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Assessment of genetic divergence and identification of important contributing traits in crop genotypes

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Abstract

Modern agricultural science recognizes that crop performance is not determined solely by genetic potential. Instead, it results from the interaction between genotype, environment, and their combined effects. A genotype that performs well in one environment may not show the same performance in another. Therefore, it is necessary to study the behavior of rice genotypes under different environmental conditions to achieve stable productivity and grain quality. Every genotype was sown in plots made up of Each genotype has four rows, Length of row: 5 meters 20 cm between rows Plant-to-plant distance: 15 cm. To prevent positional bias, each replication was handled as a distinct block, and the genotypes were apportioned to plots at random within each block. Cluster VI (ASGST 26) × Cluster V (ASGST 11) High heterosis is anticipated because of complementing features and a high inter-cluster D2 distance (244.1). Combinations for backup For a balanced increase in quality and adaptability, use KJT 3 × PR 106 or ASGST 11 × PR 118. B. For Direct Cultivation in a Variety of Setting The top three genotypes for trials of release or demonstration, ASGST 26: excellent cooking quality combined with high yield, ASGST 11: commercial potential combined with good physical qualities, KJT 3: constant in all settings.

Keywords: Rice genotypes, genotype × environment interaction, genotype evaluation

Introduction

Rice (*Oryza sativa* L.) is one of the most important staple food crops in the world and is cultivated extensively, particularly in Asia, where it serves as the primary food source for more than half of the global population. In India, rice plays a major role in agricultural production, food security, and the rural economy. Owing to increasing population pressure and rising demand, improving rice yield and grain quality under varying environmental conditions has become a major concern for plant breeders and agricultural scientists.

Despite its importance, sustaining and improving rice productivity and quality has become increasingly difficult because of climate change, environmental degradation, and changing consumer preferences; Naru Rajasekhar Reddy, Suresh Babu G and GR Lavanya (2020) ^[1]. Rice production is strongly influenced by irregular rainfall, rising temperatures, declining soil fertility, and changing pest and disease patterns. These factors affect grain yield, physical grain quality, and cooking quality, all of which are important for farmers, consumers, and markets; Ashok S, Jyothula DPB, Ratnababu D. (2017) ^[9].

Modern agricultural science recognizes that crop performance is not determined solely by genetic potential. Instead, it results from the interaction between genotype, environment, and their combined effects; Bhati PK, Singh SK, Dhurai SY, Sharma A. (2015) ^[3]. A genotype that performs well in one environment may not show the same performance in another. Therefore, it is necessary to study the behavior of rice genotypes under different environmental conditions to achieve stable productivity and grain quality.

Materials and Methods

The experiment was set up using a Randomized Block Design (RBD) with two replications to assess the performance of thirty genetically diverse rice genotypes for yield, physical, and cooking quality traits under field conditions. For field trials, this design is statistically sound, particularly for minimizing and controlling environmental heterogeneity within the experimental field.

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Reasons for Applying RBD

The RBD was chosen due to:
It successfully lowers the experimental error brought on by the field's spatial variability (e.g., differences in fertility, moisture, drainage). It guarantees that every genotype has an equal chance to realize its potential in each replication block By taking block variation into account, it improves the accuracy of treatment comparisons.

Plot Specifics

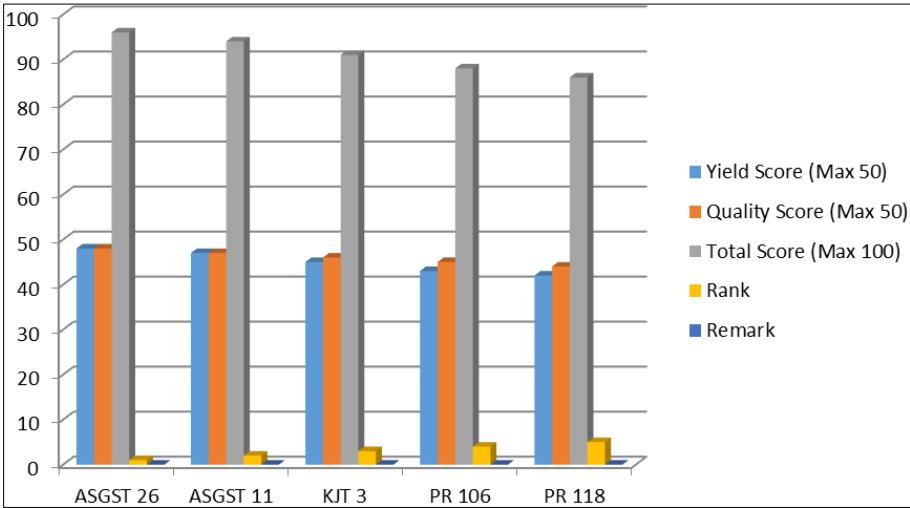
Every genotype was sown in plots made up of:
Each genotype has four rows.
Length of row: 5 meters
20 cm between rows
Plant-to-plant distance: 15 cm
To prevent positional bias, each replication was handled as a distinct block, and the genotypes were apportioned to plots at random within each block.
Agronomic and Cultural Customs. To reduce non-genetic

