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ORIGINAL RESEARCH ARTICLE

Allelopathic Effects of *Mangifera indica* L. Leaf Leachate on Germination and Early Growth of Selected Crops

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ABSTRACT
This study evaluates the allelopathic effects of *Mangifera indica* L. leaf leachate on the germination and early growth of soybeans, beans, chili peppers, okra, and maize. Aqueous extracts were prepared from crushed mature leaves and tested at concentrations of 20%, 40%, 80%, and 100% compared to a control (distilled water). Germination percentage of the seeds was recorded at intervals of 24, 48, 76, and 92 hours, while shoot and root length were measured after 10 days. Results showed a concentration-dependent inhibition of germination and growth of shoot and root, with chili pepper being the most affected and maize the least. These findings suggest that *Mangifera indica* has potential as a natural herbicide and therefore recommended that soya beans, beans, okra, and especially chili pepper should not be planted at the very closest distance from the mango tree stem due to its allelopathic effects.

INTRODUCTION
Agroforestry possesses huge potential to be climate and livelihood smart practices (Verchot *et al.*, 2007) but its associated issues that are there remain to be solved. It includes tree-crop competition for resources, allelopathic effects of trees on crops, entry of invasive species in the agricultural land, and trees serving as habitat for harmful pests and diseases. Among these challenges, allelopathy and tree crop competition are widely debated among researchers worldwide. These concerns are interconnected with the interplay between tree crops, which can be either complimentary (positive), supplementary (neutral), or competing (negative) (Khatri *et al.*, 2022a; Khatri *et al.*, 2023). Allelopathy is a biological phenomenon that occurs when an organism creates biochemical substances that affect other species' growth, survival, and reproduction. This interaction between tree crops is considered a form of allelopathy. (Cheng and Cheng, 2015; Trezzi *et al.*, 2016; Khatri *et al.*, 2022b).

The entire organs of the woody plant can potentially exhibit allelopathy (Weir *et al.*, 2004), but leaves are the most reliable source of allelopathic compounds and have the strongest allelopathic impact on target species (Tanveer *et al.*, 2010). The various components of the plant, including the root, rhizome, stem, flower, and leaves, generate allelochemicals (Ahmad *et al.*, 2011; Joshi and Joshi, 2021). The chemicals emitted by a certain plant disrupt the process of seed germination and the growth of seedlings in other plants (Aragão, 2017). The allelochemicals negatively impact crop plants' seed germination, development, and yield (Regu, 2018; Yakubu *et al.*, 2018).

Mango (*Mangifera indica*) is a significant tropical evergreen fruit tree from the Anacardiaceae family. It is widely known for its economic importance and is commonly used in agroforestry practices such as agri-horticulture and agri-horti-silviculture (Karki *et al.*, 2022; Barreto, 2008). The tree is versatile, serving multiple purposes. Apart from bearing fruit, it is renowned for its medicinal qualities (Shah *et al.*, 2010), anti-oxidant characteristics (Ajila *et al.*, 2007), anti-inflammatory effects (Garrido *et al.*, 2004), as well as its ability to combat fungal and bacterial infections (Kanwal *et al.*, 2010). Nevertheless, further investigation is necessary to explore the allelopathic capabilities of mango, as literature is scarce on this subject. Some of these studies mentioned are El-Rokiek *et al.* (2010) and Ashafa *et al.* (2012). Mango (*Mangifera indica* L.) is extensively cultivated as an agroforestry species in several regions worldwide, particularly Nigeria.

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Nevertheless, the dropping leaves of the tree are believed to have an allelopathic effect on the crops growing beneath it, making it extremely challenging for these linked crops to survive. This study aims to fill this gap by investigating the allelopathic impact of mango leaf leachate on the germination and initial growth of soybeans, beans, chilli pepper, okra, and maize. The main objectives of this study are to assess the germination percentage of soybeans, beans, chili pepper, okra, and maize at specific time intervals (24, 48, 76, and 92 hours) after being exposed to varying concentrations of mango leaf leachate; measure the shoot and root length of the crops after 10 days of exposure to mango leaf leachate to evaluate its inhibitory effects on early growth; and compare the inhibitory or stimulatory effects of mango leaf leachate on the germination, shoot, and root length of different crop species, and identify the most affected crop and thereby contributing to the understanding of allelopathy in agroecosystems.

