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A dataset of 15 maize hybrids subjected to drought, salinity, and aluminum toxicity stresses

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Abstract: Maize (*Zea mays L.*) is one of the world's main cereal crops, being widely used for human consumption, animal feed formulation, and in the production of biofuels, starch and petroleum industries. However, abiotic stresses such as drought, salinity, and aluminum toxicity have often limited crop development and yield. These stresses can also alter soil conditions, which can negatively impact the germination process and early growth of maize plants. These adverse environmental conditions affect the development of maize at various stages of plant growth; however, the initial seedling stage is one of the most vulnerable and critical growth stages in the plant's life cycle. Therefore, the search for corn genotypes tolerant to abiotic stresses is a strategy to ensure food security and the sustainability of agricultural production in tropical soils. This study presents a dataset of 15 maize hybrids, with a focus on their morphological responses under drought, salinity, and aluminum toxicity conditions. The dataset includes comprehensive measurements such as emergence rate (E), plant height (PH), length of the longest root (LR), total plant length (TPL), total root system length (TRL), root volume (RV), leaf area (LA), shoot dry matter (SDM), root dry matter (RDM), total plant dry matter (TDM), and root to shoot ratio (RS) under non-stressful (control) and stressful (drought, salinity and aluminum toxicity) conditions. The analysis of the data from this research allows for a better understanding of the genetic and phenotypic responses of corn plants associated with tolerance to abiotic stresses. This dataset provides a basis for further exploration of abiotic stress tolerance mechanisms in maize and opens new avenues for improving agricultural sustainability. Understanding the underlying mechanisms of tolerance in these hybrids will provide valuable insights for developing breeding strategies aimed at improving maize adaptation to challenging environments.

Keywords: Abiotic stress; acid soil; water restriction; salt stress; *Zea mays*.

1. Introduction

Maize (*Zea mays L.*) represents one of the most important cereal crops worldwide, serving as a staple food for humans and animals, as well as an essential raw material for various industries (Alkharabsheh et al., 2021). However, maize productivity is significantly threatened by several abiotic stress factors, including water stress (drought), soil salinity, and aluminum (Al) toxicity (Alcântara et al., 2015; Steiner et al., 2025; Vilas Boas et al., 2025). These stresses can occur in isolation or combination, exacerbating their negative effects on crop growth, development, and consequently, yield (Malenica et al., 2021).

Drought stress is a major limiting factor for maize production, negatively affecting various physiological processes such as photosynthesis, stomatal conductance, and transpiration, leading to reduced growth and final yield (Malenica et al., 2021). At the metabolic level, drought can induce the accumulation of osmoprotectants, such as proline, in some genotypes as an adaptive response.

Soil salinity, which affects approximately 20% of cultivated land and half of the irrigated areas globally, imposes a dual challenge to maize plants (Shtereva et al., 2015). Initially, it causes an osmotic effect, hindering water absorption by roots due to the high solute concentration in the soil (Alkharabsheh et al., 2021). Subsequently, the accumulation of toxic ions, mainly sodium (Na+), in plant tissues can lead to cellular damage and nutritional imbalances, affecting growth, photosynthesis, and protein synthesis. Although maize is considered moderately adapted to salinity, high levels can cause significant yield losses. Studies in sweet maize genotypes have shown considerable variation in salinity tolerance, with Na^+ exclusion and a higher K^+/Na^+ ratio in leaves correlating well with greater tolerance (Islam et al., 2022).

Aluminum (Al) toxicity is a critical factor in acidic soils, representing a substantial challenge for maize cultivation (Alcântara et al., 2015). In soils with low pH, Al becomes soluble and highly toxic to plants, inhibiting root growth, impairing nutrient uptake, and consequently reducing yield. Plants have developed Al tolerance mechanisms, which can be internal (Al complexation in the cytosol and compartmentalization in the vacuole) or exclusion (Al immobilization in the cell wall through complex formation with lignin, increased rhizosphere pH, and release of organic acids). Seed treatment with ascorbic acid has shown to reduce Al uptake in Al-sensitive genotypes, suggesting a potential to mitigate toxic effects (Alcântara et al., 2015).

