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Does Soil under Natural *Tithonia diversifolia* Vegetation Inhibit Seed Germination of Weed Species?

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ABSTRACT

Pot experiment was carried out in the screen house, Ladoke Akintola University Technology Ogbomosho, Nigeria to determine the possible impact of *Tithonia diversifolia* on the growth of thirteen selected weed species weeds growing in its surroundings. The study consisted of two treatments (*Tithonia diversifolia* infested and Non-*Tithonia diversifolia* infested soils) and from the two media, the growth of *A. hispidium*, *B. pilosa E. heterophylla*, *P. maximum* and *P. polystachion* was significantly affected in soil infested by *T. diversifolia*. The number of weed seedling emergence afore mentioned was significantly lower than what was obtained in soil not infested with *T. diversifolia* and this accounted for about 38% of the tested weed species. Germination of four of these weeds species (23%) (*A. spinosus*, *C. viscosa*, *T. procumbens* and *D. gayana*) was enhanced by the presence of *T. diversifolia*. The study further revealed that weed counts in *T. diversifolia* infested soil is significantly lower than the ones in soil without *T. diversifolia* infestation. Likewise, the vegetative growth of some species (*A. spinosus*, *C. viscosa*, *T. procumbens* and *D. gayana*) was improved in this soil. This shows that *T. diversifolia* infested soil contains allelochemicals that performed both stimulatory and inhibitory functions.

Keywords: *Tithonia diversifolia*; Allelopathy; Allelochemical; Asteraceae

1. Introduction

Weed infestation is ranked the greatest problem in agricultural systems [1], causing crop yield losses. Attention towards reducing dependency on herbicide has heightened interest in weed management strategies that combine more efficient use of herbicides with increased use of biologically based weed management methods [2].

Chemicals that are released from plants which impose negative influence on other plants are called allelochemicals or allelochemics [3]. Allelochemicals that are toxic may inhibit shoot/root growth, nutrient uptake, or may attack a naturally occurring symbiotic relationship thereby destroying the plant's usable source of a nutrient [3]. The consequent effects may be inhibited or retarded germination rate, reduced root or radicle and shoot or coleoptile extension, lack of root hairs, swelling or necrosis of root tips, curling of the root axis, increased number of seminal roots, discolouration, reduced dry weight accumulation and lowered reproductive capacity [4]. Plants in the Asteraceae family like *T. diversifolia* and *T. rotundifolia* have been reported to exhibit allelopathic traits [5,6].

Different plant parts, including flowers, leaves, leaf litter and leaf mulch, stems, bark, roots, soil and soil leachates and their derived compounds, can have allelopathic activity that varies over growing seasons [7,8]. When susceptible plants are exposed to allelochemicals, germination, growth and development may be affected. The most frequently reported gross morphological effects on plants are inhibited or retarded seed germination, deprivative effects on coleoptile elongation and on radicle, shoot and root development.

Allelopathic inhibition is complex and can involve the interaction of different classes of chemicals like phenolic compounds, flavonoids, terpenoids, alkaloids, steroids, carbohydrates, and amino acids, with mixtures of different compounds sometimes having a greater allelopathic effect than individual compounds alone [9]. Furthermore, physiological and environmental stresses, pests and diseases, solar radiation, herbicides and less than optimal nutrient, moisture, and temperature levels can also affect allelopathic weed suppression [8].

The current trend in agricultural practices which discourages the use of inorganic external input in crop and animal production makes research in allelopathy important. This is because the use of inorganic input is contributory to solve many of the problems confronting adequate food production which is void of many synthethic pesticides (herbicides inclusive). Also, in organic cropping systems where synthetic herbicides are not used, crop cultivars with enhanced allelopathic activity could be part of the weed management strategy. Weed control mediated by allelopathy—either as natural herbicides or through the release of allelopathic compounds from a living crop cultivar or from plant residues is often assumed to be advantageous for the environment compared to synthetic herbicides. In view of the fact that allelochemicals are derived from natural sources, several authors were of the opinion that these allelopathic compounds will be biodegradable and less polluting to the environment than conventional herbicides [10-12].