MATERIAL AND METHODS

Study Area

The research was conducted at the Biological Garden of the Federal University of Kashere in Gombe state, located in North Eastern Nigeria. Kashere is at a height of 431 meters above sea level and has a population of 77,015. The coordinates are 9° 52' 40" N and 11° 0' 37" E in DMS format (Degrees Minutes Seconds) (Kolawole *et al*., 2021b).

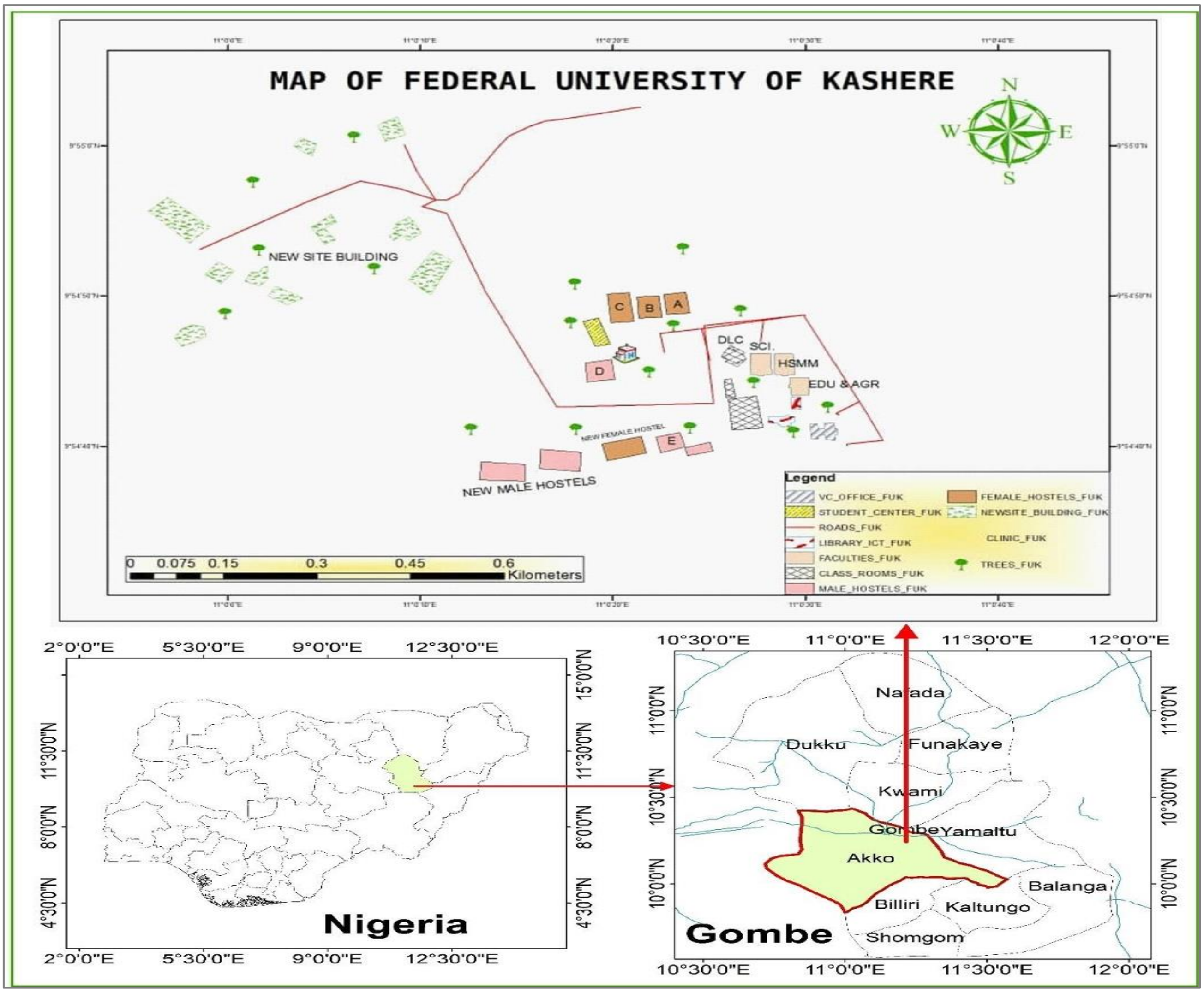

Figure 1: Map of the study area Adapted from Kolawole *et al.* (2021a)

