IOCAG 2025 Conference

The 3rd International Online Conference on Agriculture

22–24 October 2025 | Online

MDPI

Integration of plant phenomics and morpho-physiological traits to elucidate drought tolerance in pigeonpea genotypes

Basavaraj P S[1], Muniswamy S[2], Boraiah KM[1], Harisha CB[1]

1. ICAR-National Institute of Abiotic Stress Management, Baramati-413115, India
2. Zonal Agricultural Research Station, University of Agricultural Sciences, Kalaburagi 585401, India

INTRODUCTION & AIM

- Drought stress affects ~66% of arable land, causing annual losses of USD 37 billion.
- Impact is worsening due to climate change.
- Pigeonpea is crucial for semi-arid regions, however, suffers 40–50% yield loss under drought.
- Traditional breeding alone is limited in addressing complex drought responses.
- Phenomics enables rapid, precise screening of drought-related traits.
- This study integrates phenomic and morpho-physiological traits to identify drought-tolerant genotypes.
- Goal: support resilient breeding strategies for pigeonpea.

METHOD

Plant Material: 47 diverse pigeonpea genotypes
Experimental Setup: Conducted in a controlled greenhouse
Growth Conditions:
Greenhouse maintained at **32/24°C (day/night)**, RH: 60–70%, PAR: 450–750 μmol $m^{-2}s^{-1}$.
Factorial CRBD with two factors —Each treatment had 3 biological replicates
Water treatments: Well-watered (WW) and drought stress (DS)
Drought Imposition:
Water withheld from **80 to 120 DAS (flowering to pod set)**.
Soil moisture reduced to **20–22% of field capacity** (monitored gravimetrically).
Rewatering resumed after 120 DAS.
High-Throughput Phenotyping
Imaging: Plants imaged using **Scanalyzer 3D system** (LemnaTec) at 5-day intervals (7 times during stress period).
RGB and NIR images captured from **top and two side views (0° & 90°)**
NIR imaging detected **shoot water content** via **1450 nm water absorption band**
Analysis:
- Segmentation, image processing, and trait extraction done using **LemnaGrid** and **Data Miner** software.Over 15 image-based parameters recorded; 4 key traits used for analysis: **Projected Shoot Area, Convex Hull Area, Calliper Length, NIR Reflectance**

Morpho-Physiological Traits
Recorded from both WW and DS plants:
Growth traits: Plant height, branches, pods, seeds, yield
Physiological traits: NDVI, SPAD, canopy temp, RWC, MSI, proline, photosynthetic rate, transpiration, VPD
Statistical Analysis: ANOVA performed to assess treatment and genotype effects. Genetic parameters (GCV, PCV, Hb) calculated using variance components.

