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Toxicity of Plant Essential Oils and Their Spray Formulations against the Citrus Flatid Planthopper *Metcalfa pruinosa* Say (Hemiptera: Flatidae)

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Abstract The insecticidal activity of 124 plant essential oils and control efficacy of six experimental spray formulations (SF) containing 0.25, 0.5, 1, 2.5, 5, and 10% of the selected oils was examined against both nymph and adult of the citrus flatid planthopper, *Metcalfa pruinosa* using direct contact applications (leaf dipping and spray). Reponses varied according to dose (1,000 and 500 mg/L). When exposed at 1,000 mg/L for 24 h using leaf dipping assay, 19 essential oils showed strong mortality (100%) among 124 essential oils screened. At 500 mg/L, 100% mortality was observed in cinnamon technical, cinnamon green leaf, cinnamon #500, cassia tree, citronella java and pennyroyal followed by origanum, thyme white, grapefruit, savory, fennel sweet, aniseed and cinnamon bark showed considerable mortality (93.3-80%) against nymphs of *M. pruinosa*. The moderate mortality (73.3-60%) was found in thyme red, tagetes, calamus, lemoneucalptus and geranium. Oils applied as SF-10% sprays provided 100 % mortality against adult *M. pruinosa*. One hundred mortalities were achieved in cinnamon technical at >SF-0.5 formulation, in cinnamon #500, cinnamon green leaf and penny royal at >SF-2.5. To reduce the level of highly toxic synthetic insecticides in the agricultural environment, the active essential oils as potential larvicides could be provided as an alternative to control *M. pruinosa* populations.

Key words Citrus flatid planthopper, *Metcalfa pruinosa*, Plant essential oils, Botanical insecticide, Leaf dipping, Spray formulation

Introduction

The citrus flatid planthopper *Metcalfa pruinosa* (Hemiptera: Flatidae) (Say, 1830) is a North-American species that was accidentally introduced in Italy 1979 (Zangheri and Donadini, 1980). It belongs to family Flatidae which is one of the largest groups of Fulgoroidea (Hemiptera: Auchenorrhyncha), with 918 species known worldwide (Nault and Rodriguez, 1985).

The planthopper is polyphagous and feeds on a wide variety of plants throughout the Mediterranean, native and exotic particularly, such as citrus, grape vine, apple, pear, peach, and others (Mead, 1969; Pons *et al*., 2002; Souliotis *et al*., 2008). However, it prefers grapefruit to orange as host (Dean and Bailey, 1961). A large population of *M. pruinosa* is even able to destroy the host-plant, as it happened to an ornamental hedge of *Ligustrum amurense* Carr in the USA (Mead, 1969). Although infestations on some plants can be considerable, serious damage to plants is rare and restricted mainly to indirect damage via facilitation of colonization by sooty moulds, as a result of the deposition of honeydew on plants (Lauterer, 2002; Strauss, 2009). But heavy infestations of nymphs cause stunting of shoots, and particularly herbs can seriously be affected and wilt. In Italy, the quality of grapes (sugar content and acidity) was negatively affected through the sucking activity of the nymphs. Serious quantitative damage (30-40% crop loss) on soybean (*Glycine max* L.) was recorded by Ciampolini *et al*. (1987). In 2009, *M. pruinosa* was discovered at several locations in the southern to central regions of Korea. It occurred

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discontinuously but in epidemic numbers. A wide range of host plants were observed with varying degrees of damage. Compared to the collections made in 2009, a significantly larger population of *M. pruinosa* was found in 2010 (Kim *et al*., 2011).

Chemical control measure against dense nymph and adult populations might be justified on valuable trees. But for chemical control, timing is of the utmost importance, and at the very first signs of infestation, malathion, acephate, fenitrothion or pyrethroids should be applied at the edges of the fields (Ciampolini *et al*., 1987). Increasing public concerns on the environmental effects of insecticides, groundwater contamination, human health, insecticidal residues on host plant, and undesirable effects on non-target organisms intensifies when continued or repeated applications of conventional insecticides become necessary.

Plant derived bio-insecticides have been suggested as potential alternatives because of their potential source of bioactive chemicals as relatively safe and pose less risk to the environment, with minimal impacts to human health (Isman, 2000; Ahn, 2006; Isman, 2006). They often act at multiple and novel target sites (Kostyukovsky *et al*., 2002; Priestley *et al*., 2003; Isman, 2006). Much effort has been focused on them as potential sources of commercial insecticides, in part, because certain essential oil preparations meet the criteria of reduced risk insecticides (Isman, 2008). However, no information is available concerning the potential use of plant essential oils for the control of *M. pruinosa*, although insecticidal activity of plant essential oils has been well described by Isman (2000, 2006).

