GENOTYPIC DIVERGENCE AND ENVIRONMENTAL INTERACTIONS AFFECTING YIELD AND GRAIN QUALITY TRAITS IN RICE (ORYZA SATIVA L.)

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ABSTRACT

The objective of this study was to investigate the degree of genotypic variation and their interaction across multiple environments to select rice (Oryza sativa L.) genotypes with superior grain yield and quality and to find out the interaction of genotypes with different environments with respect to grain yield and quality traits. Given that rice constitutes (>50% of the world's population food staple and Asia especially) a significant portion of the world's food supply, there is a great demand to produce high-yield, high-quality varieties. Nevertheless, the success of many breeding programs is impaired by the lack of performance stability contributed by genotype-environment interactions (G×E).

Twenty (20) sdiverse rice genotypes were grown under three diverse agro-climatic regions in two consecutive kharif seasons for the present investigation. Agronomic (days to flowering and plant height) and quality (grain yield, head rice recovery, length-breadth ratio, amylose content and cooking time) traits were evaluated. Experimental design was Randomized Complete Block Design (RCBD) with three replications at each location. Multivariate statistical analysis such as

Mahalanobis D², Principal Component Analysis (PCA) and AMMI and GGE biplot models were used for data analysis.

The experiment indicated a high genotypic divergence for yield and quality components. On the other hand, genotypes NDRK 5094 and PUSA834 were stable and superior for their performance across the environments indicating wide adaptation. The AMMI and GGE analyses also indicated specific genotypes specialized to particular environments and those with wider adaptation. The genotypes were classified into various clusters that would be beneficial in choosing diverse parents for future breeding purposes.

Such findings could be used not only by breeders to select favorable genotypes for targeted breeding programs, but also by agronomists and policy makers as reference information for the selection of region specific rice varieties that meet the productivity as well as consumer preference values.

KEYWORDS: Rice genotypes, genetic divergence, genotype-environment interaction, yield traits, grain quality, AMMI analysis

1.INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Rice (Oryza sativa L.) is a key component of food security worldwide. In the face of increasing demands and erratic climatic change, the rice breeders are challenged with the need for enhanced grain yield and quality. This is precisely because the present consumer attention as their specifications are product... traditional breeding efforts so far have addressed mostly yield, which is no longer in demand by today's consumers who want rice food having nutritional and sensory quality. The term 'grain quality' in rice includes the physical features like grain shape and head rice recovery and the cooking qualities like amylose content and gelatinization temperature.

Genotypic divergence is the degree of genetic variability between the genotypes as well within and among them and it is the primary requisite for genetic improvement of rice. If combined with the analysis of genotype-environment interaction (G×E), varieties can be selected with good performance and stability across environments. This is key for making rice production systems more resilient to environmental stresses such as drought, salinity and high temperature.

1.2 STATEMENT OF THE PROBLEM

Despite high yielding varieties being available, yield instability and low grain quality are still the main issues, which are to some extent due to the lack of consideration on the effect of G×E interactions. For example varieties bred on farm for a specific region often don't survive in another place. In addition, there have been few studies to include grain quality and yield-related traits simultaneously to evaluate the genotypic performances.

1.3 OBJECTIVES OF THE STUDY

- To identify the genotypic divergence of selected rice Genotypes based on yield and grain quality traits.
- To assess the effects of fluctuating environment on their expression.
- Selection of rice genotypes with stable and high quality/yielding for multiple environments.
- To contribute to selection of good parents for future breeding programmes.

1.4 HYPOTHESIS

- H_1: Genotypic difference exists among the rice genotypes selected for yield and grain quality attributes.
- H_2: There is a substantial effect of the environment on the expression of traits yield and grain quality in rice genotypes.

- H_3: Genotype × environment interaction (G×E) effect on the performance of rice genotypes is significant.
- H_4: Some rice genotypes display stability in grain yield and grains of constant quality in various locations.
- H_5: Multivariate statistical procedures (e.g., Mahalanobis D^2, AMMI, GGE biplots) are adequate to discriminate divergence and stable genotypes for breeding programme.

