CAN ESSENTIAL OILS BE USED TO CONTROL THE GRAY FIELD SLUG?

M.L. Klein, T.G. Chastain, C.J Garbacik, and R.J. McDonnell

Introduction

To date, minimal effort has been made to develop novel molluscicides for use in seed and forage crops. Recently, however, a diverse group of plant distillates, known as essential oils, have been identified as potential candidates. The increased interest in essential oils has been driven by their classification as "generally regarded as safe" by the Food and Drug Administration and by their exemption from pesticide registration and residue tolerance requirements under Sect. 25(b) of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (Isman, 2000). The interest in essential oils is widespread, and they have been proven effective against various pests, including insects, mites, fungi, and nematodes (Isman, 2000).

Although assessments have been made on several species of marine and aquatic mollusks (Lahlou and Berrada, 2001; EL-Kamali et al., 2010), to our knowledge there are no published studies of essential oil toxicity on terrestrial slugs and only one published study on their toxicity on terrestrial snails (McDonnell et al., 2016).

The present study was undertaken because essential oils were deemed likely to be lethal to the pest slug *Deroceras reticulatum* (gray field slug) at concentrations unlikely to be phytotoxic to commercial crops. Here we present data on the toxicity of 13 essential oils and one other plant-derived toxin (caffeine) on adults of *D. reticulatum* (Table 1).

Materials and Methods

Determination of LC50 and LC99 values

In this experiment, slugs were exposed to essential oil treatments for 24 hours in ventilated petri dishes. Each petri dish contained a single 9-cm filter paper wetted with 1 ml of either an essential oil solution (essential oil, water, and Tween 80 surfactant), Slug-Fest All Weather Formula (industry standard), water (control), or Tween 80 solution (water and surfactant).

Table 1. Source and cost of essential oils and caffeine used in bioassays.

Essential oil	Cost[1]	Source
	($/liter)	
Birch tar	287.21	*Betula alba*, unspecified location
Bitter orange	41.45	*Citrus bigaradia*, *C. amara* from Brazil, Paraguay (cultivated)
Caffeine	381.59[2]	Thermo Fisher Scientific, Waltham, Massachusetts, USA
Cedarwood	17.89	*Juniperus virginiana* from USA (wildcrafted)
Cinnamon	36.42	*Cinnamomum cassia* from China (wildcrafted)
Clove bud	55.47	*Eugenia caryophylatta* from Madagascar (cultivated)
Eucalyptus	11.93	*Eucalyptus globulous* from China (wildcrafted)
Garlic	42.56	*Allium sativum* from USA, Mexico, Egypt (cultivated)
Lemongrass	16.31	*Cymbopogon citratus* from Guatemala, India (wildcrafted)
Peppermint	44.62	*Mentha piperita* from USA (cultivated)
Pine	20.08	*Pinus strobu*s from USA (wildcrafted)
Rosemary	44.09	*Rosmarinus officinalis* from Tunisia, Morocco (wildcrafted)
Spearmint	33.91	*Mentha spicata* from USA (cultivated)
Thyme	82.93	*Thymus vulgaris* from Spain (wildcrafted)

[1]Per-liter cost was calculated based on the maximum volume available (2 oz birch tar, 400 oz all other oils) and dry mass (2.5 kg) for caffeine.
[2]$/kg

Slugs were placed on the filter papers in these petri dishes, exposing them to the essential oil solution. After 24 hours, petri dishes were opened, and slug mortality was assessed. Tests were conducted at several concentrations (0.1, 0.2, 0.25, 0.5, and 1%) to calculate the Lethal Concentration 50 (LC50) and Lethal Concentration 99 (LC99) of each oil. These values denote the concentrations at which 50 and 99% of slugs died, respectively. Thirty slugs were tested at each concentration for each oil, allowing for adequate statistical power.

