75	8.72	2.97	2.94	11.67
9	Halu Gidda	27.05	115.50	136.95	24.97	14.05	17.15	8.84	3.25	2.72	14.56
10	Sampigae Batta-2	27.02	114.50	139.10	24.59	14.70	26.90	9.22	3.07	3.01	15.80
11	HP 1 (check)	31.34	90.00	114.60	20.94	21.05	20.69	8.32	2.66	3.13	21.90
12	MAS 26 (check)	16.08	102.00	72.60	20.73	15.45	26.25	10.26	2.35	4.37	15.70
13	MAS 946-1 (check)	18.60	103.50	74.30	21.73	20.70	27.75	9.84	2.38	4.14	16.50
Mean		28.25	109.60	131.54	22.83	16.45	23.85	8.33	3.20	2.62	17.25
Minimum		27.02	100.50	109.90	19.98	14.05	17.15	7.69	2.97	2.24	11.67
Maximum		30.17	122.50	152.00	24.97	21.20	28.14	9.22	3.45	3.01	23.25
Range		3.15	22.00	42.10	4.99	7.15	10.99	1.53	0.48	0.77	11.58
SE		0.34	2.84	5.16	0.59	0.65	1.00	0.16	0.05	0.08	1.17
Kurtosis		-0.82	-1.84	-1.84	-1.29	2.66	1.21	-1.16	-1.40	-0.56	-0.99
Skewness		0.60	0.27	-0.21	-0.34	1.43	-0.75	0.39	0.33	0.27	0.14

Table 12: Performance of top ten high iron content local landraces compared with checks grown under aerobic condition

Sl.No.	Landraces	Iron (ppm)	Days to 50 % flowering	Plant height (cm)	Panicle length (cm)	Number of productive tillers	Test weight (g)	Grain length (mm)	Grain breadth (mm)	L/B ratio	Grain yield $plant^{-1}$ (g)
1	Naga Batta	15.72	114.00	119.30	21.08	15.80	26.05	8.15	3.03	2.69	13.04
2	Jaddu Batta	15.09	91.00	150.30	27.50	13.30	34.65	8.97	3.74	2.40	17.96
3	Neermullare	14.98	102.50	111.60	22.01	21.20	27.00	8.35	3.04	2.75	23.25
4	Biliakki	14.67	121.50	152.00	21.75	15.60	22.10	7.84	3.13	2.50	19.50
5	Howne Kattu	14.51	103.50	116.10	22.31	17.70	24.95	7.97	3.04	2.63	13.66
6	Alibulla	14.34	102.00	112.20	21.65	16.70	25.95	8.55	2.92	2.93	22.03
7	Kaduvelpe	14.24	114.50	117.00	20.23	17.65	22.35	7.85	3.23	2.43	14.86
8	Kari Kondaga	14.22	102.50	115.97	23.46	21.43	27.75	8.04	3.53	2.28	7.34
9	DBN	14.16	100.50	109.90	23.38	16.00	23.35	7.69	3.44	2.24	21.34
10	Kesarnellu	13.62	110.00	118.40	22.94	16.10	26.10	7.99	3.32	2.41	20.31
11	HP 7 (checks)	15.21	101.50	122.60	21.38	17.20	18.40	7.77	2.24	3.48	14.04
12	MAS 26 (check)	11.03	102.00	72.60	20.73	15.45	26.25	10.26	2.35	4.37	15.70
13	MAS 946-1 (check)	11.82	103.50	74.30	21.73	20.70	27.75	9.84	2.38	4.14	16.50
Mean		14.51	106.20	122.28	22.63	17.15	26.03	8.14	3.24	2.53	17.33
Minimum		13.62	91.00	109.90	20.23	13.30	22.10	7.69	2.92	2.24	7.34
Maximum		15.22	121.50	152.00	27.50	21.43	34.65	8.97	3.74	2.93	23.25
Range		1.60	30.50	42.10	7.27	8.13	12.55	1.28	0.82	0.69	15.91
SE		0.16	2.78	4.91	0.63	0.80	1.13	0.12	0.08	0.07	1.58
Kurtosis		-0.39	0.01	1.11	4.15	0.22	3.63	1.20	-0.36	-0.48	0.06
Skewness		-0.12	0.16	1.61	1.72	0.69	1.56	1.21	0.73	0.53	-0.81

Table 13: Performance of top ten high grain protein, zinc, iron content and carbohydrate local landraces grown under aerobic condition

