CLOVE BUD OIL AS A NOVEL MOLLUSCICIDAL DRENCH FOR POTTED PLANTS

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The horticultural trade is an important pathway for the introduction and spread of invasive gastropods (Cowie and Robinson 2003; Robinson 1999) because potted plants are essentially a portable microhabitat that protect snails and slugs, especially buried eggs and juveniles, from desiccation and molluscicides. The identification of an efficacious dip treatment would therefore be an important development in helping to manage this pathway. One such option is the use of essential oils, which have received a lot of research attention as novel pesticides over the past two decades (Batish et al. 2008) but their potential efficacy against terrestrial snail and slug pests has been largely overlooked.

In this study the molluscicidal potential of eleven essential oil emulsions (bitter orange, cedarwood, cinnamon, clove bud, eucalyptus, garlic, lemongrass, peppermint, pine, rosemary, spearmint) and one terpene (D-Limonene) were tested in laboratory and greenhouse trials as potential drench treatments for potted plants infested with the eggs and juveniles of the quarantine terrestrial snail pest, *Cornu aspersum* (=*Helix aspersa*). Clove bud oil (LC50: 0.027%) was most toxic (Table 1), followed by pine (LC50: 0.082%) and spearmint (LC50: 0.103%). In phytoxicity studies with *Hosta* 'Royal Standard' clove bud oil showed no apparent toxicity to the test plants at concentrations that caused 100% snail mortality.

Table 1. LC50, and corresponding 95% fiducial limits (FL) for the seven most toxic essential oil emulsions tested against *Cornu aspersum* (modified from Mc Donnell et al. 2016).

Oil	N	LC50 (%) [1]	95% FL (%)
Cinnamon	22	$0.157^{a,b,c,d}$	0.128 - 0.206
Clove bud	19	$0.027^{a,e,f,g,h,i,j}$	0.019 - 0.031
Garlic	23	$0.115^{e,k,l}$	0.067 - 0.158
Lemongrass	23	$0.160^{f,m,n,o}$	0.147 - 0.176
Peppermint	13	$0.140^{g,k,p,q,r}$	0.126 - 0.155
Pine	17	$0.082^{b,h,m,p,s,t}$	0.075 - 0.090
Spearmint	26	$0.103^{c,i,n,q,s,u}$	0.092 - 0.119

[1] Values with the same lowercase letters indicate statistically significant differences ($P<0.05$). These differences were determined by comparing the fiducial limits of each oil, i.e., statistically significant differences exist when there is no overlap between the fiducial limits.

The development of a biorational drench that is lethal to quarantine species such as *C aspersum* without damaging plants represents a significant advance in the development of novel tools for disinfesting potted plants. However, in order for a new molluscicide to be voluntarily adopted on a

wide scale it must be both lethal to the target pest and cost effective. Clove bud oil drenches are more expensive than current molluscicidal baits but have a number of distinct advantages. For example, some molluscicides often only inhibit feeding whereas clove bud oil drenches cause rapid mortality (< 24 h) of eggs and juveniles buried in soil and of juveniles on the soil surface. This is important from a quarantine perspective because the presence of a single living snail in a pot can be sufficient to cause rejection of an entire shipment. Furthermore, clove bud oil, like most essential oils, is pleasant smelling and non-toxic to humans. Thus the U.S. Environmental Protection has listed clove bud oil as exempt from pesticide registration requirements and pesticide residue tolerance requirements under section 25(b) of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Such an exemption would greatly reduce the cost and time required for bringing a new pesticide containing clove bud oil to market. Also, because clove bud oil is a nontoxic product from botanical sources, it should qualify to be used as an organic pest control tool.

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