Many crop cultivars show strong allelopathic properties, of which rice (*Oryza sativa*) has been most studied. Beet (*Beta vulgaris* L.), lupin (*Lupinus lutens* L.), maize (*Zea mays* L.), wheat (*Triticum aestivum* L.), oats (*Avena sativa* L.), barley (*Hordeum vulgare* L.) and *Cucumis sativus* are other crops which have been studied that show allelopathic effect on other crops [7,13-15].

Reference [16] examined the toxic effect of four legumes and reported that the aqueous leachates (1%) of all the four legumes exhibited strong phytotoxic effect on the radical growth of barnyard grass (*Echinochloa crusgalli* L. P. Beauv.), alegría and amaranth (*Amaranthus hypochondriacus* L.). Similarly, the allelopathic potential of *Ipomoea* was described by [17,18] identified Tricolorin A as the major phyto-growth inhibitor from the resin glycoside mixture of the plants.

According to references [19] isothiocyanates contained in *Brassica spp* were strong suppressants of germination on some tested weed species Spiny sow thistle (*Sonchus asper* L. Hill), Scentless mayweed (*Matricaria inodora* L.), Smooth pigweed (*Amaranthus hybridus* L.), Barnyard grass (*Echinochloa crusgalli* L. Beauv.), Black grass (*Alopecurus myosuroides* Huds.) and wheat crop (*Triticum aestivum* L.). Reference [20] studied the allelopathic effect of black mustard (*Brassica nigra* L.) on germination and seedling growth of wild oat (*Avena fatua* L.); these authors found that germination and radicle length were affected by extracting solutions and the inhibitory effect on germination increased with increasing concentration of extract solution of the fresh plant parts.

Congress grass (*Parthenium hysterophorus* L.) was found to show allelopathic effect due to the presence of parthenin, a sesquiterpene lactone of pseudoguanolide nature in various parts of the plant [21-23]. Parthenin is known to have specific inhibitory effects on root and shoot growth of *Crotalaria mucronata* L., *Cassia tora* L., *Oscimum basilicum* L., *Oscimum americanum* L. and barley (*Hordeum vulgare* L.) [24,25]. Various phenolic compounds identified in *Parthenium* (caffeic, vanillic, ferulic, chlorogenic and anisic acid) [21,26,27] may be responsible for growth reduction of test crops in amended soils.

Reference [28] investigated the allelopathic effects of *Croton bonplandianum* weed on seed germination and seedling growth of crop plants (*Triticum aestivum* L., *Brassica oleracea* var. botrytis L. and *Brassica rapa* L.) and weed plants (*Melilotus alba* Medik, *Vicia sativa* L. and *Medicago hispida* Gaertn). Leaf extract was found to be the most allelopathic and growth inhibition effect was found to increase with increasing concentrations of different aqueous extracts.

Russian knapweed (*Acroptilon repens* L.) is a widely distributed and problematic weed of the Western United State. [29,30] found that the roots of *A. repens* inhibited the root growth of many plants including some weed species such as *Lactuca sativa*, *Medicago sativa*, *Echinochloa crusgalli* and *Panicum miliaceum* by 30% at concentrations comparable to those found in the soil surrounding of *A. repens* plants. Moreover, the germination of *Agropyron smithii* and *Bromus marginatus* was inhibited by aqueous leaf extracts of *A. repens* at high level concentrations, however, according to [31], germination was induced by lower concentrations. The objective of this study, therefore, is to determine whether *Tithonia diversifolia* can inhibit the growth of weeds growing in its surroundings and identify the affected weed species.