Collection of test crop seeds

Five seeds of the following test crops were chosen for the current study due to their homogeneous shape and size: cowpea (*Vigna unguilacta*), soybeans (*Glycine max*), chilli pepper (*Capsicum annuum*), maize (*Zea mays*), and okra (*Abelmoschus esculentus*). The seeds were acquired from Kashere Market in Gombe State.

Plant extract preparation

Field-grown mature leaves of *Mangifera indica* plants were carefully chosen from the botanical garden at the Federal University of Kashere, located in Gombe State. The aqueous mango extracts (*Magnifera indica* L.) were made by steeping 100g of crushed fresh mature leaves in 500 ml of distilled water for 24 hours at room temperature, then filtration using standard filter paper. These solutions were then stored in opaque conical flasks for seed irrigation (Norsworthy, 2003)

Experimental Research Design

Five seed crops were used in this research, and the experiment design carried out was a Completely Randomized Design (CRD) with 5 treatments of leaf leachate of *Mangifera indica*: T1 (control, distilled water), T2 (20%), T3 (40%), T4 (80%), and T5 (100%) of leachate solution and each treatment was replicated three times.

Germination Bioassay

A sufficient quantity of healthy seeds was tested for viability. The experiments were done in Petri dishes before Whatman filter paper was placed, and ten seeds of each food crop were placed on Whatman No. 1 filter paper. The seeds were equally scattered on the surface and saturated with the correct concentration. The seeds were monitored daily, and the quantity of germinated seeds was recorded. Distilled water was added to the control treatments, while leachate solution was added to the leachate treatment as needed to keep the seeds wet. The prepared samples were stored in a natural light-dark cycle environment and temperatures between 25 and 30 °C. The samples were labeled as T1 for control (distilled water), T2 for 20% leachate solution, T3 for 40% leachate solution, T4 for 80% leachate solution, and T5 for 100% leachate solution, using a modified approach based on Sahoo *et al.* (2010). Germination was assessed by counting the number of seeds sprouted each day up to the fourth day. The roots and shoot lengths were recorded 10 days after germination. The percentage of inhibition or stimulation effect on germination compared to the control (T1) was computed using the equation provided by Islam and Kato-Noguchi (2012) and Surendra and Pota (1978).

$$\text{Germination } (\%) = \frac{NST \times 100}{NSC} \quad (1)$$

While,

$$\text{Inhibition/stimulation } (\%) = \frac{CVSR - TVSR \times 100}{CVSR} \quad (2)$$

Key:
NST= No. of seeds germinated in the Treatment medium
NSC= No. of seeds germinated in the Control medium
CVSR = Control Value of shoot/root
TVSR = Treatment Value of shoot/root

Data Analysis

The experimental data were subjected to analysis of variance (ANOVA) and significant differences were identified. The means were then separated using Duncan's multiple range tests at a significance level of $P < 0.05$. The statistical study was conducted using IBM SPSS 20.0.

RESULTS

Effect of *Mangifera indica* leaf leachates on Germination percentage (%)