In the present study, toxicity of 124 plant essential oils against nymphs of *M. pruinosa* was evaluated using leaf dipping assay (Kim *et al*., 2002). In addition the efficacy of six experimental spray formulations containing 0.25, 0.5, 1, 2.5, 5, and 10% of the selected active oils was evaluated against adults of *M. pruinosa* using the spray bioassay to determine the most effective formulations of oils.

Materials and Methods

Chemicals

The 124 essential oils were purchased from UNIQ F&F Co. (Seoul, Korea) (Table 1). Polyoxyethylene + polyoxy-propylene (9:1) styrenated phenyl ether (Koremul-SP-1008R), a surfactant, was provided from Hannong Chemical (Anyang, Gyeonggi province, Korea). All of the other chemicals were analytical grade and available commercially.

Insects

Adult and immature citrus flatid planthopper were collected from seriously damaged host plants at Cheongwon, Gimhae, Incheon, and Iksan in Korea from May to September 2013. The collected insects were immediately transported to an insect rearing room (Rural Development Administration, Suwon) and transferred to acrylic emergence cages (40 × 40 × 40 cm) containing leaf of the rose of Sharon *Hibisscus syriacus*. Species identification of adult citrus flatid planthopper was followed Kim *et al*. (2011). Insects were kept on cages at 25 ± 1ºC and 60-70% relative humidity under a 16:8 h light:dark cycle for further bioassays.

Experimental spray formulations

Six experimental spray formulations containing active oils in 5 mL glass container with a Homewell polypropylene pump spray nozzle (5 mL, 1.7 × 8.4 cm, Seoul) were prepared to determine the effective test products (Table 2). Single spray applications of 0.25, 0.5, 1, 2.5, 5, and 10% concentrations of the oil preparations delivered ca 0.87, 1.74, 3.49, 8.72, 17.44, and 34.88 μg/cm^3 of total material to a 6.5 × 6.5 × 9.5 cm acrylic emergence cages, respectively.

Bioassay

Toxicity of the test essential oils to nymphs of *M. pruinosa* was evaluated by leaf-dipping assay (Kim *et al*., 2002). Bioassays were conducted from early April to mid-June. In a preliminary experiment, 1,000 mg/L was found to be an appropriate starting concentration for the primary screening of insecticidal activity of essential oils. Two concentrations (1,000 mg/L and 500 mg/L) of the test essential oils, each in 50 μL of ethanol were used. Control receives only ethanol-Triton X-100 solution. *Hibisscus syriacus* leaf discs (5.5 cm diameter) were dipped in each test solution for 30 s. After drying in a fume hood for 2 h, 10 nymphs of *M. pruinosa* were placed onto the treated and the control leaf discs in petri dishes (6 cm diameter × 1.5 cm height). Each dish was then covered with the lid and sealed with parafilm. If an essential oil gave more than 99% mortality, further spray formulation (SF) assays were conducted for the determination efficacy of essential oils. Six SF solutions were applied to sprayer application method against adults *M. pruinosa*. Negative controls formulation SF consisted of without test materials.

Table 1. List of 124 plant essential oils tested for insecticidal activity against *Metcalfa pruinosa*