2. Materials and Methods

The experiment was carried out in the screen house, Ladoke Akintola University Technology Ogbomosho, Nigeria

2.1. Collection of Weed Seeds

Seeds of thirteen weed species were collected from the wild in the previous season (2011) from Teaching and Research Farm Ogbomoso. The collected weed species were: *Euphorbia heterophylla*, *Pennisetum polystachion*, *Bidens pilosa* and *Ancanthospermum hispidium*. Others were *Amaranthus spinosus*, *Cleome viscosa*, *Fibristylis littoralis*, *Hyptis suaveolens*, *Senna occidentalis*, *Tridax procumbens*, *Digitaria gayana*, *Panicum maximum and Walteria indica*.

2.2. Collection of Soil Samples

A plot heavily infested by *Tithonia diversifolia* was selected for soil sampling for the experiment. The plot was adjudged heavily infested as a result of this weed constituting more than 90% of the total identifiable weed species. Other weed species present on the plot were *Imperata cylindrica*, *Boerhavia diffusa*, *and Ageratum conyzoides*. Non Tithonia infested soil has no *T. diversifolia* growing on it. Soil sampling of the *T. diversifolia* infested field and Non *T*, *diversifolia* infested field was done at the depth of 0 - 15 cm of the soil.

2.3. Soil Processing

The samples were passed through just three stages of processing before being subjected to laboratory analysis: 1) Crushing; Large soil clods were crushed to facilitate drying; 2) Air drying of the soil samples from the two different locations separately for a week under a condition that prevented contamination and finally; 3) Sieving of the soil samples through a 2 mm brass sieve.

2.4. Laboratory Analysis

The physical and chemical properties of the two soil locations were determined at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

2.5. Pot Preparation

A total of 104 pots were used for the experiment with 52 pots for each treatment replicated four times. These pots were perforated at the base to prevent water logging and filled with 2 kg soil each. The pots were laid-out in a Completely Randomized Design (CRD).

2.6. Sowing

Twenty seeds of each of the test weeds were sown in each of the treatments and replicated four times. Pots were irrigated every other day to facilitate germination. Emergence of young seedlings was observed from two weeks after planting (WAP).

2.7. Data Collection

Data were collected every week after seedling emergence on population of weed seed that emerged in each of the soil medium.

2.8. Statistical Analysis

The collected data was subjected to Analysis of Variance (ANOVA) and means were separated using LSD at 5% probability level. The result soil chemical analysis of the two locations (*Tithonia*-infested and Non-*Tithonia*-infested soils were correlated with weed seedling emergence at 6 WAP to determine the relationship between soil chemical parameters and weed seed emergence.

3. Results

3.1. Soil Physical and Chemical Parameters

The result of Physico-chemical parameters of soil in the two locations where soil samples were collected is shown in **Table 1**. From the result, the two soils differed in terms of pH and exchangeable acidity, but the level of Nitrogen, and Potassium were very close. The pH values show that the location with *Tithonia diversifolia* infestation was alkaline (8.4) while the location without *T. diversifolia* infestation was acidic (4.9). The *T. diversifolia* infested soil *was* higher in Ca, Zn and Fe composition (4.68, 188.59 and 136.89 ppm) respectively than the location without *T. diversifolia* infestation (1.07, 24.17 and 84.73 ppm) respectively but lower in Cu composition. The sand, silt, and clay composition of these locations were the same.

