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Diseases Control/ Scientific Notes

# Weed control using natural compounds

**Abstract** – The objective of this work was to evaluate the weed control efficacy of different plant-derived natural compounds in post-emergence applications. The treatments were alcohol+water (50% v/v), carvacrol (2.5% v/v), eugenol (2.5% v/v), thymol (2.5% v/v), *trans*-anethole (2.5% v/v), cinnamaldehyde (2.5% v/v), and an untreated control. The natural compounds followed a decreasing order of effectiveness: carvacrol, thymol, eugenol, *trans*-anethole, and cinnamaldehyde. *Trans*-anethole and cinnamaldehyde did not satisfactory control any of the weed species. Overall, specific plant-derived compounds are effective options for weed control.

**Index terms**: bioherbicides, family farming, organic farming, secondary metabolites.

## Controle de plantas daninhas com uso de compostos naturais

**Resumo** – O objetivo deste trabalho foi avaliar o controle de plantas daninhas por diferentes compostos derivados de plantas, em aplicações pós-emergentes. Os tratamentos foram álcool+água (50% v/v), carvacrol (2,5% v/v), eugenol (2,5% v/v), timol (2,5% v/v), *trans*-anetol (2,5% v/v), cinamaldeído (2,5% v/v) e a testemunha sem tratamento. Os compostos naturais seguiram a seguinte ordem decrescente de eficácia: carvacrol, timol, eugenol, *trans*-anetol e cinamaldeído. *Trans*-anetol e cinamaldeído não proporcionaram controle satisfatório de nenhuma das espécies de plantas daninhas. No geral, compostos específicos derivados de plantas são alternativas eficazes no controle de plantas daninhas.

**Termos para indexação**: bioherbicidas, agricultura familiar, agricultura orgânica, metabólitos secundários.

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Ensuring sustainable food production for a growing global population is one of the central challenges of twenty-first-century agriculture (Voss & Bellù, 2019). Weed management is a particularly crucial part of this effort, as weeds not only compete with cultivated crops for essential resources, such as light, water, and nutrients, but also serve as hosts for pests and pathogens. Additionally, they produce allelopathic compounds that can reduce crop yield and quality.

Although chemical herbicides remain the most efficient tools for weed control due to their rapid action and practicality, their dominance is increasingly challenged by concerns over the potential risks posed to human health and the environment (Abbas et al., 2018). Consequently, integrated weed management strategies that combine chemical, cultural, mechanical, physical, biological, and biotechnological approaches are being adopted to mitigate the negative impacts of intensive herbicide use (Knezevic et al., 2017).

Given these challenges, plant-derived natural compounds have emerged as promising tools for sustainable weed management. Essential oils and their constituents have demonstrated herbicidal potential, particularly in pre-emergence applications. However, selectivity and cost-effective extraction remain major obstacles for post-emergence use. While natural compounds such as thymol and carvacrol from thyme (*Thymus vulgaris* L.), eugenol from clove [*Syzygium aromaticum* (L.) Merr. & L.M.Perry], cinnamaldehyde from cinnamon (*Cinnamomum zeylanicum* Garcin ex Blume), and *trans*-anethole from star anise (*Illicium verum* Hook. f.) have been widely studied for insecticidal properties (Nascimento et al., 2022), a limited number of studies, according to the review by Costa et al. (2018), have evaluated their post-emergence herbicidal effects.

The objective of this work was to evaluate the weed control efficacy of different plant-derived natural compounds in post-emergence applications.

Two field experiments were conducted at Embrapa Gado de Leite, in the municipality of Coronel Pacheco, state of Minas Gerais, Brazil (21º33'0.77"S, 43º15'56.30"W), characterized by a Cwa subtropical climate (Köppen, 1948). Experiment 1 was performed during November and December 2022, while experiment 2 was carried out in November 2023. Surface soil (0–5 cm) was collected, placed in plastic trays, and maintained outdoors under daily irrigation. Seven treatments were evaluated: a water + alcohol (50% v/v) solution; carvacrol (2.5% v/v); eugenol (2.5% v/v); thymol (2.5% v/v); *trans*-anethole (2.5% v/v); cinnamaldehyde (2.5% v/v); and an untreated control. All natural compounds were mixed in the spray container with equal parts of water and alcohol (48.75% v/v). Applications were performed using a $CO_2$-pressurized backpack sprayer calibrated to 150 L $ha^{-1}$ with two 110.02 BD flat fan nozzles (MagnoJet, Ibaiti, PR, Brazil). At the time of application, broadleaf species showed one to two true leaves, and grasses had developed their first tiller.