Essential oil	Scientific name	Essential oil	Scientific name
Almond, sweet	*Prunus duleis*	Dill weed	*Anethum graveolens*
Amyris	*Amyris balsamifera*	Grapefruit	*Citrus paradisi*
Angelica root	*Angelica archangelica*	Guaiac wood	*Guaiacum sanctum*
Anise, star	*Illicium verum*	Helichrysum	*Helichrysum angustifolium*
Aniseed	*Pimpinella anisum*	Hiba	*Thufopsis dolobrata*
Armoise	*Artemisia vulgaris*	Horseraddish	*Wasabia japonica*
Basil	*Ocimum basilicum*	Ho wood	*Cinnamomum camphora*
Basil sweet	*Ocimum basilicum*	Hyssop	*Hyssopus officinalis*
Bay	*Pimenta racemosa*	Juniperberry	*Juniperus communis*
Bergamot	*Citrus bergamia*	Lavender	*Lavandula angustifolia*
Bitter orange	*Citrus aurantium*	Lavender, bulgarian	*Lavandula angustifolia*
Buchu	*Allium tuberosum*	Lemon	*Citrus limon*
Buchu leaf	*Agathosma betulina*	Lemon eucalyptus	*Eucalyptus citriodora*
Cade	*Juniperus oxycedrus*	Lemon 10F	*Citrus limon*
Cade, Spanish	*Juniperus oxycedrus*	Lemongrass	*Cymbopogon citratus*
Calamus	*Corus calamus var. angustatus*	Lime dis 5 fold	*Citrus latifolia*
Cananga	*Cananga odorata*	Litsea cubeba	*Litsea cubeba*
Caraway	*Carum carvi*	Lovage root	*Levisticum officinale*
Caraway seed	*Carum carvi*	Mace	*Myristica fragrans*
Cardamon	*Elettaria cardamomum*	Mandarin	*Citrus reticulata*
Carrot seed	*Daucus carota*	Marjoram	*Origanum majorana*
Cascarilla bark	*Croton eluteria*	Marjoram, sweet	*Origanum majorana*
Cassia oil tree	*Cinnamomum cassia*	Melissa	*Melissa officinalis*
Cassia especial	*Cinnamomum cassia*	Mustard	*Brassica nigra*
Cedar leaf	*Thuja occidentalis*	Myrrh	*Commiphora myrrha*
Cedar seed	*Cryptomeria japonica*	Myrtle	*Myrtus communis*
Cedarwood, Chinese	*Cupressus funebris*	Neroli	*Citrus aurantium*
Cedarwood, Texas	*Juniperus mexicana*	Niaouli	*Melaleuca viridiflora*
Cedarwood, Virginian	*Juniperus virginiana*	Nutmeg	*Myristica fragrans*
Celery seed	*Apium graveolens var. duke*	Orange	*Citrus sinensis*
Chamomile, blue	*Matricaria recutitia*	Origanum	*Origanum vulgare*
Chamomile, Roman	*Chamaemelum nobile*	Palmarosa	*Cymbopogon martinii*
Cinnamon bark	*Cinnamomum zeylanicum*	Parsley seed	*Petroselinum crispum*
Cinnamon bleached	*Cinnamomum zeylanicum*	Patchouli	*Pogostemon cablin*
Cinnamon green leaf	*Cinnamomum zeylanicum*	Patchouli, Indonesian	*Pogostemon heyneanus*
Cinnamon technical	*Cinnamomum zeylanicum*	Pennyroyal	*Mentha pulegium*
Cinnamon #500	*Cinnamomum zeylanicum*	Pepper, black	*Piper nigrum*
Citronella	*Cymbopogon nardus*	Peppermint	*Mentha piperita*
Citronella, Java	*Cymbopogon nardus*	Peppermint, terpenes	*Mentha arvensis*
Clary sage	*Salvia sclarea*	Petitgrain	*Citrus aurantium*
Clove bud	*Syzygium aromaticum*	Pimento berry	*Pimenta dioica*
Clove leaf	*Syzygium aromaticum*	Pine needle	*Pinus sylvestris*
Clove stem, Indo	*Syzygium aromaticum*	Rose, Damask	*Rosa damascena*
Coriander	*Coriandrum sativum*	Rosemary	*Rosmarinus officinalis*
Coriander herb	*Coriandrum sativum*	Rosewood	*Aniba rosaeodora*
Cypress	*Cupressus sempervirens*	Sage, Spanish	*Salvia lavandulifolia*
Davana	*Artemisia pallens*	Sandalwood	*Santalum album*

Table 1. continued

Essential oil	Scientific name	Essential oil	Scientific name
Eucalyptus	*Eucalyptus globulus*	Sassafras	*Sassafras albidum*
Eucalyptus, terpenes	*Eucalyptus globulus*	Savory, summer	*Satureja hortensis*
Eucalyptus, lemon	*Eucalyptus citriodora*	Spearmint	*Mentha spicata*
Fennel	*Foeniculum vulgare*	Tagetes	*Tagetes minuta*
Fennel seed	*Foeniculum vulgare*	Tangerine	*Citrus reticulata*
Fennel sweet	*Foeniculum vulgare*	Tarragon	*Artemisia dracunculus*
Galbanum	*Ferula gummosa*	Tea tree	*Melaleuca alternifolia*
Garlic	*Allium sativum*	Thyme red	*Thymus vulgaris*
Fir needle	*Abies holophylla*	Thyme white	*Thymus vulgaris*
Frankincense	*Boswellia sacra*	Valerian	*Valeriana officinalis*
Gaic wood	*Lignum vitae*	Vetiver, Haiti	*Chrysopogon zizanioides*
Geranium	*Pelargonium graveolens*	Wintergreen	*Gaultheria procumbens*
Geranium, Chinese	*Pelargonium graveolens*	Wormwood	*Artemisia absinthium*
Ginger	*Zingiber officinale*	Yarrow	*Achillea millefolium*
Ginger, Chinese	*Zingiber officinale*	Ylang ylang	*Cananga odorata*

Table 2. Six experimental spray formulations containing the selected plant essential oils

Spray formulation[a]	% Content			
	Essential oil	Surfactant[b]	Ethanol	DW[c]
SF-0.25	**0.25**	2.0	5.0	92.7
SF-0.5	**0.5**	2.0	5.0	92.5
SF-1	**1**	2.0	5.0	92.0
SF-2.5	**2.5**	2.0	5.0	90.5
SF-5	**5**	2.0	5.0	88.0
SF-10	**10**	2.0	5.0	83.0

[a] Plant essential oil 0.5, 1, 2, and 3%.
[b] Polyoxyethylene + polyoxypropylene (9:1) styrenated phenyl ether. Thyme white and origanum were used ethoxylated caster oil as surfactant.
[c] Distilled water.