3.2. Weed Emergence

The performances of the 13 weed species planted in *Tithonia* infested and Non-Tithonia infested soil are shown in **Table 2**. Amongst the weeds, 69% of the thirteen species were broadleaved while the remaining 31% were grasses. Out of the weed lot, the growth of *A. hispidium*, *B. pilosa E. heterophylla*, *P. maximum* and *P. polystachion* were significantly affected in soil infested by *T. diversifolia*. The number of weed seedling emergence afore mentioned were significantly lower than what was obtained in soil not infested with *T. diversifolia* and this account for about 38% of the tested weed species. At 1 WAP *A. hispidium*, an average of almost five (5) plants were recorded in Non-*Tithonia* infested soil while less than one plant (<1) on the average was recorded in soil infested with *T. diversifolia*. This trend continued until 6 WAP when 16 seedlings of *A. hispidium* which accounted for 78% of the seeds planted/pot were recorded in Non-*T. diversifolia* infested soil while only approximately four seedling of *A. hispidium* was recorded in *T. diversifolia* infested soil. The same trends was observable in the growth pattern of *B. pilosa*, *E. heterophylla*, *P. maximum*, *P. polystachion* and *W. indica*. It was also noted that statistically, the seedling emergence of *W. indica* in both *T. diversifolia* infested and Non-*T. diversifolia* infested soil media were not statistically significant for 1 WAP and 3 WAP but subsequently significant difference were observed.

The presence of *T. diversifolia* favoured the germination and seedling emergence of four of these weeds species (23%) and these include *A. spinosus*, *C. viscosa*, *T. procumbens* and *D. gayana*. Throughout the six weeks of the experiment, *A. spinosus* almost have no seedling emergence on the average for the six weeks except week two when average of two seedlings were recorded but these seedlings withered before the end of the experiment

Table 1. Physico-chemical properties of the experimental soils.

Soil Parameters	*Tithonia diversifolia* infested soil	Soil without *Tithonia diversifolia* infestation
pH (H_2O)	8.4	4.9
% OC	0.91	0.89
% N	0.058	0.065
P (ppm)	58.395	16.677
% SAND	82	82
% SILT	7	7
% CLAY	11	11
Ca (cmol+/Kg)	4.68	1.07
Mg (cmol+/Kg)	0.60	0.51
K (cmol+/Kg)	0.38	0.34
Na (cmol+/Kg)	0.11	0.15
Exchange acidity	0.00	1.75
Zn (ppm)	188.59	24.17
Cu (ppm)	1.72	1.14
Mn (ppm)	32.55	43.39
Fe (ppm)	136.89	84.73

Table 2. Seedling emergence response of thirteen weed species on *T. diversfolia* and non-*T. diversfolia* infested soils for a period of six weeks.