Sl.No.	Landraces	Protein (%)	Iron (ppm)	Zinc (ppm)	Carbohydrate (%)	DFF	PH	PL	TNT	GL	GB	LB	TW	GY
1	Marabatta	13.97	13.47	22.06	79.71	114.50	110.70	23.10	16.30	7.93	3.37	2.36	25.35	13.88
2	Jeerige Batta	13.75	12.31	20.70	81.95	100.50	122.30	23.68	15.40	8.36	3.26	2.57	26.20	22.16
3	Neergoli	13.66	11.83	21.13	84.13	100.50	99.75	20.99	13.65	7.85	3.14	2.50	27.20	25.42
4	Mugadhsughanda	13.64	11.90	18.20	80.17	110.50	120.60	24.33	15.70	8.64	2.73	3.16	23.20	16.34
5	Kesarnellu	13.63	13.62	23.63	82.16	110.00	118.40	22.94	16.10	7.99	3.32	2.41	26.10	20.31
6	Sampigae Batta-1	13.63	13.50	19.46	77.19	102.00	117.70	22.53	16.60	9.54	3.23	2.95	25.95	12.39
7	Naga Batta	13.56	15.72	25.25	82.11	114.00	119.30	21.08	15.80	8.15	3.03	2.69	26.05	13.04
8	Malligae	13.36	12.60	16.69	84.08	113.00	111.80	22.26	20.20	8.45	3.17	2.67	25.85	18.45
9	DBN	13.30	14.16	27.54	76.74	100.50	109.90	23.38	16.00	7.69	3.44	2.24	23.35	21.34
10	Doddiga	13.12	13.57	20.93	75.51	90.00	117.90	22.71	19.70	8.54	3.12	2.74	24.95	20.03
11	MAS 26 (check)	11.66	11.03	16.08	80.61	102.00	72.60	20.73	15.45	10.26	2.35	4.37	26.25	15.70
12	MAS 946-1 (check)	12.08	11.82	18.60	77.86	103.50	74.30	21.73	20.70	9.84	2.38	4.14	27.75	16.50
13	HP 1 (check)	12.84	12.51	31.34	76.84	90.00	114.60	20.94	21.05	8.32	2.66	3.13	20.69	21.90
14	HP 7 (check)	11.73	15.21	17.90	81.35	101.50	122.60	21.38	17.20	7.77	2.24	3.48	18.40	14.04
15	HP 9 (check)	15.67	12.64	14.99	71.80	90.00	67.40	18.80	24.40	7.82	2.47	3.17	19.80	14.37
Mean		13.56	13.22	21.56	80.38	105.55	114.84	22.70	16.55	8.31	3.18	2.63	25.42	18.34
Minimum		13.12	11.83	16.69	75.51	90.00	99.75	20.99	13.65	7.69	2.73	2.24	23.20	12.39
Maximum		13.97	15.22	27.54	84.13	114.50	122.30	24.33	20.20	9.54	3.44	3.16	27.20	25.42
SE		0.08	0.34	1.03	0.97	2.54	2.15	0.33	0.62	0.17	0.06	0.09	0.40	1.37
Kurtosis		0.25	-0.18	-0.01	-1.21	-0.37	1.51	-0.21	0.77	2.42	2.09	0.10	0.14	-1.02
Skewness		-0.36	0.35	0.45	-0.37	-0.60	-1.26	-0.43	0.97	1.34	-1.15	0.61	-0.88	-0.01

Key: DFF= Days to 50% flowering (days); PH= Plant height (cm); TNT= Total numbers of tillers; PL= Panicle length (cm); GL= Grain length (mm) GB= Grain breadth (mm); L/B ratio = Length/Breadth ratio; TW= Test weight (g); GY/P= Grain Yield per Plant (g).

V. SUMMARY

The results obtained from the experiments in genetic variability for micronutrients in local landraces of rice are summarized below.

Local landraces were evaluated for grain protein, zinc, iron content and other growth and yield attributing characters grown in *kharif* 2017 under aerobic condition. Analysis of variance revealed that there was significant variation for the characters studied. Similarly, significant variation was observed for 14 traits in the 55 rice landraces.

The GCV and PCV coupled with high heritability and genetic advance were recorded for number of tillers per plant, number of productive tillers per plant, grain yield per plant. The high GCV and PCV coupled with high heritability and genetic advance as per cent mean were recorded for all the characters studied except plant height, total productive tillers per plant, panicle length, test weight and grain yield per plant among local landraces. High PCV and GCV suggested that, these characters were under the greater influence of genetic factors and less influenced by the environmental factors. Hence, these characters could be relied upon and simple selection could be practiced for further crop improvement. High heritability broad sense and genetic advance as per cent mean indicated the presence of considerable variation and additive gene effects.

The mean of phenotypic correlation analysis was carried out to identify morphological characters influencing the grain yield and yield attributing traits. Among the local landraces, highly significant and positive correlation were observed for grain yield per plant with plant height, total number of tillers, spikelet fertility, flag leaf length and test weight. Significant negative correlation was observed between zinc content and grain yield per plant. Hence, selection for enhancement of these traits could be executed separately but simultaneously.

The phenotypic path-coefficient analysis indicated high positive direct effect of total number of tillers, grain length, test weight and harvest index on grain yield per plant. On other hand, grain protein content had low direct effect on grain yield per plant. Selection based on total number of tillers per plant for grain yield would be most effective strategy, since the trait had maximum positive direct effects as well as indirect effects on other traits.

The selection of grain yield under aerobic condition is possible but it needs to be postponed to later generations and role of number of panicles had maximum positive effect on grain yield and could be used for selection. This investigation assists breeders to select desirable genotypes suitable for aerobic conditions.

In the present study, it was observed that some local landraces such as Marabatta, Jeerige Batta, Neergoli, Mugadhsughanda, Kesarnellu had high protein (13.63- 13.97 %) and zinc (30.17 ppm) content compared to yield checks like MAS 946-1 and MAS26, but less than nutrient checks like HP1 (Zn), and HP9 (Protein). Naga Batta has high iron content (15.72ppm) compare with check HP7 (15.21ppm). Among top high yielding landraces Neergoli (25.42), Jeerige Batta (22.16g), DBN (21.34g), Kesarnellu (20.31g) and Doddiga (20.03g) had high grain yield per plant. Hence, it gave scope for selection of suitable local land race as parents in crossing program.

Future line of work:

- Superior grain quality and micronutrients used as donors to develop of aerobic rice varieties with higher potential.
- Predictable expression of these traits across seasons and years give a variety.
- Validation of the results obtained for grain protein, zinc and iron content with grain number can also be carried out in polished rice.

VI. REFERENCES

ABEBE, T., ALAMEREW, S. AND TULU, L., 2017, Genetic variability, heritability and genetic advance for yield and its related traits in rainfed lowland rice (*Oryza Sativa* L.) genotypes at Fogera and Pawe, Ethiopia. *Adv. Crop Sci. Tech.*, **5**:272-280.

AJMERA, S., SUDHEER, K. S. AND RAVINDRABABU, V., 2017, Evaluation of genetic variability, heritability and genetic advance for yield and yield components in rice genotypes. *Int. J. Pure App. Biosci.* **5 (4):** 909-915.

ANANDAN, A., RAJIV, G., ESWARAN, R. AND PRAKASH, M., 2011, Genotypic variation and relationships between quality traits and trace elements in traditional and improved rice (*Oryza sativa* L.) genotypes. *J. Food Sci.*, **76**(4): 122-130.