Efficacy of thyme and spearmint oil foliar sprays in greenhouse microcosms

The two most toxic essential oil treatments from the petri dish bioassay (thyme and spearmint oil) were tested in a greenhouse setting on slugs added to plastic containers (47 cm x 37.8 cm x 28.3 cm) planted with annual ryegrass (variety 'Bounty'). Slugs were added to microcosms when seedlings were in the second-leaf stage, which occurred after approximately 1 month of growth in the greenhouse (October 29 to November 28, 2018). Ten adults were placed in each container, and 60 ml of either thyme, spearmint, Slug-Fest, water, or Tween 80 was applied by handheld spray bottle to the potting media and plant surfaces. This volume is equivalent to the field rate for Slug-Fest (1 oz/gal/100 ft^2) and was chosen to standardize volumes across treatments. Thyme and spearmint oil were applied at 0.5% (approximately double the LC99), and Tween 80 was applied at 1%. Eight randomized blocks were used, resulting in 80 slugs per treatment.

Phytotoxicity assessment of essential oils in perennial ryegrass and tall fescue

The phytotoxic effects of thyme and spearmint oil at 0.25% and 0.5% were determined on two cultivars of perennial ryegrass ('Banfield' and 'APR2190') and two cultivars of tall fescue ('Spyder' and 'Dynamite') grown in the greenhouse. In this trial, seedlings were sprayed with 5 ml, and adult plants with 25 ml, of either thyme, spearmint, Tween 80, or water and were assessed for phytotoxicity symptoms at 3 and 17 days after treatment (DAT). Visual indications of phytotoxicity included necrotic spots, lesions, wilting, and other visible changes in plant morphology. A Minolta chlorophyll meter was used to quantify chlorophyll content, and shoot biomass was also measured by harvesting plants at soil level, drying for 24 hours at 60°C, and then weighing to determine biomass. Growth rate of seedlings was calculated based on the change in shoot biomass during each time interval.

Results and Discussion

Determination of LC50 and LC99 values

After *D. reticulatum* adults were exposed to oils at 1% concentration, birch tar, bitter orange, cedarwood, clove bud, and eucalyptus were all found to be less than 100% lethal and were therefore not subjected to further analysis. Thyme, spearmint, pine, peppermint, garlic, caffeine, rosemary, lemongrass, and cinnamon were all 100% lethal at 1%; therefore, their toxicities were determined using logit analysis. Thyme oil (LC50: 0.148%) was most toxic, followed by spearmint (LC50: 0.153%) and pine (LC50: 0.176%). Thyme, spearmint, and pine oil caused 99% mortality at 0.26, 0.302, and 0.253% respectively. While not statistically more lethal than peppermint or garlic, they were more lethal than all other treatments (Table 2).

Efficacy of thyme and spearmint oil foliar sprays in greenhouse microcosms

Eighty *D. reticulatum* adults were exposed to each treatment with thyme and spearmint (the two most toxic essential oils), Slug-Fest, water, and Tween 80. Slug-Fest was found to be 100% lethal, while spearmint and thyme were both found to be 97.5 % lethal, with only two slugs out of 80 surviving in each treatment. A single slug was missing from the Tween 80 treatment, while all other slugs in Tween 80 and all slugs in water controls were alive, indicating that any dead slugs were almost certainly dying due to the treatments, not other environmental conditions.

Phytotoxicity assessment of essential oils in perennial ryegrass and tall fescue

There were no significant differences among seedlings or adult plants for visual signs of phytotoxicity at both 3 and 17 DAT. However, at 17 DAT, spearmint oil at 0.5% showed a low incidence of visual symptoms in several cultivars. Two 'Spyder' seedlings appeared to have yellow spotted leaves, as well as one 'Banfield' and one 'APR2190'. A 'Spyder' seedling treated with Tween 80 control solution was also found to have yellow spots, indicating that the symptoms may not have been due to the essential oil treatment. These plants recovered, and there was no noticeable effect on overall growth or biomass. Variance among cultivars was observed, but the essential oils produced no quantifiable effect on biomass, growth rate, or chlorophyll content, and the observed degree of variation appeared normal.

