JOURNAL OF
EMERGING INVESTIGATORS

Article

Can essential oils be allelopathic to *Lolium multiforum* without harming *Solanum lycopersicum*?

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SUMMARY

As global demand of agricultural crops for food and fuel increases, the need for exploring eco-friendly biological methods to control weeds and enhance food crop yield is rising. Essential oils can be a safe bio-herbicide with positive effects on food crops. The objective of this experiment was to study the effects of three essential oils on seed germination and radicle length of both a weed, *Lolium multiforum* (ryegrass), and a common crop, *Solanum lycopersicum* (tomato). Both plants were exposed to turmeric, ginger, and eucalyptus oils at two different concentrations, and seed germination rate and radicle length were measured on the seventh and tenth days, respectively. We found that treatment with turmeric oil had phytotoxic potential, leading to a reduction in both seed germination and radicle length of ryegrass without a negative impact on the tomato seedlings. Ginger oil possessed allelopathic properties towards ryegrass and tomato, inhibiting seed germination in both. The study highlights that essential oils can be used as eco-friendly bio-herbicides to increase crop yields.

INTRODUCTION

Weeds are the most problematic organisms in agricultural areas, costing over $26 billion per year in yield reductions and an additional $7 billion on herbicide control (1). Reduction of crop yield by weeds is greater than the losses caused by disease, pests, and insects (1). Repeated use of herbicides results in herbicide resistance in weeds, and several synthetic herbicides have negative effects on crops as well as the environment (2). For these reasons, there is now a shift towards finding biological methods to control weeds without using these synthetic herbicides.

Allelopathy is an eco-friendly, organic, natural way to control weeds. Allelopathy is defined as the production of biochemicals, known as allelochemicals, by plant species that have beneficial or harmful effects on another plant species. Allelochemicals are nonnutritive substances mainly produced as plant secondary metabolites – which are unique to different plant species – and consist of various chemical families, including organic acids, ketones, phenols, and terpenoids (3). Commonly cited effects of allelopathy include reduced seed germination and seedling growth, due in part to alterations in photosynthesis as well as water and nutrient uptake (4).

Essential oils can be defined as either product of fragrant substances or mixtures of fragrant and odorless substances. Essential oils are aromatic, volatile liquids obtained from plant material through steam distillation and named after the plant from which they are derived. Essential oils are a complex mixture of volatile compounds and play an important role in plant-plant, and plant-animal interactions (5). Recently there has been research interest in assessing the value of these essential oils as possible candidates for weed management (2). Herbicides based on these essential oils are safer for humans and the environment and are also easily biodegradable (5). Ginger *(Zingiber officinale Rosc.*) and turmeric (*Curcuma longa*) are two spices widely used for food and medicinal purposes. Ginger is a rhizome (underground stem) of a perennial herb, while turmeric, popular in Indian cuisine, is a dried rhizome of an herbaceous plant called Indian Saffron. Curcumin, a phenol found in turmeric, has been extensively studied for its beneficial effects on diabetes, dementia, and Alzheimer's disease (6). *Eucalyptus tereticornis* is an evergreen tree species planted for paper industry with leaves rich in essential oil. Eucalyptus possesses range of biological activity, acting as both an insecticide and a fungicide (7). Intriguingly, eucalyptus essential oil may also have allelopathic potential, with a 2011 study showing that its use led to a reduction in weed seedling growth (8).

Further research is needed to explore allelopathic potential of different essential oils, especially for the above-mentioned plants. Essential oils may act as safe bio-herbicides against weeds but must not have negative effects on food crops. Eucalyptus essential oils have been studied for their allelopathic potential against pigweed and ryegrass (9). However, there is limited research on the allelopathic potential of turmeric and ginger essential oils. The primary objective of this study was to examine the effect of three different essential oils (turmeric, ginger, and eucalyptus) in two different concentrations on seed germination and radicle length of the weed *Lolium multiforum* (ryegrass) and the food crop *Solanum lycopersicum* (tomato). Growth can be assessed by measuring the radicle length. Radicle is defined as the primary root that is the first organ to appear when a seed germinates. Radicle grows downward into the soil, anchoring the seedling. We hypothesized that essential oils will negatively impact weed growth without significantly affecting food crop growth.

