



Evaluation of the Allelopathic Activity of *Mimosa pudica* (L.) Weed Extracts on the Germination of Okra Seeds

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Abstract

The objective of this study was to evaluate the allelopathic effect of *Mimosa pudica* (L.) on okra germination. The experiment was carried out in the laboratory, where the seeds (20/ Petri dish) of two okra varieties (Clemson: V1 and Hire: V2) were watered with different concentrations (C1: 25%, C2: 50%, C3: 75%, C4: 100%) of aqueous extracts from the roots (RAE), stems (SAE), and leaves (LAE) of *Mimosa*. Control seeds were watered with sterile distilled water (C0: 0%). Germination parameters such as average growth rate, coefficient of velocity, duration of germination, germination energy, germination%, germination vigor index, germination index, inhibition, last day of germination, latency time, radicle length, mean daily germination, mean germination time, phytotoxicity, seed germination index, speed of emergence, speed of germination, and time to 50% germination were evaluated. The aqueous extracts of *Mimosa* negatively affected the germination parameters, with effects being concentration-dependent. At V2, the highest germination percentage was recorded for the control (C0: 81.67%), while the lowest was observed at C4: 6.67% for LAE. In V1, radicle length was 5.77, 0.62, 0.18, 0, and 0 cm for C0, C1, C2, C3, and C4, respectively, for SAE. The seeds of V2 were less affected by aqueous extracts compared to V1, with inhibition recorded at 60.64% in V1C1 versus only 19.94% in V2C1. Inhibition was significantly stronger with LAE and SAE compared to RAE. From C1 to C4, AE phytotoxicity ranged from 0.005 to 0.01 for LAE, from 0.005 to 0.01 for SAE, and from 0.001 to 0.007 for RAE. The burial of this weed is therefore prohibited. These findings show that *Mimosa* aqueous extracts contain toxic ingredients and suggest that LAE and SAE should be tested on weeds to assess their bioactivity, as they can serve as a basis for bioherbicides.

Keywords: Allelopathic Activity; Ecology; Aqueous Extract; Germination; *Mimosa pudica*

Abbreviations:

MDG: Mean Daily Germination; AE: Aqueous Extract; PG: Germination parameters; GI: Germination Index; CVG: Coefficient of Velocity; MGT: Mean Germination Time; T₅₀: Time to 50% Germination; FDG: Latency Time; TSG:

Duration of Germination; LDG: Last Day of Germination; GE: Germination Energy; SGI: Seed Germination Index; MDG: Mean Daily Germination; GVI: Germination Vigor Index; SE: Speed Emergence; GR: Average Growth Rate; LR: Length of the Radicle; Spe: Speed of Germination; Inh: Inhibition; Tox: Phytotoxicity; GVI: Germination Vigor Index.



Introduction

Okra (*Abelmoschus esculentus* (L.) Moench) is a unique vegetable crop, as every part of the plant is used in medicine, human nutrition, industry (glossy paper, sizing agent), and crafts [1-3]. It contains high levels of calcium, iron, protein, vitamins (A, B6, B9, and C), phosphorus, magnesium, and fiber, nutrients that can help address deficiencies and reduce malnutrition in poor countries worldwide [4]. The crop is highly profitable for growers. However, Cameroon's annual production remains low (77,631.82 tons) compared to that of other countries in the sub-region, such as Nigeria (1,911,818.50 tons) [5].

Cameroon's production increased steadily from 1990 (10,000 tons) to 2016 (78,763 tons) [5]. However, since 2017 (69,060 tons), a significant decline in production has been observed at both national and regional levels, and production has not returned to its 2016 peak. Biotic and abiotic constraints are generally responsible for this decline in production [6-7]. Among the main biotic constraints is allelopathy which is the chemical inhibition of one plant by another. The interaction between grass growth and plant growth leads to yield losses due to weeds. These losses are caused by allelochemicals, which are toxic to plant germination and growth [8].

Mimosa pudica L. is an invasive species that inhibits the germination and growth of other plants, such as okra. High levels of allelochemicals have been detected in its leaves, pods, and seeds [9]. Although *M. pudica* is a widespread invasive plant in Cameroon, to our knowledge, no studies have been conducted on its allelopathic effect on seed germination and crop growth. Hence, this study aims to assess the allelopathic effect of aqueous extracts from *M. pudica* leaves, stems, and roots on okra seed germination.

Material and Methods

Study Sites

Weeds were collected from the experimental farm of the Faculty of Sciences (FS), University of Yaoundé I (UYI) (Geographic coordinates: 3°51'30"N-11°29'30"E, altitude: 710 m). The average annual temperature of the site is 24°C, with precipitation ranging from 1,000 to 2,000 mm/year. There is a four-season climate, with two rainy seasons (March to June: short season, September to November: long season) and two dry seasons (July to August: short season, December to February: long season).

The soil is sandy-loam with 34.5% sand, 35% silt, and 30.5% clay [10]. The phytotoxicity test was carried out at the Plant Biotechnology Laboratory of FS-UYI.

Plant Materials

The plant material consisted of seeds from two varieties of okra. The first was Clemson with smooth and angular fruits. It is vigorous, early (50-55 days), and heat-demanding. The second was the Hire variety, a hybrid adapted to high temperatures, early (60-65 days). Both varieties were purchased at the Mfoundi seed market (Centre Region).

The weed consisted of the organs (leaves, stem, and root) of *Mimosa pudica*.

Methods

Fresh green leaves, fresh green stems, and mature roots of *M. pudica* were first harvested. Each organ was washed with tap water and rinsed with distilled water. Then, the plant materials were dried at 48 °C in an oven for 72 hours and ground to obtain a powder with a fine and uniform texture. The powders of each sample were stored in a polyethylene bag until use.

Leaf (LEA), Stem (SAE), and Root (REA) extracts were prepared (50 g/400 mL, shaken for 24 h at 25°C; centrifuged at 2000 rpm/min). The extraction yield was 160, 150, and 240 mL for roots, stems, and leaves, respectively. For each aqueous extract (AE), different concentrations (C1: 25%, C2: 50%, C3: 75%, C4: 100%) were made. C0: 0% was sterile distilled water (control). In the lab, sterilized seeds (20/seeds per Petri dish, 3 replicates) of two okra varieties (Clemson: V1 and Hire: V2) were watered with the different concentrations of LEA, SAE, and REA.