Treated and control (ethanol only) nymph or adult were held at the same conditions as described above. Test insects were considered to be dead if its body and appendage did not move when prodded with a fine wooden dowel 24 h after treatment. Because not all bioassays could be conducted at the same time, treatments were blocked over time with a separate control treatment included in each block. Freshly prepared solutions were used for each block of bioassays (Robertson and Preisler, 1992). All treatments were replicated 3 times using 10 nymphs or adults per replicate.

Data analysis

Percent mortality was transformed to arcsine square root values for analysis of variance. The Bonferroni multiple-comparison method was used for testing significant differences among the treatments (SAS Institute, 2004). Means ± standard error (SE) of untransformed data were reported.

Results

Toxicity of essential oils to *Metcalfa pruinosa*

The toxicity of 124 essential oils at 1,000 mg/L against nymphs of *M. pruinosa* was shown in Table 3. Various responses to the essential oils and concentrations were examined. At 1,000 mg/L at 24 h post-treatment, treatments with nineteen essential oils resulted in 100% mortality, at six oils in ≥ 90%, and eleven oils in ≥ 80% mortality. Essential

Table 3. Mortality of nymphs of *Metcalfa pruinosa* when 124 essential oils were treated with 1,000 mg/L for 24 h using leaf-dipping method

Essential oil[a]	Mortality (%) ± SE [b]	Essential oil[a]	Mortality (%) ± SE [b]
Almond, sweet	100a	Parsley seed	93 ± 3.5cde
Angelica root	100a	Lime dis 5 fold	93 ± 3.5cde
Aniseed	100a	Calamus	90 ± 0.0def
Carrot seed	100a	Celery seed	90 ± 0.0def
Cassia tree	100a	Bitter orange	89 ± 5.7def
Chamomile, Roman	100a	Litsea cubeba	89 ± 2.7def
Cinnamon technical	100a	Tangerine	88 ± 3.3def
Cinnamon green leaf	100a	Peppermint	88 ± 2.3defg
Cinnamon #500	100a	Mace	88 ± 2.defg
Citronella, Java	100a	Cascarilla bark	87 ± 2.2efg
Eucalyptus	100a	Cassia especial	87 ± 3.3efg
Geranium	100a	Davana	85 ± 3.7fgh
Lovage	100a	Sassafras	83 ± 4.8fgh
Niaouli	100a	Garlic	81± 4.2ghi
Palmarosa	100a	Galbanum	80 ± 0.0ghi
Pennyroyal	100a	Lemon 10F	80 ± 2.5hi
Rosewood	100a	Basil	77 ± 3.3hij
Tagetes	100a	Vetiver, Haiti	72 ± 4.7jk
Thyme white	100a	Cedawood, Texas	70 ± 0.0jkl
Citronella	98 ± 2.1b	Basil sweet	69 ± 1.1jkl
Origanum	98 ± 2.1b	Ginger	69 ± 1.0jkl
Grapefruit	97 ± 3.3bc	Tee tree	68 ± 2.1jkl
Lemongrass	97 ± 3.3bc	Valerian	68 ± 2.1jkl
Nutmug	97 ± 3.3bc	Caraway	67 ± 3.3kl
Rosemary	97 ± 3.3bc	Eucalyptus	65 ± 2.5kl
Savory, summer	97 ± 3.3bc	Myrtle	65 ± 2.9kl
Thyme red	97 ± 3.3bc	Buchu leaf	63 ± 3.3kl
Lemon eucalyptus	94 ± 3.2cd	Lavender	63 ± 3.3kl
Cinnamon bark	93 ± 3.3cd	Sage, Spanish	61 ± 1.2l
Fennel sweet	93 ± 3.3cd	Eucalyptus terpenes	60 ± 5.8l
Patchouli	93 ± 3.3cd	Spearmint	60 ± 0.0l
Guaic wood	93 ± 3.5cde	Helichrysum	60 ± 0.0l

[a] Essential oils exerting >60% mortality at 1,000 mg/L are reported.
[b] Means within a column followed by the same letter are not significantly different at P = 0.05 (Bonferroni test).

oils showed ≥ 60% mortality at 1,000 mg/L were subjected to further bioassay at 500 mg/L (Table 4). Among them six oil treatments resulted in 100% mortality at 24 h post-treatment, four oils in ≥ 90%, and three oils in ≥ 80%.