Table 2. LC50, LC99, and corresponding 95% confidence intervals for thyme, spearmint, pine, peppermint, garlic, caffeine, rosemary, lemongrass, and cinnamon oils tested on *D. reticulatum* adults.[1]

Oil	N	LC50	95% CI[2]	LC99	95% CI[2]
		(%)		(%)	
Thyme[3]	150	0.148 a	0.111–0.185	0.260 a	0.160–0.360
Spearmint[3]	150	0.153 a	0.113–0.193	0.302 a,b	0.191–0.413
Pine	150	0.176 a	0.147–0.205	0.253 a	0.186–0.320
Peppermint	120	0.199 a,b	0.167–0.231	0.344 a,b	0.241–0.447
Garlic	150	0.204 a,b	0.175–0.233	0.329 a,b	0.237–0.421
Caffeine	144	0.264 b	0.223–0.305	0.535 b,c	0.410–0.660
Rosemary	120	0.307 b	0.244–0.370	0.554 b,c,d	0.384–0.724
Lemongrass	150	0.320 b	0.261–0.379	0.720 d,e	0.561–0.879
Cinnamon	150	0.420 c	0.396–0.444	0.799 e	0.728–0.870

[1]Values with the same letters indicate no statistically significant differences, as determined by comparing the confidence intervals of each oil. Significant differences exist when there is no overlap between confidence intervals.
[2]CI = confidence interval
[3]LC99 values for thyme and spearmint were used in the greenhouse microcosm and phytotoxicity bioassays.

Conclusion

With limited options for controlling slugs in the Willamette Valley, the development of a new molluscicide would represent a significant achievement. Thyme and spearmint solutions appear highly lethal under lab and greenhouse conditions and may prove effective under field conditions. However, these potential new molluscicides must also be cost-effective if they are to be adopted on a wide scale.

The thyme oil used in our bioassays costs $82.93 per liter (based on the maximum bulk volume available for purchase at The Essential Oil Company, http://www.essentialoil.com/), whereas the industry standard liquid metaldehyde (Slug-Fest All Weather Formula) costs $15.26 per liter (Nutrien Ag Solutions, https://www.nutrienagsolutions.com/). Based on recommended application rates for grass seed production (10 oz metaldehyde in 10 gal water/1,000 ft^2), treating an acre with Slug-Fest would cost approximately $196, while treating an acre with 0.5% thyme solution would cost approximately $682. However, spearmint oil, comparably toxic to thyme, costs only $33.91 per liter, which at 0.5% equates to $279 per acre, a more competitive price.

Although more expensive, thyme and spearmint oil have a number of advantages over metaldehyde. For example, metaldehyde has often been shown to only inhibit feeding (Glen and Orsman, 1986), whereas thyme and spearmint oil applications caused rapid mortality (in less than 24 hours). Additionally, *D. reticulatum* are known to exhibit modified behavior in the presence of metaldehyde baits, with overexposure causing slugs to avoid contact with bait pellets. It remains unclear whether a similar behavior would emerge in response to an essential oil, but as evidenced by our greenhouse microcosm study, under relatively low concentrations, these oils can be highly lethal to slugs.

The U.S. Environmental Protection Agency has listed thyme and spearmint oil as exempt from pesticide registration and residue tolerance requirements under Sect. 25(b) of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). This exemption greatly reduces the potential costs and testing requirements of bringing an essential oil product to market. Also, since thyme oil is derived from a botanical source, it should be possible to use this product on certified organic operations, although care should be taken when applying to forage or other feed crops to minimize any unknown effects on livestock.

The results described here suggest that thyme and spearmint oils could be effective botanical pesticides for controlling *D. reticulatum* in ryegrass and tall fescue. Our investigation of these oils will continue with field trials in spring 2019, with the goal of confirming effectiveness and essential oils' utility in actual cropping systems.

References

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Acknowledgments

We are grateful to the Oregon Seed Council, who funded this research, and to Andrew Colton and Maria Cordoba, who helped collect slugs for use in the lab and greenhouse bioassays.