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Tolerance of peppermint to tiafenacil applied postharvest

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Research Article

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Nomenclature:
tiafenacil; peppermint; *Mentha* ×*piperita* L. (pro sp.) [*aquatica* × *spicata*] 'Redefined Murray Mitchem'

Keywords:
Dose response; herbicide tolerance; injury

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Abstract

Trials were conducted in two experimental runs at the Purdue University Horticulture Greenhouses, West Lafayette, IN, to determine 'Redefined Murray Mitcham' peppermint tolerance to tiafenacil. Established peppermint in 20-cm-diameter polyethylene pots was subjected to a simulated harvest by removing aboveground biomass at the substrate surface; then, tiafenacil was applied at 0, 25, 50, 100, and 200 g ai ha^{-1}. Visible crop injury, height, and aboveground dry biomass data were subjected to regression analysis to generate predictive models. At 2 wk after treatment (WAT), peppermint injury increased from 63% to 86% and from 25% to 76% in Experimental Run 1 and 2, respectively, as tiafenacil rate increased from 25 to 200 g ha^{-1}. At 4 WAT, injury increased from 0% to 63% and from 4% to 37% in Experimental Run 1 and 2, respectively, as tiafenacil rate increased from 25 to 200 g ha^{-1}. By 7 WAT (both experimental runs), injury increased from 0% to 17% as tiafenacil rate increased from 25 to 200 g ha^{-1}. At 4 WAT, height decreased from 23.0 to 8.6 cm and from 17.6 to 10.3 cm in Experimental Run 1 and 2, respectively, as tiafenacil rate increased from 0 to 200 g ha^{-1}. At 7 WAT, height decreased from 28.1 to 21.4 cm as tiafenacil rate increased from 0 to 200 g ha^{-1}. Aboveground dry weight of the nontreated check was 20.3 g pot^{-1} and decreased from 19.3 to 7.0 g pot^{-1} as tiafenacil rate increased from 25 to 200 g ha^{-1}. Despite acute necrosis, injury from tiafenacil at lower rates was not persistent. The proposed 1X rate of tiafenacil for peppermint, 25 g ha^{-1}, resulted in ≤4% injury 4 and 7 WAT and in only a 3% reduction in plant height and a 4.7% reduction in aboveground dry weight compared to the nontreated check.

Introduction

Peppermint production in the United States is concentrated in the Pacific Northwest and within the Midwest in the states of Indiana, Wisconsin, and Michigan. In 2020, 19,830 ha of peppermint production in the United States yielded 2.26 million kg of oil with a value of US$94.4 million (USDA-NASS 2021). The same year, Indiana producers harvested 2,270 ha of peppermint (USDA-NASS 2021). In the Midwest, peppermint is grown as a short-term perennial in rotation with traditional field crops. The aboveground portion (mint hay) is harvested once or twice in the summer months. After mint is cut, it is allowed to dry in the field for 24 to 36 h and is then steam-distilled to extract mint oil. Weed interference can result in reduced yield of mint hay, oil, or both. Yield loss ranges from 40% to 80% in high infestations of broadleaf and grass weeds, respectively (Weller et al. 2000). Additionally, weeds can contaminate the mint hay and oil, imparting off-flavors and greatly reducing the quality and value of the oil.

Winter annual weeds are managed either by field cultivation with a tractor and disk or with burndown herbicides applied prior to mint breaking dormancy. Historically, burndown applications included paraquat, often combined with a preemergence herbicide. A postemergence herbicide application may also be made to small weeds after peppermint has broken dormancy in the spring. Following harvest, weeds must be managed to ensure proper regrowth of peppermint for a second harvest or to increase crop stand for the following season. Kothari et al. (1991) reported that the postharvest critical weed-free period in Japanese mint (*Mentha arvensis* L.) production was 15 to 45 d. However, the two broad-spectrum postemergence contact herbicides registered in mint (carfentrazone-ethyl and paraquat) are restricted to applications made to dormant mint and are not registered for use on actively growing mint (Anonymous 2016; Anonymous 2019).