Germination parameters (seed germination percentage (PG), germination index (GI), coefficient of velocity (CVG), mean germination time (MGT), time to 50% germination (T50), latency time (FDG), duration of germination (TSG), last day of germination (LDG), Germination energy (GE: % of germinated seeds after 4 days from the start of the experiment), seed germination index (SGI), mean daily germination (MDG), germination vigor index (GVI), speed emergence (SE), average growth rate (GR), length of the radicle (LR), speed of germination (Spe), inhibition (Inh), phytotoxicity (Tox)) were evaluated [10-14].

$$\text{Inhibition (\%)} = \left[\frac{(\text{control} - \text{extract})}{\text{control}} \right] * 100 \quad (1)$$

$$\text{Phytotoxicity} = \left[1 - (\text{extract} / \text{control}) \right] / 100 \quad (2)$$

$$\text{PG (\%)} = \frac{\text{Number of germinated seeds}}{\text{Total seed number}} * 100 \quad (3)$$

$$\text{GI} = \frac{\text{N}^{\circ} \text{ of germinated seeds in first count}}{\text{Days of first count}} + \dots + \frac{\text{N}^{\circ} \text{ of germinated seeds in final count}}{\text{Days of final count}} \quad (4)$$

$$\text{CVG} = \frac{(G_1 + G_2 + \dots + G_n)}{(1 \times G_1 + 2 \times G_2 + \dots + n \times G_n)} * 100; \text{ With G: N}^{\circ} \text{ of germinated}$$

seeds, n: last day of germination (5)

$$MGT = \frac{\sum(Dn)}{\sum n}; \text{With } n: \text{N}^\circ \text{ of seeds germinated on each}$$

day and D: day of counting (6)

$$T_{50}(\text{day}) = T_1 + \frac{(T_2 - T_1) \times (0.5 - G_1)}{(G_2 - G_1)}; G_1: \text{cumulative GR}$$

using the value flanking to 50% thru smaller value, G_2 : cumulative GR using the value flanking to 50% thru greater value, T_1 : day whose cumulative GR was nearer to 50% by smaller value, T_2 : day whose cumulative GR was nearer to 50% by greater value (7)

$$GVI = LR(\text{cm}) \times GI(8)$$

$$SE = \frac{\text{N}^\circ \text{ of germinated seeds on the 1}^{\text{st}} \text{ day}}{\text{N}^\circ \text{ of germinated seeds on the last day}} \times 100 \quad (9)$$

$$GR = \frac{x_1}{y_1} + \frac{x_2 - x_1}{y_2} + \dots + \frac{x_n - x_{n-1}}{y_n} \quad (10)$$

x_n : N° of seeds germinated on day n, y_n = N° of days from start of trial to day n

$$MDG = \frac{PGF}{N_j}; PGF: \% \text{ of final germination, } N_j: \text{N}^\circ \text{ of days}$$

to full final germination (11).

$SGI = \sum D_i N_i / W D_i$: N° of days after seeding, N_i : N° of seeds germinated on day 1, W : whole N° of seeds sowed (12)

$Spe = [N_1/1 + N_2/2 \dots] \times 100$; N_i/i : ratio between N° of seeds germinated/day (13)

Data Analysis

The collected data were subjected to analysis of variance using R Studio version 4.0.5 and IBM SPSS Statistics 20 software. Means were compared with each other using Duncan's test at the 5% threshold. Graphical representations were made using Graphpad software.

Results and Discussion

Seed Germination Percentage

Aqueous extract (AE), variety, and organ of *M. pudica* significantly ($P < 0.05$) affected the germination of okra seeds. From Day 2, the interaction of variety \times treatment \times organ was significant ($P < 0.01$). With increasing AE from C1 to C4, a gradual decrease in seed germination parameters was observed in V1 and V2 (Figures 1 & 2, Table 1).

At V1, on Day 9, the highest seed germination percentage was recorded for C0 (Leaf: $68.33 \pm 2.89\%$, Stem: $80 \pm 5\%$, Root: $63.33 \pm 2.89\%$) and the lowest for C4 (Leaf: $1.67 \pm 2.89\%$, Stem: 0% , Root: $8.33 \pm 2.89\%$).

At V2, the highest seed germination percentage was recorded for C0 (Leaf: $81.67 \pm 2.89\%$, Stem: $86.67 \pm 2.89\%$, Root: $63.33 \pm 2.89\%$) and the lowest for C4 (Leaf: $6.67 \pm 2.89\%$, Stem: $3.33 \pm 5.77\%$, Root: $33.33 \pm 7.64\%$).

Toxicity was higher for SAE (Stem AE) and LAE (Leaf AE) compared to RAE (Root AE). V2 showed the best germination percentage.

SV	PG	PG	PG	PG	PG	PG	PG	PG	PG	MDG	GE	GVI	GR	Spe	SGI	GI	LR	T50	CVG	MGT
	day1	day2	day3	day4	day5	day6	day7	day8	day9											
Variety (V)	ns	*	**	***	***	***	***	***	***	***	***	***	***	***	***	***	***	ns	ns	ns
Treatment (T)	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Organ (O)	*	**	***	***	***	***	***	***	***	***	***	***	***	***	***	***	ns	***	***	***
V*T	ns	***	**	***	***	***	***	***	***	***	***	***	***	***	***	***	***	*	ns	ns
V*O	ns	*	***	***	***	***	***	***	***	***	***	ns	***	***	***	***	ns	*	ns	ns
T*O	**	**	***	***	***	***	***	***	***	***	***	***	***	***	***	***	**	**	***	***
V*T*O	ns	***	***	***	***	***	**	**	**	**	***	***	***	***	***	***	***	-	ns	ns
SV	Inh	Inh	Inh	Inh	Inh	Inh	Inh	Inh	Tox	Tox	Tox	Tox	Tox	Tox	Tox	Tox	TSG	SE	FDG	LDG
	day2	day3	day4	day5	day6	day7	day8	day9	day2	day3	day4	day5	day6	day7	day8	Day9				
Variety (V)	*	**	***	***	***	***	***	***	*	**	ns	***	ns	***	***	***	***	ns	ns	**
Treatment (T)	***	***	***	***	***	***	***	***	***	ns	***	ns	***	***	***	***	***	***	***	*
Organ (O)	***	***	***	***	***	***	***	***	***	ns	***	ns	***	***	***	***	**	ns	***	ns

V*T	ns	ns	***	***	***	**	**	**	ns	ns	ns	***	ns	**	**	**	ns	ns	ns	ns
V*O	ns	ns	***	***	*	ns	ns	ns	ns	ns	ns	***	ns	ns	ns	ns	ns	ns	ns	ns
T*O	**	***	***	**	ns	ns	ns	ns	**	***	ns	**	ns	ns	ns	ns	*	**	***	*
V*T*O	*	***	***	***	***	**	**	**	*	***	ns	***	ns	**	**	**	ns	ns	ns	ns

Table 1: Significance of considered parameters.

SV: Source of variation, PG: germination capacity, GR: Average growth rate, CVG: coefficient of velocity, FDG: latency (first day of germination), GE: germination energy, GI: germination index, GVI: germination vigor index, Inh: Inhibition, LDG: last day of germination, LR: length of radicle, MDG: mean daily germination, MGT: mean germination time,

SE: speed emergence, SGI: seed germination index, Spe: speed of germination, T_{50} : time to 50% germination, TSG: duration of germination, Tox: phytotoxicity. *, ** and ***: significant at the 0.05, 0.01 and 0.001 levels, respectively, ns: no significant difference at the 0.05 level.