Efficacy of experimental spray formulations

Because of good lethality of essential oils as stated above, the toxicity of the 12 essential formulations was examined at different concentrations. The control efficacy of six experimental spray formulations containing selective oils was evaluated against adult *M. pruinosa* using the spray bioassay (Table 5). All the oils applied as SF-10% sprays provided 100 % mortality against *M. pruinosa*. In particular, cinnamon technical showed very strong (>SF-0.5 = 100%) effect, followed by cinnamon #500, cinnamon green leaf and pennyroyal (all the three oils; >SF-2.5 = 100%). Citronella java, origanum, fennel sweet, tagetes, and savory showed moderate effects showing 100% mortality at >SF-5. The

Table 4. Mortality of nymphs of *Metcalfa pruinosa* when selected essential oils were treated with 500 mg/L for 24 h using leaf-dipping method

Essential oil	Mortality (%) ± SE [a]	Essential oil	Mortality (%) ± SE [a]
Cinnamon technical	100a	Lemongrass	52 ± 1.9l
Cinnamon green leaf	100a	Patchouli	52 ± 1.9l
Cinnamon #500	100a	Nutmug	49 ± 4.6m
Cassia tree	100a	Palmarosa	45 ± 2.9n
Citronella, Java	100a	Citronella	43 ± 3.3o
Pennyroyal	100a	Lovage root	43 ± 3.3o
Origanum	93 ± 3.3b	Carrot seed	42 ± 1.5p
Thyme white	93 ± 3.3b	Niaouli	37 ± 3.3q
Grapefruit	90 ± 0.0c	Chamomile, Roman	37 ± 3.3q
Savory, summer	90 ± 0.0c	Eucalyptus	34 ± 2.9r
Fennel sweet	86 ± 3.2d	Rosemary	30 ± 0.0s
Aniseed	83 ± 3.8e	Almond, sweet	28 ± 4.0t
Cinnamon bark	80 ± 3.3f	Guaic wood	26 ± 3.0u
Thyme red	73 ± 3.3g	Lime dis 5 fold	20 ± 0.0v
Tagetes	67 ± 3.3h	Parsley seed	17 ± 3.8w
Calamus	66 ± 2.9i	Angelica root	13 ± 3.3x
Lemon eucalyptus	60 ± 0.0j	Celery seed	10 ± 5.8y
Geranium	53 ± 3.3k	Rosewood	10 ± 0.0y

[a] Means within a column followed by the same letter are not significantly different at $P = 0.05$ (Bonferroni test).

Table 5. Toxicity of spray formulation of 12 selected essential oils against adults *Metcalfa pruinosa* at 24 h after treatment

Oils	Mortality (%) ± SE [a]					
	10 (%)	5 (%)	2.5 (%)	1 (%)	0.5 (%)	0.25 (%)
Cinnamon technical	100a	100a	100a	100a	100a	73 ± 3.3a
Cinnamon #500	100a	100a	100a	97 ± 3.3b	87 ± 2.7b	49 ± 1.5c
Cinnamon green leaf	100a	100a	100a	90 ± 0.0c	83 ± 3.3c	53 ± 3.3b
Pennyroyal	100a	100a	100a	53 ± 3.3g	26 ± 3.0d	-
Origanum	100a	100a	93 ± 3.3b	83 ± 3.3d	-	-
Citronella, Java	100a	100a	97 ± 3.3c	63 ± 3.3e	7 ± 3.3e	-
Fennel sweet	100a	100a	89 ± 6.4d	10 ± 0.4j	-	-
Tagetes	100a	100a	76 ± 3.0e	62 ± 4.3f	26 ± 3.0d	-
Savory, summer	100a	100a	45 ± 2.9f	12 ± 2.9i	-	-
Chamomile, Roman	100a	63 ± 3.3b	40 ± 5.8g	23 ± 3.3h	-	-
Thyme red	100a	63 ± 3.3b	7 ± 3.3h	-	-	-
Thyme white	100a	59 ± 4.8c	7 ± 3.3h	-	-	-

[a] Means within a column followed by the same letter are not significantly different at $P = 0.05$ (Bonferroni test).

chamomile roman, thyme red, and thyme white showed low effects, compared with other formulations.

Discussion

Over the past 15 years, interest in botanical insecticides has increased as a result of environmental concerns and insect populations becoming resistant to conventional chemicals. In spite of the wide-spread recognition that many plants possess insecticidal properties, only a handful of pest control products directly obtained from plants are in use because the commercialization of new botanicals can be hindered by a number of issues (Isman, 1997). Botanicals used as insecticides presently constitute 1% of the world insecticide market (Rozman *et al*., 2007). Many essential oils are known to possess various bio-efficacy such as repellency and deterrence, reduced palatability, growth inhibition through altered protein availability, enzyme inhibition, and direct toxicity (Harborne, 1993; Ahn, 2006; Isman, 2006).