In many agricultural regions, these three abiotic stresses frequently co-occur, creating multiple stress scenarios that can have synergistic or antagonistic impacts on plants (Malenica et al., 2021). Plant response to stress combinations can be more complex than the sum of responses to individual stresses, with overlapping or distinct signaling pathways and tolerance mechanisms. Understanding the physiological, biochemical, and molecular responses of maize under these combined stress conditions is crucial for the development of effective breeding strategies (Ishitani et al., 2004).

Given this scenario, the identification of maize hybrids that exhibit tolerance to multiple abiotic stresses, including drought, salinity, and aluminum toxicity, is of fundamental importance to ensure crop productivity and sustainability in affected areas. The characterization of superior genotypes under these conditions will allow the selection of promising genetic materials for breeding programs, aiming at the development of more resilient cultivars adapted to the challenges imposed by climate change and adverse soil conditions(Alkharabsheh et al., 2021).

The present study aims to provide researchers with a comprehensive dataset containing the morphological responses of 15 maize hybrids grown under drought, salinity, and aluminum toxicity conditions, with the objective of identifying genotypes that exhibit greater tolerance to these stresses and developing new methodologies for the analysis of hybrids subjected to abiotic stress. Understanding the underlying mechanisms of tolerance in these hybrids will provide valuable information for the development of breeding strategies aimed at enhancing maize adaptation to challenging environments.

2. The experiment

2.1 Plant materials and Stress treatments

Seeds from 15 commercial maize hybrids for the Brazilian Cerrado region were purchased from the agricultural seed market in the municipalities of Chapadão do Sul and Cassilândia, State of Mato Grosso do Sul, Brazil. These hybrids were considered because they are the most cultivated in the Cerrado. Before starting the study, the water content, the thousand seed weight, and the germination rate were determined as described in the Rules for Seed Analysis (BRASIL, 2009). The main characteristics of maize seeds and hybrids are shown in Table 1.

Table 1. Agronomic characteristics, thousand seed weight (1,000-SW), water content (WC), and germination rate (GR) of the 15 corn hybrids used in this study.

N°	Hybrid	Agronomic characteristics				1,000-SW (g)	WC (%)	GR (%)
		Biotechnological Event	Maturation Cycle	Plant Height (cm)	Yield Potential			
1	AG 8088 PRO2	VT PRO 2®	Early	250	High	330	12.1	82
2	AG 8700 PRO4	VT PRO 4®	Early	235	High	356	12.5	97
3	AG 8701 PRO4	VT PRO 4®	Early	242	High	384	12.3	100
4	AS 1868 PRO4	VT PRO 4®	Early	238	High	379	13.0	83
5	B 2800 VYHR	Leptra®	Early	272	High	372	12.1	91
6	BP 2201 VIP3	Agrisure Viptera® 3	Early	265	High	385	11.9	83
7	DKB 360 PRO3	VT PRO 3®	Early	247	High	390	12.4	82
8	DKB 390 PRO4	VT PRO 4®	Early	245	High	388	12.7	95
9	FS 575 PWU	Power Core® Ultra	Early	245	High	340	11.8	99
10	GALO VIP3	Agrisure Viptera® 3	Early	225	High	365	12.6	94
11	GNZ 7757 VIP3	Agrisure Viptera® 3	Early	240	High	355	12.6	96
12	LG 36745 PRO4	VT PRO 4®	Early	240	High	379	12.0	90
13	MG 545 PWU	Power Core® Ultra	Early	233	High	365	11.9	92
14	ONÇA PRO2	VT PRO 2®	Early	230	High	362	12.5	94
15	STINE 9075 VIP3	Agrisure Viptera® 3	Early	266	High	360	12.8	83

The seeds were first sterilized with 2% (w/v) sodium hypochlorite (NaOCl) solution for 8 minutes and washed immediately with distilled water many times. The sterilized seeds were shade-dried at laboratory room temperature for 96 hours and finally allowed to germinate under non-stressful (control) and stressful (drought, salinity and aluminum toxicity) conditions.

