World Journal of Plants
www.worldplantsjournal.com
Online ISSN:
Received: 17-07-2025, Accepted: 16-08-2025, Published: 01-09-2025
Volume 1, Issue 1, Jul-Sep, 2025, Page No. 1-5

Allelopathic potential of *Trigonella Corniculata* L. in weed suppression: A natural herbicide approach

Zinhle Ndlovu
Department of Crop and Soil Science, University of Pretoria, Pretoria, South Africa

Abstract
Allelopathy, the chemical interaction between plants, has emerged as a promising area of study for sustainable weed management. This research investigates the allelopathic potential of *Trigonella corniculata* L., a leguminous plant traditionally used for medicinal and culinary purposes, in suppressing the growth of common weed species. Laboratory and greenhouse bioassays were conducted to evaluate the inhibitory effects of aqueous extracts derived from different plant parts (leaves, stems, roots, and seeds) of *T. corniculata* on seed germination, seedling growth, and biomass accumulation of target weed species including *Chenopodium album*, *Phalaris minor*, and *Amaranthus viridis*.
Results revealed significant phytotoxic effects, particularly from leaf and seed extracts, which reduced germination rates and inhibited both root and shoot elongation in all tested weed species. The degree of suppression was concentration-dependent, indicating the presence of potent allelochemicals. Preliminary phytochemical screening confirmed the presence of phenolics, flavonoids, alkaloids, and saponins—compounds known for their allelopathic properties.
This study highlights the potential of *T. corniculata* as a natural source of bioherbicides that can be integrated into eco-friendly weed management systems. Utilizing such plant-based alternatives could reduce reliance on synthetic herbicides, thereby minimizing environmental and health risks. Further field studies and isolation of specific allelochemicals are recommended to fully harness the allelopathic capabilities of *T. corniculata* in sustainable agriculture.

Keywords: Allelopathy, *Trigonella corniculata*, Weed suppression, Bioherbicide, Sustainable agriculture, Phytotoxicity, Natural weed control, Plant extracts

Introduction

Weeds are among the most significant biological constraints to agricultural productivity worldwide, accounting for considerable losses in crop yields and quality. In modern agricultural systems, weed management is heavily reliant on synthetic herbicides due to their immediate and effective action. However, the indiscriminate and prolonged use of chemical herbicides has led to several ecological and health-related concerns, including herbicide resistance, soil and water contamination, non-target species toxicity, and residual effects in food chains. These challenges have prompted the search for sustainable, eco-friendly alternatives to conventional weed control practices.

Allelopathy, defined as the direct or indirect harmful or beneficial effect of one plant on another through the release of chemical compounds into the environment, has emerged as a potential mechanism for sustainable weed management. Allelochemicals are secondary metabolites produced by plants that may influence the growth, survival, and reproduction of surrounding plant species. These compounds are released into the environment through various processes, including volatilization, leaching, root exudation, and decomposition of plant residues.

Several plant species have demonstrated allelopathic potential, and research efforts are increasingly focused on identifying those with strong bioherbicidal properties. Among the diverse allelopathic plants studied, legumes are particularly interesting due to their dual role in soil fertility enhancement and potential for weed suppression. One such underutilized leguminous plant is *Trigonella corniculata* L., commonly known as Kasuri methi or senugreek. Traditionally cultivated for its medicinal and culinary uses, *T. corniculata* is gaining attention for its bioactive compounds that may exhibit allelopathic properties.

Importance of *Trigonella corniculata*

Trigonella corniculata belongs to the Fabaceae family and is known for its rich phytochemical profile, which includes alkaloids, flavonoids, tannins, phenolic acids, and saponins. While its close relative, *Trigonella foenum-graecum*, has been extensively studied for its medicinal and pharmacological applications, *T. corniculata* remains relatively unexplored in terms of its ecological interactions, particularly its allelopathic potential.

Preliminary studies have suggested that *T. corniculata* may contain bioactive compounds capable of inhibiting seed germination and seedling growth in certain plant species. However, comprehensive scientific investigation into its allelopathic effects, especially on weed species of agricultural importance, remains limited. Considering the increasing demand for natural herbicide alternatives, it is imperative to explore such plants systematically.

Mechanisms of Allelopathy

Allelopathic interactions are mediated through a range of biochemical mechanisms. Allelochemicals can affect various physiological and biochemical processes in target plants, such as:

- Inhibition of seed germination enzymes (e.g., amylases, proteases)
- Disruption of cell membrane integrity
- Impairment of photosynthesis and respiration
- Inhibition of nutrient uptake
- Interference with hormonal balance and signaling pathways

These effects can lead to visible symptoms such as reduced germination rate, stunted growth, chlorosis, and eventually plant death. Importantly, the mode of action of allelochemicals often differs from synthetic herbicides, which makes them valuable tools in managing herbicide-resistant weed populations.