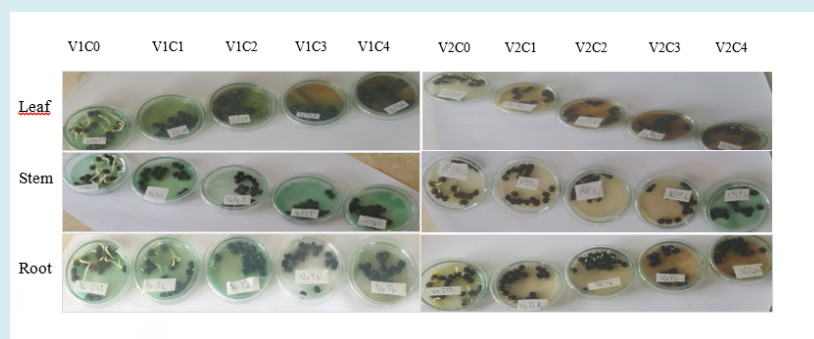


Figure 1: Seeds germination of okra with different AE. C0: sterile distilled water (Control), C1: 25% of AE, C2: 50% of AE, C3: 75% of AE, C4: 100% of AE, V1: Clemson, V2: Hire.

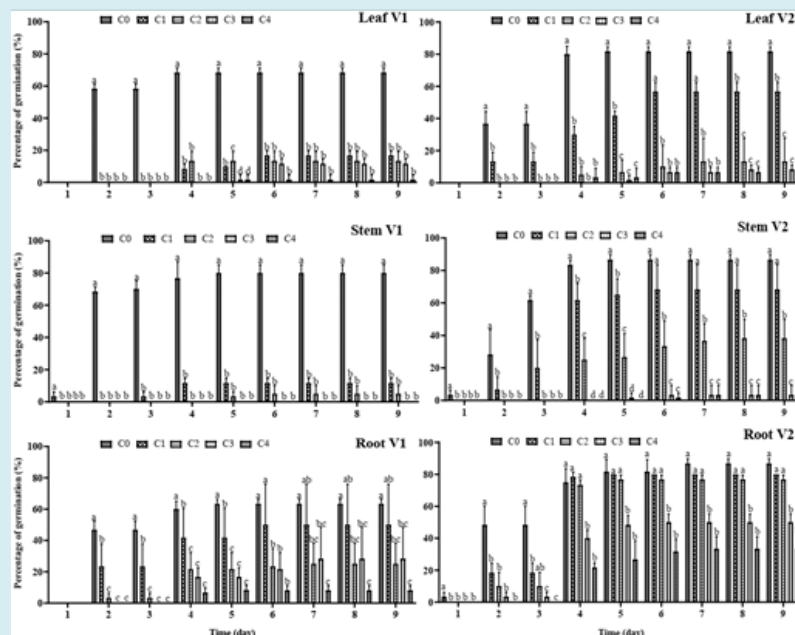


Figure 2: Effect of aqueous extract (AE) on germination percentage of okra's seed. C0: sterile distilled water (Control), C1: 25% of AE, C2: 50% of AE, C3: 75% of AE, C4: 100% of AE, V1: Clemson, V2: Hire. For each graph, at each time, the average \pm standard deviation with the identical inscription was not differing significantly at the 0.05 level of Duncan's test.

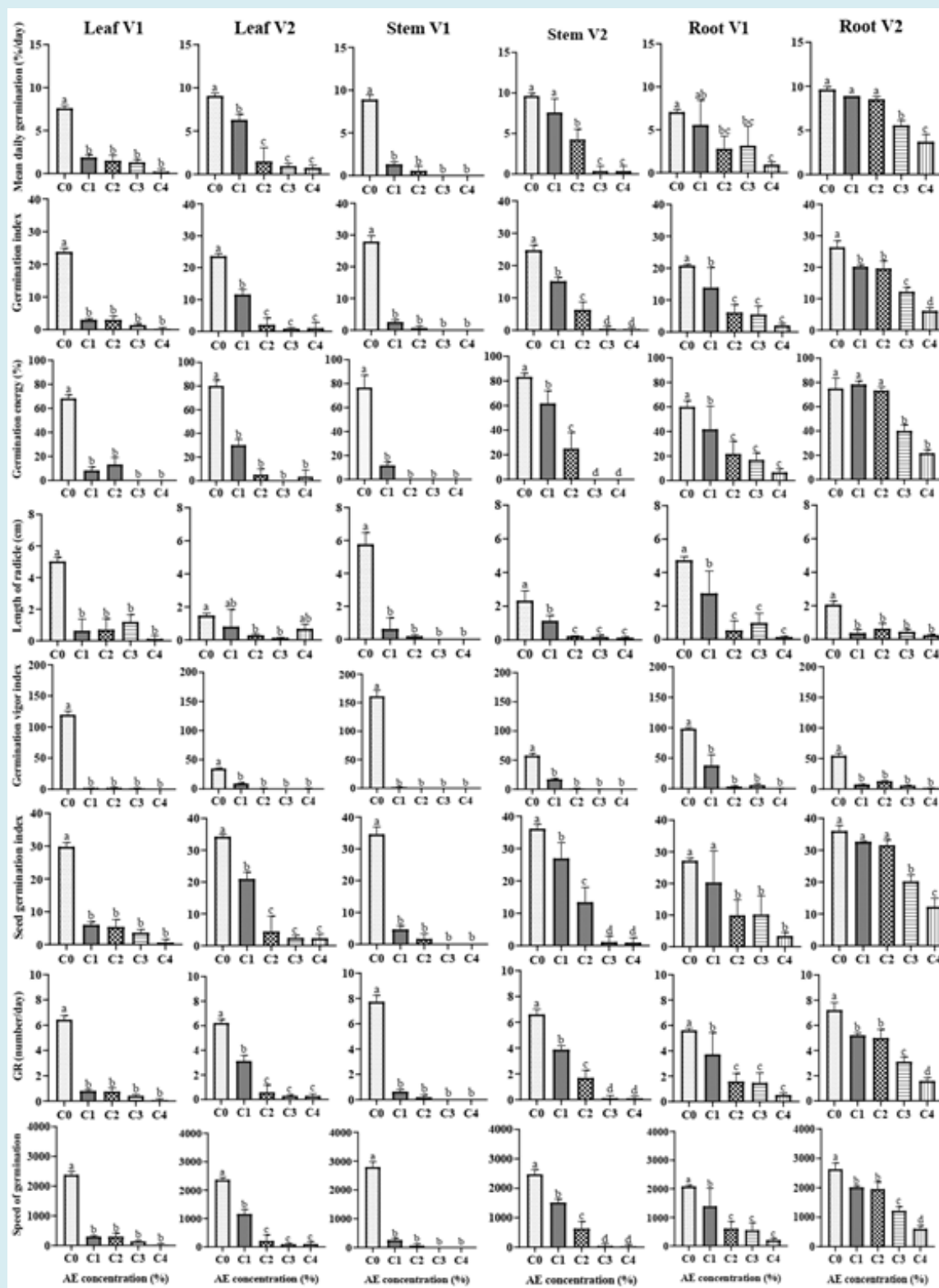


Figure 3: Effect of aqueous extract (AE), organ and variety on germination parameters of okra's seed. C0: distilled water, C1: 25% of AE, C2: 50% of AE, C3: 75% of AE, C4: 100% of AE, V1: Clemson, V2: Hire. GR: average growth rate. For each graph, the average \pm standard deviation with the identical inscription was not differing significantly at the 0.05 level of Duncan's test.