ANJUM, F. M., PASHA, I., BUGTI, M. A. AND BUTT, M. S., 2007, Mineral composition of different rice varieties and their milling fractions. *Pak. J. Agric. Sci.*, **44**(2): 332-336.

ANONYMOUS, 1996, Zinc: a key micronutrient. *Fertilizer Int.*, **429**: 1-2.

ANONYMOUS, 2008, *Package of Practice of field crops*, Univ. Agric. Sci., GKVK, Bangalore, p. 67-71.

ANURADHA, K., AGARWAL, S., RAO, V. Y., RAO, K. V., VIRAKTAMATH, B. C. AND SARLA, N., 2012, Mapping QTLs and candidate genes for iron and zinc concentrations in unpolished rice of Madhukar× Swarna RILs. *Gene*, **508**: 233-240.

ARNOLD, J. M. AND BAUMAN, L. F., 1976, Inheritance of and interrelationship among maize kernel traits and elemental contents. *Crop Sci*., **16**: 439 – 440.

BALINT, A. F., KOVACS, G., ERDEI, L. AND SUTKA, J., 2001, Comparison of the Cu, Zn, Fe, Ca and Mg contents of the grains of wild, ancient and cultivated wheat species. *Cereal Res. Commu.,* **29**: 375-382.

BANERJEE, S. AND CHANDEL, G., 2011, Understanding the role of metal homeostasis related candidate genes in Fe/Zn uptake, transport and redistribution in rice using semi-quantitative RT-PCR. *J. Plant Mol. Biol. Biotechnol*., **2**(1): 33-46.

BANZIGER, M. AND LONG, M., 2000, The potential for increasing iron and zinc density of maize through plant-breeding. *Food Nutr. Bull*., **21**: 397-400.

BASHIR, S. A., APURVA, K., GOPALA, K. S., SINGH, U. D., RATHOUR, R., TONAPI, V., SHARMA, T. R., NAGARAJAN, M., PRABHU, K. V. AND SINGH, A. K., 2013, Molecular analysis and phenotypic validation of blast resistance genes *Pita* and *Pita*2 in landraces of rice (*Oryza sativa* L.). *Indian J. Genet.,* **73**(2):131-141.

BEKELE, B. D., RAKHI, S., NAVEEN, G. K., KUNDUR, P. J. AND SHASHIDHAR, H. E., 2013, Estimation of genetic variability and correlation studies for grain zinc concentrations and yield related traits in selected rice (*Oryza Sativa* L.) genotypes. *Asian J. Exp. Biol. Sci.,* **4**(3)*:* 345-351.

BHATTACHARYA, K. R., SOWBHAGYA, C. M. AND INDUDHARA SWAMY, Y. M., 1982, Quality profiles of rice: A tentative scheme for classification. *J. Food Sci*., **47**:564-569.

BOONCHUAY, P., CAKMAK, I., RERKASEM, B. AND PROM-U-THAI, C., 2013, Effect of different foliar zinc application at different growth stages on seed zinc concentration and its impact on seedling vigor in rice. *Soil sci. Plant nutr.*, **59**: 180–188.

BOSE, L. K. AND PRADHAN, S. K., 2005, Genetic divergence in deep water rice genotypes. *J. Cent. Eur. Agric.*, **6**(4): 635-640.

BOUIS, H. AND WELCH, R., 2010, Biofortification. A sustainable agricultural strategy for reducing micronutrient malnutrition in the global south. *Crop Sci.*, **50**:20-32.

BOUIS, H. E., 2001, Increasing the micronutrient content of rice through plant breeding. AACC annual meeting, Charlotte, North Carolina.

BOUMAN, B. A. M., PENG, S., CASTANEDA, A. R. AND VISPERAS, R. M., 2005, Yield and water use of irrigated tropical aerobic rice systems. *Agric. Water Manag*, **74**: 87-105.

BROADLEY, M. R., WHITE, P. J., HAMMOND, J. P., ZELKO, I. AND LUX, A., 2007, Zinc in plants. *New Phytol*., **173**(4): 677-702.

BURTON, G. W. AND DEVANE, E. H., 1953, Estimating heritability in tall fescue (festuca arundinacea) from replicated clonal material. *Agron. J.,* **45** (10): 478–481.

CAMACHO-VILLA , T. C., MAXTED, N., SCHOLTEN, M., FORD-LLOYD, B., 2005, Defining and identifying crop landraces. *Plant Genet. Resour. Charact. Util.,* **3**: 373-384.

CHAKRABORTI, M., HOSSAIN, F., KUMAR, R., GUPTA, H. S. AND PRASANNA, B. M., 2009, Genetic evaluation of grain yield and kernel micronutrient traits in maize. *Pusa Agril. Sci*., **32**: 11-16.

CHAUHAN, J. S., 1996, Genotypic and phenotypic correlations between grain yield and other associated characters in early duration elite breeding cultures of rice. *Oryza*, **33**: 26 - 30.

CHAUHAN, J. S., NANDA, J. S., CHAUHAN, U. S. AND RAM, H. H., 1987, Inheritance and inter relationship of some grain quality components in rice. *Oryza*, **24**: 123-126.

CHOO, T. M. AND REINBERGS, E., 1982, Analysis of skewness and kurtosis for detecting gene interaction in a double haploid population. *Crop Sci*., **22**: 231 -235.

COCHRAN, W. G. AND COX, G. M., 1957, Experimental Designs, *Inc., New York*, pp. 611.

DEWEY, D. R. AND LU, K. H., 1959, A path analysis of crested grass seed production. *Agron. J*., **51:** 515-518.

DHANRAJ, A. AND JAGADISH, C. A., 1987, Studies on character association in F_2 generation of ten selected crosses in rice (*Oryza sativa* L.). *J. Res. A FAU,* **15**: 64-65.

ESQUINAS- ALCÁZAR, J., 2005, Science and society: protecting crop genetic diversity for food security: political, ethical and technical challenges. *Nat. Rev. Genet*., **6**(12):946-53.