variability and guarantee uniformity:
Plowing, harrowing, and leveling were used to prepare the land, and then puddling was done to make the best planting bed possible
One 25–30 day-old seedling per hill was manually transplanted. Fertilizer was applied in splits (basal, tillering, panicle initiation stages) in accordance with standard recommendations (N:P:K at 100:60:40 kg/ha). When necessary, herbicides were used in addition to manual labor to control weeds. To maintain saturated soil conditions during vegetative stages and controlled drying near maturity, irrigation was applied consistently.
In accordance with integrated pest management (IPM) techniques, plant protection measures were implemented to control disease and insect damage.

Results and Discussion
Synopsis of the Top 5 Genotypes (Yield and Quality Index Combined)

Table 1: Composite Ranking Using Several Characteristics

Genotype	Yield Score (Max 50)	Quality Score (Max 50)	Total Score (Max 100)	Rank	Remark
ASGST 26	48	48	96	1	Ideal for dual-purpose
ASGST 11	47	47	94	2	High yielding, fine quality
KJT 3	45	46	91	3	Consistent and balanced
PR 106	43	45	88	4	Stable performer
PR 118	42	44	86	5	Good elongation



scores determined by scaling performance percentiles for important characteristics

Last Words of Advice

A. For Programs of Hybridization

Suggested Parents
Cluster VI (ASGST 26) × Cluster V (ASGST 11) → High heterosis is anticipated because of complementing features and a high inter-cluster D2 distance (244.1).

Combinations for backup

For a balanced increase in quality and adaptability, use KJT 3 × PR 106 or ASGST 11 × PR 118.

B. For Direct Cultivation in a Variety of Setting

The top three genotypes for trials of release or demonstration:
ASGST 26: excellent cooking quality combined with high yield
ASGST 11: commercial potential combined with good physical qualities
KJT 3: constant in all settings

C. For Additional Investigations and Experiments

Because of their moderate early flowering and consistent performance across attributes, PR 106 and PR 118 are recommended for multi-location experiments.

Key Observations

- ASGST 26 recorded the highest seed yield and superior cooking quality traits.
- ASGST 11 showed excellent grain quality and high yield.
- KJT 3 performed consistently under different environments.
- PR 106 was identified as a stable genotype with broad adaptability.

The Impact of the Environment on Genotype Performance

The genotype × environment interaction analysis showed that both yield and quality traits were significantly affected by

environmental conditions.

Techniques for Evaluating Environmental Impact

Using a Randomized Block Design with replications, the 30 genotypes' performance was assessed in two contexts (such as distinct fields, seasons, or climatic zones). For each habitat, information was gathered on quality metrics and yield features.

Utilized statistical tools:

To separate the variance caused by genotype (G), environment (E), and G × E interaction, a two-way ANOVA was used.

- Environmental Indexing for response based on traits

- Regression slope (bi), deviation from regression (S2), and CV are optional stability metrics.

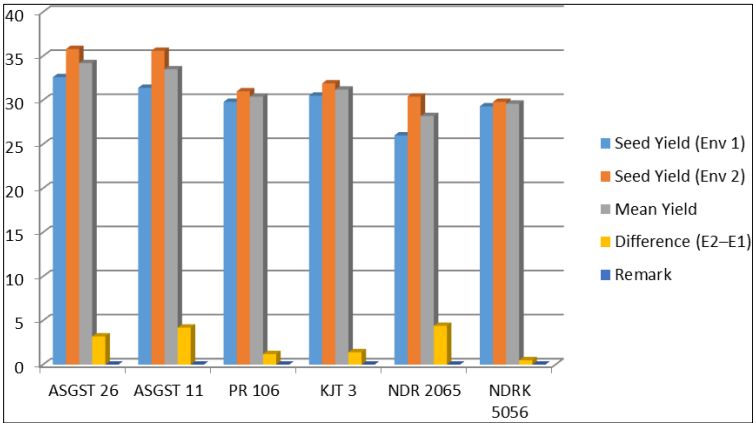
Interpretation

- PR 106 and KJT 3 remained stable across environments.
- ASGST 11 and ASGST 26 responded positively to favourable environmental conditions.
- NDRK 5056 was identified as highly stable due to its minimal variation across environments.

