

Research Article

Allelopathic Effect of Tamarind (*Tamarindus indica* L.) Aqueous Extracts on Germination, Seedling Growth and Photosynthesis of Cowpea (*Vigna unguiculata* (L.) Walp) Varieties

Abba Abdulkadir^{1*}, Aminu Shehu Lawal², Bilkisu Abdulaziz³

¹Department of Ecology, Faculty of Science, Abubakar Tafawa Balewa University, Bauchi, Nigeria

²Department of Biological Sciences, Faculty of Science, Federal University Gusau, Zamfara State, Nigeria

³Department of Ecology, Faculty of Science, Abubakar Tafawa Balewa University, Bauchi, Nigeria

*Corresponding Author: 

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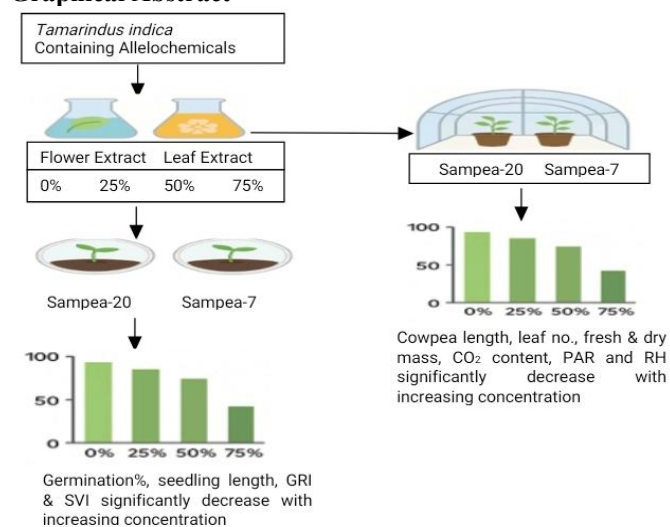


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Abstract— The increasing distribution of *Tamarindus indica* in northern Nigeria raises concern about its effects on food crops. However, its effect was not evaluated on *Vigna unguiculata*. This study therefore examined the effects of aqueous leaf and flower extracts of *T. indica* on seed germination, seedling growth and photosynthesis of two cowpea cultivars: Sampea-20 and Sampea-7, under laboratory and screen house conditions. Extract concentrations of 0, 25, 50, and 75% were prepared from 20g/L of Tamarind crude extract. Parameters such as germination percentage, germination rate index, seedling length, and seedling biomass, leaf number, Carbon (iv) Oxide (CO₂) content, Photosynthetic Active Radiation (PAR) and Relative Humidity (RH) were measured. The study revealed both flower and leaf extracts significantly ($P < 0.05$) reduced germination, seedling length and seedling vigor in all concentrations compared with the control. Seedling height, leaf number and biomass were also significantly reduced at 50% and 75% ($P < 0.05$). Photosynthetic activity was affected by both flower and leaf extracts through the significant reduction of CO₂ content at 75% concentrations. PAR and RH slightly decreased with increasing extracts concentrations. Moreover, the flower extracts delineated greater inhibitory effects than leaf extracts with Sampea-7 revealing higher tolerance compared to Sampea-20. The findings suggest allelochemicals from *T. indica* can inhibit cowpea establishment, growth and photosynthetic activity. Hence, planting cowpea at farmlands with *T. indica* abundance should be avoided.

Keywords— Allelopathy, *Tamarindus indica*, Cowpea, Germination, Seedling growth, Photosynthesis

Graphical Abstract-



Graphical Abstract Description

The graphical abstract summarizes the flow chart and the core findings of the research as follows.

- The research was conducted invitro in the Laboratory and Screen house comprising two cowpea varieties.
- Germination parameters of both varieties significantly reduced with increasing concentrations in petri dishes.
- Seedling growth and photosynthesis parameters observed in this study were also significantly reduced with increasing concentration for both cowpea varieties.
- *T. indica* Leaf and flower aqueous extracts affect sampea-20 and sampea-7 seedling establishment and physiological function.

1. Introduction

Tamarindus indica is an important leguminous species belonging to the family Fabaceae and thrives well under

tropical and subtropical conditions, it is also known for its ability to withstand prolonged dry seasons lasting up to five to six months [1]. It is rich in a wide range of secondary metabolites, including phenolic compounds, flavonoids, alkaloids, tannins, saponins, and organic acids [2]. These compounds are responsible for the plant's strong analgesic and anti-inflammatory properties, which explain its extensive use in traditional medicine and pharmacology [3]. Beyond its medicinal significance, these phytochemicals may also act as allelochemicals capable of influencing the germination and growth of neighbouring plants [4].