Name of the weed	Week 1			Week 2			Week 3			Week 4			Week 5			Week 6		
	TIS	**NTS**	***LSD***	**TIS**	**NTS**	***LSD***	**TIS**	**NTS**	***LSD***	**TIS**	**NTS**	***LSD***	**TIS**	**NTS**	***LSD***	**TIS**	**NTS**	***LSD***
Broadleaves																		
Amaranthus spinosus	1.0	0.0	1.3^{NS}	4.0	2.0	1.6^{NS}	3.5	0.6	1.6^{NS}	4.0	0.0	2.6^{NS}	4.0	0.0	2.6^{NS}	4.0	0.0	2.6^{NS}
Ancanthospermum hispidum	0.8	4.8	1.3*	0.8	6.5	0.8*	1.8	8.8	1.3*	3.3	12.0	1.5*	3.3	15.3	3.4*	3.5	15.5	3.9*
Bidens pilosa	0.5	8..0	2.8*	0.5	9.8	2.0*	0.5	13.3	3.5*	0.8	15.3	2.1*	1.5	17.3	2.7*	1.8	17.8	4.3*
Cleome viscosa	2.5	1.0	1.3*	4.8	2.3	1.4*	6.5	4.3	1.3*	7.8	5.5	0.8*	10.5	7.8	1.2*	12.3	8.8	1.4*
Euphorbia heterophylla	5.5	10.3	1.5*	7.8	12	2.4*	8	13.5	2.1*	9.0	15.0	1.3*	10.3	16.3	2.3*	10.5	16.5	2.6*
Fibristylis littoralis	0.0	0.0	0.0^{NS}	0.0	0.0	0.0^{NS}	0.3	0.8	0.9^{NS}	0.5	1.3	1.5	0.5	1.3	1.5	0.5	1.3	1.5
Hyptis suaveolens	1.8	3.8	2.6^{NS}	3.3	4.0	1.5^{NS}	5.3	5.8	2.1^{NS}	5.3	6.5	1.5^{NS}	5.3	9.0	2.0	5.3	9.0	2.0
Senna occidentalis	0.3	0.5	0.5^{NS}	0.5	0.8	0.8^{NS}	0.5	0.8	0.5^{NS}	0.8	1.0	0.8^{NS}	0.8	1.3	0.9^{NS}	1.3	1.8	1.6^{NS}
Tridax procumbens	6.0	0.0	2.6*	7.0	0.0	1.8*	8.5	0.3	5.3*	8.5	0.5	5.0*	8.5	0.5	5.0*	8.5	0.5	5.0*
Grasses																		
Digitaria gayana	6.3	4.3	0.0*	7.3	6.0	1.5^{NS}	8.8	6.5	2.0*	10.0	7.8	0.8*	10.5	8.5	2.6^{NS}	10.5	8.5	2.6^{NS}
Panicum maximum	1.0	4.8	2.0*	2.5	6.0	2.8*	3.5	7.0	3.0*	4.0	12.5	6.7*	4.0	16.0	9.3*	4.0	17.8	8.8*
Pennisetum polysachion	4.5	5.8	1.2*	5.5	7.8	0.8*	7.0	11.5	0.0*	8.8	14.5	0.0*	9.0	15.5	0.0*	9.0	15.5	0.0*
Walteria indica	0.0	0.5	0.9^{NS}	0.0	1.3	2.0^{NS}	0.5	3.3	3.5^{NS}	1.0	4.8	2.4*	1.3	5.5	2.7*	1.5	6.3	4.0*

Key: TIS: *T. diversfolia* Infested Soil; TNS: Non-*T. diversfolia* Infested Soil; LSD: Least Significant Difference; NS: Non Significantly different; *Significantly Different.

on non-*T. diversifolia* infested soil. When this result was compared to what was obtainable on *T. diversifolia* infested soil, *A. spinosus* seed germinated and seedling emerged from one (1) at 1 WAP to four seedings between 4 - 6 WAP. The same observation was made on *C. viscosa*, *T. procumbens* and *D.gayana*; the number of these weed seeds (*A. spinosus*, *C. viscosa*, *T. procumbens* and *D. gayana*) that emerged on soil not infested with *T. diversifolia* was significantly lower than the number of weed seed that emerged on soil infested with *T. diversi-*

folia.

Germination of *Fibristylis littoralis*, *Hyptis suaveolens and Senna occidentalis* seeds were generally poor. These weed species were not responsive in either *T. diversifolia* infested soil or Non-*T. diversifolia* infested soil. It was observed that the first emergence on *Fibristylis littoralis* pots was noticed on the third week when an average of less than one (<1) seedling was recorded in the two soil media. *Senna occidentalis* has lower germination from the first week but did not increase appreciably throughout the 6 week experimental period.

Based on the response of weed species to their growth in the two media, *A. hispidium*, *B. pilosa*, *P. maximum* and *P. polysachion* showed the highest response to the *T. diversifolia* infested soil media during the six weeks of the study with reduced number of seedling that emerged when compared with Non-*T. diversifolia* infested soil (**Table 3**). *A. hispidium*, on infested soil, has as low as 0.8 plant/pot average seedling during the first week after planting and 3.5 plants/pot was recorded at 6 WAP while in non-infested soil, 4.8 plants/pot was recorded in first weed after planting and was significantly greater than the number of seedling recorded at 6 WAP for *T. diversifolia* infested soil. At 6 WAP, an average of 78% (15.5 plants/pot) of *A. hispidium* seeds planted in soil not infested with *T. diversifolia* soil germinated. The same trend was observed for *B. pilosa*, *P. maximum* and *P. polysachion* which belong to the category of weed that were significantly affected by *T. diversifolia* infested soil.