Certain plant essentials oils and their constituents manifest insecticidal activity against different insect species (Isman, 2000; Choi *et al*., 2003; Yi *et al*., 2006; Han *et al*., 2010; Kim *et al*., 2012) and have been proposed as alternatives. However, plants essential oils have been reported to have potential activity against agricultural insect pest include, citronella, cedar, verbena, pennyroyal, geranium, lavender, pine, cinnamon, rosemary, basil, thyme, and peppermint (Isman, 2006). Lee *et al*. (1997) reported on the toxicity of a range of essential oil constituents to the western corn rootworm (*Diabrotica virgifera*), the two-spotted spider mite (*Tetranychus urticae*) and the housefly (*Musca domestica*), and dietary effects of a number of monoterpenoids against the European corn borer (*Ostrinia nubilalis*). Plant essential oils have potential as products for *M. pruinosa* control because some of them are selective, biodegrade to nontoxic products, and have less harmful effects on non-target organisms (Isman, 2000; 2006). No work has been done to consider their potential to manage *M. pruinosa* population. In the present study, potent toxicity against the nymphs of *M. pruinosa* was obtained from almond sweet, angelica root, aniseed, carrot seed, cassia tree, chamomile roman, cinnamon technical, cinnamon green leaf, cinnamon #500, citronella java, eucalyptus geranium, lovage root, niaouli, palmarosa, pennyroyal, rosewood, tagetes, and thyme white.

The genus Cinnamomum comprises 250 species that are distributed in Asia and Australia (Jayaprakasha *et al*., 2003). Chang *et al*. (2001, 2002) found that the leaf essential oil of the cinnamaldehyde type *C. osmophloeum* has an excellent inhibitory effect against bacteria, termites, mites, mildew, and fungi. Huang and Ho (1998) reported that a methylene chloride extract of cinnamon, *Cinnamomum aromaticum* Nees, was shown to be insecticidal to *Tribolium castaneum* (Herbst) and *Sitophilus zeamais* Motsch. However, there are no prior studies for *M. pruinosa* activity of essential oils and their composition from Cinnamomum. There are several other examples of essential oils, such as lemon grass (*Cimbopogon winteriana*), *Eulcalyptus globulus*, rosemary (*Rosemarinus officinalis*), vetiver (*Vetiveria zizanoides)*, clove (*Eugenia caryophyllus*), and thyme (*Thymus vulgaris*), which are known for their pest control properties. While peppermint (*Mentha piperita*) repels ants, flies, lice, and moths, pennyroyal (*Mentha pulegium*) wards off fleas, ants, lice, mosquitoes, ticks, and moths. Spearmint (*Mentha spicata*) and basil (*Ocimum basilicum*) are also effective in warding off flies (Koul *et al*., 2008). Similarly, essential oil bearing plants like *Artemesia vulgaris*, *Melaleuca leucadendron*, *Pelargonium roseum*, *Lavandula angustifolia*, *Mentha piperita*, and *Juniperus virginiana* are also effective to various insects and fungal pathogens (Kordali *et al*., 2005; Opender *et al*., 2008).

Although not yet proven, the octopaminergic and γ-aminobutyric acid (GABA) receptors have been suggested as novel target sites for some essential oil constituents by Kostyukovsky *et al*. (2002) and Priestley *et al*. (2003), respectively. This provide practically important information for arthropod control, such as the most appropriate formulations and delivery means to be adapted for their future commercialization. In the present study, a spray bioassay was used to assess the potential of six experimental sprays containing the twelve selected essential oils. All the >0.5-1% spray formulations provided good control efficacies. Many essential oils primarily act as fumigants with additional contact action.

In conclusion, the essential oils described such as cinnamon technical, cinnamon #500, cinnamon green leaf, pennyroyal, citronella java or origanum could be useful as insecticides in the control of *M. pruinosa* populations, particularly in the light of their toxicity against both nymphs and adults of *M. pruinosa.* For the practical use of the essential oils as novel insecticides to proceed, further research on their human safety remains to be established. For the practical use of the essential oils as novel insecticides to proceed, further research on their potential modes of action and human safety need to be established and also the formulations for improving potency and stability, thereby reducing costs, need to be developed.

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Literature Cited

Ahn, Y. J., S. I. Kim, H. K. Kim and J. H. Tak (2006) Naturally occurring house dust mites control agents: development and commercialization, *In* M. Rai and M. C. Carpinella (eds.), Naturally occurring bioactive compounds, pp. 269-289. Elsevier, London, United Kingdom.