The results in Table 1 displayed the allelopathic effect of leaf leachate of *Mangifera indica* on the germination and early growth of soya beans, maize, okra, beans, and chilli pepper. A significant difference ($P > 0.05$) was recorded on most of the test crops across different treatments except in chilli pepper, where no significant difference was recorded on T1 at 24 hours after sowing. Germination percentage of above 50% was recorded in all the control treatments within 48 hours of sowing in almost all the test crops, while below 50% was recorded on the beans chilli pepper. It was observed that the rate of germination decreased with an increase in concentration except in maize, which recorded an increase in germination percentage from 24 hours after planting and 96 hours after planting at maximum leachate concentration (Figure 2). It is interesting to know that as the treatments/concentrations increase across the hours after planting, germination percentage decreases at 96 hours (4 days) after planting compared to the control, chilli pepper germinated at T3 and T4 after 72 hours, recording a low germination percentage of 25% compared to other test crops used in the study, more so, no germination was recorded on chilli pepper treated with the highest concentration (T5) of leachate across the 96 hours (4 days). The subsequent patterns of inhibited seed germination percentage in the test crops by leaf leachate of *Mangifera indica* were obtained as chilli pepper > okra > soya beans > bean > maize (Table 1: Figure 2).

Effect of *Mangifera indica* leaf leachate on Shoots Elongation

The results in Table 2 displayed the allelopathic effect of leaf leachate of *Mangifera indica* on shoot elongation, and the result revealed that the inhibitory/stimulatory effects of leaf leachate on shoot elongation of the test crops are a concentration-dependent phenomenon, i.e., increase in concentration exerted more inhibition on the shoot elongation of most of the test species. Maximum shoot length was recorded in the control treatments of almost all the test species, while the lowest shoot length was recorded in the T5 (maximum concentration) of leachate except for maize, where the maximum concentration of aqueous leaf extract slightly stimulated its shoot elongation better than the control.

There was no inhibitory effect on T3 and T5 of aqueous leaf extract of *Mangifera indica* on maize as it shows the stimulatory effect of (+2.09) and (+2.41), respectively compared to other treatments where inhibitory effects were recorded on the remaining test crops. The highest inhibitory effect on the shoot was observed in chili pepper and okra at T5 (highest concentration) of leaf leachate with an inhibitory percentage of (-100%) and (-28.98%), respectively. However, the differences in the effect on shoot elongation were significantly different ($p < 0.05$) in almost all the crops across different treatments except in maize, where a slight significant difference was recorded (Table 2).

Effect of *Mangifera indica* leaf leachates on Roots Elongation

The results in Table 3 displayed the allelopathic effect of leaf leachate of *Mangifera indica* on root elongation, and the result revealed that the inhibitory effects of leaf leachate on root elongation are also a concentration concentration-dependent phenomenon, i.e., increase in concentration exerted more inhibition on the root elongation of most of the test species. As the concentration increases stimulatory effect decreases, too. This was observed in this study, which showed that an increase in concentration leads to an increase in inhibitory effect on the root elongation of soya beans, bean, okra, and chilli pepper, while maize shows stimulatory effects on root elongation on two varying treatments (T3 and T5). The highest stimulatory effect of root elongation on the test species was recorded on maize at T3 and soya beans at T2 with a stimulatory percentage of (+8.01%) and (+3.64%) respectively, while the highest inhibitory effect on root elongation was observed in chilli pepper, soya bean and bean at highest concentration (T5) of leaf leachate of *Mangifera indica* with percentage inhibition of (-100%), (-37.56%) and (-27.04%) respectively. A significant difference ($p<0.05$) in the effect of root elongation in all the test crops across different concentrations/treatments in comparison with control was recorded (Table 3).

Table 1: Effect of *Mangifera indica* leaf leachates on Germination (%)