Allelopathy is a biological phenomenon in which one plant species releases bioactive compounds, known as allelochemicals, that influence the growth and development of neighbouring plants [5]. These allelochemicals, often secondary metabolites, are released into the environment through leaf litter decomposition, root exudation, volatilization, or leaching, where they interfere with vital physiological and biochemical processes of other plants [6]. Such interactions may suppress seed germination, inhibit enzyme activities, disrupt hormonal balance, and reduce photosynthetic efficiency [7]. In agricultural systems, allelopathy has become an important ecological factor affecting crop productivity and sustainability. It may be advantageous when used for natural weed suppression or detrimental when food crops are negatively influenced [8]. In addition with the increasing pressure on global food demand driven by population growth, the agricultural sector faces several constraints, including weeds, pests, diseases, abiotic stresses, allelopathic interference, and nutrient imbalances [9], [10]. Plants naturally produce and release allelochemicals through residues, exudates, and leachates from their leaves, stems, roots, fruits, and seeds, which may directly or indirectly affect the growth of surrounding vegetation. [11]. These substances often act during seed germination and seedling establishment, where plants are most vulnerable, although allelopathic interactions are generally harmful, in some cases they can be beneficial by regulating plant competition and maintaining ecological balance [12]. The toxic compounds released may inhibit root or shoot elongation, interfere with nutrient uptake, or disrupt beneficial symbiotic relationships, thereby limiting plant growth and productivity [13].

1.1 Objectives of the Study

This study aimed at evaluating the effect of Tamarind (*Tamarindus indica*) Aqueous Extracts on Germination, Seedling Growth and Photosynthesis of Cowpea (*Vigna unguiculata*) Varieties. The objectives of the study are to:

- i. determine the effects of different concentrations of *T. indica* leaf and flower aqueous extracts on seed germination percentage, germination rate, and seedling vigor of sampea-20 and sampea-7 cowpea varieties.
- ii. Assess the influence of the tamarind extracts on early seedling growth parameters, including seedling length, plant height, leaf number, and biomass

accumulation of sampea-20 and sampea-7 cowpea varieties

- iii. Evaluate the impact of *T. indica* extracts on photosynthetic activity of cowpea seedlings using CO₂ content, relative humidity, and photosynthetically active radiation of sampea-20 and sampea-7 cowpea varieties

1.2 Statement of the Problem

Tamarindus indica L. is a widely distributed leguminous tree in northern Nigeria, valued for its nutritional, medicinal, and economic uses. The species is rich in secondary metabolites such as phenolics, flavonoids, tannins, alkaloids, and saponins, many of which are known to function as allelochemicals capable of influencing neighbouring plant species [14]. Previous studies have shown that tamarind residues and extracts can suppress seed germination and early growth of crops and weeds, suggesting strong allelopathic potential [15], [16], [17]. However, most of these studies have focused on weed suppression or general phytotoxicity, with limited attention given to staple food crops cultivated under tamarind dominated agroecosystems.

In northern Nigeria, *T. indica* trees are commonly retained on farmlands for shade, fruit production, and soil conservation, leading to frequent accumulation of leaf litter and floral residues on cultivated soils. These residues may release allelochemicals through leaching and decomposition, potentially interfering with seed germination, seedling growth, and physiological processes such as photosynthesis, particularly during the highly sensitive early stages of crop establishment could be altered. Despite this ecological reality, there is a clear lack of empirical data on the allelopathic effects of *T. indica* on cowpea, especially regarding concentration dependent responses, varietal tolerance, and physiological mechanisms such as photosynthetic disruption.

1.3 Significance of the Study

Cowpea is a major staple legume in sub-Saharan Africa and plays a vital role in food security, income generation, and soil fertility improvement, particularly in northern Nigeria. However, its productivity is often constrained by poor seed germination, weak seedling establishment, and physiological stress during early growth stages. While considerable attention has been given to pests, diseases, and nutrient limitations, allelopathic interference from dominant tree species remains largely overlooked as a hidden but potentially serious constraint to cowpea production.

This study is justified as it provides empirical, crop-specific evidence on the allelopathic influence of *T. indica* on cowpea, integrates physiological indicators such as photosynthetic activity, and compares varietal tolerance under controlled conditions. The findings are expected to inform farmers, agronomists, and land-use planners on appropriate crop placement, tree-crop interactions, and residue management practices. Ultimately, the study contributes to sustainable agroecosystem management and supports food security initiatives in regions where *T. indica* and cowpea coexist.

2. Related Work

Allelochemicals disrupt hormonal balance, nutrient uptake, membrane stability, and photosynthesis in receptor plants, ultimately leading to reduced germination and growth [18], [19]. Laboratory bioassays and field trials revealed allelochemicals released by Numerous plant species, including; *Chromolaena odorata*, *Euphorbia heterophylla*, *Tridax procumbens*, sorghum, ginger, sunflower, barley, *Cistus*, *Lantana*, *Terminalia*, *Tithonia*, *Khaya*, and *Eucalyptus* etc. have demonstrated significant allelopathic inhibitory effect on seed germination and early seedling development of economically important crops such as maize, wheat, cowpea, Capsicum, and soybean [20], [21], [22], [23], [24]. These effects are often concentration dependent and particularly pronounced during germination and early growth stages, which are highly sensitive to allelochemical interference.

Tamarind secondary metabolites play important ecological roles, particularly in plant-plant and plant-soil interactions. Phenolic compounds, which are abundant in tamarind tissues, have been shown to influence soil biochemical processes, including nitrogen transformation, by altering microbial activity and enzyme function, thereby indirectly affecting plant growth and nutrient availability [25].