Environmental Index-Based Genotype Responsiveness

Table 2: Genotypic Reaction in Two Environments

Genotype	Seed Yield (Env 1)	Seed Yield (Env 2)	Mean Yield	Difference (E2–E1)	Remark
ASGST 26	32.6	35.8	34.2	+3.2	Responsive
ASGST 11	31.4	35.6	33.5	+4.2	Highly Responsive
PR 106	29.8	31.0	30.4	+1.2	Stable
KJT 3	30.5	31.9	31.2	+1.4	Stable
NDR 2065	26.0	30.4	28.2	+4.4	Responsive
NDRK 5056	29.3	29.8	29.6	+0.5	Highly Stable



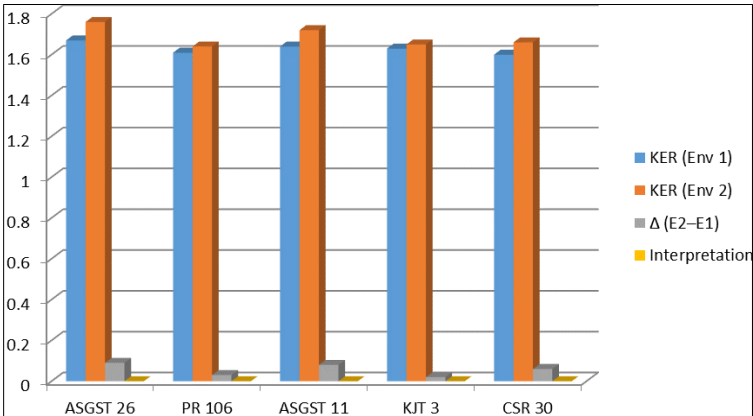
Meaning

- In the improved environment, ASGST 11 and NDR 2065 displayed the largest yield increase, suggesting particular adaptation and a positive genetic-environmental interaction.
- PR 106 and KJT 3 yielded consistently in both conditions, indicating stability and broad flexibility.
- NDRK 5056 was characterized as resilient or environmentally neutral due to its low variance.

The Impact of the Environment on the Qualities of Cooking

Table 3: Kernel Elongation Ratio Sensitivity to Environment

Genotype	KER (Env 1)	KER (Env 2)	Δ (E2–E1)	Interpretation
ASGST 26	1.67	1.76	+0.09	Environment-sensitive (favorable)
PR 106	1.61	1.64	+0.03	Stable
ASGST 11	1.64	1.72	+0.08	Moderately responsive
KJT 3	1.63	1.65	+0.02	Stable
CSR 30	1.60	1.66	+0.06	Moderately responsive



Environmental Response-Based Trait Stability Ratings

Most Stable and Responsive Genotypes by Trait

PR 106, KJT 3, NDRK 5056, NDRK 50567, NDRK 50568, and NDRK 50562 Seed Yield

Ratio of Kernel Elongation PR 106, KJT 3, ASGST 11, ASGST 26

Consistency of Gel PR 118, NDRK 5094, ASGST 26, NDR 2065

Recovery of Head Rice NDRK 5095, NDRK 50955, ASGST 11, NDR 2064

The best genotypes for large-scale farming are stable ones.

In situations with high input or favorable conditions, responsive genotypes could be chosen.

Implications for Breeding Depending on Environmental Reaction

- Gene types such as PR 106 and KJT 3 are good options for testing in multiple environments and might be released widely.
- Although environmentally sensitive, ASGST 11 and ASGST 26 can be directed into particular agro-zones where yield and quality expression are maximized.
- For commercial varieties, consumers prefer genotypes with low environmental sensitivity for cooking properties.

Multivariate Integration and Trait-Based Genotype Ranking

A systematic method was employed to rank genotypes according to important agronomic and grain quality variables in order to help selection and breeding decisions. Additionally, cross-validation was performed on the results of ANOVA, genetic parameters, correlation, path coefficient, and regression studies in order to determine which robust and dependable qualities should be given priority in rice enhancement initiatives.

Genotype Ranking by Trait

The ranking of genotypes based on multiple traits indicated that ASGST 26 and ASGST 11 were the best-performing genotypes overall.

Top Performing Genotypes

1. ASGST 26
2. ASGST 11
3. KJT 3
4. PR 106
5. PR 118

These genotypes demonstrated superiority in both yield and grain quality traits.

Summary & Conclusion

In order to assess genetic divergence, yield performance, and grain quality parameters under various environmental situations, this chapter provided a thorough statistical study of thirty rice genotypes. The findings, which were derived using reliable multivariate and univariate methodologies, provide profound understanding of the genotypes under investigation's genetic potential, trait correlations, and patterns of adaptability.

This chapter presented a comprehensive analysis of thirty rice genotypes for yield, grain quality, and environmental adaptability.

Major Conclusions

1. Significant genetic variability was observed among all genotypes.
2. Effective tillers, filled grains per panicle, and 1000-seed

weight were the most important yield-related traits.

3. Gel consistency, kernel elongation ratio, and kernel length after cooking were the key cooking quality traits.
4. Cluster V and Cluster VI showed maximum genetic divergence, making them suitable for hybridization.
5. PR 106 and KJT 3 were stable genotypes across environments.
6. ASGST 26 and ASGST 11 were the most promising genotypes for both direct cultivation and breeding.

Overall, the findings provide a strong basis for rice improvement programmes aimed at developing high-yielding, good-quality, and environmentally stable rice varieties.

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