FAO, 2010, Second report on the world's plant genetic resources for food and agriculture. United Nations Food and Agriculture Organization (FAO), Rome, Italy.

FAO/WHO, 2000, Preliminary report on recommended nutrient intakes. Joint FAO/WHO Expert consultation on human vitamin and mineral requirements.

FATHELRAHMAN, S. A., ALSADIG, A. I. AND DAGASH, Y. I., 2015, Genetic variability in rice genotypes (*Oryza sativa* l.) in yield and yield component under semi-arid zone (sudan). *J. for. Prod. Ind.*, **4**(2), 21-32.

FISHER, R. A., IMMER, F. R. AND TEDIN, O., 1932, The genetical interpretation of statistics of the third degree in the study of quantitative inheritance. *Genet.*, **17:** 107-124.

GANAPATHY, S., GANESH, S. K., VIVEKANANDAN, P., SHANMUGASUNDARAM, P. AND BABU, R, C., 2007, Variability and interrelationship between yield and physio-morphological traits in rice (*Oryza sativa* L.) under moisture stress condition. *Crop Res.*, **34**(1/3): 260-262.

GANDHI, R.V., RUDRESH, N. S., SHIVAMURTHY, M. AND HITTALMANI, S., 2012, Performance and adoption of new aerobic rice variety MAS 946-1 (Sharada) in southern Karnataka, *Karnataka J. Agric. Sci.*, **25** (1): 5-8.

GAO, X., ZOU, C., FAN, X., ZHANG, F. AND HOFFLAND, E., 2009, From flooded to aerobic conditions in rice cultivation: consequences for zinc uptake. *Plant Soil*, **280**(1): 41-47.

GEARING, M. E., 2015, Good as gold: Can golden rice and other biofortified crops prevent malnutrition. Science in the news, Harvard University. *Blog, special edition on GMOS.*

GOPALAN, C., RAMASASTRI, B. V. AND BALASUBRAMANIAN, S. C., 2014, Revised and reprinted), Nutritive value of Indian foods. *National Institute of Nutrition, ICMR, Hyderabad*.

GRAHAM, R. D., SENADHIRA, D., BEEBE, S., IGLESIAS, C. AND MONASTERIO, I., 1999, Breeding for micronutrient density in edible portions of staple food crops: conventional approaches. *Field Crop Res*., **60**: 57-80.

GRAHAM, R. D., WELCH, R. M. AND QEOUIS, H. E., 2000, Addressing micronutrient malnutrition through enhancing the nutritional quality of staple food: principles, perspectives and knowledge gaps. *Adv. Agron*., **70**: 77-142.

GREGORIO, G. B. AND HTUT, T., 2003, Micronutrient dense rice: developing breeding tools at IRRI. *Rice sci*., **11**(2): 371-378.

GREGORIO, G. B., SENADHIRA, D., GRAHAM, R. D. AND HTUT, T., 1999, Improving iron and zinc value of rice for human nutrition. *Agric. Dev.*, **23**: 68-81.

GUERINOT, M. L. AND SALT, D. E., 2001, Fortified foods and phytoremediation. Two sides of the same coin. *Plant Physiol.*, **125**: 164-167.

HALLAUER, A. R. AND CARENA, M. J., 2009, Maize breeding. In: Carena M. J. (Ed.). Handbook of Plant Breeding: *Cereals. Springer, New York*. P.3-98.

HANAMARATTI, N. G., PRASHANTHI, S. K., SALIMATH, P. M., HANCHINAL, R. R., MOHANKUMAR, H. D., PRARAMASHWARAPPA, K. G. AND RAIKAR, S. D., 2008, Traiditional landraces of rice in Karnataka: Reservoirs of valuable traits. *Curr. Sci*., **94**(2): 242-247.

HARADARI, C. AND HITTALMANI, S., 2017, Trait association and construction of selection indices in rice (*Oryza sativa L.*) under aerobic condition. *Int. J. Agric. Sci*., **9**: 4416-4421.

HUANG, X., WEI, X., SANG, T., ZHAO, Q., FENG, Q. AND ZHAO, Y., 2010, Genome-wide association studies of 14 agronomic traits in rice landraces. *Nat. Genet*., **42**, 961–967.

JOHNSON, H. W., ROBINSON, H. F. AND COMSTOCK, R. E., 1955, Estimates of genetic and environmental variability in soybeans. *Agron. J.*, **47** (7): 314–318.

KAHANI, F. AND HITTALMANI, S., 2015a, Aerobic rice and inheritance of traits, First edition. *Statperson Publishing Corporation. ISBN*: 978-1-329-86579, P.89-130.

KAHANI, F., HITTALMANI, S., 2015b. Genetic analysis and traits association in F_2 intervarietal populations in rice under aerobic condition. *J. Rice Res*., **3**:152. doi:10.4172/2375-4338.1000152

KARIM, D., SARKAR, U., SIDDIQUE, M. N. A., KHALEQUE MIAH, M. A. AND HASNAT, M. Z., 2007, Variability and genetic parameter analysis in aromatic rice. *Int. J. Sustain. Crop Prod.*, **2**(5):15-18**.**

KAYODE, A., SANNI, E. I., FAWOLE, E. R. G., GUEI, E. D. K., OJO, E., EKLOU, A., SOMADO, E. D., DANIELTIA, E. S., AYONI, O. AND SANCHEZ, I., 2008, Geographical patterns of phenotypic diversity in *Oryza sativa* landraces of Coˆte d‟Ivoire, *Euphytica*, **160**:389–400.

KOBAYASHI, A., EBANA, K., FUKUOKA, S. AND NAGAMINE, T., 2006, Microsatellite markers revealed the genetic diversity of an old Japanese rice landrace 'Echizen'. *Genet. Resour. Crop Evol.,* **53**: 499-506.

KOTCH, G. P., ORTIZ, R. AND ROSS, W. M., 1992, Genetic analysis by use of potato haploid populations. *Genome*, **35**: 103-108.