The drought and salinity stresses were induced by exposing seeds to –0.30 MPa iso-osmotic solutions prepared with polyethylene glycol (PEG-6000) and sodium chloride (NaCl), respectively. The amount of PEG-6,000 required to prepare the solution with –0.30 MPa osmotic potential was calculated using the equation of (Michel & Kaufmann, 1973): $\Psi s = [-(1.18 \times 10^{-2}) \times C - (1.18 \times 10^{-4}) \times C^2 + (2.67 \times 10^{-4}) \times C \times T + (8.39 \times 10^{-7}) \times C^2 \times T]/10$, where Ψs is the osmotic potential (MPa), C is the concentration (g L^{-1} of PEG-6,000) and T is the temperature (°C). The amount of NaCl required to prepare the saline solution with –0.30 MPa osmotic potential was calculated using the van't Hoff equation (Hillel, 1971): $\Psi s = -R \times T \times C \times i$, where R is the universal constant of noble gases (0.008314 MPa mol^{-1} K^{-1}), T is the absolute temperature (273.15 + °C), C is the molar concentration of the solute (mol L^{-1}) and i is the van't Hoff factor, that is the number of ions released when the solute is dissolved in water [i.e., for NaCl this value is 2.0 (Na^+ and Cl^-).

Aluminum toxicity stress was induced by exposing seeds to solution containing 200 µmol L^{-1} Al^{3+} and 1,000 µmol L^{-1} Ca^{2+} prepared with aluminum sulfate octadecahydrate [$Al_2(SO_4)_3.18H_2O$] and calcium chloride dihydrate ($CaCl_2.2H_2O$), respectively. The pH of the solution containing Al^{3+} was adjusted to 4.3 by adding 0.5 mol L^{-1} HCl. The use of solutions containing between 165 and 220 µmol L^{-1} of Al^{3+}, combined with 1,000 µmol L^{-1} of Ca^{2+}, has been efficient in determining the degree of tolerance of corn hybrids to aluminum toxicity (Mazzocato et al., 2002; Paterniani & Furlani, 2002). Distilled water with an osmotic potential of 0.00 MPa was used as control treatment.

2.2 Plant Growth Condition

Six 40-seeds replicates were sown in plastic containers (44 × 30 × 7.5 cm) filled with quartz sand, at a depth of 2.0 cm. The sand used as substrate was previously sieved through a mesh with a diameter of 0.05 to 0.8 mm. The sand was then moistened with distilled water (control), PEG-6,000 solution (drought stress), NaCl solution (salinity stress) or $Al_2(SO_4)_3.18H_2O$ solution (aluminum toxicity) in a proportion of 70% of the substrate's water retention capacity (BRASIL, 2009), equivalent to 120 mL of aqueous solution for each kilogram of sand. The plastic containers were kept in laboratory conditions using artificial light supplementation with red (620-630 nm) and blue (455-475 nm) wavelengths at the ratio of 85% (red) and 15% (blue) from light-emitting diodes (LEDs) at a 400 ± 60 μmol m^{-2} s^{-1} light intensity, temperature of 25.2 °C (± 2.4 °C) and a photoperiod of 14 h/10 h (light/darkness) cycle, for 18 days. There were no environmental variations, as the experiments were carried out in a laboratory under controlled conditions.

2.3 Measurement of morphological traits

At 18 days after the beginning of the abiotic stresses, the emergence rate (E) of maize seedlings was recorded. Subsequently, five plants per replicate were randomly chosen to determine plant height (PH); length of the longest root (LR); total plant length (TPL); total root system length (TRL); root volume (RV); leaf area (LA); and dry matter of the plant organs.

The plants were separated into shoots (leaves and stem) and roots, oven-dried at 85℃ for three days and then shoot dry matter (SDM); root dry matter (RDM); and total plant dry matter (TDM) were recorded in an analytical balance (±0.0001 g). The PH, LR, and TPL were measured using a ruler. The LA was determined using an automatic leaf area meter (Li-Cor®, model LI-3100, Lincoln, Nebraska, USA). For the determination of TRL and RV, the plant roots were scanned using an optical scanner (Scanjet 4C/T, HP) at 300 dpi resolution, and the digitized images were analyzed with WinRhizo program version 3.8-b (Regent Instrument Inc., Quebec, Canada).

2.4 Experimental design and Statistical analysis

The experimental bioassay was arranged in a completely randomized design in a 4 x 15 factorial scheme: four stress treatments [control, drought, salinity and aluminum toxicity) and 15 commercial corn hybrids, with six replicates of 40 seeds.

The data were previously tested for homoscedasticity of variances (Levene test; $p > 0.05$) and normality of residues (Kolmogorov–Smirnov test; $p > 0.05$) and, then were submitted to analysis of variance (ANOVA). The means were compared by the Scott-Knott test at the 0.05 level of confidence. The analyses were performed using Rbio® software version 140 for Windows (Ferreira, 2019).