Recently, herbicides containing the newly released active ingredient tiafenacil have become commercially available. Tiafenacil is a protoporphyrinogen oxidase (PPO) inhibitor (Group 14) currently registered for burndown use in soybean [*Glycine max* (L.) Merr.], corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), wheat (*Triticum aestivum* L.), and grape (*Vitis* spp.), as well as in fallow and noncrop areas (Anonymous 2020a; Anonymous 2020b). Peer-reviewed research regarding the spectrum of weed control provided by tiafenacil is limited. However the product label states that tiafenacil used alone can provide control of many troublesome summer annual broadleaf weeds commonly found in Indiana mint fields: common lambsquarters (*Chenopodium album* L.), common ragweed (*Ambrosia artemisiifolia* L.), giant ragweed (*Ambrosia trifida* L.), velvetleaf (*Abutilon theophrasti* Medik.), and waterhemp [*Amaranthus tuberculatus* (Moq.) Sauer] (Anonymous 2020b). Park et al. (2018) reported that the tiafenacil half-maximal inhibitory concentration (IC_{50}) for PPO enzymes in waterhemp was like those for butafenacil, saflufenacil, and flumioxazin. Pigweed species are found in all Indiana peppermint fields and are historically the most difficult weeds to control (Weller et al. 2000). This research aimed to determine the tolerance of peppermint to a simulated postharvest application of tiafenacil.

Materials and Methods

Greenhouse experiments were conducted in two separate experimental runs at the Purdue University Horticulture Greenhouses, West Lafayette, IN (40.4208°N, 86.9147°W), using 'Redefined Murray Mitcham' peppermint. The source material consisted of whole plants harvested from a commercial production field in Rensselaer, IN (40.9988°N, 87.2378°W), on December 6, 2019. The plant material was placed into 19-L polyethylene buckets with field soil and stored at 4 C until the initiation of the trial. The experimental unit consisted of a single 20-cm-diameter polyethylene pot. A coffee filter was placed into the bottom of the pot, which was subsequently filled with a 1:1 (v/v) mix of potting soil (Metro-Mix 510, Sungro Horticulture, Agawam, MA, USA) and sand. The resultant substrate had pH 7.2, 5.8% organic matter, and sandy texture. For Experimental Run 1, two rhizomes, each 10 to 15 cm, were placed into each pot and buried approximately 2 cm deep on January 21, 2020. At the same time, stock plants were created in the same manner for future propagation. For Experimental Run 2, four mint shoot tip cuttings were removed from stock plants and stuck into the same substrate used in Experimental Run 1 on June 3, 2020. Aboveground biomass of mint plants in Experimental Runs 1 and 2 was hand-cut on June 10 and August 11, respectively, at the substrate surface to simulate a harvest operation. On the same day, tiafenacil treatments were applied.

Five rates of tiafenacil (0, 25, 50, 100, and 200 g ai ha^{-1}) (DCC-3825, 30% SC, ISK Biosciences, Concord, OH, USA) plus 0.25% (v/v) nonionic surfactant (Hum-AC 820, Drexel Chemical, Memphis, TN, USA) were applied using a CO_2-pressurized spray booth (Generation III track sprayer, DeVries Manufacturing, Hollandale, MN, USA) fitted with a single TeeJet® 8002 EVS nozzle tip (Spraying Systems, Wheaton, IL, USA) calibrated to deliver 187 L ha^{-1} at 207 kPa. After herbicide application, all pots were returned to the greenhouse and not irrigated for at least 24 h. For the duration of the study, pots were watered as needed to maintain even soil moisture, but not with sufficient volume to result in excessive leaching from the pot. The experiment design was a randomized complete block with four replications.

Data collection consisted of visual crop injury ratings on a scale of 0% (no injury) to 100% (crop death) 2, 4, and 7 wk after treatment (WAT). At 4 and 7 WAT, height data were collected by measuring the tallest shoot in each pot from the substrate surface to the shoot apical meristem. Mint was harvested 7 WAT by cutting aboveground biomass with a hand pruner at the substrate surface. Fresh weight was recorded, then samples were oven-dried at 65 C for 3 d to determine dry weight.