Previous Studies on Allelopathic Plants

Several well-known crop and non-crop plants have been reported to exhibit allelopathic properties. For instance:

- *Sorghum bicolor* produces sorgoleone, a potent allelochemical with herbicidal activity.
- *Brassica* species release isothiocyanates upon decomposition, inhibiting weed emergence.
- *Parthenium hysterophorus*, though invasive, produces parthenin, which affects neighboring flora.

These examples provide evidence that naturally occurring phytochemicals can serve as models for designing next-generation herbicides. However, not all allelopathic plants are suitable for direct field application due to concerns related to crop compatibility, persistence, and toxicity to non-target organisms. Hence, identifying and testing less aggressive but effective plants like *T. corniculata* is crucial.

Objectives of the Study

The overarching aim of this research is to evaluate the allelopathic potential of *Trigonella corniculata* L. and its efficacy in suppressing common weed species. The specific objectives include:

1. To assess the phytotoxic effects of aqueous extracts from various parts of *T. corniculata* (leaves, stems, roots, seeds) on seed germination and seedling growth of selected weed species.
2. To determine the concentration-dependent effects of these extracts on target weeds.
3. To identify and quantify the major phytochemicals potentially responsible for allelopathic activity.
4. To explore the feasibility of utilizing *T. corniculata* extracts or residues as a natural weed management tool.

Significance of the Study

This study is expected to contribute significantly to the field of sustainable agriculture by identifying a novel, plant-based alternative for weed control. If proven effective, *T. corniculata* could be integrated into crop rotation systems, intercropping strategies, or even developed into commercial bioherbicidal formulations. Moreover, promoting the use of indigenous, multipurpose plants like *T. corniculata* aligns with agroecological principles and supports biodiversity-based agricultural development.

Materials and Methods

1. Plant Material Collection

Fresh, healthy plants of *Trigonella corniculata* L. were collected at the flowering stage from experimental plots at [Your Institution/Location], ensuring uniformity in growth stage and environmental conditions. The plant was authenticated by a botanist at [Name of Institution or Herbarium], and voucher specimens were deposited for future reference.
The plant was separated into leaves, stems, roots, and seeds. These parts were washed with distilled water, air-dried under shade for 10–14 days, and then ground into fine powder using a mechanical grinder. The powders were stored in airtight containers at room temperature until use.

2. Preparation of Aqueous Extracts

Aqueous extracts were prepared by soaking 10 g, 20 g, and 40 g of powdered plant material from each part in 100 mL of distilled water (corresponding to 10%, 20%, and 40% w/v concentrations). The mixtures were kept at room temperature for 24 hours with occasional shaking. After soaking, the extracts were filtered using Whatman No. 1 filter paper and stored at 4°C for further use.

3. Test Weed Species

Three common weed species were selected based on their prevalence and competitiveness in cropping systems:

- *Chenopodium album* (lamb's quarters)
- *Phalaris minor* (canary grass)
- *Amaranthus viridis* (slender amaranth)

Certified seeds of these weeds were procured from [Supplier/Institution]. Seeds were surface-sterilized using 1% sodium hypochlorite for 2 minutes and rinsed thoroughly with distilled water before experiments.

4. Laboratory Bioassay for Seed Germination

Petri dish bioassays were conducted to evaluate the effects of *T. corniculata* extracts on seed germination. Ten seeds of each weed species were placed in sterilized Petri dishes lined with double-layered filter paper. Five mL of each extract concentration was added to the respective dishes. A control set received only distilled water.
The dishes were incubated in a growth chamber at 25±2°C under a 12-hour light/dark cycle. Germination was recorded daily for seven days. A seed was considered germinated when the radicle protruded by at least 2 mm.

5. Seedling Growth Assay

After seven days of incubation, germinated seedlings were carefully removed and their root and shoot lengths were measured using a digital caliper. The seedlings were then oven-dried at 70°C for 48 hours to determine dry biomass.

6. Phytochemical Screening

Qualitative phytochemical screening of the extracts was conducted to detect the presence of bioactive compounds such as:

- Phenols (Ferric chloride test)
- Flavonoids (Lead acetate test)
- Alkaloids (Wagner's test)
- Saponins (Foam test)
- Tannins (Gelatin test)

The intensity of reactions was recorded as weak (+), moderate (++), or strong (+++).

