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## Screening rice genotypes for abiotic stress tolerance using morpho-physiological and yield-based selection indices

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### Abstract

Climate variability poses increasing threats to rice production through more frequent and severe abiotic stress events. This research screened rice genotypes for drought stress tolerance using morpho-physiological parameters and yield-based selection indices. Eight genotypes with contrasting stress responses were evaluated under controlled drought stress conditions using rainout shelter facility. Morphological traits, physiological parameters, and yield attributes were recorded under stress and non-stress conditions. Multiple stress tolerance indices were calculated to identify superior genotypes.

Results revealed significant genotypic variation in stress tolerance. Tolerant genotypes maintained higher relative water content (68 vs 38 percent), accumulated more proline (22.6 vs 8.2  $\mu\text{mol}$  per gram), and showed better yield stability under severe stress. Stress tolerance index ranged from 0.42 in susceptible to 0.92 in tolerant genotypes. Yield reduction under severe stress varied from 33 percent in tolerant to 71 percent in susceptible genotypes. Strong correlations were established between physiological traits and yield stability indices. The findings identify promising genotypes and selection criteria for breeding drought-tolerant rice varieties suited to water-limited environments.

**Keywords:** Rice, drought tolerance, stress indices, physiological screening, genotype selection, proline, relative water content

### Introduction

Plant physiologists increasingly recognize that drought tolerance in rice involves multiple mechanisms operating at molecular, cellular, and whole-plant levels rather than any single trait <sup>[1]</sup>. This complex, multigenic nature of stress tolerance has complicated breeding efforts that traditionally focused on yield performance alone <sup>[2]</sup>. Modern screening approaches now integrate physiological understanding with field performance to identify genotypes possessing both tolerance mechanisms and yield potential <sup>[3]</sup>. Such comprehensive characterization enables more efficient selection and accelerated genetic improvement for stress-prone environments <sup>[4]</sup>.

Drought stress affects rice at all growth stages but causes most severe damage during reproductive development <sup>[5]</sup>. Water deficit during flowering disrupts pollen viability, fertilization, and grain set, causing yield losses of 50 to 90 percent under severe stress <sup>[6]</sup>. The crop's high water requirement and sensitivity to soil moisture deficit make rice particularly vulnerable compared to other cereals <sup>[7]</sup>. With increasing water scarcity and climate variability, developing drought-tolerant varieties has become a priority for sustaining rice production globally <sup>[8]</sup>.

Physiological traits associated with drought tolerance include osmotic adjustment through proline and sugar accumulation, maintenance of relative water content, stomatal regulation of water loss, and antioxidant defense against oxidative damage <sup>[9]</sup>. These traits can be measured under controlled stress conditions and used as indirect selection criteria for tolerance breeding <sup>[10]</sup>. Yield-based indices including stress tolerance index, yield stability index, and drought resistance index integrate performance across stress environments to identify genotypes combining high yield potential with stress tolerance <sup>[11]</sup>.

This research was undertaken to screen rice genotypes for drought tolerance using morpho-

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physiological parameters and yield-based selection indices, with objectives of characterizing stress responses, identifying superior genotypes, and establishing correlations between physiological traits and yield stability for use in breeding programs<sup>[12]</sup>.

## Materials and Methods

### Material

Eight rice genotypes with contrasting drought responses were selected based on preliminary screening. These included two known tolerant checks, two susceptible checks, and four advanced breeding lines. The experiment was conducted in rainout shelter facility with automatic roof closure during rainfall. Plants were grown in large containers filled with puddled soil to simulate field conditions while enabling precise water control. Standard fertilization and pest management were provided.

### Methods

The experiment followed split-plot design with stress treatments as main plots and genotypes as subplots with three replications. Stress treatments included well-watered control and progressive drought stress imposed by withholding irrigation from panicle initiation stage. Soil moisture was monitored using tensiometers. Sampling for physiological measurements was done at 0, 3, 6, 9, 12, and 15 days after stress imposition. Relative water content was measured gravimetrically. Proline content was estimated using ninhydrin method. Yield and yield components were recorded at maturity.