Chang, S. T., P. F. Chen and S. C. Chang (2001) Antibacterial activity of leaf essential oils and their constituents from *Cinnamomum osmophloeum*. J. Ethnopharmacol. 77:123-127.

Chang, S. T. and S. S. Cheng (2002) Antitermitic activity of leaf essential oils and components from *Cinnamomum osmophleum*. J. Agric. Food Chem. 50:1389-1392.

Choi, W. I., E. H. Lee, B. R. Choi, H. M. Park and Y. J. Ahn (2003) Toxicity of plant essential oils to *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae). J. Econ. Entomol. 96:1479-1984.

Ciampolini, M., A. Grossi and G. Zottarelli (1987) Damage to soyabean through attack by *Metcalfa pruinosa*. L'Inf. Agrar. 43:101-103.

Dean, H. A. and J. C. Bailey (1961) A flatid planthopper, *Metcalfa pruinosa* J. Econ. Entomol. 54:1104-1106.

Han, J., B. R. Choi, S. G. Lee, S. I. Kim and Y. J. Ahn (2010) Toxicity of plant essential oils to acaricide-susceptible and -resistant *Tetranychus urticae* (Acari: Tetranychidae) and *Neoseiulus californicus* (Acari: Phytoseiidae). J. Econ. Entomol. 103:1293-1298.

Harborne, J. B. (1993) Introduction to ecological biochemistry, 4th ed. Academic Press.

Huang, Y. and S. H. Ho (1998) Toxicity and antifeedant activities of cinnamaldehyde against the grain storage insects, *Tribolium castaneum* (Herbst) and *Sitophilus zeamais* Motsch. J. Stored Prod. Res. 34:11-17.

Isman, M. B. (1997) Neem and other botanical insecticides commercialization. Phytoparasitica 25:339-344.

Isman, M. B. (2000) Plant essential oils for pest and disease management. Crop Prot. 19:603-608.

Isman, M. B. (2006) Botanical insecticides, deterrents, and repellents in modern agriculture and increasingly regulated world. Annu. Rev. Entomol. 51:45-66.

Isman, M. B. (2008) Botanical insecticides: for richer, for poorer. Pest Manag. Sci. 64:8-11.

Jayaprakasha, G. K., L. Jagan Mohan Rao and K. K. Sakariah (2003) Volatile constituents from *Cinnamomum zeylanicum* fruit stalks and their antioxidant activities. J. Agric. Food Chem. 51:4344-4348.

Kim, J. R., H. Perumalsamy, B. K. Son and Y. J. Ahn (2012) Fumigant toxicity of plant essential oils against *Camptomyia corticalis* (Diptera: Cecidomyiidae) J. Econ. Entomol. 105:1329-1334.

Kim, J. R., S. H. Yeon, H. S. Kim and Y. J. Ahn (2002) Larvicidal activity against *Plutella xylostella* of cordycepin from the fruiting body of *Cordyceps militaris*. Pest Manag. Sci. 58:713-717.

Kim, Y., M. Y. Kim, K. J. Hong and S. H. Lee (2011) Outbreak of an exotic flatid, *Metcalfa pruinosa* (Say) (Hemiptera: Flatidae), in the capital region of Korea. Journal of Asia-Pacific Entomology 14:473-478.

Kordali, S., A. Cakir, A. Mavi, H. Kilic and A. Yildirim (2005) Screening of chemical composition and antifungal activity of essential oils from three Turkish Artemisia species. J. Agric. Food Chem. 53:1408-1416.

Kostyukovsky, M., A. Rafaeli, C. Gileadi, N. Demchenko and E. Shaaya (2002) Activation of octopaminergic receptors by essential oil constituents isolated from aromatic plants: possible mode of action against insect pests. Pest Manag. Sci. 58:1101-1106.

Koul, O., S. Walia and G. S. Dhaliwal (2008) Essential oils as green pesticides: potential and constraints. Biopestic. Int. 4:63-84.

Lauterer, P. (2002) Citrus flatid planthopper - *Metcalfa pruinosa* (Hemiptera:Flatidae), a new pest of ornamental horticulture in the Czech Republic. Plant Protect. Sci. 38:145-148.

Lee, S., R. Tsao, C. J. Peterson and J. R. Coats (1997) Insecticidal activity of monoterpenoids to western corn rootworm (Coleoptera: Chrysomelidae), twospotted spider mite (Acari: Tetranychidae), and house fly (Diptera: Muscidae). J. Econ. Entomol. 90:883-892.

Mead, F. W. (1969) Citrus flatid planthopper, *Metcalfa pruinosa* (Say). Homoptera: Flatidae. Entomol. Circular, Florida *DA* 85:1-2.