KUMAR, B., THAKUR, R., MISHRA, S. B. AND SINGH, D. N., 2001, Variability studies in segregating population of rice (*Oryza sativa* L.). *Ann. Biol*., **17**(1): 43-45.

LAKSHMANA, D., BIRADAR, B. D. AND KUMAR, R. R. L., 2009, Genetic variability studies for quantitative traits in a pool of restorers and maintainers lines of pearl millet (*Pennisetum glaucum* L.). *Karnataka J. Agric. Sci.*, **22** (4): 881 - 882.

LIU, B. H., 1998, Statistical Genomics CRC Press LLC, Boca Raton, Florida.

LUSH, J. L., 1949, Heritability of quantitative characters in farm animals. Proc. 8th Congr. Genet. *Heriditas,* **35**: Suppl., pp. 35.

MADHAVILATHA, L., REDDI, S. M., SUNEETHA, Y. AND SRINIVAS, T., 2005, Genetic variability, correlation and path analysis for yield and quality traits in rice (*Oryza sativa* L.). *Res. Crops*., **6**(3): 527 - 534.

MADHUSUDHAN., 2001, Development of trait differential lines and detection of near isogenic lines by phenotypic and molecular characterization in early segregating generation in rice (*Oryza sativa* L.). M.Sc. (Agri.) *Thesis*, Univ. Agril. Sci., *Bangalore*, P.96.

MALL, A. K., BABU, J. D. P. AND BABU, G. S., 2005, Estimation of genetic variability in rice. *J. Maharashtra Agril. Univ*., **30**(2): 166-168.

MANAY, S. AND SHADAKSHARASWAMY, M., 2005., Foods, Facts and principles New Age international (P) Ltd publishers, New Delhi.

MARSCHNER., 2008, Enrichment of cereal grains with zinc: Agronomic or genetic biofortification. *Plant Soil.*, **302**(1):1-17.

MARTINEZ, C. P., BORRERO, J., CARABALI, S. J., DELGAD, D., CORREA, F. AND TOHME, J., 2006, High iron and zinc rice lines for Latin America. 31st Rice Technical Working Group, February 26 to March 1, 2006. *Wood lands, Texas, USA.*

MARTÍNEZ, C. P., BORRERO, R., TABOADA, J. L., VIANA, P., NEVES, L., NARVAEZ, V., ADAMES P. A. AND VARGAS, A., 2010, Rice cultivars with enhanced iron and zinc content to improve human nutrition. 28th International Rice Research Conference, 8-12 November 2010, Hanoi, Vietnam OP10: Quality Grain, Health, and Nutrition.

MORAGHAN, J. T. AND GRAFTON, K., 1999, Seed zinc concentration and the zinc-efficiency trait in navy bean. *Soil Sci. Soc. Am. J.,* **63**: 918 - 922.

MOYANO, L. T. M., BONNEAU, J. P., JOS, T., PALACIOS, S., JOSEPH, T. AND JOHNSON, J. T., 2016, Association of increased grain iron and zinc concentrations with agro-morphological traits of biofortified rice. *Front Plant Sci.*, **7**: 1452-1463.

NAGABHUSHAN, K., 2003, Detection of main QTL controlling plant traits and identification of RAPD markers associated with plant height in rice (*Oryza sativa* L.). M.Sc. *Thesis,* Univ. Agril. Sci., Bangalore, P. 136.

NAGARATHNA, T. K., SHANKAR, A. G. AND UDAYAKUMAR, M., 2010, Assessment of genetic variation in zinc acquisition and transport to seed in diversified germplasm lines of rice (*Oryza sativa* L.). J. *Agri. Technol*., **6**: 171-78.

NAGESH, R. V., USHARANI, G. AND REDDY, T. D., 2012, Grain iron and zinc association studies in rice (*Oryza sativa* L.) F_1 progenies, *Appl. Sci. Res.,* **4**(1): 696-702.

NAIDU, B. S., GOUDA, B. B. C. AND LAXMI, A. B., 1986, Grain type classification of high yielding rice varieties in Karnataka. *Curr. Res.,* **15**(7/8): 61-63.

NANDAN, R., SWETA. AND SINGH, S. K., 2010, Character association and path analysis in rice (*Oryza sativa L*.) genotypes. *World J. Agri. Sci.,* **6**(2): 201-206.

NDUKAUBA, J., NWOFIA, G. E., OKOCHA, P. I. AND ENE-OBONG, E. E., 2015, Variability in egusi melon genotypes (*Citrullus lanatus* (Thumb) matsum and nakai) in derived savannah environment in South- Eastern Nigeria. *Int. J. Plant Res.,* **5**(1):19-26.

ORTIZ-MONASTERIO, J. L. AND GRAHAM, R. D., 2000, Breeding for trace minerals in wheat. *Food Nutr. Bull.,* **21**: 392-396.

PANSE. V. G. AND SUKHATME, P. V., 1984, Statistical methods for agricultural workers. Third Edition, *Indian Council of Agricultural Research, New Delhi*.

PFEIFFER, W. H. AND MCCLAFFERTY, B., 2007, Harvest plus: Breeding crops for better nutrition. International plant breeding symposium. *Crop Sci.,* **47**(3): 88-105.

PINGALI, P. L., HOSSAIN, M. AND GERPACIO, R. V., 1997, Asian rice bowls: The returning crisis. International Rice Research Institute (IRRI), *Los Banos*, P-341.

PRAMILA, C. K., RAME GOWDA., SHARANAPPA., PAVITHRA., VANI, B. V. AND RAMACHANDRA, R., 2011, Genotypic variation for milling, cooking and nutrient quality as influenced by methods of production in rice. *Res. J. Agril. Sci.*, **2**(3):468-473.

QUI, L. C., PAN, J. AND DAN, B. W., 1995, The mineral nutrient component and characteristic of color and white brown rice. *Chin. J. Rice Sci.*, **7**(2): 95-100.

RAHMAN, M. A., BAHL, P. N., 1986, Evaluation of early generation testing in chickpea. *Plant Breed*., **97**: 82-85.