Statistically, the mean of seedling recorded at *E. heterophylla* pot was not significant but there a slight differential in average number of seedling recorded. For example, at 1 WAP, the number of *E. heterophylla* seedling for both *T. diversifolia* infested and non *T. diversifolia* infested soil were 5.5 and 10.3 plants/pot respectively and at 6 WAP, the average number of *E. heterophylla* seedlings was 10.5 and 16.5 plants/pot for *T. diversifolia* infested and non *T. diversifolia* infested soil respectively. The seedling emergence of *A. spinosus*, *C. viscosa*, *T. procumbens* and *D. gayana* were not affected by *T. diversifolia* infested soil. Among all the weed seeds planted, *F. littoralis* had average of 0.3 and 0.8 plants/pot in both *T. diversifolia* infested soil and non *T. diversifolia* infested soil respectively at 3 WAP. There was no emergence of the weed at 1 and 2 WAP. A highest average of 1.5 plants/pot was recorded on soil not infested soil.

3.3. Correlation between Weed Seed Emergence and Some Selected Soil Chemical Parameters

Correlation between soil physico-chemical parameters and weed emergence in the two soil media were shown in **Tables 4** and **5**. The correlation of soil with *T. diversifolia* infestation and weed emergence showed that only two weed species (*C. viscosa* and *F. littoralis*) showed correlation that was significant (**Table 4**). It was obvious

Table 3. Rating of thirteen weed species in Tithonia infested soil.

Species	Score of allelopathic Response of weeds to Tithonia infested soil			
	← Rating* →			
	High	Moderate	Low	Non
Broadleaves				
Amaranthus spinosus				✓
Ancanthospermum hispidum	✓			
Bidens pilosa	✓			
Cleome viscosa				✓
Euphorbia heterophylla		✓		
Fibristylis littoralis			✓	
Hyptis suaveolens			✓	
Senna occidentalis			✓	
Tridax procumbens				✓
Grasses				
Digitaria gayana				✓
Panicum maximum	✓			
Pennisetum polysachion	✓			
Walteria indica		✓		

*Key to Rating: **High**: < 30% of seeds planted/pot in *T. diversifolia* infested soil germinated by sixth week; **Moderate**: <50% of the seeds planted/pot in *T. diversifolia* infested soil germinated by sixth week; **Low**: <75% of the seeds planted/pot in *T. diversifolia* infested soil germinated by sixth week; **Non**: Induces the growth of the weed seeds.

Table 4. Pearson correlation coefficients of weed emergence at 6 weeks after planting and chemical parameters in soil under Tithonia infested field.