Nault, L. R. and J. G. Rodriguez (1985) The leafhoppers and planthoppers. A Wiley-Interscience Publication, p. 70.

Opender, K., W. Suresh and G. S. Dhaliwal (2008) Essential oils as green pesticides: Potential and Constraints. Biopestic. Int. 4:63-84.

Pons, X., B. Lumbierres, S. Garcia and P. L. Manetti (2002) *Metcalfa pruinosa* (Say) (Homoptera: Flatidae), una plaga potencial de plantas ornamentales en espacios verdes urbanos de Cataluña. Bol. San. Veg. Plagas. 28:217-222.

Priestley, C. M., E. M. Williamson, K. A. Wafford and D. B. Sattelle (2003) Thymol, a constituent of thyme essential oil, is a positive allosteric modulator of human $GABA_A$ receptors and a homo-oligomeric GABA receptor from *Drosophila melanogaster*. Br. J. Pharmacol. 140:1363-1372.

Robertson, J. L. and H. K. Preisler (1992) Bioassays with arthropods. CRC, Boca Raton, FL.

Rozman, V., I. Kalinovic and Z. Korunic (2007) Toxicity of naturally occurring compounds of Lamiaceae and Lauraceae to three stored product insects. J. Stored Prod. Res. 43:349-355.

SAS Institute. 2004. SAS OnlineDoc®, version 8.01, SAS Institute, Cary, NC.

Say, T. (1830) Description of new North American Hemipterous insects, belonging to the first family of the section Homoptera of Latreille. J. Acad. Nat. Sci. Philadelphia 6:235-244.

Souliotis, C., N. E. Papanikolaou, D. Papachristos and N. Fatouros (2008) Host plants of the planthopper *Metcalfa pruinosa* (Say) (Hemiptera: Flatidae) and observations on its phenology in Greece. Hellenic Plant Protection Journal 1:39-41.

Strauss, G. (2009) Host range testing of the neararctic beneficial parasitoid *Neodryinus typhlocybae*. BioControl 54:163-171.

Yi, C. G., B. R. Choi, H. M. Park, C. G. Park and Y. J. Ahn (2006) Fumigant toxicity of plant essential oils to *Thrips palmi* (Thysanoptera: Thripidae) and *Orius strigicollis* (Heteroptera: Anthocoridae). J. Econ. Entomol. 99:1733-1738.

Zangheri, S. and P. Donadini (1980) Comparsa nel Veneto di un Omottero neartico: *Metcalfa pruinosa* (Say) (Homoptera, Flatidae). Redia (Firenze) 63:301-305.

미국선녀벌레(*Metcalfa pruinosa* Say)에 대한 식물정유와 그 분무제형의 살충 활성

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요 약 본 연구에서는 식물정유 124종과 6종의 분무제형(SF-0.25, 0.5, 1, 2.5, 5 및 10% sprays)을 대상으로 미국선녀벌레 약충과 성충에 대한 독성을 평가 하였다. 약충에 대한 실험은 1,000 mg/L와 500 mg/L로 실시 하였으며, 엽침지법을 사용하였다. 미국선녀벌레 약충에 대한 124종의 식물정유의 살충성을 스크리닝한 결과, 64종의 식물정유가 60% 이상의 사충률을 보였고, 이 중 19종의 식물정유는 100%의 사충률을 보였다. 일차 활성이 좋은 식물정유를 500 mg/L로 검정한 결과 cinnamon technical, cinnamon green leaf, cinnamon #500, cassia tree, citronella java 및 pennyroyal oil이 100%의 살충활성을 나타냈고, origanum, thyme white, grapefruit, savory, fennel sweet, aniseed 및 cinnamon bark oil 순으로 93.3%에서 80%까지 높은 살충활성을 보였다. Thyme red, tagetes, calamus, lemon eucalyptus, geranium oil은 73.3%에서 60% 정도의 살충활성을 보였다. 이중 100%의 높은 살충활성을 보인 정유 12종을 6농도의 분무제형으로 미국선녀벌레 성충에 대한 살충활성을 검정한 결과, cinnamon technical oil이 SF-0.5의 제형에서 100%의 살충활성을 보였으며, cinnamon #500, cinnamon green leaf, pennyroyal oil은 SF-2.5에서 100%의 살충활성을 보였다. 농업환경에서 고독성 합성살충제의 사용을 줄일 수 있는 방안으로 본 논문에서 선발한 식물정유가 미국선녀벌레의 약충 및 성충 방제에 유용한 수단으로 이용될 수 있을 것으로 생각된다.

색인어 미국선녀벌레, 식물정유, 식물살충제, 엽침지법, 분무제형