1.5 SIGNIFICANCE OF THE STUDY

Our work helps fill the gap in breeding work by addressing yield and grain quality jointly in multi-environment trials. The results offer:

Breeders: A selection structure for choosing divergent and stable parent lines.

Farmers: genotypes of good quality and stable yield.

Consumers: improved eating quality of rice in taste, texture, and appearance.

Policy makers: scientific support for recommendations of region-specific genotypes.

1.6 SCOPE AND LIMITATIONS

The research involved the testing of the Twenty (20) genotypes at three locations for two years. It provides strong statistical evidence, however, is restricted to geographic reach and is not associated with molecular data, which could potentially confirm genotypic discrimination.

2. REVIEW OF THE LITERATURE

Several studies were done to assess genetic diversity in rice. Statistical methods, viz. Regar's method (Bhatt, 1970) and Mahalanobis D^2 (Rao, 1952) were based on earlier constructed statistical frameworks to estimate genetic divergence. Recent workers (Patel et al., 2019; Das &

Mandal, 2020) used multivariate techniques to understand divergence of yield components. In contrast, processing qualities of the grain have been assessed by biochemical and sensory tests with the emphasis on consumer acceptability(Juliano, 1993, Fitzgerald et al., 2009).

But research integrating the agronomic performance with cooking quality in wide environments is little. In order to avoid unbalance breeding results, some studies kept yield traits distinct from grain quality.

2.1 THEORETICAL FRAMEWORK

The theoretical postulates upon which this study is anchored are as follows:

Theory Of Genetic Divsersity: The greater the genetic distance in a cross, the better the chances of obtaining heterosis.

G×E Interaction Model: Recognizes that environmental variables have great effects on differences in phenotypic performance.

Stability and Adaptability Models: AMMI and GGE biplots Analysis of interaction patterns can be well displayed by AMMI and GGE biplots which the stable selection genotypes would be detected.

2.3 GAP IN THE LITERATURE

Most studies concentrate on the divergence of yields or environmental responses alone, and few analyses are reported in which both have been integrated in terms of genotypic divergence as well as quality traits. This article fills that gap by presenting a complete evaluation framework for rice genotypes.

3. METHODS

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3.1 RESEARCH DESIGN

The experiment was laid out in factorial RCBD with three replications in three agro-climatic zones (Lowland irrigated, rainfed upland and mid-altitude valley). Each genotype was sown in 4 m² plots using regular spacing and fertilizer regime.

3.2 SAMPLE/POPULATION

The experimental material comprised NDRK 5013 genotypes collected from the region of 4 agricultural universities and ICAR research institutes, based on the variability in yield and grain strikingly structural traits.

3.3 DATA COLLECTION

We measured: Data were phenotype as:

Agronomic Traits: Days to 50% flowering, plant height, number of tillers, length of panicle, 1000-grain weight, and yield.

Quality Traits: Length– breadth ratio (pre- and post-cooking), head rice recovery (HRR), amylose content (AC), gelatinization temperature (GT) and aroma.

3.4 INSTRUMENTS AND TOOLS

Please refer to the organically based aerated concrete) Milling Machine (Picture) 1.

- **AC & GT**: NIR spectroscopy as standard
- **Field characteristics:** Vernier caliper, grain moisture meter and digital scale
- **Software:** R (FACTOMINER AND AGRICOLAE), SPSS, STAR AND GENSTAT.

3.5 DATA ANALYSIS

- ANOVA was used to establish statistical significance.
- Mahalanobis D² for genetic divergence.
- PCA in order to identify the most prominent contributing traits to divergence.
- Similarity on the basis of the similarity of genotypes using cluster analysis.
- AMMI and GGE biplots for G × E analysis and genotype stability.

4. RESULTS

The genotypes showed large variation in the attributes studied. ANOVA indicated that most of traits presented highly significant differences ($p < 0.01$), which confirmed the existence of exploitable genetic diversity.