RAJESH, T., PARAMASIVAM, K. AND THIRUMENI, S., 2010, Genetic divergence in landraces of rice. *Electron. J. Plant Breed.*, **1**(2): 199-204.

RAM, S. G., THIRUVENGADAM, V. AND VINOD, K. K., 2007, Genetic diversity among cultivars, landraces and wild relatives of rice as revealed by microsatellite markers. *J. Appl. Genet*., **48**(4): 337-345.

RAWAT, N., NEELAM, K., TIWARI, V. K. AND DHALIWAL, H. S., 2013, Biofortification of cereals to overcome hidden hunger. *Plant Breed*., **132**: 437-445.

ROBSON, D. S., 1956, Application of K4 statistics to genetic variance component analysis. *Biometrics*, **12**: 433-444.

SARMA, M. K., RICHHARIA, A. K. AND AGARWAL, R. K., 2004, Characterization of ahu rice of Assam for morphological and agronomic traits under transplanted conditions. *Oryza*, **41**(1&2): 8-12.

SATHEESHKUMAR, P. AND SARAVANAN, K., 2012, Genetic variability, correlation and path analysis in rice (*Oryza sativa* L.). *Inter. J. Curr. Res.*, **4**:82-85.

SELLAPPAN, K., DATTA, K., PARKHI, V. AND DATTA, S. K., 2009, Rice caryopsis structure in relation to distribution of micronutrients (iron, zinc, carotene) of rice cultivars including transgenic indica rice. *Plant Sci*., **177**: 557–562.

SHAILAJA HITTALMANI, 2007a, Aerobic rice cultivation Brochure, MAS lab, Univ. Agric. Sci., GKVK, Bangalore.

SHAILAJA HITTALMANI, 2007b, MAS946-1, A new aerobic rice variety for water scarce situation. Aerobic rice cultivation Brochure, MAS lab, Univ. Agric. Sci., GKVK, Bangalore.

SHAILAJA HITTALMANI, 2008, MAS, 26, a new aerobic rice variety for water saving and safe environment. Aerobic rice cultivation Brochure, MAS lab, Univ. Agric. Sci., GKVK, Bangalore.

SHANMUGASUNDARAM, P., SOUFRAMANIEN, J. AND SADASIVAM, S., 2000. Genetic divergence among rice varieties released from paddy breeding station, Coimbatore, India. *Oryza*, **37**(3): 225-228.

SHARMA, R. S. AND CHOUBEY, S. D., 1985, Correlation studies in upland rice. *Indian J. Agron.*, **30**(1): 87-88.

SINGH, S., MISHRA, S. AND KALPANA, K., 2010, Phenotypic diversity in grain yield and nutritional traits of rice (*Oryza sativa* L.). *Pest Sci. Manag*., **6**:1-4.

SIVASUBRAMANIAN, S. AND MADHAVAMENON, P.,1973, Combing ability in rice. *Madras Agric. J*., **60:** 419-421.

SPEROTTOA, R. A., KLEIN, F. R., VINICIUS DE ABREU, W. AND FETT, J. P., 2012, Iron biofortification in rice: It's a long way to the top. *Plant Sci*., **190**: 24-39.

SUREK, H. AND KORKUT, K. Z., 1998, Diallel analysis of some quantitative characters in F_1 and F_2 generations in rice (*Oryza sativa* L.). *Egypt. J. Agric. Res.*, **76**(2): 651-663.

SUSANTO, U., BAROKAH, U., HIDAYATULLAH, A. AND SWAMY, M., 2017, Yield and zn content of biofortified rice genotypes in an Indonesian rice agro-ecosystem. *Nusantara Biosci.*, **9**(4): 288-294.

TANG, S. X., JIANG, Y. Z., WEI X. H., LI Z. C. AND YU, H. Y., 2002, Genetic diversity of isozymes of cultivated rice in china. *Acta Agron. Sin*., **28**: 203-207.

THAKUR, S. K., SHARMA, N. P. AND SHARMA, S. N., 2000, Genetic variation and association studies in segregating population of rice (*Oryza sativa* L.). *J. Soils and Crop*, **10**(2): 316-318.

VANITHA, J., KUMARI, R. U., AMUDHA, K. AND ROBIN, S., 2015, Genetic evaluation of rice genotypes for zinc deficiency tolerance and yield traits under aerobic condition in rice. *Electron J. Plant Breed.*, **6**(1): 191–195.

WANG, G., PARPIA, B. AND WEN, Z., 1997, The composition of Chinese foods. Institute of nutrition and food hygiene, Chinese academy of preventive medicine. ILSI Press, Washington D. C.

WATERS, B. AND SANKARAN, R. P., 2011, Moving micronutrients from the soil to the seeds: Genes and physiological processes from a biofortification perspective. *Plant Sci.*, **180**: 562–574.

WELCH, R. M. AND GRAHAM, R. D., 2004, Breeding for micronutrients in staple food crops from a human nutrition perspective. *J. Exp. Bot*., **55**: 353-364.

WHITE, P. J. AND BROADELY, M. R., 2011, Physiological limits to zinc biofortification of edible crops. *Front. Plant Sci*., **2**: 1-11.

WIERINGA, F., DIJKHUIZEN, M., FIORENTINO, M., LAILLOU, A. AND BERGER, J., 2015, Determination of zinc status in humans: Which indicator should we use? *Nutrients*, **7:** 3252-3263.

WORLD HEALTH ORGANIZATION, 2002, Zinc for better health: The world health report: Geneva, Switzerland, P.52-56.

WRIGHT, S., 1921, Correlation and Causation. *J. Agric. Res.*, **20**: 557-585.

XIAOGUANG, Y., BOUMAN, B. A. M., HUAQI, W., ZHIMIN, W., JUNFANG, Z. AND BIN, C., 2004, Performance of temperate aerobic rice under different water regimes in North China. *Agric. Water Manag.*, **74**(2): 107–122.

YADAV, R. S. AND BHUSHAN, C., 2001, Effect of moisture stress on growth and yield in rice genotypes. *Indian J. Agri. Res.*, **2**: 104-107.