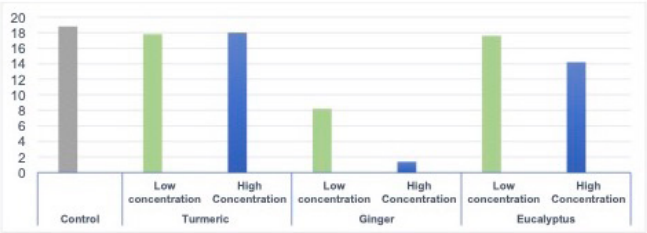

Figure 1: Average number of germinated seeds and germination rate for tomato. Plants were exposed to control (distilled water) or low vs. high concentration of either turmeric, ginger, or eucalyptus oil. Germinated seeds were counted at day 7. Average across five trials is shown.

RESULTS

To test the effect of these essential oils on weed growth, we placed equal number of seeds of each food crop and the weed in two different oil concentrations. Each essential oil sample had a low concentration and a high concentration. The low concentration was 0.4% and the high concentration was 0.8%. As a control, we incubated seeds with an equal volume of distilled water without any oils and measured the proportion of seeds germinated and the average radicle length at days 7 and 10, respectively, for all conditions.

We first checked whether the essential oils had any effect on the growth of the tomato plant. The average number of germinated seeds over five trials for tomato was highest in the control (94%), followed by high (90%) and low (89%) concentration of turmeric oil. The mean germination percentage over five trials showed a similar trend **(Figure 1)**. Ginger oil negatively affected tomato seed germination with only 41% and 7% of total seeds germinated in low and high concentration, respectively **(Figure 1)**. Tomato seed germination was not affected by turmeric or eucalyptus oil.

To test for phytotoxicity against weeds, we then compared seed germination rates for ryegrass seeds. The average germinated ryegrass seeds were highest in the control

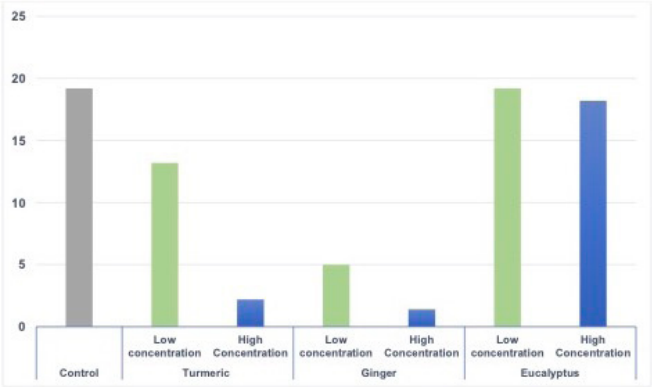

Figure 2: Average number of germinated seeds for ryegrass. Plants were exposed to control (distilled water) or low vs. high concentration of either turmeric, ginger, or eucalyptus oil. Germinated seeds were counted at day 7. Average across five trials is shown.

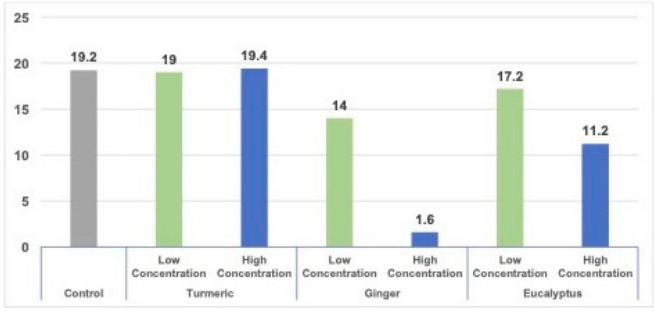

Figure 3: Average radicle length for tomato. Plants were exposed to control (distilled water) or low vs. high concentration of either Turmeric, Ginger, or Eucalyptus oil. Radicle length of the 5 longest seedlings at day 7 in each petri dish was measured on the 10th day. Data is an average of five trials.

group (96%) with much lower numbers following treatment with turmeric (66% in low concentration and 11% in high concentration) and ginger oil (25% for low concentration and 18% in high concentration). The average germinated ryegrass seeds following treatment with Eucalyptus oil was 96% in low and 91% in high concentrations. **(Figure 2)**. To test the effects of essential oils on radicle length of both weeds and crops, we measured the radicel length of five longest seedlings at day seven. The radicle length showed similar patterns to seed germination. The mean radicle length for tomato seedlings was comparable to the control with 19.2 mm for the control group and low concentration and high concentration of turmeric oil being 19 mm and 19.4 mm respectively. Radicle length for tomato seedlings exposed to ginger and eucalyptus oils was much shorter **(Figure 3)**. Mean ryegrass radicle length tended to be shorter for seedlings exposed to turmeric and ginger oil as compared to control and eucalyptus oil highlighting the negative impact on the weed **(Figure 4)**. There was a significant effect of both oil type and concentration on both ryegrass and tomato seed germination shown by two-way ANOVA with significant p values < 0.05.