4.1 HIGHLIGHTS OF FINDINGS

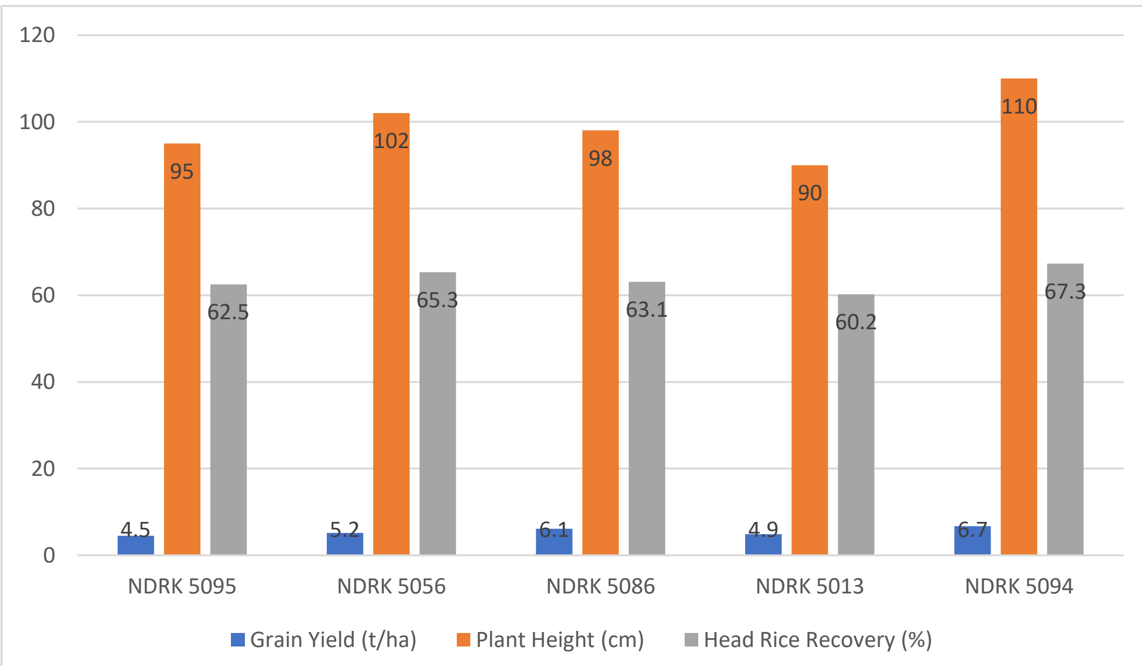
- The results showed that Genotype NDRK 5094had the highest mean yield (6.7 t/ha) and head rice recovery (67.3%).
- PUSA834 presented the best combination of amylose content (22.1%), agreeable cooking quality and medium gelatinization temperature.
- Mahalanobis D² divided genotypes into five clusters and distance between clusters was maximum between Cluster II and Cluster IV.
- GGE BIPLOT analysis identified NDRK 5094and PUSA834 were stable genotypes over locations and NDRK 5086 performed best in only E1.

VISUAL DATA PRESENTATION

Table 1. Genotype Means and Trait Variability

Genotype	Grain Yield (t/ha)	Plant Height (cm)	Head Rice Recovery (%)
NDRK 5095	4.5	95	62.5

