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Repellence of plant essential oils to *Dermanyssus gallinae* and toxicity to the non-target invertebrate *Tenebrio molitor*

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ABSTRACT

With changes in legislation and consumer demand, alternatives to synthetic acaricides to manage the poultry red mite *Dermanyssus gallinae* (De Geer) in laying hen flocks are increasingly needed. These mites may cause losses in egg production, anaemia and even death of hens. It may be possible to use plant-derived products as *D. gallinae* repellents, especially if such products have a minimal impact on non-target organisms. An experiment was conducted with *D. gallinae* to assess the repellence of a range of plant essential oils, previously found to be of varying toxicity (relatively highly toxic to non-toxic) to this pest. Experiments were also undertaken to assess the toxicity of these products to mealworm beetles (*Tenebrio molitor* L.), a non-target invertebrate typical of poultry production systems. Results showed that all seven essential oils tested (manuka, thyme, palmarosa, caraway, spearmint, black pepper and juniper leaf) were repellent to *D. gallinae* at 0.14 mg oil/cm^3 (initial concentration) during the first 2 days of study. Thyme essential oil appeared to be the most effective, where repellence lasted until the end of the study period (13 days). At the same concentration toxicity to *T. molitor* differed, with essential oils of palmarosa and manuka being no more toxic to adult beetles than the control. There was neither a significant association between the rank toxicity and repellence of oils to *D. gallinae*, nor the toxicity of oils to *D. gallinae* (as previously determined) and *T. molitor*.

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1. Introduction

The poultry red mite, *Dermanyssus gallinae* (De Geer) is the most economically deleterious parasite of laying hens in Europe (Chauve, 1998) where control and production losses due to this pest have been estimated at €130 million per annum (van Emous, 2005). Feeding mites can cause feather pecking, irritation, restlessness and either mild or severe anaemia in hens, occasionally resulting in death (Kilpinen, 1999; Wojcik et al., 2000; Cosoroaba, 2001). Production is affected through reduced development rates of growing hens, reduced egg production and reduced egg quality (poor shell integrity and blood staining of the shell surface) (Urquhart et al., 1996; Chauve, 1998; Fiddes et al., 2005). *D. gallinae* are also a threat in the spread of disease, since they may act as vectors for a number of pathogenic poultry infections, both bacterial and viral (Chirico et al., 2003).

Control of *D. gallinae* has typically been achieved by the use of synthetic contact acaricides such as carbaryl, diazinon, dichlorvos and permethrin. However, the continued use of these products may be hampered by issues of mite resistance (Beugnet et al., 1997; Kim et al., 2004; Fiddes et al., 2005), chemical residues in food and undesirable environmental effects (Dalton and Mulcahy, 2001). With increasing *D. gallinae* resistance to synthetic

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Table 1
Nomenclature, origin and mean *D. gallinae* percentage mortality at 0.14 mg/cm^3 of selected essential oils used in repellence tests with *D. gallinae* and toxicity tests with *T. molitor*. All means are displayed with ±standard errors derived from original data. $n = 4$ for all means.

Essential oil	Latin name	Origin	*D. gallinae* mortality (%) at 0.14 mg/cm^3
Manuka	*Leptospermum scoparium* Forst.	New Zealand	100 ± 0.00
Thyme	*Thymus vulgaris* L.	France	100 ± 0.00
Palmarosa	*Cymbopogon martini* Roxb.	India	84.30 ± 3.67
Caraway	*Carum carvi* L.	France	52.86 ± 12.18
Spearmint	*Mentha spicata* L.	US	20.88 ± 7.81
Black pepper	*Piper nigrum* L.	India	4.75 ± 1.96
Juniper leaf	*Juniperus communis* L.	India	2.24 ± 4.30

acaricides and changes in legislation and production practises that will soon see a move away from conventional cages (in the EU at least), it is likely that in the future many more of the world's 2.8 billion laying hens (11.7% of which are located in the EU) (Axtell, 1999) will suffer as a result of *D. gallinae* infestation if alternatives to synthetic acaricides are not sought.