Data were subjected to analysis of variance (ANOVA) by SAS PROC GLM (SAS 9.4, SAS Institute, Cary, NC, USA) with the fixed effect of tiafenacil rate and random effects of experimental run and replication within experimental run to test for experimental run × tiafenacil rate interaction for all data. When no significant ($P \leq 0.05$) interaction existed, mean data from both experimental runs were subjected to regression analysis by JMP (JMP Pro 14, SAS Institute) using the nonlinear curve-fitting function to compare potential polynomial, exponential, and logarithmic models. When an experimental run × tiafenacil rate interaction was significant, data were subjected to the same curve-fitting procedure separately by experimental run. To be a good fit, each parameter estimate of the model had to be significant ($P \leq 0.05$), and the model had to be biologically meaningful. Data were fit to the following models:

Linear Equation:

$$Y = A + BX \quad [1]$$

where Y is the predicted value, A is the y intercept, B is the slope of the line, and X is tiafenacil rate in g ha^{-1};

Three-Parameter Exponential Equation:

$$Y = A + B[Exp(CX)] \quad [2]$$

where Y is the predicted value, A is the upper limit, B is the scale, C is the growth rate, and X is tiafenacil rate in g ha^{-1};

Three-Parameter Logistic Equation:

$$Y = C/\{1 + Exp[-A(X - B)]\} \quad [3]$$

where Y is the predicted value, A is the growth rate, B is the inflection point, C is the upper limit, and X is tiafenacil rate in g ha^{-1}.

Results and Discussion

Owing to significant experimental run × treatment interactions, data for injury at 2 WAT ($P < 0.0001$) and 4 WAT ($P = 0.0003$) and plant height 4 WAT ($P = 0.0066$) were analyzed separately by experimental run. Data were pooled across experimental runs for injury and plant height at 7 WAT and plant dry weight. Injury symptoms from tiafenacil exposure included acute necrosis followed by stunting. Visual crop injury data 2 WAT fit a three-parameter exponential regression model; injury data 4 and 7 WAT fit a three-parameter logistic regression model (Figure 1). At 2 WAT, predicted peppermint injury increased from 63% to 86% and from 25% to 76% in Experimental Run 1 and 2, respectively, as tiafenacil rate increased from 25 to 200 g ha^{-1} (Figure 1 A). Predicted injury in both experimental runs decreased between 2 and 4 WAT. At 4 WAT, predicted injury increased from 0% to 63% and from 4% to 37% in Experimental Run 1 and 2, respectively, as tiafenacil rate increased from 25 to 200 g ha^{-1} (Figure 1 B). By 7 WAT, injury pooled across both experimental runs increased from 0% to 17% as tiafenacil rate increased from 25 to 200 g ha^{-1} (Figure 1 C). Walsh and Baker (2020) applied tiafenacil postharvest at a rate of 75 g ha^{-1} to a commercial peppermint field and reported 57% and 32% crop injury at 20 and 25 d after treatment (DAT), respectively. In the present study, predicted visual crop injury at 75 g ha^{-1} was 55% and 84% 2 WAT, 11% and 20% 4 WAT, and 1% 7 WAT. Although the observation