2.5 Variables description

The biometric variables collected are those commonly used for index calculations.

- **Emergence rate (E):** variable expressed as a percentage of plants emerged.
- **Plant height (PH), Longest root (LR), total root system length (TRL) and total plant length (TPL)**: variables measured in centimeters (cm) according to the methodology described in the previous section.
- **Leaf area (LA) and Root volume (RV):** variables measured in square centimeters (cm^2) and cubic centimeters (cm^3), respectively, according to the methodology described above.

- **Shoot dry matter (SDM), Root dry matter (RDM) and Total dry matter (TDM):** variables measured in milligrams per plant (mg/plant) as previously described.
- **Root to shoot ratio (RS):** the ratio between root dry matter (RDM) and shoot dry matter (SDM) was calculated by dividing root dry matter by shoot dry matter.

3. Data Description

The following tables present the raw data obtained in the experiment described in the previous section, using the methods described, as well as the discriminative information of these data. These tables aim to clarify the information obtained for the purpose of computational implementation and statistical analysis of the data.

Table 2. Data types and values assumed in the dataset.

Column	Data type	Values
Treatment	Categorical	Control Drought Salinity Aluminum Toxicity
Hybrid	Categorical	Hybrid names according to Table 1.
Repetition	Integer	1 to 6
Emergence rate (E), plant height (PH), total plant length (TPL), leaf area (LA), length of the longest root (LR), total root system length (TRL), root volume (RV), Root to shoot ratio (RS); shoot dry matter (SDM); root dry matter (RDM); and total plant dry matter (TDM)	Continuous	Ranging from 2.90 to 100.00

Table 3. Example dataset for the "AG 8088 PRO2" hybrid.

Hybrid	Treatment	Rep.	E	PH	TPL	LA	LR	TRL	RV	RS	SDM	RDM	TDM
AG 8088 PRO2	Control	1	68	14.0	37.0	17.3	23.0	58.4	12.8	0.92	26.3	24.2	50.5
AG 8088 PRO2	Control	2	68	16.0	37.0	16.8	21.0	60.9	13.4	0.86	28.9	24.8	53.7
AG 8088 PRO2	Control	3	70	18.0	41.0	18.9	23.0	62.8	13.8	0.84	32.5	27.2	59.7
AG 8088 PRO2	Control	4	70	19.0	39.5	20.2	20.5	64.1	14.1	0.76	34.8	26.3	61.1
AG 8088 PRO2	Control	5	78	20.0	43.0	21.1	23.0	66.0	14.5	0.75	36.2	27.2	63.4
AG 8088 PRO2	Control	6	78	23.5	48.5	21.4	25.0	68.5	15.1	0.73	41.6	30.5	72.1

"Rep." means repetition.

Table 5. Dataset summary with approximate values to two decimal places.

	E	PH	TPL	LA	LR	TRL	RV	RS	SDM	RDM	TDM
mean	79.2888	18.9736	39.5030	28.9053	20.5294	75.4342	23.3792	1.1480	45.8573	47.8426	93.6081
std	16.4024	6.2429	11.7735	15.4505	6.4464	28.8325	9.3101	0.4375	20.8787	18.0015	35.0211
min	42.0000	5.0000	9.0000	3.4040	3.5000	10.4000	1.9593	0.3544	6.40000	2.8000	9.5000
25%	68.0000	15.0000	32.3750	18.8250	17.0000	57.0630	17.5796	0.8191	32.0750	37.5384	70.8500
50%	82.0000	18.5000	39.5000	26.4150	20.5000	75.3930	22.7072	1.0809	44.8500	50.3028	98.7703
75%	94.0000	22.5000	47.5000	35.9160	24.5000	91.5750	28.3161	1.4194	60.2250	60.7590	118.8379
max	100.0000	34.0000	71.5000	87.9120	40.0000	162.4320	47.7447	2.5582	93.8000	89.4285	176.0124

"std.", "min" and "max" means standard deviation, minimum and maximum, respectively.

4. Availability

The dataset obtained from the experiments reported above and a Python Google Colab code for reading these data is available at: https://github.com/brunobro/dataset-15-corn-hybrids-subjected-to-abiotic-stresses-water-salt-aluminum-toxicity

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6. Additional Information

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6.3 Conflicts of Interest

The authors declare that there are no conflicts of interest.