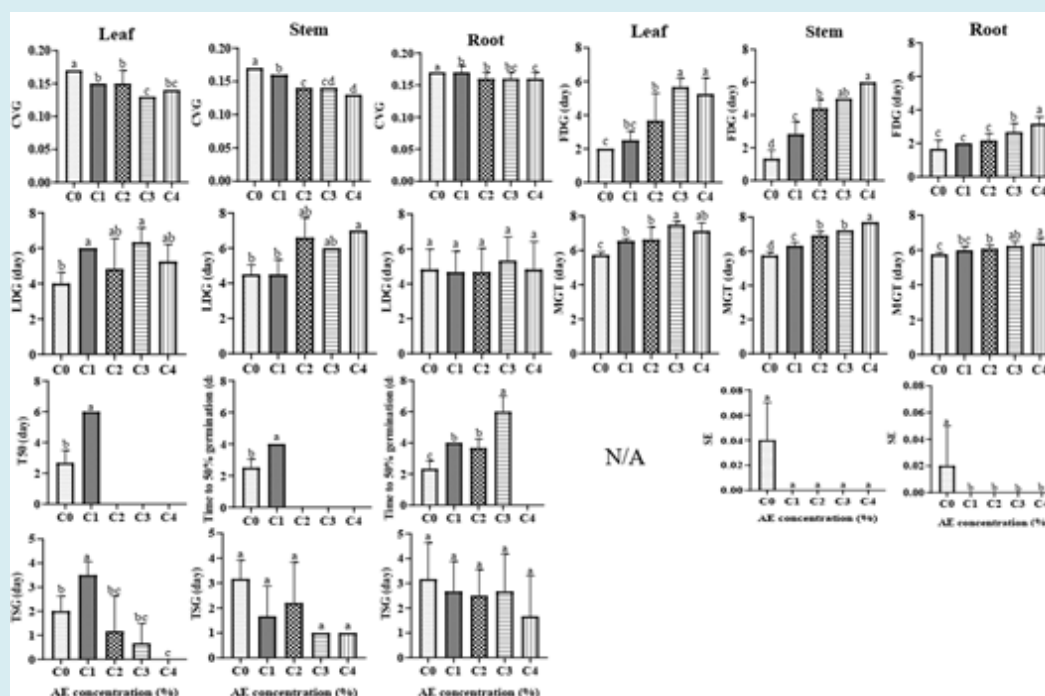


Figure 4: Effect of aqueous extract (AE) and organ on germination parameters of okra's seed. C0: sterile distilled water (Control), C1: 25% of AE, C2: 50% of AE, C3: 75% of AE, C4: 100% of AE, V1: Clemson, V2: Hire. CVG: coefficient of velocity, FDG: latency (first day of germination), LDG: last day of germination, MGT: mean germination time, SE: speed emergence, T_{50} : time to 50% germination, TSG: duration of germination, N/A: not available. For each graph, the average \pm standard deviation with the identical inscription was not differing significantly at the 0.05 level of Duncan's test.

Speed of Germination

AE, variety, and organ significantly ($P < 0.001$) affected the speed of germination of okra seeds. The interaction between variety \times treatment \times organ was significant ($P < 0.001$) (Table 1, Figure 3).

With increasing AE from C1 to C4, a gradual decrease in the speed of germination of okra seeds was observed in V1 and V2. V2 showed the highest germination speed with RAE (Figures 5 & 6).

Germination Vigor Index (GVI)

AE, variety, and organ significantly ($P < 0.001$) affected the SGI of okra seeds. The interaction between variety \times treatment \times organ was significant ($P < 0.001$) (Table 1, Figure 3). AE significantly ($P < 0.001$) reduced the SGI. V2 showed the highest SGI with Root AE.

The lowest SGI was found at C4 (0.58 ± 1.01) for LAE; at C3 (0 ± 0) and C4 (0 ± 0) for SAE; and at C4 (3.38 ± 1.13) for RAE in V1. For V2, the lowest SGI was found at C4 for LAE (2.3 ± 1.39), SAE (0.9 ± 1.56), and RAE (12.25 ± 2.7).

Length of Radicle

AE and variety significantly ($P < 0.001$) affected the length of the radicle. The interaction between variety \times treatment \times organ was significant ($P < 0.001$) (Table 1, Figure 3). AE significantly ($P < 0.05$) reduced the length of okra radicle. The mean length of radicles observed after the 9th day in V1 Leaf was 5.03, 0.63, 0.7, 1.2 and 0.12 cm respectively for C0, C1, C2, C3 and C4; in V2 Leaf was 1.47, 0.8, 0.28, 0.12 and 0.67 cm respectively for C0, C1, C2, C3 and C4. In V1 Stem, it was 5.77, 0.62, 0.18, 0 and 0 cm respectively for C0, C1, C2, C3 and C4; in V2 Stem, it was 2.33, 1.13, 0.22, 0.18 and 0.13 cm respectively for C0, C1, C2, C3 and C4. In V1 Root, it was 4.73, 2.75, 0.53, 0.98 and 0.13 cm respectively for C0, C1, C2, C3 and C4; in V2 Root it was 2.07, 0.37, 0.63, 0.45 and 0.25 cm respectively for C0, C1, C2, C3 and C4.

Mean Daily Germination (MDG)

AE, variety, and organ significantly ($P < 0.001$) affected the MDG of okra seeds. The interaction between variety \times treatment \times organ was significant ($P < 0.001$) (Table 1, Figure 3). With increasing AE from C1 to C4, a gradual decrease in the MDG was observed in V1 and V2. V2 showed the highest

MDG with RAE (Figures 5 & 6).