3. Experimental Method/Procedure/Design

Study Area

The study was conducted in Ecology Laboratory and Screen house of Biological Sciences Department, Abubakar Tafawa Balewa University (ATBU), Bauchi, Nigeria at Latitude 10.329°N and Longitude 9.845°E.

Sample Collection and Preparation

Tamarindus indica trees leaves and flowers were collected from Bauchi State College of Agriculture School Farmland Area. Leaves and freshly opened flowers were collected in the morning washed thoroughly with tap water and air-dried at room temperature until constant weight, and ground to fine powder using mortar and pestle. Powdered leaf and flower materials were separately weighed. Crude extract of 100% (w/v) was prepared by soaking 20 g powder in 1 L distilled water for 24 h at room temperature with occasional stirring. The mixture was filtered through muslin cloth and Whatman No.1 filter paper. 75%, 50%, 25% and 5% (v/v) were prepared from the crude extract, while distilled water served as a control. The prepared extracts were stored at 4°C prior bioassay.

Cowpea seed varieties (sampea -20 and sampea -7) were obtained from Bauchi State Agricultural Development Programme (BSADP). The seeds were surface sterilized using 1% sodium hypochlorite for 5 minutes, rinsed three times with sterile distilled water, and air-dried on sterile filter paper and subsequently followed the bioassay.

Experimental Design and Germination Bioassay

The experiment was conducted using a Completely Randomized Block Design (CRBD) to evaluate the allelopathic effects of *Tamarindus indica* aqueous extracts on cowpea (*Vigna unguiculata*). Two cowpea varieties (Sampea-20 and Sampea-7) were treated with aqueous extracts prepared from tamarind flowers and leaves at four concentrations (0, 25, 50, and 75%). Each treatment was replicated three times. For germination tests, each replicate consisted of one Petri dish containing ten seeds, while in the screen house experiment each replicate comprised one pot. All experimental units were randomly arranged to minimize bias. Each dish received 10 mL of the respective extract or distilled water for control every 48 h to maintain moisture [26]. Dishes were incubated in a growth chamber at $25 \pm 1^\circ\text{C}$ with 12 h photoperiod. Germination was recorded daily for up to 10 days. A seed was considered germinated when there is radicle emergence with not less than 2mm length [27].

Screen House Experiment

Sterilized cowpea seeds were sown in pots containing sandy-loam soil. Extracts were incorporated into soil at equivalent concentrations with the germination bioassay. Seedling growth parameters measured included plant height, number of leaves, shoot and root fresh and dry weights.

Photosynthetic Activity

CO₂ content, relative humidity (RH), and Photosynthetically Active Radiation (PAR) were assessed from seedling leaves using a digitalized photosynthetic meter.

Data collection

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated} \times 100}{\text{Number of the total seeds}} \quad (1)$$

$$\text{Germination Rate Index (GRI)} = \sum (G_t / D_t) \quad (2)$$

Where, G_t is the number of seeds that germinated on a specific day, D_t is the day number on which the germination is counted.

Radicle and shoot length were measured from seedlings at the tenth day of the experiment.

Fresh and dry seedling weight (g): 10 seedlings per replicate were weighed fresh and then oven-dried at 70°C to constant weight.

Seedling Vigour Index (SVI)

$$= \text{Germination(\%)} \times \text{Mean Seedling Length} \quad (3)$$

Data analysis

Analysis of Variance (ANOVA) was performed for germination parameters, growth parameters and photosynthetic effect parameters. Significant effects ($p < 0.05$) were further separated using Turkey's test. SPSS version 23 statistical tool was used in this study. RH, PAR and CO_2 were analyzed in EXCEL and presented as mean and standard deviation in straight line graphs with error bars.

4. Results and Discussion

Results

Effect *T. indica* Flower and Leaves Aqueous Extract on Germination of *V. unguiculata* (Sampea 20) Plant: Table 1 revealed germination of *Vigna unguiculata* (Sampea 20) was significantly ($p < 0.05$) inhibited by increasing concentrations of *Tamarindus indica* flower and leaf aqueous extracts. Both extracts caused a dose-dependent decline in germination percentage, germination rate index, and seedling vigor index. The control showed 100% germination, GRI (17.9) and SVI

(922.5) while the 75% concentration produced the lowest values across all parameters i.e. Germination percentage (12.5%), GRI (1.4) and SVI (22.0) for flower extract effect, while for the leaf extract followed similar inhibitory pattern. Flower extract exhibited slightly stronger inhibitory effects than the leaf extract.

Effect *T. indica* Flower and Leaves Aqueous Extract on Germination of *V. unguiculata* (Sampea 7) Plant: Germination and seedling vigor of *Vigna unguiculata* (Sampea 7) were significantly ($p < 0.05$) reduced by increasing concentrations of *Tamarindus indica* flower and leaf extracts (Table 2). Similar trend was observed as in sampea- 20 (see table 1), both extracts resulted to a progressive decrease in germination percentage, germination rate index, and vigor index compared to the control. The control maintained 100% germination, highest GRI and vigor index, while the 75% concentration recorded the lowest values. Flower extracts exhibited stronger inhibitory effects than leaf extracts.