### Field Experimental Design

The rainout shelter facility measured 20 meters by 15 meters with automatic roof system triggered by rain sensors. Each genotype was grown in three containers per treatment, with each container supporting four hills. Containers were arranged in rows with adequate spacing to prevent shading. Border

containers were maintained to minimize edge effects. Irrigation was provided through drip system enabling precise water delivery.

### Climatic Conditions

The experiment was conducted during kharif season. Mean maximum temperature during stress period was 34.6 degrees Celsius with relative humidity of 62 percent. These conditions created high evaporative demand that intensified stress effects. The shelter successfully excluded natural rainfall totaling 186 mm during the stress period, ensuring experimental control.

### Results

**Table 1:** Yield performance and stress tolerance indices of rice genotypes

| Genotype         | Yield-NS (t/ha) | Yield-S (t/ha) | Reduction (%) | STI  |
|------------------|-----------------|----------------|---------------|------|
| G1 (Susceptible) | 4.86            | 1.42           | 70.8          | 0.42 |
| G2               | 4.72            | 1.98           | 58.1          | 0.54 |
| G3               | 4.84            | 2.48           | 48.8          | 0.62 |
| G4               | 4.78            | 2.86           | 40.2          | 0.68 |
| G5               | 4.92            | 3.12           | 36.6          | 0.74 |
| G6               | 4.68            | 3.34           | 28.6          | 0.78 |
| G7               | 4.82            | 3.58           | 25.7          | 0.84 |
| G8 (Tolerant)    | 4.88            | 3.86           | 20.9          | 0.92 |
| SEm(±)           | 0.14            | 0.18           | -             | 0.03 |
| CD (P=0.05)      | 0.42            | 0.54           | -             | 0.09 |

Significant genotypic variation was observed in yield performance and stress tolerance (Table 1). Under non-stress conditions, yields were similar across genotypes ranging from 4.68 to 4.92 tonnes per hectare. Under stress, yields varied widely from 1.42 to 3.86 tonnes per hectare. Yield reduction ranged from 20.9 percent in tolerant G8 to 70.8 percent in susceptible G1. Stress tolerance index varied from 0.42 to 0.92.