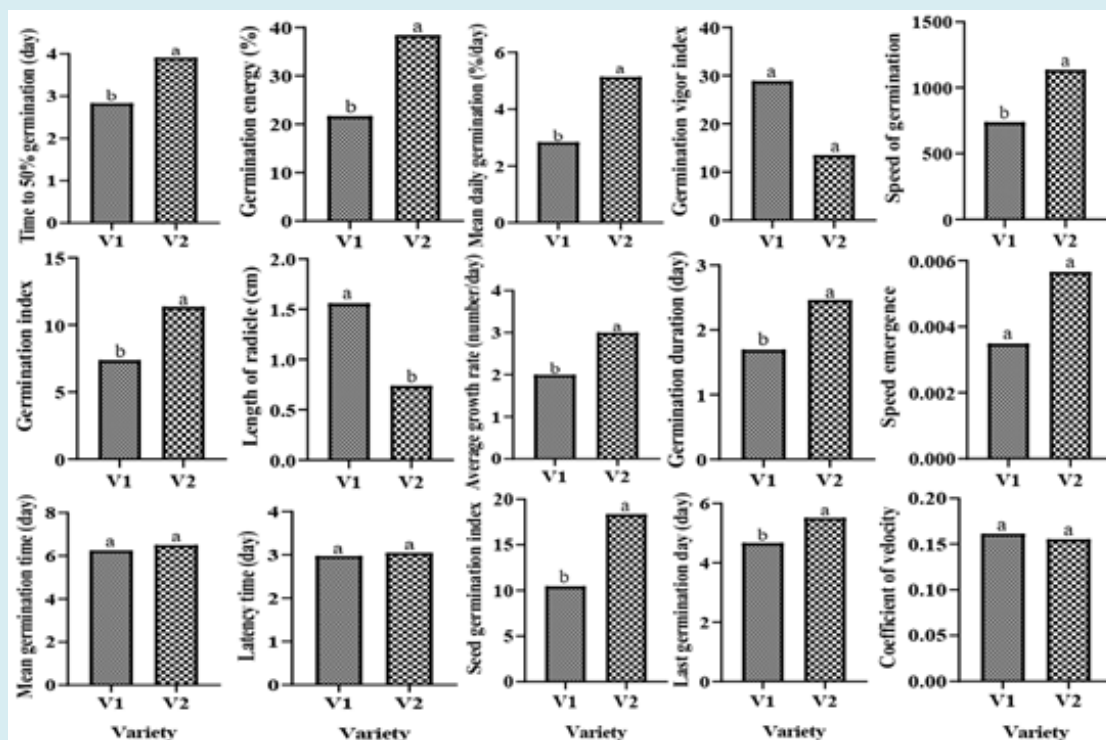


Figure 5: Effect of variety on germination parameters of okra's seed. For each parameter, the average with the identical inscription was not differing significantly at the 0.05 level of Duncan's test.

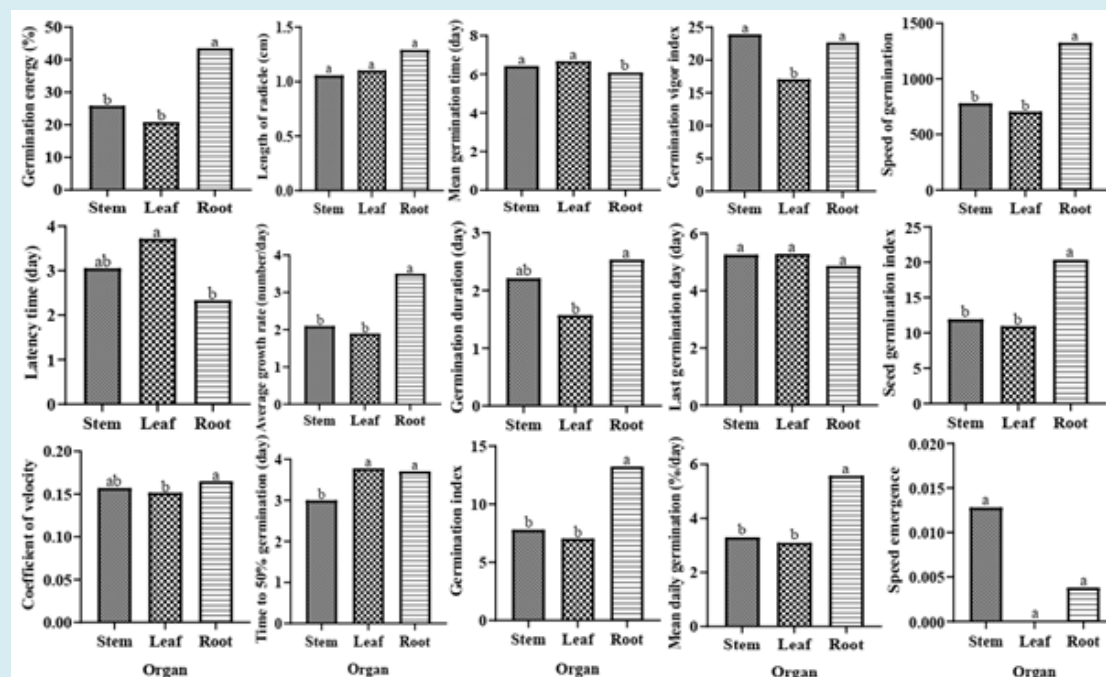


Figure 6: Effect of organ on germination parameters of okra's seed. For each parameter, the average with the identical inscription was not differing significantly at the 0.05 level of Duncan's test.

Germination Energy

AE, variety, and organ significantly ($P < 0.001$) affected the GE of okra seeds. The interaction between variety \times treatment \times organ was significant ($P < 0.001$) (Table 1, Figure 3). With increasing AE from C1 to C4, a continuous decrease in GE was observed in V1 and V2. V2 exhibited the maximum GE with RAE. The lowest GE was observed at C3 and C4 for Leaf AE (0 ± 0); at C1, C2, C3, and C4 for SAE (0 ± 0); and at C4 for RAE (6.67 ± 2.89) in V1. For V2, the lowest GE was observed at C3 for LAE (0 ± 0), at C3 and C4 for SAE (0 ± 0), and for RAE (21.67 ± 2.89).

Germination Index

AE, variety, and organ significantly ($P < 0.001$) affected the germination index of okra seeds. The interaction between variety \times treatment \times organ was significant ($P < 0.001$) (Table 1, Figure 3). With increasing AE from C1 to C4, a continuous decrease in the germination energy was observed in V1 and V2. V2 showed the highest germination energy with RAE (Figures 5 & 6).

Average Growth Rate (GR)

AE, variety, and organ significantly ($P < 0.001$) affected the GR of okra seeds. The interaction between variety \times treatment \times organ was significant ($P < 0.001$) (Table 1, Figure 3). With increasing AE from C1 to C4, a steady decline in GR was noted in V1 and V2. V2 showed the highest GR with RAE.

Latency (FDG)

AE significantly ($P < 0.001$) increased the latency time of okra germination. The variety did not significantly ($P > 0.05$) influence the latency time. Organ significantly ($P < 0.001$) influenced the latency time. The interactions between variety \times treatment \times organ; variety and treatment; and variety and organ were not significant ($P > 0.05$), but the interaction between treatment and organ was significant ($P < 0.001$).

With increasing AE from C1 to C4, a gradual increase in latency duration was observed (Table 1, Figure 4). The highest latency time was recorded at C3 (5.67 ± 0.52 days) and C4 (5.25 ± 0.96 days) for LAE; at C3 (5.0 ± 0 days) and C4 (6 ± 0 days) for SAE; and at C4 (3.17 ± 0.41 days) for RAE.