Weed Species	Weed Emergence (6 WAP)	pH	Phosphorus (P)	Calcium (Ca)	Zinc (Zn)	Iron (Fe)
Amaranthus spinosus	1.00000	−0.19612	−0.03997	−0.67082	0.32285	0.67082
		(p = 0.8039)	0.9600	0.3292	0.6771	0.3292
Ancanthospermum hispidum	1.00000	0.12105	−0.34536	−0.89709	0.23663	0.75907
		0.8790	0.6546	0.1029	0.7634	0.2409
Bidens pilosa	1.00000	−0.44540	0.29825	0.00000	0.66777	0.43529
		0.5546	0.7018	1.0000	0.3322	0.5647
Cleome viscosa	1.00000	0.43611	−0.62215	−0.79559	0.74786	0.99449
		0.5639	0.3778	0.2044	0.2521	0.0055
Digitaria gayana	1.00000	0.16013	0.03263	0.36515	−0.75788	−0.73030
		0.8399	0.9674	0.6349	0.2421	0.2697
Euphorbia heterophylla	1.00000	−0.80064	0.81584	0.73030	0.16476	−0.36515
		0.1994	0.1842	0.2697	0.8352	0.6349
Fibristylis littoralis	1.00000	−0.55470	0.73480	0.94868	−0.51366	−0.94868
		0.4453	0.2652	0.0513	0.4863	0.0513
Hyptis suaveolens	1.00000	0.41812	−0.42606	−0.57208	−0.60229	0.00000
		0.5819	0.5739	0.4279	0.3977	1.0000
Panicum maximum	1.00000	−0.19612	−0.03997	−0.67082	0.32285	0.67082
		0.8039	0.9600	0.3292	0.6771	0.3292
Pennisetum polysachion	1.0000	−0.48954	0.56534	0.80623	0.35817	−0.31009
		0.5105	0.4347	0.1938	0.6418	0.6899
Senna occidentalis	1.0000	−0.80064	0.81584	0.73030	0.16476	−0.36515
		0.1994	0.1842	0.2697	0.8352	0.6349
Tridax procumbens	1.0000	0.00000	0.00000	0.31623	0.85610	0.31623
		1.0000	1.0000	0.6838	0.1439	0.6838
Walteria indica	1.0000	0.49614	−0.27806	0.42426	−0.17867	−0.42426
		0.5039	0.7219	0.5757	0.8213	0.5757

that there was significant positive correlation between *C. viscosa* and iron (Fe) content of the soil with correlation coefficient of 0.99. Moreover, *F. littoralis* was positively correlated to calcium (Ca) 0.95 and negatively correlated to Fe with coefficient of −0.95.

In non *T. diversifolia* infested soil (**Table 5**), only two weed species showed significant correlation to soil chemical properties. *C. viscosa* was positively correlated to pH (0.99) and *D. gayana* was positively correlated Ca (0.95) and Zn (0.95) and negatively correlated to acidity (−0.94). The rest were not statistically significant.

4. Discussion

The presence of *T. diversifolia* on arable field could suggest several changes which may be taken place within such ecosystem as indicated in this study. From the soil analysis carried out on the soil of the two locations (*T. diversifolia* infested soil and Non *T. diversifolia* infested soil), the differential pH in soils from the two locations could be one of the factors that affect the germination of the weed seeds. References [32] reported that the germination of Texas weed (*Caperonia palustris*) increased at pH between 4 and 8 and decreasing germination at pH levels of 9 and 10. This differential pH could be as a result of impact of crop architecture of *T. diversifolia* which control the degree of exposure to environmental factors like erosion and other weathering activities since *T. diversifolia* is a shade plant. Several of the weed seeds introduced in *T. diversifolia* infested soil were suppressed at varying degrees.

E. heterophylla showed average susceptibility to *T.diversifolia* suppression as 50% of its total seeds introduced emerged. Although, it was observed that leaves of *E. heterophylla* appeared to be healthier in *T. diversifolia* infested soil than in soil without *T. diversifolia*. This may however be an indication of stimulatory effect of allelopathy. Reference [33] reported that *T. diversifolia*

Table 5. Pearson correlation coefficients of weed emergence at 6 weeks after planting and chemical parameters in soil under non-Tithonia infested field.