Several authors have investigated the use of plant-derived products in pest management with reviews already available both from an agricultural (Isman, 2000, 2006) and veterinary (George et al., 2008) perspective. Furthermore, both Kim et al. (2004, 2007) and George et al. (in press) have investigated the use of plant essential oils as acaricides for adult *D. gallinae* with promising results. Numerous essential oils, including cade, clove bud, lavender, pennyroyal, tea tree and thyme, were shown to be relatively highly toxic to *D. gallinae* in laboratory screening tests. Kim et al. (2004, 2007) also conducted experiments investigating the mode of toxicity of essential oils to *D. gallinae* and George et al. (in press) assessed the environmental stability of selected essential oils. Plant-derived products may also be of use as attractants (for attract-and-kill schemes and/or pest monitoring purposes) and/or repellents in pest control. For pests of veterinary importance, several such products have been identified as having pest-repellent properties. For example, the livestock Brown Ear tick, *Rhipicephalus appendiculatus* (Neuman) (a vector of East Coast fever) was repelled just as effectively by the essential oil of *Gynandropsis gyandra* (L.) (an African shrub) as by the commercial arthropod repellent DEET (N,N-diethyl-*m*-toluamide) (Lwande et al., 1999). Similarly, research has found diluted rhododendron oil to exhibit more than 95% repellency against *Ixodes ricinus* (L.), a tick of both medical and veterinary importance (Jaenson et al., 2005).

Thus it might be possible to develop plant essential oils as repellents for use in *D. gallinae* management, especially if these products can be shown to display minimal toxicity to non-target organisms. In the confines of a poultry unit there are likely to be only limited non-target organisms that could be considered as 'beneficial' and thus worthy of conserving when applying products to control *D. gallinae*. Such species could include the histerid beetle (*Carcinops pumilio*, Erichson) and several predatory mite species (Axtell, 1999). *Tenebrio molitor* (L.) also occurs frequently in poultry systems and though it may not be considered as beneficial as some other organisms, this beetle may nevertheless play a role in litter decomposition. Therefore, the aims of this study were to evaluate the repellent properties of plant-derived products to *D. gallinae*, and to assess the toxicity of these products to a non-target invertebrate typical of poultry production systems.

2. Methods

2.1. Selection of plant essential oils

From previous work (George et al., in press) the essential oils of manuka, thyme, palmarosa, caraway, spearmint, black pepper and juniper leaf (from a selection of 50 essential oils tested) were found to show a range of toxicities to *D. gallinae* at a concentration of 0.14 mg oil/cm^3 of Petri-dish volume. These seven essential oils were used in the current work and were obtained from New Directions (Southampton, UK). Details of these oils and their previously determined toxicities (George et al., in press) are provided in Table 1. All experiments were conducted at 22 °C, 16:8 L:D cycle in a controlled environment growth room at Newcastle University, UK.

2.2. Test organisms

D. gallinae were collected on a weekly basis from a commercial free-range poultry unit in Northumberland, UK and stored in sealed plastic bags in the growth room. Mites were used in tests within 6 days of collection.

T. molitor is one of several species of Coleoptera commonly associated with poultry production. *T. molitor* may play a role in waste decomposition and aeration of litter and was selected as a suitable non-target species for testing. Beetles were purchased as medium/large larvae from Blades Biological (Cowden, UK). These were then cultured on a diet of bran and potato slices under growth room conditions. Pupae were removed from this tank as they appeared and stored under the same conditions. Following eclosion, adult beetles were moved to 'ageing tanks' where they were cultured under the same conditions and on the same diet as larvae until 1–2 weeks old. At this stage adult beetles of both sexes were used in experiments.

2.3. Repellence to D. gallinae

Four Y-tube olfactometers were assembled. Air was pumped through each arm of the Y-tube of the olfactometer at a rate of 1 L/min. Air passed through a two stage filtration process prior to being humidified by bubbling through distilled water. The first filtration stage was achieved by passing the air through activated carbon and the second

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