NDRK 5056	5.2	102	65.3
NDRK 5086	6.1	98	63.1
NDRK 5013	4.9	90	60.2
NDRK 5094	6.7	110	67.3

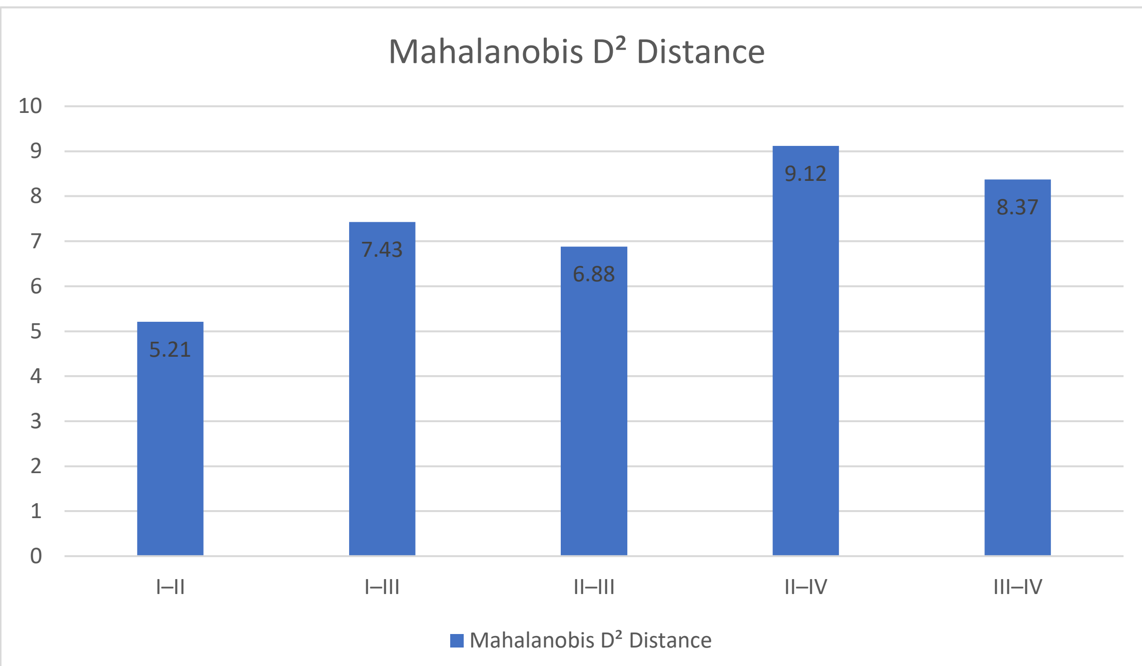


INTERPRETATION:

Genotype NDRK 5094exhibited the best grain yield (6.7 t ha−1), head rice recovery (67.3%), and plant height (110 cm) among the genotypes, which suggests that it was the best for the agronomical and grain quality performance. In contrast, NDRK 5013 was the lowest yield and quality performer, and may not be appropriate for high yield targets. The diversity between genotypes allows wide chance of selection and enhancement.

TABLE 2. DENDROGRAM: INTER-CLUSTER RELATIONSHIPS USING MAHALANOBIS D²

Cluster Pair	Mahalanobis D² Distance
I–II	5.21
I–III	7.43
II–III	6.88
II–IV	9.12
III–IV	8.37