In experiment 1, the predominant weeds were *Commelina benghalensis* L., *Eleusine indica* (L.) Gaertn., *Amaranthus* spp., and *Cyperus* spp. Total weed control was visually assessed at 1 and 3 days after treatment application (DAA), using a percentage scale from 0 to 100% (Velini et al., 1995), followed by a weed density assessment per tray at 15 DAA. In experiment 2, *C. benghalensis*, *Megathyrsus maximus* (Jacq.), *Amaranthus* spp., and *Alternanthera tenella* Colla predominated. The same visual assessment protocol was followed, with an additional third visual assessment at 15 DAA. For both experiments, species-specific control percentages as well as the fresh and dry weed biomass per tray were obtained at 15 DAA.

The experiments were conducted in a completely randomized design, with four replicates. Data, expressed as a percentage relative to the control, were square-root transformed (x + 1) and initially evaluated for normality and homogeneity of variances using Kolmogorov-Smirnov's and Levene's test, respectively. Once these assumptions were met, a one-way analysis of variance (ANOVA) was performed, followed by the Least Significant Difference test for post hoc multiple comparisons. Statistical analyses were carried out using the car (Fox & Weisberg, 2019), agricolae (Mendiburu, 2019), and multcomp (Hothorn et al., 2008) packages. All tests were conducted at a 5% significance level ($p<0.05$), and all analyses were performed using R version 4.2.2 (R Core Team, 2022).

Across both experiments, carvacrol consistently showed the highest herbicidal activity. At 3 DAA, this compound achieved 90% control in experiment 1 and 93% in experiment 2, outperforming all other treatments (Table 1). Furthermore, carvacrol resulted in the lowest weed density and the lowest fresh and dry biomass at 15 DAA. These results corroborate previous studies in which the substance caused rapid phytotoxicity and growth inhibition in several weed species (Hazrati et al., 2017). The mechanism of action for carvacrol is associated with the disruption of cellular membranes and interference with microtubule function (Chaimovitsh et al., 2017). It also induces genotoxic effects, such as chromosomal abnormalities in *Lactuca sativa* L. (Pinheiro et al., 2015) and DNA damage in sorghum [*Sorghum bicolor* (L.) Moench] (Alves et al., 2018), which likely contribute to its herbicidal activity.

Thymol and eugenol also produced phytotoxic responses, albeit at lower intensities than carvacrol. At 3 DAA, thymol showed 57% control in experiment 1 and 71% in experiment 2. Eugenol offered weaker suppression, with control ranging from 24 to 58% depending on the experiment. In contrast, *trans*-anethole and cinnamaldehyde showed minimal


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herbicidal action across both experiments. Not only cinnamaldehyde has recognized antimicrobial and acaricidal properties (Muñoz et al., 2020), but Saad et al. (2019) also reported herbicidal effects, such as its ability to suppress *Echinochloa crus-galli* (L.) P.Beauv. fresh biomass. However, the current results indicate low potential for post-emergence weed control at the tested concentration.

Species-specific evaluations revealed that carvacrol was highly effective against *C. benghalensis* and *Amaranthus* spp., achieving nearly 100% control in both experiments. This result aligns with Muñoz et al. (2020), who reported complete mortality of *Amaranthus retroflexus* within 1 day of exposure to carvacrol at concentrations of 8–32%. *E. indica* was strongly controlled in experiment 1, and *M. maximus* and *A. tenella* were effectively controlled in experiment 2. However, no natural compounds successfully controlled *Cyperus* spp., indicating a high tolerance of sedges to the tested compounds and concentrations.

Considering the total weed control percentages, thymol showed moderate activity. While it was efficient particularly against *Amaranthus* spp., *M. maximus*, and *A. tenella*, it did not match the broad-spectrum reliability of carvacrol. Eugenol was ineffective in experiment 1, but it suppressed *Amaranthus* spp. and *A. tenella* in experiment 2. This result is consistent with reports of its phytotoxicity on dicot weeds (Bainard et al., 2006).

Despite the growing interest in natural compounds with herbicidal activity, turning them into fully field-applicable technologies remains a substantial challenge due to limitations such as volatility, rapid degradation, low persistence, and the need for high rates. Consequently, further studies are essential to optimize formulations, elucidate mechanisms of action, and evaluate performance under different environmental

**Table 1.** Weed control percentages at 1, 3, and 15 days after treatment application, and weed density and fresh and dry matter per tray, and specific control percentages of *Commelina benghalensis*, *Eleusine indica*, *Amaranthus* spp., *Cyperus* spp., *Megathyrsus maximus*, and *Alternanthera tenella*[(1)].