Test crops	Treatments/Time(hr)	24hr	48hr	72hr	96hr
Soya Beans	T1	28.57±1.15^{c}	57.14±0.57^{c}	71.25±0.72^{d}	100.00±0.00^{d}
	T2	14.00±2.51^{b}	28.57±0.01^{b}	42.86±0.04^{c}	57.14±1.15^{c}
	T3	14.00±2.08^{b}	28.40±0.23^{b}	28.57±1.15^{b}	43.51±0.66^{b}
	T4	14.00±0.90^{b}	14.00±0.57^{a}	28.57±0.01^{b}	42.85±0.00^{b}
	T5	0.00±0.00^{a}	14.00±0.57^{a}	14.36±0.24^{a}	29.08±0.51^{a}
Maize	T1	22.22±0.00^{b}	55.55±1.15^{d}	77.77±0.57^{c}	100.00±0.00^{d}
	T2	21.88±0.33^{b}	33.33±0.00^{c}	44.77±0.33^{b}	55.55±1.14^{b}
	T3	11.44±0.33^{a}	21.48±0.74^{b}	33.33±0.00^{a}	55.55±0.00^{b}
	T4	11.11±0.00^{a}	11.11±0.00^{a}	33.33±1.73^{a}	44.44±0.00^{a}
	T5	21.88±0.33^{b}	52.88±0.66^{d}	52.88±0.02^{b}	66.66±1.12^{c}
Okra	T1	37.50±0.50^{d}	50.00±5.77^{c}	87.50±0.00^{d}	100.00±0.00^{d}
	T2	25.00±0.00^{c}	37.50±0.28^{b}	50.00±2.88^{b}	62.50±0.57^{c}
	T3	12.50±1.15^{b}	25.00±0.00^{ab}	63.30±0.10^{c}	62.50±0.00^{c}
	T4	0.00±0.00^{a}	25.00±2.88^{ab}	25.33±1.45^{a}	37.50±0.00^{b}
	T5	0.00±0.00^{a}	12.50±1.00^{a}	25.00±0.00^{a}	25.00±0.57^{a}
Beans	T1	14.28±0.00^{b}	42.85±0.00^{c}	85.71±2.88^{d}	100.00±0.00^{d}
	T2	14.25±0.02^{b}	28.57±0.04^{b}	71.42±0.00^{c}	85.71±0.57^{c}
	T3	14.25±0.02^{b}	14.25±0.02^{a}	42.85±0.10^{b}	57.14±0.00^{b}
	T4	0.00±0.00^{a}	14.18±0.09^{a}	28.57±0.00^{a}	57.14±0.02^{b}
	T5	0.00±0.00^{a}	14.18±0.09^{a}	28.57±0.57^{a}	42.85±0.57^{a}
Chilli pepper	T1	0.00±0.00^{a}	25.00±0.28^{b}	75.00±0.00^{c}	100.00±0.00^{d}
	T2	0.00±0.00^{a}	25.00±0.00^{b}	25.00±1.73^{b}	50.00±1.15^{c}
	T3	0.00±0.00^{a}	0.00±0.00^{a}	25.00±0.00^{b}	25.00±0.00^{b}
	T4	0.00±0.00^{a}	0.00±0.00^{a}	25.00±0.57^{b}	25.00±2.51^{b}
	T5	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}

Values are mean ± standard error of three replications. Means in a column with different superscripts are significantly different using DMRT at $p<0.05$