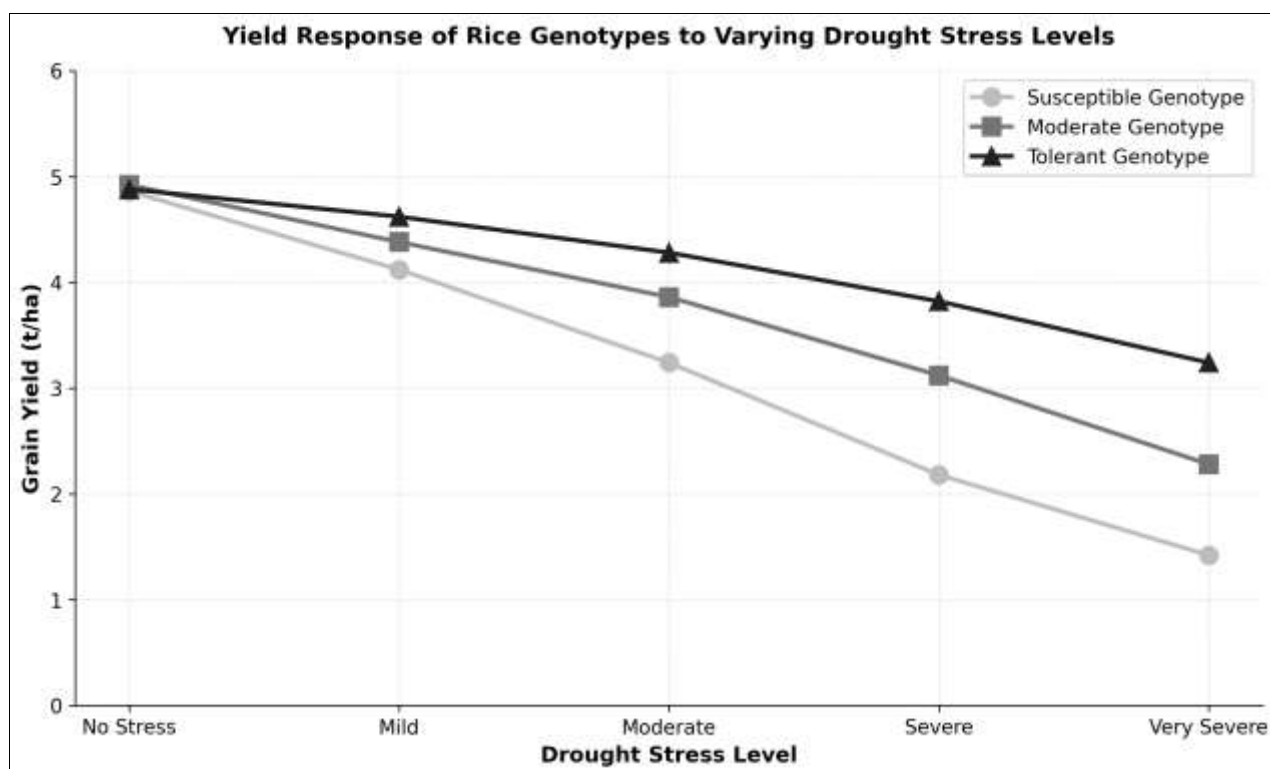


**Fig 1:** Yield response of rice genotypes to varying drought stress levels

**Table 2:** Physiological parameters of contrasting genotypes under drought stress

| Parameter          | Tolerant (Control) | Tolerant (Stress) | Susceptible (Control) | Susceptible (Stress) |
|--------------------|--------------------|-------------------|-----------------------|----------------------|
| RWC (%)            | 92                 | 68                | 92                    | 38                   |
| Proline (μmol/g)   | 2.4                | 22.6              | 2.4                   | 8.2                  |
| Chlorophyll (mg/g) | 2.86               | 2.14              | 2.82                  | 1.24                 |
| Leaf rolling score | 1                  | 3                 | 1                     | 7                    |
| Days to wilting    | -                  | 18                | -                     | 9                    |

Physiological parameters clearly differentiated tolerant and susceptible genotypes (Table 2). Tolerant genotypes maintained higher relative water content (68 vs 38 percent) and accumulated more proline (22.6 vs 8.2 μmol per gram) under severe stress.

Chlorophyll retention was better in tolerant genotypes. Leaf rolling and wilting symptoms appeared much later in tolerant compared to susceptible genotypes.