Table 1: Effect of *T. indica* Flower and Leaves Aqueous Extract on Germination of *V. unguiculata* (Sampea 20) Plant

Tamarind Parts	Conc.	Germination %	Germination Rate Index (GRI)	Seedling Vigor index (SVI)
Flower	Control	100.0±0.00a	17.9±0.55a	922.5±10.31a
	5%	72.8±2.50b	12.7±0.53b	326.5±13.93b
	25%	60.0±4.08b	9.8±0.95c	197.8±14.29c
	50%	22.5±4.8c	2.5±0.65d	52.1±12.39d
	75%	12.5±2.5c	1.4±0.33d	22.0±4.67d
P- Value	0.000	0.000	0.000	0.000
Leaves	Control	100.0±0.00a	15.3±0.29a	1005.0±13.23a
	5%	72.5±2.50b	11.9±1.09ab	402.8±7.98b
	25%	60.0±0.00bc	8.5±0.35bc	202.5±2.87c
	50%	42.5±4.79c	6.2±1.16cd	87.5±8.10d
	75%	20.0±10.00d	2.5±1.46d	36.0±18.00d
P- Value	0.000	0.000	0.000	0.000

Note: Mean ± SE values having different alphabet in each column are significantly different ($P < 0.05$) and similar alphabets in each column show no significant difference ($P > 0.05$) and Turkey test was used to separate the means.

Table 2: Effect *T. indica* Flower and Leaves Aqueous Extract on Germination of *V. unguiculata* (Sampea-7) Plant

<i>T. indica</i> Parts	Concentrations	Germ %	GRI	Vigor index
Flower	Control	100.0±0.00a	18.1±0.48a	1097.5±17.02a
	5%	95.0±2.89ab	17.2±0.64a	598.5±44.37b
	25%	82.5±2.50ab	13.2±0.57b	481.0±21.32c
	50%	77.5±2.50b	10.2±0.93b	153.0±6.61d
	75%	55.0±5.66c	5.1±0.94c	67.8±11.75d
P- Value		0.000	0.000	0.000
Leaves	Control	100.0±0.00a	18.1±0.48a	1175.0±16.58a
	5%	87.5±2.50b	16.0±0.77ab	566.0±10.65b
	25%	87.5±2.50b	15.0±0.52bc	298.0±14.16c
	50%	80.0±4.08b	14.0±0.59c	204.6±15.40d
	75%	62.5±2.50c	9.8±0.33d	58.0±4.69e
P- Value		0.000	0.000	0.000

Mean ± SE values having different alphabet in each column are significantly different ($P < 0.05$) and similar alphabets in each column show no significant difference and Turkey test was used to separate the means ($P > 0.05$).

Effect of Aqueous leaf and flower extract on seedling length of *V. unguiculata* (Sampea-20 and Sampea-7): Figure 2 illustrates the effect of *Tamarindus indica* flower and leaf aqueous extracts on the mean seedling length of

Vigna unguiculata (Sampea 20 and Sampea 7) at different concentrations. Seedling length decreased progressively with increasing extract concentration for both varieties and plant parts. The control treatments exhibited the highest mean

seedling length (above 10 cm), while the 75% concentrations produced the shortest seedlings (around 2 cm or less). This shows a strong concentration-dependent inhibition of seedling growth. Moreover, flower extracts generally delineated with greater decrease of seedling length than leaf extracts, and Sampea 7 appeared slightly more tolerant than Sampea 20. Generally, there is significant decrease in mean seedling length of *V. unguiculata* (Sampea 20 and Sampea 7) treated with flower and leaf extract compared with the control.

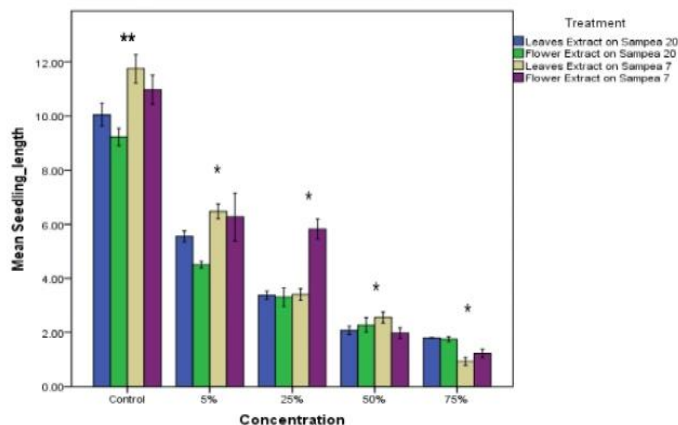


Figure 1: Effect of Aqueous leaf and flower extract on plumule and radicle length of *V. unguiculata* (Sampea-20 and Sampea-7)

Note: ** Showed significant variation in mean seedling length of the control with that of the treatments * at $p < 0.05$