Time to 50% germination (T_{50})

The variety did not significantly ($P > 0.05$) influence the T_{50} of okra seeds. However, AE and organ significantly ($P < 0.001$) influenced the T_{50} . AE and organ ($P < 0.01$), variety and organ ($P < 0.05$), and variety and treatment ($P < 0.05$) interactions were significant. With increasing AE, an increase in T_{50} was noted (Table 1, Figure 4). T_{50} was not reached at C2, C3, and C4 for LAE and SAE, and at C4 for RAE.

Mean Germination Time (Mgt)

AE and organ significantly ($P < 0.001$) influenced the MGT of okra. The variety did not significantly ($P > 0.05$) influence this MGT. The interactions variety \times treatment \times organ, variety \times treatment, variety \times organ and variety \times treatment were not significant ($P > 0.05$), but the interaction treatment \times organ was significant ($P < 0.001$).

With increasing AE from C1 to C4, a continuous decrease in MGT was noted (Table 1, Figure 4). The highest value was recorded at C3 (7.48) and C4 (7.13) for LAE; at C4 (7.71) for SAE; and at C4 (6.37) and C3 (6.23) for RAE.

Speed Emergence (SE)

AE significantly ($P < 0.001$) reduced the SE of okra seed. The variety and organ did not significantly ($P > 0.05$) influence the SE. The interactions variety \times treatment \times organ, variety \times treatment, variety \times organ were not significant ($P > 0.05$), but the interaction between treatment \times organ was significant ($P < 0.01$).

With increasing AE from C1 to C4, a decrease in SE was observed (Table 1, Figure 4). The highest SE was found at C0 for SAE (0.04) and RAE (0.02).

Coefficient of Velocity (Cvg)

AE and organ significantly ($P < 0.001$) influenced the CVG of okra's seed. The variety did not significantly ($P > 0.05$) influence CVG. The interactions variety \times treatment \times organ, variety \times treatment, variety \times organ and variety \times treatment were not significant ($P > 0.05$), but interaction treatment \times organ was significant ($P < 0.001$). With increasing AE from C1 to C4, a continuing reducing in CVG was noted (Table 1, Figure 4). The least value was detected at C3 (0.13) and C4 (0.14) for LAE; at C4 (0.13) and C3 (0.14) for SAE; and at C3 (0.16) and C4 (0.16) for RAE.

Duration of Germination (TSG)

AE ($P < 0.001$), variety ($P < 0.001$) and organ ($P < 0.01$) significantly affected the TSG of okra seeds. The interactions variety \times treatment \times organ, variety \times treatment, variety \times organ were not significant ($P > 0.05$), but interaction treatment \times organ was significant ($P < 0.05$). With increasing AE from C1 to C4, a reducing in TSG was noted (Table 1, Figure 4). The least value was noted at C4 for LAE (0.0), SAE (0.0) and RAE (1.67). V2 showed highest TSG.

Last Day of Germination (LDG)

AE ($P < 0.05$) and variety ($P < 0.01$) significantly affected the LDG of okra seeds. The interactions variety \times treatment

× organ, variety × treatment, variety × organ were not significant ($P>0.05$), but interaction treatment × organ was significant ($P<0.05$). With increasing AE from C1 to C4, a rising in LDG was noted (Table 1, Figure 4). The highest LDG was noted at C3 (6.33 ± 0.82) for LAE, C4 (7 ± 0) for SAE and C3 (5.33 ± 1.37) for RAE. V2 showed highest LDG.

Germination Inhibition (Inh)

AE, variety and organ significantly ($P<0.05$) affected the germination inhibition of okra seeds. The interaction variety × treatment × organ was significant ($P<0.001$) (Table 1).

Germination inhibition decreased over time. It increased with increasing AE concentration in the germination medium (Tables 2 and 3). It was highest at C4 concentration (V1C1: 60.64%, V1C2: 78.22%, V1C3: 79.36%, V1C4: 94.8%) (Table 2). Inhibition was higher in the V1 variety than in V2. On Day 9, inhibition was 60.64% in V1C1 versus only 19.94% in V2C1 (Table 2). Inhibition also varied significantly according to the organ from which AE was extracted. It was higher in leaves and stems than in roots. Thus, at Day 10, at C4 concentration, germination inhibition was 94.71% for Leaf, 98.08% for Stem, versus 74.19% for Root (Table 3).

Var	[AE] (%)	Time (day)							
		day 2	day 3	day 4	day 5	day 6	day 7	day 8	day 9
V1	C1	83.45±9.73 ^{ab}	74.64±10.41 ^{abc}	67.72±10.73 ^{bc}	68.19±9.96 ^{bc}	60.51±12.23 ^{bc}	60.51±12.23 ^{bc}	60.51±12.23 ^{bc}	60.64±12.16 ^{bc}
	C2	97.64±1.56 ^a	87.34±5.1 ^{ab}	81.43±6.13 ^{ab}	80.61±5.38 ^{ab}	79.04±5.68 ^{ab}	78.15±6.24 ^{ab}	78.15±6.24 ^{ab}	78.22±6.21 ^{ab}
	C3	100±0 ^a	89.9±5.34 ^{ab}	90.74±4.9 ^{ab}	90.37±4.54 ^{ab}	82.82±5.72 ^{ab}	79.29±8.49 ^{ab}	79.29±8.49 ^{ab}	79.36±8.44 ^{ab}
	C4	100±0 ^a	95.96±2.2 ^a	96.3±2.02 ^a	94.77±2.28 ^a	94.77±2.28 ^a	94.77±2.28 ^a	94.77±2.28 ^a	94.8±2.27 ^a
V2	C1	67.32±6.04 ^c	62.65±7.03 ^c	27.92±9.98 ^d	25.64±7.04 ^d	20.13±4.57 ^d	20.13±4.57 ^d	20.13±4.57 ^d	19.94±4.61 ^d
	C2	93.06±4.59 ^{ab}	71.56±13.46 ^{bc}	55.28±14.01 ^c	55.91±13.17 ^c	53.79±11.68 ^c	51.16±11.1 ^c	50.52±11.1 ^c	50.37±11.14 ^c
	C3	97.68±1.53 ^a	81.2±9.43 ^{ab}	82.22±8.96 ^{ab}	79.04±9.6ab	76.86±8.75 ^{ab}	76.86±8.75 ^{ab}	76.18±8.61 ^{ab}	76.11±8.64 ^{ab}
	C4	100±0 ^a	97.44±1.81 ^a	88.98±4.71 ^{ab}	87.8±5.75ab	84.52±5.56 ^{ab}	83.24±5.76 ^{ab}	83.24±5.76 ^{ab}	83.19±5.78 ^{ab}

Table 2: Inhibition of germination by aqueous extract (AE) of *Mimosa pudica* (interaction AE*variety). Var: variety, C0: sterile distilled water (Control), C1: 25% of AE, C2: 50% of AE, C3: 75% of AE, C4: 100% of AE, V1: Clemson, V2: Hire. For each day, the average ± standard error with the identical inscription was not differing significantly at the 0.05 level of Duncan's test.