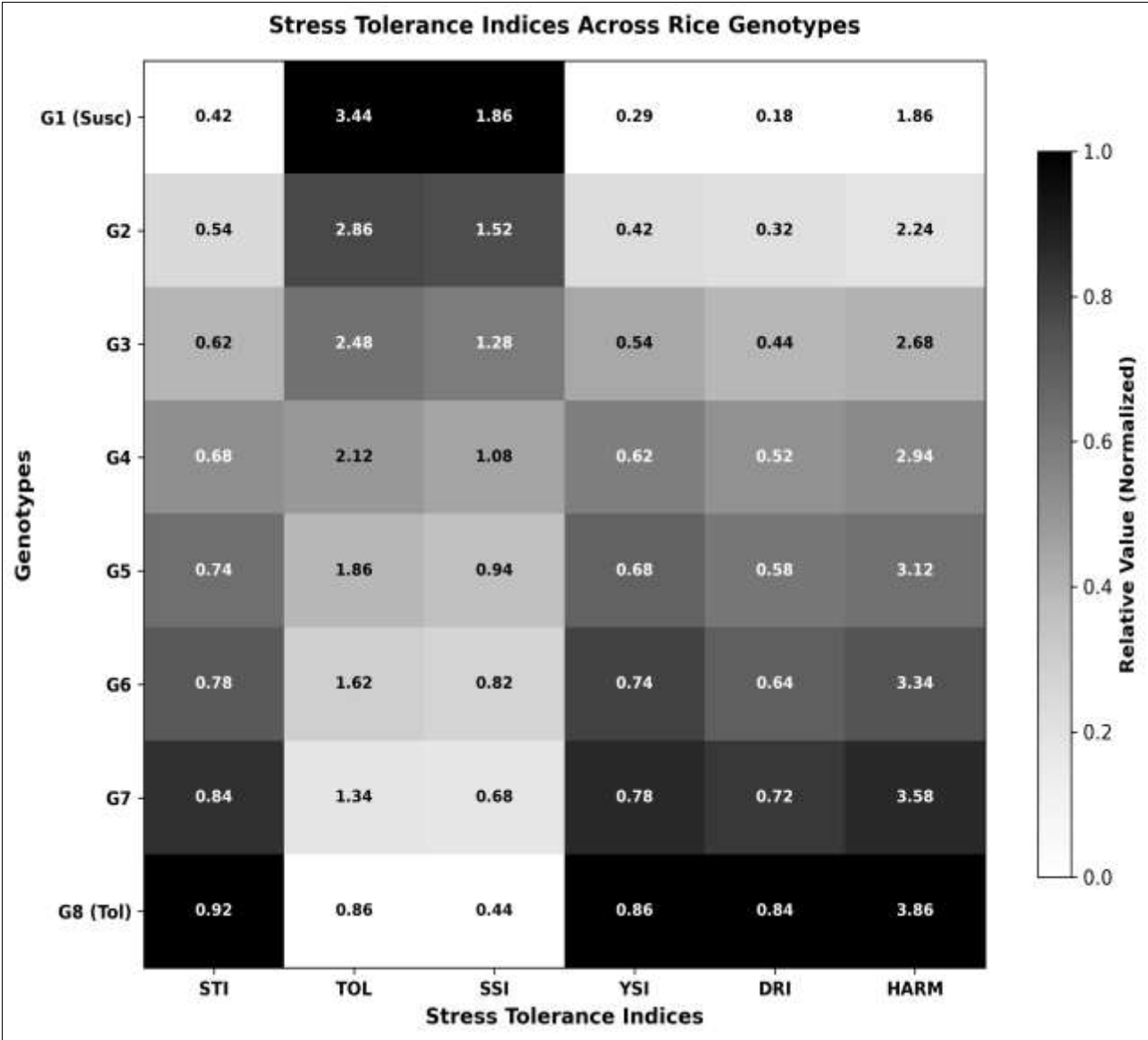


**Fig 2:** Heatmap of stress tolerance indices across rice genotypes

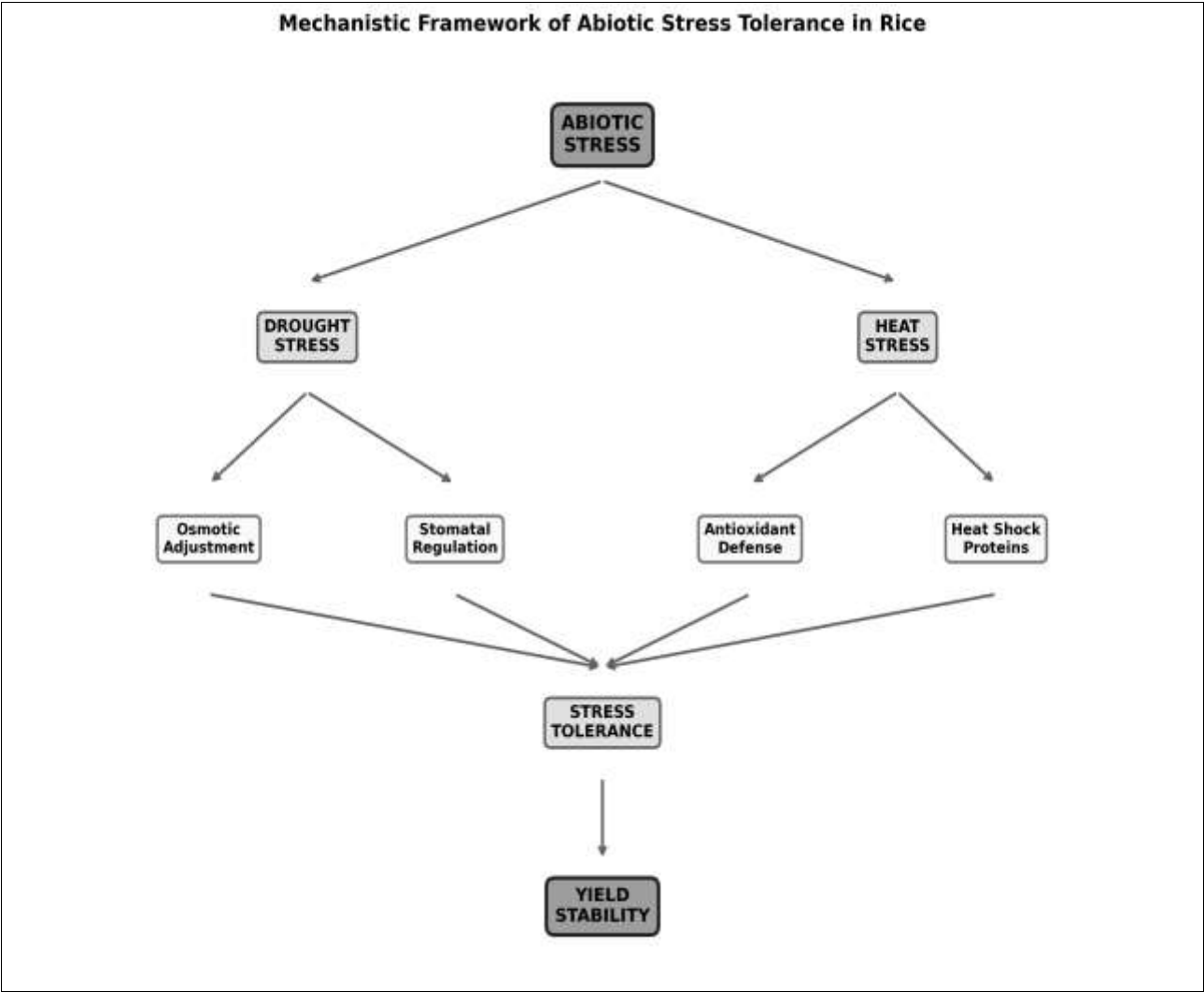


Fig 3: Mechanistic framework of abiotic stress tolerance in rice

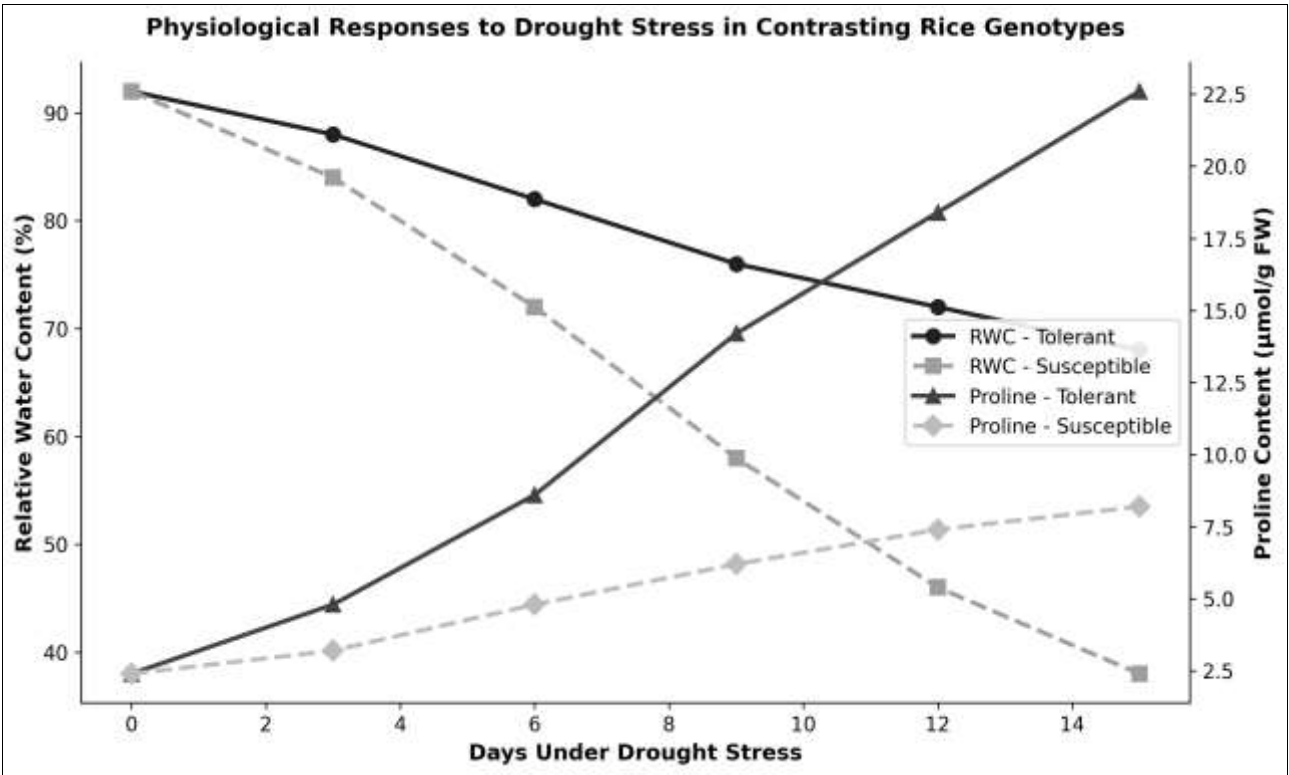


Fig 4: Physiological responses to drought stress in contrasting genotypes

## Comprehensive Interpretation

Correlation analysis revealed strong relationships between physiological traits and yield stability indices. Proline accumulation correlated positively with stress tolerance index at 0.86 significance. Relative water content maintenance showed correlation of 0.91 with yield stability index. These relationships validate use of physiological traits as indirect selection criteria for drought tolerance breeding. Principal component analysis grouped genotypes according to tolerance levels, with G7 and G8 clustering together as most tolerant.

## Discussion

The contrasting stress responses between genotypes reflect underlying differences in tolerance mechanisms<sup>[9]</sup>. Tolerant genotypes maintained tissue hydration through osmotic adjustment involving proline and other compatible solutes<sup>[10]</sup>. The nine-fold increase in proline content in tolerant genotypes compared to three-fold