Effect of *T. indica* Flower and Leaves Extracts on Seedling growth of *V. unguiculata* (Sampea 7) Plant: Table 3 showed the aqueous extracts of *Tamarindus indica* flowers and leaves significantly inhibited the seedling growth of *Vigna unguiculata* in a concentration-dependent manner ($P < 0.05$). Control plants showed the highest number of leaves, plant height, and biomass values, while these parameters reduced progressively with increasing extract concentration. At 50% and 75%, both flower and leaf extracts caused severe growth decrease, with almost complete inhibition at 75%. Lower concentrations (5–25%) produced mild to moderate effects, with leaves showing slightly less toxicity than flowers. The results suggest strong allelopathic effects of *T. indica*, especially at higher concentrations

Effect of *T. indica* Flower and Leaves Extracts on Seedling growth of *V. unguiculata* (Sampea 20) Plant: Table 4 showed that aqueous extracts of *Tamarindus indica* flower and leaf significantly reduced the seedling growth of *Vigna unguiculata* (Sampea 20) in a concentration-dependent manner ($P < 0.05$). Control plants have the highest leaf number (4.0 ± 0.00), height (12.2 ± 0.16), and biomass, while growth progressively declined with increasing extract concentration. At 50% and 75%, both extracts completely inhibited growth, indicating strong allelopathic activity. Moderate concentrations (5–25%) caused partial suppression, though less severe in leaf extracts than in flower extracts. *T. indica* extracts, especially flowers, exhibited pronounced inhibitory effects.

Table 3: Effect of *T. indica* Flower and Leaves Extracts on Seedling growth of *V. unguiculata* (Sampea-7) Plant

Tamarind parts	Concentration	No. of Leaves	Plant height	Shoot Fresh Weight	Root fresh Weight	Shoot dry weight	Root dry weight
Flower	Control	$4.0 \pm 0.00a$	$12.2 \pm 0.16a$	$2.3 \pm 0.38a$	$1.3 \pm 0.21a$	$0.3 \pm 0.03a$	$0.1 \pm 0.02a$
	5%	$3.0 \pm 0.875a$	$7.3 \pm 2.44ab$	$1.3 \pm 0.48ab$	$0.7 \pm 0.29ab$	$0.2 \pm 0.06ab$	$0.1 \pm 0.03ab$
	25%	$2.0 \pm 0.89ab$	$3.6 \pm 1.27bc$	$1.2 \pm 0.39ab$	$0.7 \pm 0.25ab$	$0.2 \pm 0.06ab$	$0.1 \pm 0.03ab$
	50%	$0.0 \pm 0.00b$	$0.0 \pm 0.00c$	$0.0 \pm 0.00b$	$0.0 \pm 0.00b$	$0.0 \pm 0.00b$	$0.1 \pm 0.00b$
	75%	$0.0 \pm 0.00b$	$0.0 \pm 0.00c$	$0.0 \pm 0.00b$	$0.0 \pm 0.00b$	$0.0 \pm 0.00b$	$0.1 \pm 0.00b$
P-Value		0.001	0.000	0.001	0.001	0.000	0.001
Leaves	Control	$4.0 \pm 0.00a$	$11.8 \pm 1.03a$	$2.1 \pm 0.33a$	$1.19 \pm 0.23a$	$0.3 \pm 0.04a$	$0.2 \pm 0.03a$
	5%	$3.0 \pm 0.13a$	$7.8 \pm 0.89ab$	$0.9 \pm 0.26ab$	$0.6 \pm 0.16ab$	$0.1 \pm 0.04b$	$0.1 \pm 0.02ab$
	25%	$3.0 \pm 0.88a$	$5.8 \pm 1.95abc$	$1.5 \pm 0.54ab$	$0.8 \pm 0.31ab$	$0.2 \pm 0.07ab$	$0.1 \pm 0.03ab$
	50%	$1.0 \pm 0.85ab$	$3.3 \pm 1.92bc$	$0.6 \pm 0.38b$	$0.3 \pm 0.23ab$	$0.1 \pm 0.06b$	$0.0 \pm 0.03b$
	75%	$0.0 \pm 0.00b$	$0.0 \pm 0.00c$	$0.0 \pm 0.00b$	$0.0 \pm 0.00b$	$0.0 \pm 0.00b$	$0.0 \pm 0.00b$
P- Value		0.001	0.000	0.001	0.001	0.000	0.001

Mean $\pm$ SE values having different alphabet in each column are significantly different ($P < 0.05$) and same alphabets in each column show no significant difference ($P > 0.05$) and Turkey test was used to separate the means.

Table 4: Effect of *T. indica* Flower and Leaf Aqueous Extract on Seedling Growth of *V. unguiculata* (Sampea-20)