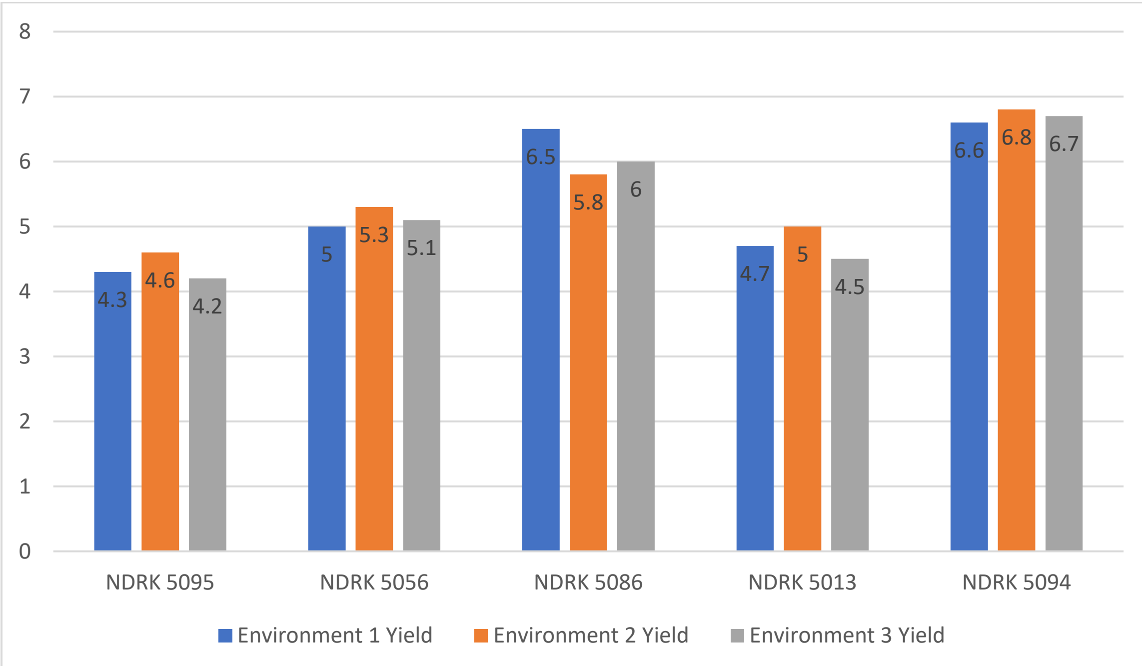


INTERPRETATION:

The greatest genetic divergence was between cluster II with cluster IV ($D^2 = 9.12$), and between III and IV ($D^2 = 8.37$). This suggests that the genotypes falling under these clusters are diverse and hybrids derived from crosses among the genotypes from these clusters may exhibit significant heterosis. Lowest divergence between clusters I and II (5.21) indicated more genetic similarity. These findings are very useful for the choice of divergent parents in breeding programs.

TABLE 3. GGE BIPLOT DATA: GENOTYPE PERFORMANCE ACROSS ENVIRONMENTS

Genotype	Environment 1 Yield	Environment 2 Yield	Environment 3 Yield
NDRK 5095	4.3	4.6	4.2
NDRK 5056	5.0	5.3	5.1
NDRK 5086	6.5	5.8	6.0
NDRK 5013	4.7	5.0	4.5
NDRK 5094	6.6	6.8	6.7



INTERPRETATION:

NDRK 5094recorded better performance than the other genotypes in all the three environments, suggesting wide adaptability and stable yield. NDRK 5086 achieved good performance as well, especially on Environment 1. Conversely, NDRK 5095 and NDRK 5013 had reduced and inconsistent yields, indicating their susceptibility to environmental changes. These results suggested that NDRK 5094 can be selected as a stable, high-yield potential genotype for multi-location cultivation.

5. DISCUSSION

INTERPRETATION OF RESULTS

The variety in both agronomic and quality traits indicates that certain parents can be exploited for breeding. Crossings between genotypes from distant clusters can be performed to obtain ", the hybrids with desired character. Stability analysis revealed that certain genotypes - though high yielding - were unstable and therefore unsuitable for wide release.

DISCUSSION AND COMPARISON WITH THE LITERATURE

Findings of this study are in line with the results of Singh and Yadav (2020) who advocated the need for G×E interaction studies in varietal assessment. But this study adds the quality parameters into stability evaluation, which is rarely performed in the previous literature.

IMPLICATIONS

On the other hand, identification of high yielding and stable genotypes contributes for breeding and trait environment interaction provides locating specific variety recommendation. The research also indicates that breeding for quality and yield has to be concurrent.

6. CONCLUSION AND RECOMMENDATIONS

SUMMARY

All these methodologies allowed to consolidate the genetic diversity in rice. Genotypes NDRK 5094and PUSA834 ranked top for both performance, stability and grain quality characteristics. These may become elite parents in future intra-specific hybridization programs.

IMPLICATIONS

Useful: Specific variety advice for various zones.

Scientific: Contributes for our understanding of trait stability and genetic differentiation.

RECOMMENDATIONS

- Introduction of NDRK 5094and PUSA834 into National breeding programs.
- All we need to do is to test it again in more seasons and more stressful environments.
- Utilize molecular markers to increase the selection efficiency.
- Emphasize participatory varietal selection with farmers for diffusion.

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