Org-an	[AE] (%)	Time (day)							
		day 2	day 3	day 4	day 5	day 6	day 7	day 8	day 9
Stem	C1	88.1±8.83 ^{ab}	81.49±9.54 ^a	55.28±13.65 ^{cd}	55.35±13.8 ^{cd}	53.44±15.03 ^{bc}	53.44±15.03 ^{bc}	53.44±15.03 ^{bc}	53.3±15.1 ^{bc}
	C2	100±0 ^a	100±0 ^a	84.94±7.89 ^{ab}	82.59±7.37 ^{abc}	77.72±8.11 ^{ab}	75.8±8.75 ^{ab}	74.84±9.27 ^{ab}	74.84±9.27 ^{ab}
	C3	100±0 ^a	100±0 ^a	100±0 ^a	99.04±0.96 ^a	98.08±1.92 ^a	98.08±1.92 ^a	98.08±1.92 ^a	98.08±1.92 ^a
	C4	100±0 ^a	100±0 ^a	100±0 ^a	100±0 ^a	99.04±0.96 ^a	98.08±1.92 ^a	98.08±1.92 ^a	98.08±1.92 ^a
Leaf	C1	81.98±9.01 ^b	84.49±4.37 ^a	75.12±5.97 ^{abc}	67.24±8.13 ^{abc}	53.19±10.2 ^{bc}	53.19±10.2 ^{bc}	53.19±10.2 ^{bc}	53.19±10.2 ^{bc}
	C2	100±0 ^a	93.23±1.37 ^a	87.07±4.04 ^{ab}	86.13±4.14 ^{ab}	84.1±5 ^a	82.07±5.1 ^a	82.07±5.1 ^a	82.07±5.1 ^a
	C3	100±0 ^a	100±0 ^a	100±0 ^a	97.76±1.43 ^a	87.36±2.47 ^a	87.36±2.47 ^a	86.34±2.12 ^a	86.34±2.12 ^a
	C4	100±0 ^a	100±0 ^a	97.92±2.08 ^a	96.74±2.15 ^a	94.71±1.91 ^a	94.71±1.91 ^a	94.71±1.91 ^a	94.71±1.91 ^a
Root	C1	56.08±8.89 ^c	39.98±6.52 ^b	13.06±11.34 ^e	18.15±10.47 ^e	14.34±11.01 ^d	14.34±11.01 ^d	14.34±11.01 ^d	14.37±11.01 ^d
	C2	86.04±5.8 ^{ab}	45.11±13.21 ^b	33.06±14.53 ^d	36.1±13.9 ^d	37.42±12.39 ^{cd}	36.1±12.14 ^{cd}	36.1±12.14 ^{cd}	36.04±12.23 ^{cd}
	C3	96.53±2.2 ^{ab}	56.64±6.54 ^b	59.44±6.47 ^{bcd}	57.3±7.85 ^{cd}	54.07±6.86 ^{bc}	48.78±8.87 ^{bc}	48.78±8.87 ^{bc}	48.79±8.86 ^{bc}
	C4	100±0 ^a	90.09±2.6 ^a	80±4.28 ^{abc}	77.13±5.77 ^{abc}	75.19±5.78 ^{ab}	74.23±6.17 ^{ab}	74.23±6.17 ^{ab}	74.19±6.21 ^{ab}

Table 3: Inhibition of germination by aqueous extract (AE) of *Mimosa pudica* (interaction AE*organ). C0: sterile distilled water (Control), C1: 25% of AE, C2: 50% of AE, C3: 75% of AE, C4: 100% of AE. For each day, the average ± standard error with the identical inscription was not differing significantly at the 0.05 level of Duncan's test.

Var	[AE] (%)	Time (day)							
		day 2	day 3	day 4	day 5	day 6	day 7	day 8	day 9
V1	C1	0.008±0.001 ^b	0.008±0.001 ^{abc}	0.007±0.001 ^{bc}	0.007±0.001 ^{bc}	0.006±0.001 ^{bc}	0.006±0.003 ^{bc}	0.006±0.001 ^{bc}	0.006±0.001 ^{bc}
	C2	0.01±0 ^a	0.009±0.001 ^{ab}	0.008±0.001 ^{ab}	0.008±0.001 ^{ab}	0.008±0.001 ^{ab}	0.008±0.001 ^{ab}	0.008±0.001 ^{ab}	0.008±0.001 ^{ab}
	C3	0.01±0 ^a	0.009±0.001 ^{ab}	0.009±0.001 ^{ab}	0.009±0.001 ^{ab}	0.008±0.001 ^{ab}	0.008±0.002 ^{ab}	0.008±0.001 ^{ab}	0.008±0.001 ^{ab}
	C4	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a
V2	C1	0.007±0.001 ^c	0.006±0.001 ^c	0.003±0.001 ^d	0.003±0.001 ^d	0.002±0.001 ^d	0.002±0.001 ^d	0.002±0.001 ^d	0.002±0.001 ^d
	C2	0.009±0.001 ^{ab}	0.007±0.001 ^b	0.006±0.001 ^c	0.006±0.001 ^c	0.005±0.001 ^c	0.005±0.001 ^c	0.005±0.001 ^c	0.005±0.001 ^c
	C3	0.01±0 ^a	0.008±0.001 ^{abc}	0.008±0.001 ^{abc}	0.008±0.001 ^{abc}	0.008±0.001 ^{ab}	0.008±0.001 ^{ab}	0.008±0.001 ^{ab}	0.008±0.001 ^{ab}
	C4	0.01±0 ^a	0.01±0 ^a	0.009±0.001 ^{ab}	0.009±0.001 ^{ab}	0.009±0.001 ^{ab}	0.008±0.001 ^{ab}	0.008±0.001 ^{ab}	0.008±0.001 ^{ab}

Table 4: Phytotoxicity of aqueous extract (AE) of *Mimosa pudica* (interaction AE*variety). Var: variety, C0: sterile distilled water (Control), C1: 25% of AE, C2: 50% of AE, C3: 75% of AE, C4: 100% of AE, V1: Clemson, V2: Hire. For each day, the average ± standard error with the identical inscription was not differing significantly at the 0.05 level of Duncan's test.