Tamarind Parts	Concentration	No. of Leaves	Plant height	Shoot Fresh Weight	Root fresh Weight	Shoot dry weight	Root dry weight
Flower	Control	$4.0 \pm 0.00a$	$12.8 \pm 1.17a$	$2.2 \pm 0.37a$	$1.3 \pm 0.20a$	$0.3 \pm 0.04a$	$0.1 \pm 0.021a$
	5%	$4.0 \pm 0.00a$	$9.9 \pm 0.41a$	$1.8 \pm 0.35ab$	$1.0 \pm 0.13ab$	$0.3 \pm 0.01ab$	$0.1 \pm 0.09a$
	25%	$3.0 \pm 0.95a$	$4.9 \pm 1.9b$	$1.1 \pm 0.77bc$	$0.6 \pm 0.21bc$	$0.1 \pm 0.57bc$	$0.1 \pm 0.02ab$
	50%	$1.0 \pm 0.50b$	$1.3 \pm 1.3bc$	$0.3 \pm 0.66cd$	$0.2 \pm 0.21c$	$0.0 \pm 0.03c$	$0.0 \pm 0.03b$
	75%	$0.0 \pm 0.00b$	$0.0 \pm 0.00c$	$0.0 \pm 0.00d$	$0.0 \pm 0.00c$	$0.0 \pm 0.00c$	$0.0 \pm 0.00b$
P- Value		0.000	0.000	0.000	0.002	0.001	0.003

Leaves	Control	4.0±0.00a	11.5±0.60a	2.2±0.37a	1.3±0.2a	0.3±0.04a	0.1±0.21a
	5%	3.0±1.00a	6.7±2.25ab	1.8±0.35ab	1.0±0.13ab	0.3±0.01a	0.1±0.09ab
	25%	3.8±0.25a	7.5±0.20a	1.1±0.77a	0.6±0.21a	0.1±0.57a	0.1±0.02a
	50%	0.5±0.50b	1.3±1.31b	0.3±0.66b	0.2±0.21b	0.0±0.03b	0.0±0.03b
	75%	0.3±0.25b	5.7±1.31b	0.0±0.00b	0.0±0.00b	0.0±0.00b	0.0±0.00b
P- Value		0.000	0.000	0.000	0.002	0.001	0.003

Mean ± SE values having different alphabet in each column are significantly different ($P < 0.05$) and same alphabets in each column show no significant difference ($P > 0.05$) and Turkey test was used to separate the means.

Effect of *T. indica* aqueous flower and leaf aqueous extracts on Photosynthetic Activity of *V. unguiculata* (Sampea-20) cultivars: Figure 2 & 3 displayed the significant decrease in leaf carbon (iv) oxide content (CO_2) at higher concentrations of 75% for leaf extract while 50% and 75% for flower extract compared with the control. Meanwhile, Relative humidity and Photosynthetic Active Radiation were significantly reduced as well, on Sampea-20 treated with leaf extract at 75% concentration. while relative humidity and photosynthetic active radiation showed no significant variation with the control in sampea-20 photosynthetic activity treated with flower extract.

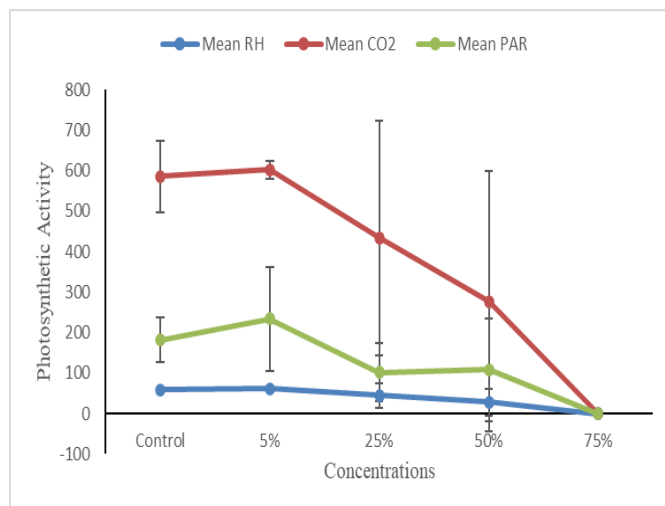


Figure 2. Effect of *T. indica* leaf Aqueous Extract on Photosynthetic Activity of *V. unguiculata* (Sampea-20) Plant

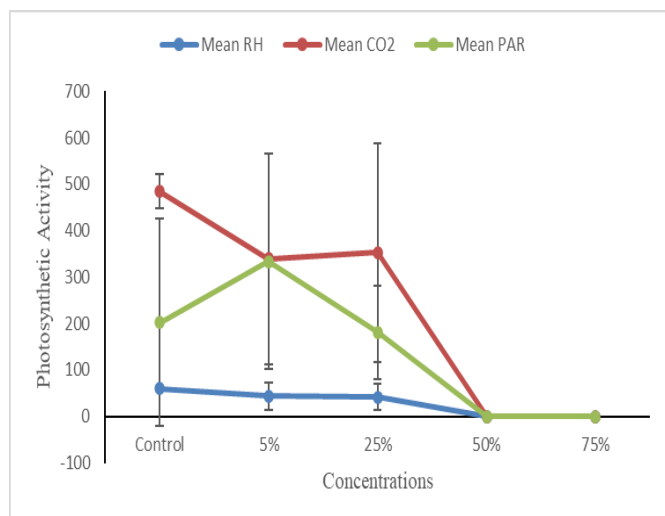


Figure 3. Effect of *T. indica* Flower Aqueous Extract on Photosynthetic Activity of *V. unguiculata* (Sampea 20) Plant.