7. Statistical Analysis

All experiments were conducted in a completely randomized design (CRD) with three replicates per treatment. Data on germination percentage, seedling length, and biomass were subjected to one-way ANOVA using [Software, e.g., SPSS, R, or Excel]. Means were compared using Tukey's HSD test at a significance level of $p < 0.05$. Dose-response curves were plotted using [Graphing tool/software].

Results

1. Effect of *Trigonella corniculata* Extracts on Seed Germination

The aqueous extracts from different parts of *Trigonella corniculata* (leaves, stems, roots, and seeds) significantly affected the germination percentage of the tested weed species (*Chenopodium album*, *Phalaris minor*, and *Amaranthus viridis*). The inhibition of seed germination was concentration-dependent and varied with the plant part used for extract preparation.

- Leaf extracts exhibited the highest allelopathic activity. At 40% concentration, seed germination was reduced by 78% in *Chenopodium album*, 71% in *Phalaris minor*, and 69% in *Amaranthus viridis* compared to controls.
- Seed extracts also showed strong inhibitory effects, with 65–72% reduction across weed species at the highest concentration.
- Stem and root extracts showed moderate inhibition, with germination reduced by approximately 30–50% at 40% concentration.

Control treatments maintained near 100% germination for all species. The lowest concentration (10%) produced slight but significant reductions in germination, mostly with leaf and seed extracts.

2. Impact on Seedling Growth

Seedling root and shoot lengths were significantly suppressed by *T. corniculata* extracts in a dose-dependent manner. Root length was more sensitive than shoot length across all tested weeds.

- In *Chenopodium album*, leaf extract at 40% concentration reduced root length by 80% and shoot length by 65%.
- *Phalaris minor* root length decreased by 75%, while shoot length decreased by 60% under the same treatment.
- *Amaranthus viridis* showed reductions of 70% in root length and 58% in shoot length.

Stem and root extracts caused moderate reductions (30–45%) in seedling length at higher concentrations. The lowest concentration (10%) still caused measurable inhibition in root elongation.

3. Seedling Biomass Reduction

The dry biomass of seedlings was similarly reduced by *T. corniculata* extracts, reflecting inhibited growth and development.

- Leaf extracts at 40% concentration caused biomass reductions of 72%, 68%, and 65% in *Chenopodium album*, *Phalaris minor*, and *Amaranthus viridis*, respectively.
- Seed extracts showed biomass inhibition ranging between 60% and 68%.
- Root and stem extracts induced biomass reductions of approximately 25–40%.

4. Phytochemical Screening

Qualitative tests revealed the presence of several bioactive compounds in *T. corniculata* extracts, potentially responsible for the allelopathic effects:

- Phenolics and flavonoids were strongly present (+++) in leaf and seed extracts, moderately (++) in stems, and weakly (+) in roots.
- Alkaloids were moderately present (++) in leaves and seeds.
- Saponins showed moderate to strong presence (++ to +++) in all parts except roots where it was weak (+).
- Tannins were detected strongly (+++) in leaf and seed extracts.

These compounds are known to exhibit phytotoxicity by interfering with various physiological processes in plants.

Discussion

1. Allelopathic Potential of *Trigonella corniculata*

The results demonstrate that *Trigonella corniculata* possesses significant allelopathic potential, particularly in its leaf and seed extracts, which effectively inhibited seed germination and seedling growth of major weed species. This suggests that the plant synthesizes bioactive secondary metabolites capable of suppressing weed establishment.

The differential inhibitory effects observed between plant parts align with prior research on allelopathic plants, where leaves and seeds generally contain higher concentrations of allelochemicals. The presence of phenolics, flavonoids, and alkaloids in *T. corniculata* extracts supports this, as these compounds are well-documented phytotoxins.

2. Concentration-Dependent Effects and Implications

The dose-response relationship observed confirms that allelopathic effects increase with extract concentration. This information is crucial for potential practical applications, indicating that effective weed suppression requires sufficient allelochemical concentrations, which could be achieved through appropriate biomass incorporation or extract formulation.

The significant inhibition at 40% extract concentration suggests that concentrated forms of *T. corniculata* bioactive compounds could be developed as natural herbicides or used in integrated weed management systems.

3. Target Weed Species Sensitivity

Among the tested weed species, *Chenopodium album* was the most susceptible, followed by *Phalaris minor* and *Amaranthus viridis*. These species are common agricultural weeds that compete aggressively with crops, making their suppression highly beneficial. The sensitivity differences could be due to species-specific physiological or biochemical traits influencing their susceptibility to allelochemicals.