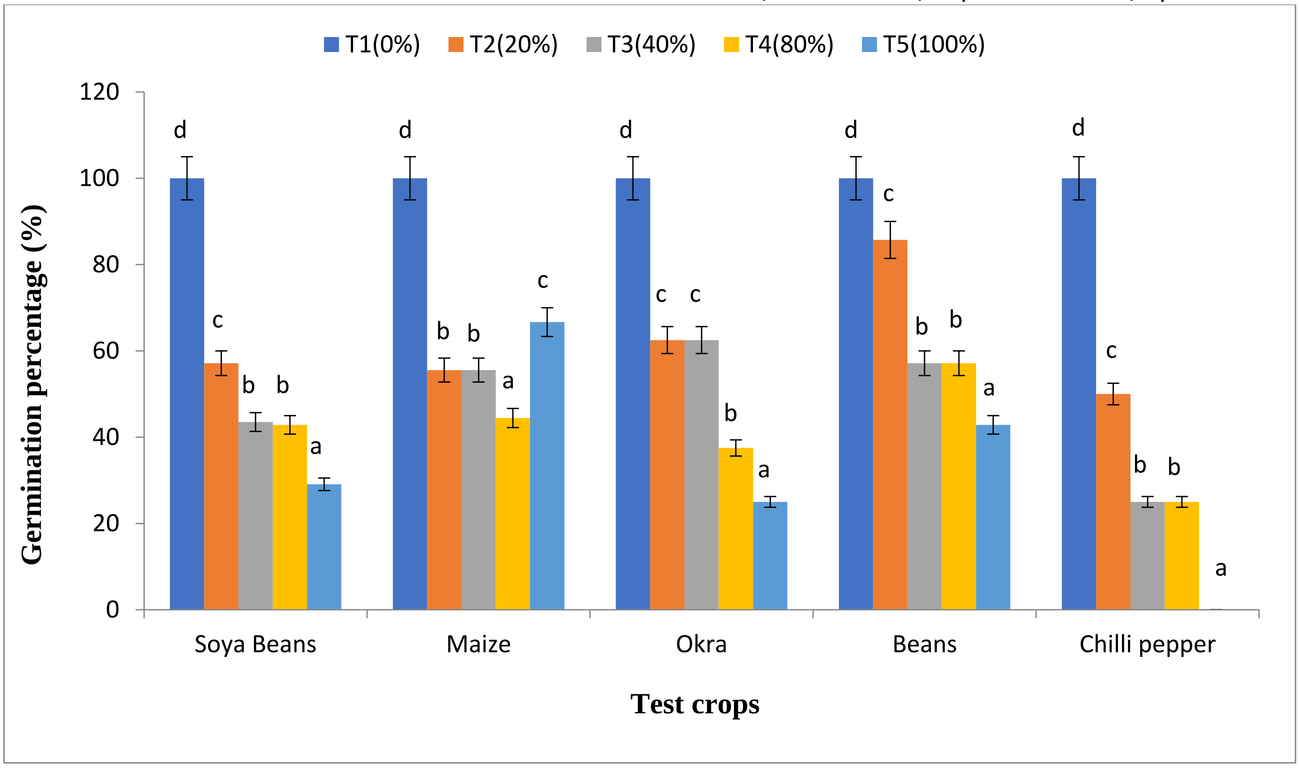

Figure 2: Effect of *Mangifera indica* leaf leachate on germination percentage (%) of the test crops recorded at 4 days (96 hours) after planting.

Table 2: Effect of *Mangifera indica* leaf leachates (T1=0% (Control), T2=20%, T3=40%, T4=80%, T5=100% on shoot length of test crops.

Test crops	Soya bean	Maize	Bean	Okra	Chilli Pepper
Treatments					
T1 (Control)	11.13± 0.40^{c}	12.40±1.40^{a}	12.60±0.60^{b}	10.46±0.60^{b}	5.56±0.33^{c}
T2	10.90±0.34^{bc} (-2.06)	11.36±1.44^{a} (-8.38)	11.66±0.63^{ab} (-7.46)	9.76±0.67^{b} (-6.69)	5.00±0.49^{bc} (-10.07)
T3	10.00±0.05^{ab} (-10.15)	12.66±0.86^{a} (+2.09)	12.03±0.73^{ab} (-4.52)	9.66±0.89^{b} (-7.64)	4.20±0.15^{b} (-24.46)
T4	10.20±0.20^{ab} (-8.35)	10.86±0.26^{a} (-12.41)	11.70±0.75^{ab} (-7.14)	9.10±0.11^{ab} (-13.00)	4.06±0.54^{b} (-26.97)
T5	9.53±0.26^{a} (-14.37)	12.70±0.90^{ab} (+2.41)	9.53±0.74^{a} (-24.36)	7.43±0.35^{a} (-28.98)	0.00±0.00^{a} (-100)

Mean value ± standard error in a column with different superscripts significantly different at $p<0.05$.
Values in the parenthesis indicates the (%) of inhibitory (-) or stimulatory (+) effects in comparison to control (T1)

Table 3: Effect of *Mangifera indica* leaf leachates (T1=0% (Control), T2=20%, T3=40%, T4=80%, T5=100% on root length of test crops.