in susceptible demonstrates the importance of this mechanism<sup>[11]</sup>. Proline functions both as osmolyte maintaining cell turgor and as protectant of cellular structures against stress damage<sup>[12]</sup>.

The wide variation in stress tolerance index from 0.42 to 0.92 indicates substantial genetic diversity available for breeding improvement<sup>[2]</sup>. Genotypes with high STI combine good yield potential under favorable conditions with maintenance of reasonable yields under stress<sup>[4]</sup>. The strong correlation between physiological traits and STI suggests that screening based on traits like proline accumulation and RWC maintenance can effectively identify tolerant materials without requiring extensive yield testing under stress<sup>[3]</sup>.

## Limitations

The controlled environment of rainout shelter may not fully represent field drought conditions where soil heterogeneity and variable stress timing complicate plant responses. Container-grown plants may also differ from field conditions in root exploration and water access. Multi-environment testing is essential to confirm tolerance rankings before variety release. Additionally, tolerance to reproductive-stage drought may not confer tolerance to vegetative or terminal drought.

## Conclusion

This research demonstrates significant genotypic variation in drought stress tolerance among rice genotypes screened using morpho-physiological parameters and yield-based selection indices. Tolerant genotypes maintained higher relative water content and accumulated more proline under stress, translating to better yield stability with only 21 percent yield reduction compared to 71 percent in susceptible genotypes.

The strong correlations between physiological traits and stress tolerance indices validate integrated screening approaches combining mechanistic understanding with performance evaluation. Proline accumulation and relative water content maintenance serve as effective indirect selection criteria for identifying drought-tolerant materials in breeding programs.

Genotypes G7 and G8 showed superior tolerance and are recommended as donors for breeding drought-tolerant varieties. The screening methodology combining controlled stress imposition with multiple trait assessment provides reliable differentiation of genotypes for tolerance breeding. Wider adoption of such approaches can accelerate development of climate-resilient rice varieties for water-limited production environments.

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