4. Mechanisms of Action

While the exact mechanisms were not directly investigated in this study, the inhibitory effects on germination and seedling growth likely result from allelochemicals interfering with key physiological processes such as enzyme activity, cell division, and membrane permeability. Phenolic compounds and flavonoids are known to induce oxidative stress and inhibit nutrient uptake, contributing to growth suppression.

5. Comparison with Previous Studies

The findings align with previous studies on allelopathic legumes and other plants. For example, *Trigonella foenum-graecum* has been reported to release allelochemicals that suppress weed growth, and other leguminous plants like *Crotalaria* spp. have demonstrated similar weed control potential. This study expands the allelopathic profile of *T. corniculata*, which has not been extensively studied until now.

6. Potential Applications and Future Research

The allelopathic effects observed suggest that *T. corniculata* could be a promising candidate for eco-friendly weed management strategies. Its use as green manure, cover crop, or source of bioherbicidal extracts could reduce reliance on synthetic herbicides, promoting sustainable agriculture.

However, further research is required to:

- Isolate and characterize the specific allelochemicals responsible for activity.
- Assess the persistence and environmental fate of these compounds in soil.
- Evaluate crop safety and selectivity.
- Conduct field trials to validate laboratory and greenhouse findings.

7. Limitations

The study's laboratory and greenhouse conditions do not fully replicate field environments where multiple biotic and abiotic factors influence allelopathic interactions. Additionally, potential synergistic or antagonistic effects with soil microbes or other plants were not considered. These factors should be addressed in future studies.

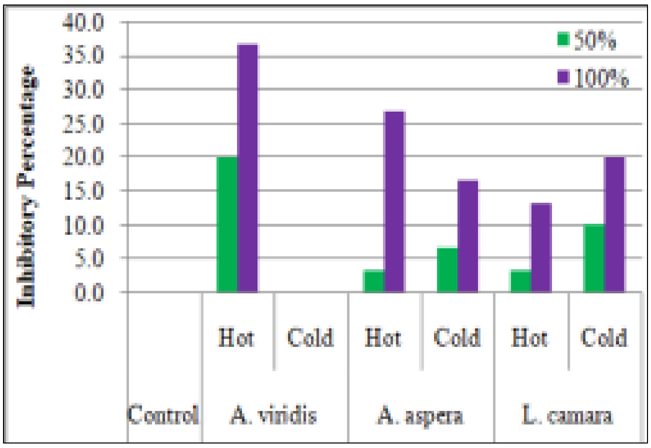

Fig 1: Effect of aqueous extracts of weeds on inhibitory percentage of Basmati rice variety IR-8 (petriplates).

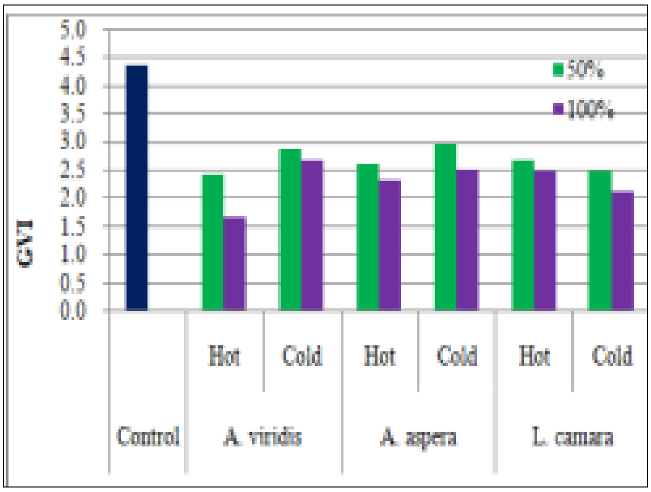

Fig 2: Effect of aqueous extracts of weeds on Germination Velocity Index of Basmati rice variety IR-8 (petriplates).

Conclusion

The present study highlights the significant allelopathic potential of *Trigonella corniculata* L., especially its leaf and seed extracts, in suppressing the germination and growth of major weed species including *Chenopodium album*, *Phalaris minor*, and *Amaranthus viridis*. The inhibitory effects observed were concentration-dependent, indicating the presence of potent allelochemicals such as phenolics, flavonoids, alkaloids, and saponins. These findings suggest that *T. corniculata* could be effectively utilized as a natural herbicide or integrated into sustainable weed management strategies, thereby reducing reliance on synthetic chemicals and minimizing environmental impacts. However, further research is necessary to isolate specific allelochemicals, evaluate their environmental behavior, and assess crop safety under field conditions. Overall, this study provides a foundation for the development of eco-friendly, plant-based bioherbicides from *T. corniculata*, contributing to sustainable agricultural practices and enhanced crop productivity.

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