YAGI, K., TSURUTA, H. AND MINAMI, K., 1997, Possible options for mitigating methane emission from rice cultivation. *Nutr. Cycl. Agroecosyst.*, **49**(1): 213-220.

YOGAMEENAKSHI, P. AND VIVEKANANDAN, P., 2010, Association analysis in F_1 and F_2 generations of rice under reproductive stage drought stress. *Electron J. Plant Breed.*, **1**(4): 890-898.

YU, J., XIONG, H., ZHU, X., ZHANG, H., HUIHUI, L., MIAO, J., WANG, W., TANG, Z., ZHANG, Z., YAO, G., ZHANG, Q., PAN, Y., WANG, X., RASHID, M, A, R., JINJIE, L., GAO, Y., ZHIKANG, L., YANG, W., XIANGDONG, F. AND ZICHAO L., 2017, OsLG3 contributing to rice grain length and yield was mined by Ho-LAMap. *BMC Bio.*, **15**: 28-37.

ZENG, Y., SHEN, S., WANG, L., LIU, J., PU, X., DU, J. AND QIU, M., 2005, Correlation of plant morphological and grain quality traits with mineral element contents in yunnan rice. *Rice Sci.*, **12**(2): 101-106.

ZHANG, M. W., GUO, B. J. AND PENG, Z. M., 2004, Genetic effects on Fe, Zn, Mn and P content in *Indica* black pericarp rice and their genetic correlations with grain characteristics. *Euphytica*, **135**: 315-323

APPENDIX -I: Mean values of growth and yield attributing in local landraces of rice.

Sl. No.	Genotypes	PH	DFF	DTM	TNT	NPT	SF	FLL	PL	GL	GB	L/B	TW	HI	GY/P
1	Alibulla	112.20	102.00	157.50	17.80	16.70	70.32	33.67	21.65	8.55	2.92	2.93	25.95	0.52	22.03
2	Alugidda	96.50	95.00	159.50	17.00	15.90	85.17	32.35	24.13	9.27	2.54	3.66	20.00	0.52	15.85
3	Anthrasali	108.60	100.00	159.50	13.60	12.70	84.69	25.38	22.49	10.26	2.63	3.90	30.55	0.52	21.57
4	DBN	109.90	100.50	179.00	17.30	16.00	83.30	32.18	23.38	7.69	3.44	2.24	23.35	0.54	21.34
5	Biliakki	152.00	121.50	178.00	16.50	15.60	70.77	27.04	21.75	7.84	3.13	2.50	22.10	0.64	19.50
6	Biliakki-1	98.30	111.50	161.00	13.90	13.20	85.50	22.15	20.90	8.37	2.72	3.08	21.70	0.56	16.60
7	Bilidoddi Marthayala	111.40	95.50	147.00	19.40	18.00	85.79	40.15	25.79	7.33	3.16	2.32	20.90	0.62	20.80
8	Rajmudi	119.50	120.50	167.00	16.30	15.20	70.44	28.36	23.42	8.17	2.40	3.40	18.40	0.66	19.40
9	Bilidoddi	119.50	96.00	145.50	20.50	18.50	93.31	41.35	23.18	8.07	3.11	2.59	28.70	0.60	21.95
10	Budda	119.00	110.50	161.00	19.30	17.80	86.89	33.61	22.13	7.66	3.32	2.31	26.75	0.60	27.29
11	Combatore Sanna	115.30	87.50	135.00	19.20	18.30	88.51	39.15	22.00	7.81	3.34	2.34	28.60	0.55	18.22
12	Dodda Batta	96.60	115.50	161.00	14.20	13.30	81.95	24.85	21.92	8.38	2.67	3.14	21.50	0.48	12.65
13	Dadda Mullare	102.70	105.50	153.50	16.00	15.10	85.59	30.15	22.53	6.22	2.71	2.30	17.90	0.45	11.69
14	Dadda Mullare-1	107.40	103.50	155.00	15.40	14.40	87.24	29.14	23.15	8.71	3.47	2.51	27.85	0.59	21.61
15	Doddiga	117.90	90.00	135.00	22.20	19.70	79.73	37.62	22.71	8.54	3.12	2.74	24.95	0.54	20.03
16	Gowri Sanna	138.60	116.50	161.00	12.60	11.70	84.58	27.75	23.49	8.62	2.93	2.95	23.70	0.47	15.52

Key:

DFF= Days to 50% flowering (days); PH= Plant height (cm); DTM= Days to maturity; TNT= Total numbers of tillers; NPT= Number of productive tillers; SF= Spikelet fertility (%); FLL= Flag leaf length (cm); PL= Panicle length (cm); GL= Grain length (mm); GB= Grain breadth (mm); L/B ratio = Length/Breadth ratio; TW= Test weight (g); GY/P= Grain Yield per Plant (g); HI= Harvest Index