RESULTS & DISCUSSION

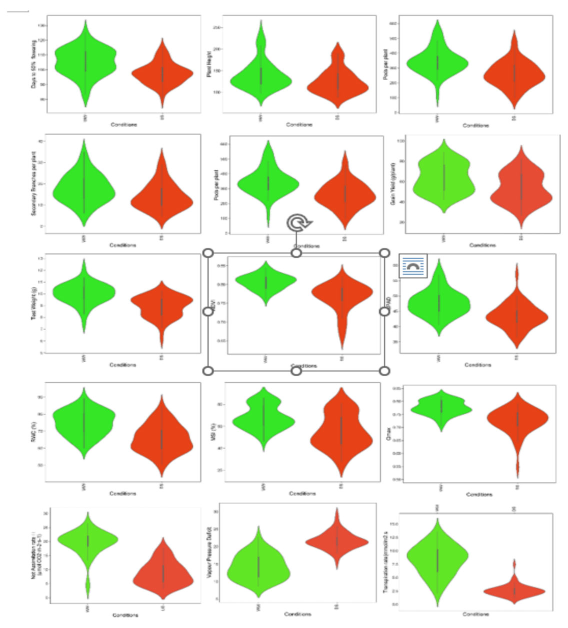
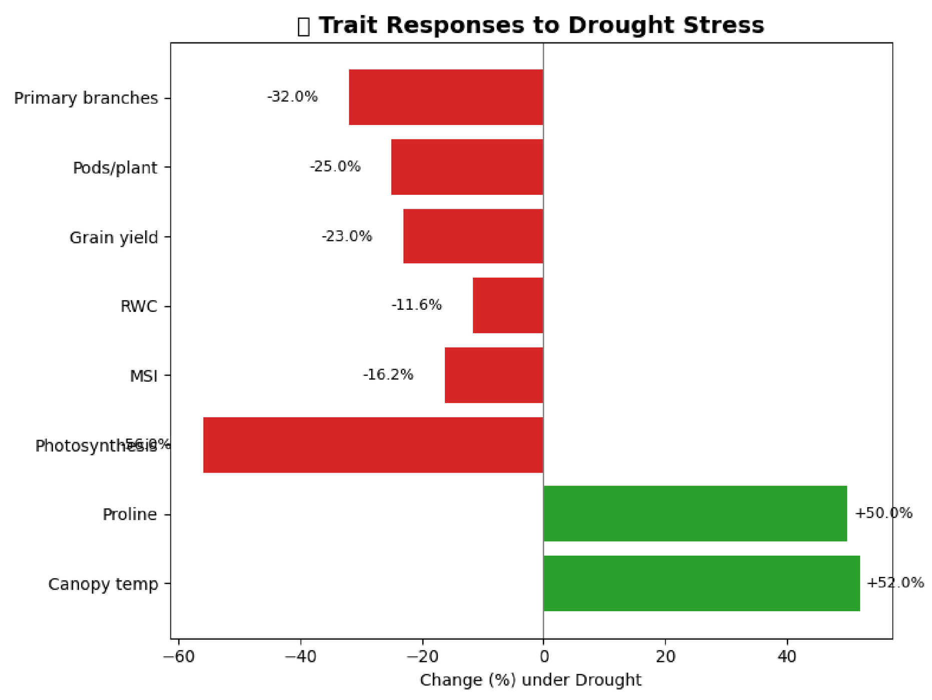


Figure 1. Violin plot depicting the morpho-physiological trait variation of pigeonpea genotypes under well-watered and drought stress conditions.



🌱 *Phenotypic Variation*
•Significant variation for **genotypes**, **water treatments**, and their **interaction** (G × W).
•Suggests differential responses to drought among genotypes.
🌿 ✅ Some genotypes (e.g. **ICPX140203-B-1**) maintained high yield & physiology under stress.

📈 *Genetic Parameters*
High **GCV & heritability** for: **Grain yield, plant height, proline, photosynthesis**
Traits with **high heritability & genetic gain** are best for selection (e.g. PB, GYPP, A, proline).

Trait	% Change under DS	Remarks
📷 Projected shoot Area	↓ 32.3%	Biomass loss
📏 calliper length	↓ 11.4%	Shoot elongation reduced
🌿 Convex hull area	↓ 26.3%	Less leaf spread
🔬 NIR intensity	↑ 36.6%	Reflects dehydration

•**Drought impacts reproduction & biomass** → biggest yield penalties.
•Tolerant genotypes showed:
•Better **water status** (RWC, MSI), Higher **photosynthesis**
•**Less tissue dehydration** (NIR)
•**Phenomics** = powerful tool to detect early stress responses.
•**Top performers** (e.g. ICPX140196-B-1, ICPX140203-B-1) are breeding candidates.

CONCLUSION

🔍 **Dual-approach phenotyping** (morpho-physiological + high-throughput) yielded **valuable insights** into drought responses.
- 🌿 **Key traits for selection**:
  - **Physiological**: Photosynthesis, RWC
  - **Phenomics**: Digital Area (DA), Convex Hull Area (CHA), Calliper Length (CL), NIR reflectance
- 🌾 **Substantial genetic diversity** identified:
  - Enables discovery of **drought-tolerant** and **susceptible** lines
  - Useful for **breeding programs**
- 📷 **High-throughput imaging**:
  - Enabled **non-destructive**, whole-plant level evaluation
  - Efficient for large-scale screening under **moisture stress**
- 🔄 **Integrated trait analysis**:
  - Combining traditional and image-derived traits improves **genotype selection accuracy**
  - Detects **subtle stress responses**

FUTURE WORK / REFERENCES

🌱 **Future potential**:
•Diverse genotypes identified can be used for:
- Genetic enhancement
- Breeding drought-resilient cultivars
- Studying **root architecture** for deeper drought adaptation insights