Weed Species	Weed Emergence (6 WAP)	pH	Phosphorus (P)	Calcium (Ca)	Acidity	Zinc (Zn)	Iron (Fe)
Amaranthus spinosus	–	–	–	–		–	–
		–	–	–		–	–
Ancanthospermum hispidum	1.00000	0.79982	0.61280	−0.54865	0.06820	−0.57869	0.57869
		(p = 0.2002)	0.3872	0.4513	0.9318	0.4213	0.4213
Bidens pilosa	1.00000	−0.87494	−0.40754	0.27873	0.22678	0.32071	−0.53452
		0.1251	0.5925	0.7213	0.7732	0.6793	0.4655
Cleome viscosa	1.00000	0.99239	0.59082	−0.28437	−0.11066	−0.36515	0.88679
		0.0076	0.4092	0.7156	0.8893	0.6349	0.1132
Digitaria gayana	1.00000	−0.13436	−0.91660	0.94917	−0.94388	0.95346	−0.57208
		0.8656	0.0834	0.0508	0.0561	0.0465	0.4279
Euphorbia heterophylla	1.00000	−0.71316	0.09482	−0.22599	0.67420	−0.19069	−0.19069
		0.2868	0.9052	0.7740	0.3258	0.8093	0.8093
Fibristylis littoralis	1.00000	0.24379	0.61727	−0.37830	0.51299	−0.43529	0.72548
		0.7562	0.3827	0.6217	0.4870	0.5647	0.2745
Hyptis suaveolens	1.00000	0.51419	−0.03494	0.00000	−0.44721	0.00000	0.00000
		0.4858	0.9651	1.0000	0.5528	1.0000	1.0000
Panicum maximum	1.00000	−0.42959	−0.21270	0.33279	0.09608	0.31704	−0.04529
		0.5704	0.7873	0.6672	0.9039	0.6830	0.9547
Pennisetum polysachion	1.0000	−0.66631	−0.23537	0.23080	0.25820	0.24343	−0.24343
		0.3337	0.7646	0.7692	0.7418	0.7566	0.7566
Senna occidentalis	1.0000	−0.21770	−0.82714	0.69239	−0.77460	0.73030	−0.73030
		0.7823	0.1729	0.3076	0.2254	0.2697	0.2697
Tridax procumbens	1.0000	−0.66631	−0.23537	0.23080	0.25820	0.24343	−0.24343
		0.3337	0.7646	0.7692	0.7418	0.7566	0.7566
Walteria indica	1.0000	0.58463	0.65963	−0.33177	0.29111	−0.41169	0.90573
		0.4154	0.3404	0.6682	0.7089	0.5883	0.0943

is a potential green manure and organic fertilizer for vegetable crops.

B. pilosa was the most susceptible to *T. diversifolia* suppression out of the selected weed plants as only 5% emerged. The result obtained in this study was similar to the work of [34] who studied the allelopathic potential of aqueous extracts from the aerial part of *L. leucocephala* on *Desmodium purpureum*, *B. pilosa* and *Amaranthus hybridus* L and found out that *B. pilosa* and *A. hybridus* were the most sensitive species to the extract in the bioassays. However, some workers have also observed inhibitory effects of some plants on other test plants. References [35] reported that *Chromolaena odorata* contains a large amount of allelochemicals especially in the leaves, which inhibit the growth of many plants in nurseries and plantations. Reference [36] has demonstrated that aqueous extract and shoot extract of *T. diversifolia* was inhibitory to the germination and growth of *Amaranthus cruentus*. Similarly, reference [37] has reported that the bark, leaf and leaf extract of *Quercus glauca* and *Q. leucotricophora* significantly reduced germination, plumule and radicle length of wheat (*Triticum* sp.) and mustard seeds. Earlier investigators have suggested that allelochemicals or toxins are released from the weed by the action of micro-organisms during decomposition, which may interfere with the plant growth processes [38].

This study reveals that weed counts in *T. diversifolia* infested soil is significantly lower than the ones in soil without *T. diversifolia* infestation. Likewise, the vegetative growth of some species (*A. spinosus*, *C. viscosa*, *T. procumbens* and *D. gayana)* was improved in this soil. This shows that *T. diversifolia infested* soil contain allelochemicals that performed both stimulatory and inhibitory functions.

5. Conclusion

It is clear from our discussion that there is immense prospect of allelopathic mechanism as a weed management tool. Impacts of allelopathy on different weed species have been identified. In spite of that, some factors have to be considered before application of allelochemicals as natural herbicide and such factors include soil properties, type of weed species to be controlled and time of application of the allelopathic mechanism in controlling specific weed species.

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