APPENDIX -I: Con'td…

Sl. No.	Genotypes	PH	DFF	DTM	TNT	NPT	SF	FLL	PL	GL	GB	L/B	TW	HI	GY/P
17	Gidda Rajakamala	130.70	100.00	145.00	15.10	15.10	71.62	31.84	31.84	8.38	3.43	2.45	29.35	0.43	11.51
18	Gud Batta	136.67	100.50	161.00	16.17	15.00	73.15	26.98	19.98	8.15	3.35	2.43	28.14	0.57	19.07
19	Halu Gidda	136.95	115.50	158.50	15.75	14.05	79.54	27.53	24.97	8.84	3.25	2.72	17.15	0.57	14.56
20	Howne Kattu	116.10	103.50	161.00	18.80	17.70	78.60	28.98	22.31	7.97	3.04	2.63	24.95	0.51	13.66
21	Jaddu Batta	150.30	91.00	138.00	14.40	13.30	87.12	51.85	27.50	8.97	3.74	2.40	34.65	0.60	17.96
22	Jeerige Batta	122.30	100.50	161.00	16.50	15.40	73.69	43.74	23.68	8.36	3.26	2.57	26.20	0.51	22.16
23	Kadullite	134.10	124.50	181.00	16.00	15.00	72.87	31.89	22.73	7.65	2.87	2.67	12.95	0.65	17.70
24	Kaduvelpe	117.00	114.50	161.00	19.03	17.65	81.43	29.68	20.23	7.85	3.23	2.43	22.35	0.45	14.86
25	Kalajeera	108.10	96.50	158.00	18.00	16.90	83.25	32.06	19.25	8.15	2.41	3.40	19.75	0.47	16.95
26	Kalu Mottaga	122.10	103.00	161.00	18.60	17.40	82.68	35.04	23.14	8.12	3.32	2.44	28.95	0.53	22.73
27	Karihasali	100.60	100.50	159.50	18.30	17.30	83.70	29.95	21.73	7.07	2.81	2.52	17.25	0.51	15.53
28	Kari Kondaga	115.97	102.50	158.00	23.27	21.43	68.88	37.66	23.46	8.04	3.53	2.28	27.75	0.35	7.34
29	Kanakasali	148.30	100.50	176.00	17.80	16.60	74.78	22.33	24.12	8.72	2.97	2.94	23.75	0.44	11.67
30	Karijaddu	105.00	110.50	159.00	25.20	23.70	76.73	24.60	20.33	7.75	2.91	2.66	24.70	0.45	15.24
31	Karidoddi	121.20	94.00	142.00	18.05	17.00	78.37	41.74	23.10	8.40	2.73	3.08	22.80	0.50	20.96
32	Rajmudi-1	127.20	122.00	159.00	18.00	16.40	69.70	31.57	22.17	7.92	2.41	3.29	17.85	0.60	15.10
33	kesarnellu	118.40	110.00	159.00	17.40	16.10	84.54	38.77	22.94	7.99	3.32	2.41	26.10	0.52	20.31
34	Kirwana	127.30	93.00	160.00	14.30	13.30	83.45	37.71	22.63	8.13	3.73	2.18	33.75	0.68	29.01
35	Marabatta	110.70	114.50	161.00	17.10	16.30	71.87	26.84	23.10	7.93	3.37	2.36	25.35	0.48	13.88
36	Neerguli	99.75	100.50	159.00	14.65	13.65	83.56	29.74	20.99	7.85	3.14	2.50	27.20	0.61	25.42
37	Malligae	111.80	113.00	158.50	21.80	20.20	78.73	29.36	22.26	8.45	3.17	2.67	25.85	0.54	18.45

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APPENDIX -I: Con'td…

Sl. No.	Genotypes	PH	DFF	DTM	TNT	NPT	SF	FLL	PL	GL	GB	L/B	TW	HI	GY
38	Mysore Malligae	120.00	90.00	149.00	19.80	18.60	76.13	41.80	23.39	8.87	3.23	2.74	28.70	0.62	23.26
39	Putta Batta	142.00	98.50	157.50	17.00	15.90	87.92	43.49	24.20	7.85	3.24	2.43	20.25	0.62	17.66
40	Raj Bhog	131.40	121.00	183.00	15.00	13.70	71.59	29.25	26.06	8.36	2.98	2.81	19.15	0.58	14.45
41	Naga Batta	119.30	114.00	161.00	16.60	15.80	76.52	29.82	21.08	8.15	3.03	2.69	26.05	0.48	13.04
42	Navasali	118.05	100.00	161.00	14.65	13.50	79.56	33.80	22.90	7.73	3.52	2.20	27.15	0.66	28.39
43	Sampigae Batta-1	117.70	102.00	162.00	17.60	16.60	81.57	31.98	22.53	9.54	3.23	2.95	25.95	0.46	12.39
44	Sampigae Batta-2	139.10	114.50	159.00	15.90	14.70	78.19	25.53	24.59	9.22	3.07	3.01	26.90	0.51	15.80
45	Sanesali	141.20	92.00	147.50	14.80	13.90	81.89	44.56	23.09	9.14	3.72	2.46	33.40	0.70	27.67
46	Mattalaga	96.50	109.50	160.00	23.30	21.60	70.01	26.12	22.38	8.86	2.61	3.39	20.35	0.50	15.44
47	Mugadhsughanda	120.60	110.50	159.50	16.90	15.70	73.91	35.20	24.33	8.64	2.73	3.16	23.20	0.50	16.34
48	Sannakki Batta	124.00	103.50	160.00	16.90	15.60	75.68	31.19	21.55	8.37	3.16	2.65	26.30	0.47	15.35
49	Neermullare	111.60	102.50	161.00	22.70	21.20	83.45	32.02	22.01	8.35	3.04	2.75	27.00	0.61	23.25
50	Sanna Mullu	147.80	122.50	183.00	16.60	16.00	72.81	35.40	24.91	8.71	3.45	2.53	22.85	0.62	18.75
51	MAS 946-1	74.30	103.50	154.00	21.70	20.70	80.19	26.79	21.73	9.84	2.38	4.14	27.75	0.57	16.50
52	MAS 26	72.60	102.00	155.00	16.55	15.45	81.55	24.78	20.73	10.26	2.35	4.37	26.25	0.68	15.70
53	HP 1	114.60	90.00	154.50	22.40	21.05	87.59	27.97	20.94	8.32	2.66	3.13	20.69	0.60	21.90
54	HP 7	122.60	101.50	157.00	18.70	17.20	81.37	32.82	21.38	7.77	2.24	3.48	18.40	0.50	14.04
55	HP 9	67.40	90.00	135.00	24.90	24.40	74.90	27.40	18.80	7.82	2.47	3.17	19.80	0.55	14.37
56	**Min**	67.40	87.50	135.00	12.60	11.70	68.88	22.15	18.80	6.22	2.24	2.18	12.95	0.35	7.34
57	**Max**	152.00	124.50	183.00	25.20	24.40	93.31	51.85	31.84	10.26	3.74	4.37	34.65	0.70	29.01

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