Effect of *T. indica* aqueous flower and leaf extracts on Photosynthetic Activity of *V. unguiculata* (Sampea-7) cultivars: Similar trend was observed in Figure 4 & 5, showing significant decrease in leaf carbon (iv) content (CO_2) at 50% and 75% concentrations compared with the control while relative humidity and photosynthetic active radiation showed no significant variation with the control in sampea-20 photosynthetic activity.

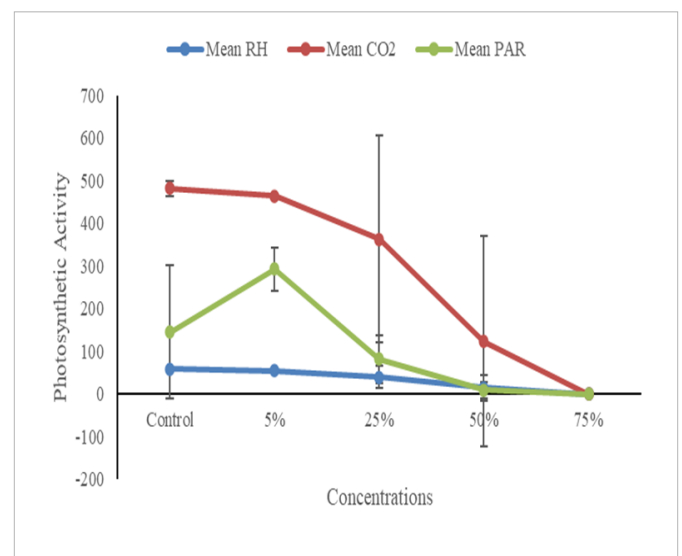


Figure 4. Effect of *T. indica* Flower Aqueous Extract on Photosynthetic Activity of *V. unguiculata* (Sampea-7) Plant.

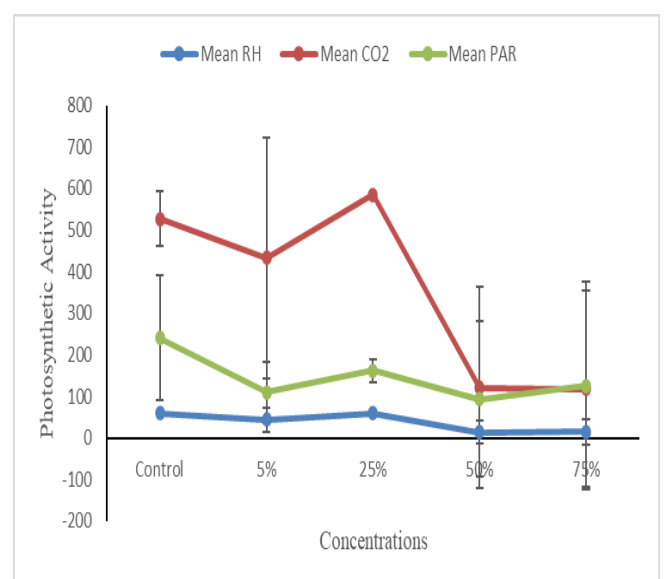


Figure 5. Effect of *T. indica* Leaf Aqueous Extract on Photosynthetic Activity of *V. unguiculata* (Sampea-7) Plant.

Discussion

T. indica flower and leaf aqueous extract indicate dose-dependent effect, by impeding seed germination and seedling length at highest concentration the most. The stronger effect of flower extract compared to leaf extract may indicate a higher concentration or distinct profile of allelochemicals in the flowers. High amounts of flavonoids, alkaloids, tannins, saponins, and steroids were found in *T. indica* extracts, especially in the butanol and ethyl acetate fractions [28]. Aqueous extracts of sunflower, barley, and *Lantana camara*, were found to suppress seedling development and vigor of wheat and chili pepper [29], [30]. Similarly, *T. indica* allelochemicals has potency in inhibiting germination and seedling length on both weeds and edible crops [31]. Moreover, methanolic and aqueous extracts of *Tithonia diversifolia* exhibited concentration-dependent phytotoxic effects on the germination and seedling growth of *Vigna unguiculata*. Likewise, aqueous extracts derived from sesame plant parts significantly reduced germination as well as radicle and plumule lengths in maize and sorghum, indicating strong allelopathic inhibition [32], [33].

Reduction in morphological growth metrics such as stem length, shoot and root mass, etc. could be due to suppressed nutrient uptake, disruption of photosynthetic apparatus, cell division impairment or hormonal imbalances induced by the extracts. The greater inhibition by flower extracts further emphasizes the potency of floral allelochemicals inhibitory effect. *Artemisia argyi* allelopathy, also breaks hormonal balance, disrupt the process of normal cell division, elongation, and differentiation, and inhibits the uptake of nutrients in the roots of receptor plants [34].

The reduction in CO₂ assimilation in both cultivars suggests that *T. indica* extracts impaired with photosynthetic carbon fixation, possibly via stomatal closure, enzyme inhibition (e.g., Rubisco) by reducing water uptake, or damage to chloroplast machinery. Water stress in plant leads to disruption in Rubisco, stomatal closure and generally reduces photosynthetic activity [35].