| Treatments | Experiment 1 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | DDA1 | DDA3 | NWT | FM | DM | CCB | CEI | CA | CC |
| | (%) | | (weeds/tray) | (g) | | (%) | | | |
| Water/alcohol | 0.0d | 0.0e | 132.0a | 30.17ab | 13.59a | 0.0e | 0.0f | 0.0f | 0.0 |
| Carvacrol | 82.6a | 90.3a | 56.6c | 20.07c | 10.46b | 97.3a | 84.6a | 95.3a | 0.0 |
| Eugenol | 21.0c | 24.0c | 107.0b | 26.23bc | 12.09ab | 20.3b | 31.3c | 51.0c | 0.0 |
| Thymol | 50.0b | 57.0b | 65.3c | 29.88ab | 13.07a | 21.6b | 52.0b | 81.6b | 0.0 |
| *Trans*-anethole | 0.0d | 2.3d | 123.6ab | 29.78ab | 13.02a | 11.3c | 10.6d | 9.3d | 0.0 |
| Cinnamaldehyde | 0.0d | 2.3d | 117.6ab | 31.61ab | 13.20a | 4.3d | 4.6e | 5.3e | 0.0 |
| Control | 0.0d | 0.0e | 129.3ab | 34.14a | 13.65a | 0.0e | 0.0f | 0.0f | 0.0 |
| CV (%) | 2.5 | 2.0 | 13.6 | 13.5 | 8.8 | 3.6 | 1.9 | 1.4 | - |
| Treatments | Experiment 2 | | | | | | | | |
| | DDA1 | DDA3 | DDA15 | FM | DM | CCB | CMM | CA | CAT |
| | (%) | | | (g) | | (%) | | | |
| Water/alcohol | 0.0e | 0.0e | 0.0e | 168.0a | 18.2a | 0.0f | 0.0f | 0.0e | 0.0e |
| Carvacrol | 83.3a | 93.3a | 94.3a | 62.9d | 2.9c | 98.0a | 97.6a | 98.6a | 92.0a |
| Eugenol | 57.0c | 58.0c | 61.0c | 119.0c | 9.1b | 22.0c | 66.3c | 82.0b | 81.3c |
| Thymol | 70.0b | 71.3b | 72.3b | 73.1d | 4.8c | 72.0b | 87.3b | 99.3a | 85.6b |
| *Trans*-anethole | 30.0d | 32.6d | 33.6d | 128.3bc | 10.0b | 9.0d | 10.3d | 20.0c | 69.3d |
| Cinnamaldehyde | 31.0d | 32.3d | 34.0d | 134.0abc | 9.7b | 3.6e | 6.0e | 14.0d | 71.0d |
| Control | 0.0e | 0.0e | 0.0e | 162.1ab | 16.9a | 0.0f | 0.0f | 0.0e | 0.0e |
| CV (%) | 3.1 | 2.8 | 3.4 | 16.4 | 21.9 | 2.1 | 2.4 | 1.4 | 1.8 |

[(1)]Means followed by different letters indicate statistically significant differences among treatments according to the Least Significant Difference test for post hoc multiple comparisons, at 5% probability. DDA1, 1 day after treatment application; DDA3, 3 days after treatment application; DDA15, 15 days after treatment application; NWT, weed density; FM, fresh matter; DM, dry matter; CCB, *Commelina benghalensis*; CEI, *Eleusine indica*; CA, *Amaranthus* spp.; CC, *Cyperus* spp.; CV, coefficient of variation; CMM, *Megathyrsus maximus*; and CAT, *Alternanthera tenella*.


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conditions, in order to ensure agronomic efficiency and safety prior to large-scale adoption.

The findings indicate that natural compounds provide control of weed species in the following decreasing order of effectiveness: carvacrol, thymol, eugenol, *trans*-anethole, and cinnamaldehyde. Specifically, carvacrol effectively controlled *C. benghalensis*, *E. indica*, *Amaranthus* spp., *M. maximus*, and *A. tenella*. Thymol showed efficiency against *Amaranthus* spp., *M. maximus*, and *A. tenella*, while eugenol showed moderate control of *Amaranthus* spp. and *A. tenella*. Neither *trans*-anethole nor cinnamaldehyde achieved satisfactory control of any weed species. Notably, *Cyperus* spp. was not controlled by any of the natural compounds tested.

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**Alexandre Magno Brighenti**: project administration, conceptualization, data curation, investigation, methodology; **Alexander Machado Auad**: investigation, conceptualization, methodology, funding acquisition; **Luís Augusto Calsavara**: data curation, formal analysis.

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Data in article: research data are available in the published article.

## Declaration of use of AI technologies

No generative artificial intelligence (AI) was used in this study.

## Conflict of interest statement

The authors declare no conflicts of interest.

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