Org-an	[AE] (%)	Time (Day)							
		day 2	day 3	day 4	day 5	day 6	day 7	day 8	day 9
Stem	C1	0.009±0.001 ^{ab}	0.008±0.001 ^a	0.006±0.001 ^{cd}	0.006±0.001 ^{cd}	0.005±0.002 ^{bc}	0.005±0.002 ^{bc}	0.005±0.002 ^{bc}	0.005±0.002 ^{bc}
	C2	0.01±0 ^a	0.01±0 ^a	0.009±0.001 ^{ab}	0.008±0.001 ^{abc}	0.008±0.001 ^{ab}	0.008±0.001 ^{ab}	0.008±0.001 ^{ab}	0.008±0.001 ^{ab}
	C3	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a
	C4	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a
Leaf	C1	0.008±0.001 ^b	0.008±0 ^a	0.008±0.001 ^{abc}	0.007±0.001 ^{bc}	0.005±0.001 ^{bc}	0.005±0.001 ^{bc}	0.005±0.001 ^{bc}	0.005±0.001 ^{bc}
	C2	0.01±0 ^a	0.009±0 ^a	0.009±0 ^{ab}	0.0086±0 ^{ab}	0.008±0.001 ^{ab}	0.008±0.001 ^{ab}	0.008±0.001 ^a	0.008±0.001 ^a
	C3	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.009±0 ^a	0.009±0 ^a	0.009±0 ^a	0.009±0 ^a
	C4	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.009±0 ^a	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a	0.01±0 ^a
Root	C1	0.006±0.001 ^c	0.004±0.001 ^b	0.001±0.001 ^e	0.002±0.001 ^e	0.001±0.001 ^d	0.001±0.001 ^d	0.001±0.001 ^d	0.001±0.001 ^d
	C2	0.009±0.001 ^{ab}	0.005±0.001 ^b	0.003±0.001 ^{de}	0.004±0.001 ^{de}	0.004±0.001 ^{cd}	0.004±0.001 ^{cd}	0.004±0.001 ^{cd}	0.004±0.001 ^{cd}
	C3	0.009±0 ^{ab}	0.006±0.001 ^b	0.006±0.001 ^{cd}	0.006±0.001 ^{cd}	0.005±0.001 ^{bc}	0.005±0.001 ^{bc}	0.005±0.001 ^{bc}	0.005±0.001 ^{bc}
	C4	0.01±0 ^a	0.009±0.001 ^a	0.008±0.001 ^{abc}	0.008±0.001 ^{abc}	0.008±0.001 ^{ab}	0.007±0.001 ^{ab}	0.007±0.001 ^{ab}	0.007±0.001 ^{ab}

Table 5: Phytotoxicity of aqueous extract (AE) of *Mimosa pudica* (interaction AE*organ). C0: sterile distilled water (Control), C1, C2, C3, C4: 25, 50, 75, 100% of AE respectively. For each day, the average ± standard error with the identical inscription was not differing significantly at the 0.05 level of Duncan's test.

Phytotoxicity (Tox)

AE, variety and organ significantly ($P<0.05$) affected the phytotoxicity of *Mimosa pudica* AE on germination of okra seeds. Interaction variety × treatment × organ was significant ($P<0.001$) (Table 1).

Overall, the phytotoxicity of *M. pudica* AEs on okra seed germination decreased over time. It increased with increasing AE concentration in the germination medium (Tables 2 & 3). It was highest at C4 concentration (C1_Root: 0.001, C2_Root: 0.004, C3_Root: 0.005, C4_Root: 0.007) (Table 5). Phytotoxicity was higher in the V1 variety than in V2. On Day 9, it was 0.006 for V1C1 versus only 0.002 for V2C1 (Table 2).

Phytotoxicity also varied significantly according to the organ from which the AE was extracted. Thus, it was higher in leaves and stems than in roots. At Day 10, from C1 to C4, AE phytotoxicity ranged from 0.005 to 0.01 for LAE, from 0.005 to 0.01 for SAE, and from 0.001 to 0.007 for RAE (Table 3) [10-13].

Discussion

With increasing AE from C1 to C4, an increase in latency duration, mean germination time, time to 50% germination, germination inhibition, and phytotoxicity was observed. Similar results were reported by Pratap Chandran R [12] on *Brassica juncea*. With increasing AE from C1 to C4, a decrease in the percentage of germination, speed of germination, seed germination index, germination vigor index, length of

radicle, germination energy, germination index, mean daily germination, coefficient of velocity, speed of emergence, duration of germination, and last day of germination of okra seeds was observed. Similar results were reported by Pratap Chandran R [12] on *Brassica juncea*, [14] on *Poaceae*, and [15] on *Bidens pilosa*.

The different AEs of *M. pudica* negatively affected all the germination parameters evaluated. The negative impact of *M. pudica* AEs on okra seed germination is attributed to the action of allelochemicals in the extracts. Indeed, they negatively affect the physiological mechanisms throughout germination. Mimosine is a key allelochemical present in the *Mimosa* genus, reported to be responsible for the high allelopathic action by inhibiting the germination of crop seeds, and it is found in great amounts in the leaves, pods, and seeds of tropical pulses [9,12]. The reduction in radicle length by AEs may be caused by the inhibition of cell division and cell elongation.

AE toxicity was higher in leaves and stems than in roots. This result is similar to those of this result could be explained by the higher levels of allelochemicals in the leaves and stems of *M. pudica*. It could also be explained by the different chemical compositions of the tested organs, hence the different allelopathic effects [13-15]. Burial is one of the most popular agricultural practices in the region, aiming to restore soil fertility. However, given the presence of very high allelochemical substances in the leaves and stems that inhibit the germination of okra seeds, the removal of the residues of this weed from the plots should be encouraged to increase the rate of seedling emergence and consequently the yield of okra in the locality.

Variety V2 was less affected by AEs compared to V1. Variety inconsistency related to germination traits may be explained by the heterogeneity of their genetic make-up [16-17]. Indeed, due to its intrinsic characteristics, a variety can be more resistant to diseases [18-19], more suitable for symbiosis [20-25], or more tolerant to stress than another [26-29]. These traits thus give it a better adaptation to the different hazards of the environment.

The phytotoxic effect of *Mimosa* species causes root growth retardation in target weeds such as *Echinochloa crus-galli* (barnyard grass) and *Ruellia tuberosa* L. [30-32]. It could also be tested on local target weeds competing with okra, such as *Commelina benghalensis* L., *Echinochloa pyramidalis* (Lam.) Hitchc. & Chase, *Bidens pilosa* L., etc. The extraction costs and application methods of *Mimosa* species as bioherbicides have not yet been documented. Conventional (sprays, granules) and modern (application platforms with sensors, drones, etc.) application methods can be tested.

Conclusion

This work reports the inhibitory effect of *M. pudica* on all okra seed germination parameters depending on the concentration of root, stem or leaf extracts. The seeds of V2 were less affected by the extracts compared to those of V1; the V2 variety is therefore recommendable to farmers in this region. Inhibition was significantly stronger with leaf and stem aqueous extract compared to the root. The burial of this weed is therefore not recommended for better emergence of okra seeds. In view of its allelopathic effect on okra seed germination, our findings suggest that *M. pudica* leaf and stem extracts should be tested on weeds to ensure their bioactivity as they can be utilized as a source of natural herbicides.

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