The consistency of inhibitory patterns across the two cultivars suggests that the allelopathic potential of *T. indica* extracts is broadly effective against *V. unguiculata*. The slightly greater tolerance of Sampea-7 than Sampea-20 may reflect varietal differences in sensitivity. *V. unguiculata* cultivars respond differently to allelopathic effect of *Khaya senegalensis* and *Eucalyptus camaldulensis* [36].

5. Conclusion and Future Scope

The present study provides clear empirical evidence that *Tamarindus indica* possesses strong allelopathic potential capable of significantly impairing germination, early seedling growth, and photosynthetic performance of cowpea (*Vigna unguiculata*). Both laboratory and screen house experiments consistently demonstrated that aqueous extracts derived from tamarind leaves and flowers posed concentration dependent inhibitory effects on the two tested cowpea cultivars,

Sampea-20 and Sampea-7. As extract concentration increased, key germination parameters such as germination percentage, germination rate index, and seedling vigor index declined markedly, indicating that the early stages of cowpea establishment are particularly vulnerable to allelochemical interference from *T. indica*.

Beyond germination, seedling growth attributes including plant height, leaf number, fresh and dry biomass were significantly suppressed, especially at higher concentrations (50% and 75%). Nearly Complete inhibition at these levels revealed the potency of tamarind allelochemicals in disrupting physiological processes essential for normal plant development. The observed reduction in photosynthetic activity, particularly the decline in leaf CO₂ assimilation, further confirms the inhibitory effects of *T. indica* are not limited to early growth stages but extend to fundamental metabolic functions such as carbon fixation.

Comparatively, flower extracts consistently exhibited stronger inhibitory effects than leaf extracts across most measured parameters, suggesting a higher concentration or a more active profile of allelochemicals in floral tissues. This distinction is ecologically important, as flowers and floral residues may represent a critical yet often overlooked source of allelopathic influence in agroecosystems. Additionally, varietal differences were observed, with Sampea-7 displaying relatively greater tolerance to tamarind extracts than Sampea-20. Such variability highlights the role of genetic factors in modulating crop responses to allelopathic stress and points to the possibility of selecting or breeding more tolerant cowpea varieties for cultivation in affected areas.

This study strongly suggests that the increasing abundance of *T. indica* in northern Nigerian farmlands may pose a tangible risk to cowpea production, particularly when cowpea is cultivated near tamarind trees or in soils receiving tamarind litter. From agronomic perspective, avoiding cowpea cultivation under or near dense *T. indica* stands, or managing tamarind residues carefully, may be necessary to minimize yield losses and ensure sustainable crop production.

Future Scope

Despite this study evaluates the allelopathic effects of *T. indica* on cowpea, several avenues remain open for further investigation. Future research should focus on the qualitative and quantitative identification of specific allelochemicals present in tamarind leaves and flowers using advanced analytical techniques such as High-Performance Liquid Chromatography (HPLC). Understanding which compounds are primarily responsible for the observed phytotoxicity will provide mechanistic insight and allow better prediction and conclusion.

Long-term field studies are also required to validate laboratory and screen house findings under natural soil, climatic, and microbial conditions, where allelopathic effects may be moderated or amplified. Additionally, investigating soil-mediated effects, including interactions between

tamarind allelochemicals and soil microorganisms, nutrient dynamics, and rhizosphere processes, would enhance ecological relevance. Screening a wider range of cowpea genotypes and other staple crops for tolerance could support breeding programs aimed at improving resilience to allelopathic stress. Finally, given the strong inhibitory effects observed, controlled exploration of *T. indica* extracts as potential natural bioherbicides may offer environmentally friendly alternatives for weed management, provided crop safety can be ensured.

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Conflict of Interest

The Authors declare no conflict of interest.

Authors' Contributions

Abba Abdulkadir- Conceptualization and Data curation, Aminu Shehu Lawal- Wrote the Original draft of Manuscript and Analysis, Bilkisu Abdulaziz- Financial Support and Proof-reading.

Data Availability

All Data used in this study could be available to anybody on request via the corresponding author's email

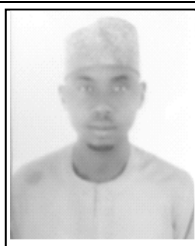
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AUTHORS PROFILE

Abba Abdulkadir is currently an MSc. student in the department of Applied Ecology at Abubakar Tafawa Balewa University (ATBU), Bauchi. He has a strong interest in research and is a member of academic staff at the Federal Polytechnic, Bauchi. His area of professional interest is environmental ecology.



Aminu Shehu Lawal earned his BSc. Biology from Ahmadu Bello University, in 2015. MSc. Applied Ecology from Abubakar Tafawa Balewa University (ATBU), Bauchi in 2023. He is currently pursuing his PhD. in Applied Ecology at the later institution, at the same time an academic staff of Federal University Gusau. He published many scholarly articles in reputable journals and a member of Ecological Society of Nigeria (ECOSON).



Bilkisu Abdulaziz obtained her BSc. in Botany at University of Maiduguri in the year 2014 and MSc. in Applied Ecology at Abubakar Tafawa Balewa University (ATBU), Bauchi in 2024. She has an interest in pursuing her PhD. in Applied Ecology.