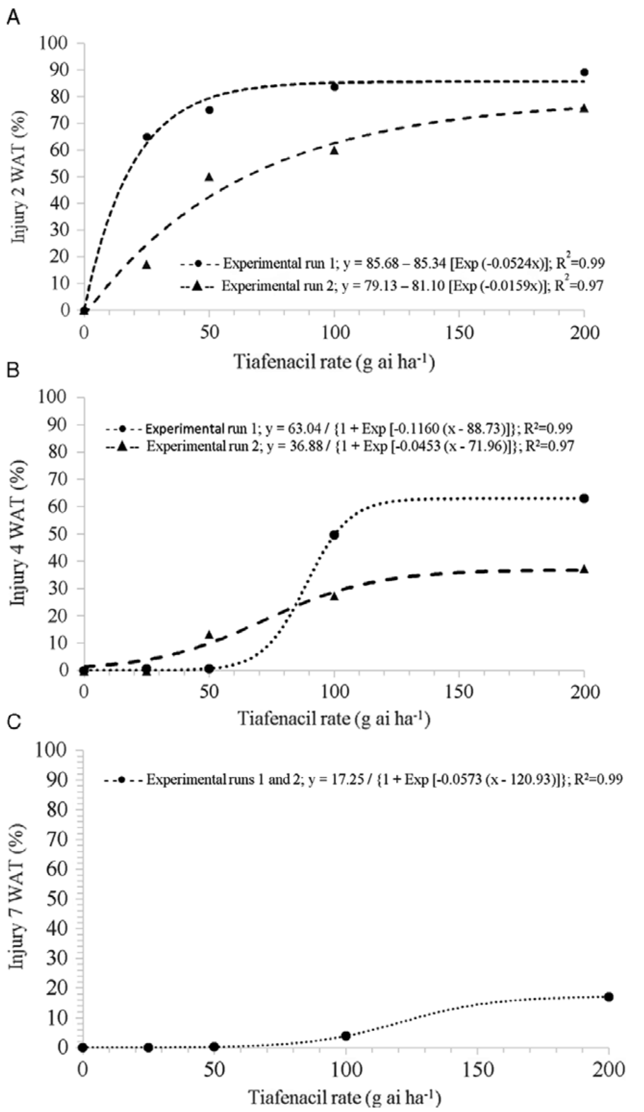

Figure 1. Peppermint injury 2 wk (A), 4 wk (B), and 7 wk (C) after application of tiafenacil at the Horticulture Greenhouse, West Lafayette, IN, in 2020. Points represent observed mean data. Lines represent the predicted peppermint injury based on three-parameter exponential (Equation 2) or three-parameter logistic (Equation 3) models.

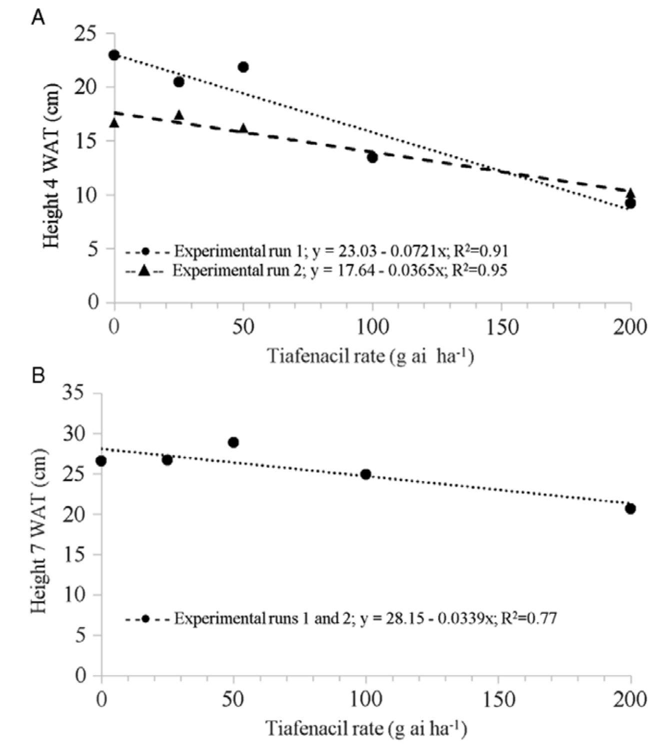

Figure 2. Peppermint plant height 4 wk (A) and 7 wk (B) after application of tiafenacil at the Horticulture Greenhouse, West Lafayette, IN, in 2020. Points represent observed mean data. Lines represent the predicted peppermint height based on a linear regression model (Equation 1).

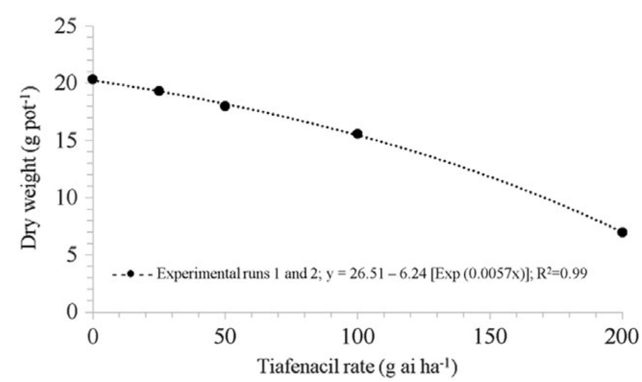

Figure 3. Peppermint shoot dry weight 7 wk after application of tiafenacil at the Horticulture Greenhouse, West Lafayette, IN, in 2020. Points represent observed mean data. Lines represent the predicted peppermint shoot dry weight based on a three-parameter exponential model (Equation 2).

timings, injury ratings, and growing environments vary between the two studies, the findings of Walsh and Baker (2020) concur with those of the present study in that peppermint quickly recovered from tiafenacil at 75 g ha^{-1}.