Test crops	Soya bean	Maize	Bean	Okra	Chilli Pepper
Treatments					
T1 (Control)	12.06±0.78^{bc}	16.60±0.92^{ab}	13.20±0.85^{b}	8.50±.30^{c}	6.20±.32^{b}
T2	12.50±1.02^{c} (+3.64)	15.30±0.52^{ab} (-7.83)	12.63±0.64^{b} (-4.31)	7.43±0.24^{b} (-12.58)	5.43±0.24^{b} (-12.41)
T3	9.60±0.05^{ab} (-20.39)	17.93±1.29^{b} (+8.01)	11.40±0.55^{ab} (-13.63)	7.50±0.26^{b} (-11.70)	5.33±0.33^{b} (-14.03)
T4	8.70±0.94^{a} (-27.86)	14.63±0.27^{a} (-11.63)	11.23±0.69^{ab} (-14.92)	6.76±0.18^{ab} (-20.47)	5.53±0.37^{b} (-10.80)
T5	7.53±0.74^{a} (-37.56)	16.66±0.33^{ab} (+0.36)	9.63±0.58^{a} (-27.04)	6.36±0.37^{a} (-25.17)	0.00±0.00^{a} (-100)

Means value ± standard error in a column with different superscripts significantly different at $p<0.05$
Values in the parenthesis indicates the inhibitory (-) or stimulatory (+) effects in comparison to control (T1)

DISCUSSION

Allelopathy is a documented phenomenon where plants interact with each other in a way that can either harm or benefit them. The bioassay investigation demonstrated that the leaf leachate of *Mangifera indica* caused a significant decrease in germination, shoot length, and root length compared to the control. This effect was observed on almost all the tested crops and was found to be dependent on the concentration of the leachate. This supports the findings of Liu *et al.* (2011) that high concentrations of allelopathic substances hindered crop growth. This can be attributed to allelochemicals in the leaf leachate of *Mangifera indica*, which inhibit the production of growth hormones and consequently hinder cell division (Al-Wakeel *et al*., 2007). Allelochemicals reduce root and shoot length by impairing metabolic activities (Saeid *et al*., 2010).

However, the germination percentage and the growth of both shoot and root in maize treated with the highest concentration of *Mangifera indica* leaf leachate were not hindered but instead experienced a little enhancement when compared to the other crops that were examined. Desalegn (2014) also observed a comparable outcome, reporting that *Lantana camara* stimulated allelopathy by releasing natural plant compounds known as allelochemicals. The germination percentage and early growth of the examined crops, particularly soybeans, beans, and okra, were affected by the allelopathic properties of *Mangifera indica* leaf leachate. The leachate hindered the germination and elongation of shoot and root at higher concentrations. Ghebrenhiwot *et al.* (2013) found that high concentrations of plant extracts can impede germination, whereas lower quantities can enhance germination and early growth of specific plant species. It is important to acknowledge that maize may have a tolerance to allelochemicals. This is because different plant species respond differently to allelochemical materials based on their genetic composition (Rice, 1984; Mokganya and Ligavha-Mbelengwa, 2022).

On the other hand, chilli pepper exhibited significant and strong inhibition on germination, shoot, and root elongation, indicating its high sensitivity to the allelochemicals present in *Mangifera indica*. As a result, chilli pepper cannot thrive in the allelopathic effect of *Mangifera indica*. The current results support the previous study conducted by Aman *et al.* (2023), which observed that the concentration of mango leaf extract significantly inhibited the germination and early growth of cereal and pulse crops. Ashafa *et al.* (2012) previously observed that the inhibitory effect of mango leaf extract on shoot and root growth is directly related to the concentration of the extract. The inhibitory effect of mango leaf extract on shoot and root growth was proportional to the extract's concentration, which was also reported earlier by Ashafa *et al.* (2012) for *C. occidentalis*. The investigations conducted by Sahoo *et al.* (2010) similarly observed comparable patterns of inhibitory action in mango leaf extracts.

CONCLUSION

The study validates the allelopathic capacity of *Mangifera indica*, as demonstrated by its inhibitory impact on the germination and growth of soya beans, beans, and okra. Among these, chilli pepper was found to be the most adversely affected. The results align with prior research that documented the existence of allelochemicals in mango leaves. The observed enhancement in maize growth at elevated concentrations indicates a reaction peculiar to this particular species, which justifies the need for additional research. Hence, considering the surrounding environmental circumstances, additional research is required to comprehend the combined impact of donor and receptor crops in a field. Gaining insight into these interactions can facilitate the creation of organic herbicides, hence decreasing dependence on artificial chemicals.

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