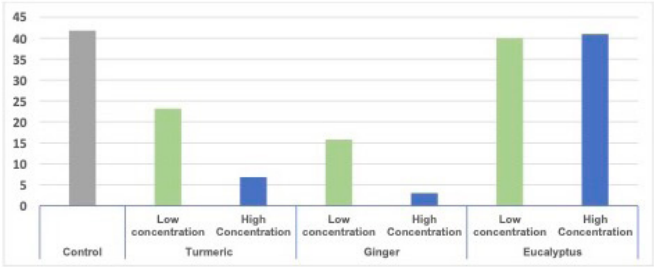

Figure 4: Average radicle length for ryegrass. Plants were exposed to control (distilled water) or low vs. high concentration of either turmeric, ginger, or eucalyptus oil. Radicle length of the 5 longest seedlings at day 7 in each petri dish was measured on the 10th day. Data is an average of five trials.

DISCUSSION

This study indicates that turmeric oil inhibits seed germination and reduces radicle length of ryegrass seeds but does not have any negative effects on tomato seeds. Conversely, seed germination and radicle length of both tomato and ryegrass seeds were significantly inhibited by ginger oil, while eucalyptus oil had no effect on either plant species at the concentrations used. The result of ANOVA further highlights a significant interaction between oil concentration and oil type in their effect on seed germination for tomato and ryegrass. Germination rate and radicle length declined more with higher concentration of turmeric and ginger oil.

Our study highlights the potential for using essential oils, particularly turmeric oil, as a bioherbicide in possible weed reduction without affecting the food crop. Different essential oils have varying inhibitory properties towards different plants, however. Indeed, a study by Hazrati and colleagues showed similar findings, with varying responses exhibited by weed and tomato species to the application of essential oils (9). This property may be used to develop selective organic herbicides. Some of the mechanisms implicated in the effects of essential oils on weed species are that allelochemicals, like terpenes in essential oils, inhibit cell respiration, damage cell membranes, and generate free radicals that damage the cells (4). One of the key limitations of our study, however, is that we did not separate the compounds in the essential oils with gas chromatography. Therefore, it is not certain what the active components of each oil were, nor can we speculate as to the mechanism of growth inhibition. Turmeric oil potentially showed phytotoxic effects on the weed, ryegrass, without negative impact on the food crop, tomato. Turmeric oil can be used as potential natural bioherbicide. Ginger oil possesses allelopathic properties towards ryegrass and tomato. Eucalyptus oil did not have any phytotoxic effects on the ryegrass and tomato at concentrations used in this study. Future field studies are recommended to assess the effect of essential oils on different weed species that often coexists with certain food crops, as well as the effect of other oil concentrations.

MATERIALS AND METHODS

Preparation of Oil Concentrations

The low concentration for each oil was made by mixing 0.08ml of each oil into 20ml of distilled water, giving a concentration of 0.4% and similarly the high concentration was made by mixing 0.16 ml of each oil with 20ml of distilled water, leading to a concentration of 0.8%.

Setting Up the Seeds

For each growth assay, 20 tomato seeds or 20 ryegrass seeds were placed in a petri dish between two pieces of filter paper moistened with either distilled water or the desired concentration of oil. All petri dishes were closed, wrapped in towels, and placed in a cool dry place with a constant temperature of 65˚F. The number of seeds germinated in each petri dish was recorded on the 7th day. Seeds were considered germinated when the radicle was at least 2 mm long. Radicle length of the 5 longest seedlings at day 7 in each petri dish was measured on the 10th day. The entire procedure and data collection was repeated for a total of 5 trials. The mean number of germinated seeds, as well as the mean radicle lengths, were calculated using Excel for all 5 trials. Excel was used for all analyses and for making tables and graphs. The relationship between seed germination rate, radicle length, and essential oil concentration was assessed using two factor Analysis of Variance (ANOVA) in Excel.

Received: December 5, 2020
Accepted: November 6, 2021
Published: November 13, 2021

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