Peppermint plant height displayed a negative linear response to tiafenacil rate (Figure 2). At 4 WAT, predicted height decreased from 23.0 to 8.6 cm and from 17.6 to 10.3 cm in Experimental Run 1 and 2, respectively, as tiafenacil rate increased from 0 to 200 g ha^{-1} (Figure 2 A). At 7 WAT, height decreased from 28.1 to 21.4 cm as tiafenacil rate increased from 0 to 200 g ha^{-1} (Figure 2 B). Walsh and Baker (2020) discovered that 75 g ha^{-1} tiafenacil applied postharvest to peppermint resulted in a 25.7% and 15.5% reduction in plant height compared to a nontreated check 25 and 38 DAT, respectively. The present study's predicted plant height reduction at 75 g ha^{-1} tiafenacil is 23.5% (Experimental Run 1) and 15.5% (Experimental Run 2) at 4 WAT and 9.0% at 7 WAT. As with visual crop injury, in both the present study and that of Walsh and Baker (2020), the reduction in plant height relative to a nontreated check decreased with time. Peppermint dry weight fit a three-parameter exponential regression model (Figure 3). Predicted aboveground dry weight of the nontreated check was 20.3 g pot^{-1} and decreased from 19.3 to 7.0 g pot^{-1} as tiafenacil rate increased from 25 to 200 g ha^{-1}.

Despite acute necrosis, injury from tiafenacil at lower rates was not persistent. The proposed 1X rate of tiafenacil for peppermint, 25 g ha^{-1}, resulted in ≤4% crop injury at 4 and 7 WAT and in only a 3% reduction in plant height and a 4.7% reduction in aboveground dry weight compared to the nontreated check. At 7 WAT, the 2X rate resulted in <1% visible injury and in a 6% and 10% reduction in plant height and dry weight, respectively, compared to the nontreated check. On the basis of these preliminary greenhouse results, field trials with postharvest application of tiafenacil should be conducted to confirm these findings. Additional research should be conducted to determine the optimal timing of tiafenacil application to maximize weed control and minimized mint injury.

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References

Anonymous (2016) Aim® EC herbicide label. Philadelphia, PA: FMC Corp. 20 p

Anonymous (2019) Gramoxone® SL 2.0 label. Greensboro, NC: Syngenta Crop Protection. 55 p

Anonymous (2020a) Gamma® herbicide label. Tampa, FL: Helm Agro US. 10 p

Anonymous (2020b) Reviton® herbicide label. Tampa, FL: Helm Agro US. 11 p

Kothari SK, Singh DV, Singh K (1991) Critical periods of weed interference in Japanese mint (*Mentha arvensis* L.). Int J Pest Manag 37:85–90

Park J, Ahn YO, Nam JW, Hong MK, Song N, Kim T, Yu GH, Sung SK (2018) Biochemical and physiological mode of action of tiafenacil, a new protoporphyrinogen IX oxidase-inhibiting herbicide. Pestic Biochem Physiol 152:38–44

[USDA-NASS] U.S. Department of Agriculture–National Agriculture Statistics Service (2021) Quick stats. https://quickstats.nass.usda.gov/results/D9C05018-B9D8-3906-B630-9C077F73547B. Accessed: October 13, 2021

Walsh D, Baker R (2020) Washington mint weed research report. Pages 18–31 *in* Washington Mint Growers 2020 Conference Proceedings. https://www.wamintgrowers.org/uploads/5/5/0/6/55065965/proceedings_book_-_final.pdf. Accessed: October 12, 2021

Weller S, Green R Jr, Janssen C, Whitford F (2000) Mint Production and Pest Management in Indiana. PPP-103. West Lafayette, IN: Purdue University Cooperative Extension Service. 13 p