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Résumé de l'article

Les effets d'un savon insecticide sur la survie, le développement et la fécondité du puceron vert du pêcher, *Myzus persicae*, ont été étudiés. Vingt-quatre heures après son application à une concentration de 37,50 g L⁻¹, le savon a causé 100 % de mortalité chez tous les stades de pucerons et les CL₅₀ (concentrations létales causant 50 % de mortalité dans la population) pour *M. persicae* étaient de 1,50, 3,25 et 5,50 g L⁻¹ pour les premier et deuxième stades, pour les troisième et quatrième stades et pour le stade adulte, respectivement. Les pucerons ayant survécu aux CL₅₀ n'ont pas vécu aussi longtemps que ceux du traitement témoin. Il est possible d'utiliser le savon insecticide et des parasitoïdes sur des cultures, mais comme les CL₅₀ des troisième et quatrième stades et des adultes de *M. persicae* sont plus élevées que celles du parasitoïde *Aphidius colemani* (2,75 g L⁻¹), il est important de ne traiter les pucerons avec du savon que lorsque les parasitoïdes adultes sont absents de la culture.

Toxicity effects of an insecticidal soap on the green peach aphid [Homoptera: Aphididae]

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Effects of an insecticidal soap on the survival, development and reproduction of the green peach aphid, *Myzus persicae*, were studied. Twenty-four hours after application at a concentration of 37.50 g L⁻¹, the soap caused 100% mortality in all aphid instars, and LC₅₀ (lethal concentrations causing 50% mortality in the population) were 1.50, 3.25 and 5.50 g L⁻¹ for first and second instars, third and fourth instars, and adult *M. persicae*, respectively. Aphids that survived the LC₅₀ had a shorter longevity than the controls. Both insecticidal soap and parasitoids could be used on a crop but, as the LC₅₀ of the third and fourth instars and adult *M. persicae* are higher than that of the aphid parasitoid *Aphidius colemani* (2.75 g L⁻¹), it is essential to avoid treating aphids with insecticidal soap when adult parasitoids are present in the crop.

Keywords: Insecticidal soap, integrated pest management, LC₅₀, *Myzus persicae*.

[Toxicité d'un savon insecticide sur le puceron vert du pêcher (Homoptera : Aphididae)]

Les effets d'un savon insecticide sur la survie, le développement et la fécondité du puceron vert du pêcher, *Myzus persicae*, ont été étudiés. Vingt-quatre heures après son application à une concentration de 37,50 g L⁻¹, le savon a causé 100 % de mortalité chez tous les stades de pucerons et les CL₅₀ (concentrations létales causant 50 % de mortalité dans la population) pour *M. persicae* étaient de 1,50, 3,25 et 5,50 g L⁻¹ pour les premier et deuxième stades, pour les troisième et quatrième stades et pour le stade adulte, respectivement. Les pucerons ayant survécu aux CL₅₀ n'ont pas vécu aussi longtemps que ceux du traitement témoin. Il est possible d'utiliser le savon insecticide et des parasitoïdes sur des cultures, mais comme les CL₅₀ des troisième et quatrième stades et des adultes de *M. persicae* sont plus élevées que celles du parasitoïde *Aphidius colemani* (2,75 g L⁻¹), il est important de ne traiter les pucerons avec du savon que lorsque les parasitoïdes adultes sont absents de la culture.

Mots clés: CL₅₀, lutte intégrée, *Myzus persicae*, savon insecticide.

Potassium salts, or soaps, have long been known as contact insecticides (van der Meulen and van Leeuwen 1929). Since the 1980s, several commercial soap formulations have been available on the North American market (Copping 2004) to control soft bodied arthropods, such as spider mites, psyllids and aphids, that are pests of ornamentals, fruits and vegetables (Koehler *et al.* 1983). Insecticidal soaps can successfully suppress different aphid species, including the green peach aphid, *Myzus persicae* (Sulzer) [Homoptera: Aphididae] (Miller and Uetz 1998; Parry *et al.* 1989), and could therefore be interesting alternatives to synthetic pesticides in integrated pest management (IPM) programs. However, if insecticidal soaps are to be used in IPM programs, their compatibility with other pest control approaches, such as biological control, should be investigated. The aphid

parasitoid *Aphidius colemani* Viereck [Hymenoptera: Aphidiidae] is used in greenhouses against a variety of aphid pests. The susceptibility of *A. colemani* to a newly formulated insecticidal soap was evaluated (Tremblay *et al.* 2008) and the results have shown that although the soap was toxic to the parasitoid when it came into direct contact, it was relatively harmless when the parasitoid came into contact with sprayed aphids. In addition, this formulation is stable at room temperature and it readily mixes with water (A. Bélanger, personal communication). However, if both control techniques are to be used in greenhouses, the susceptibility of an aphid pest to this insecticidal soap must also be evaluated.

Myzus persicae is found throughout the world, including all areas of North America. In Canada, it

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causes damage to both field-grown and greenhouse-grown vegetables and ornamentals. Damage is mostly due to honeydew, which provides a suitable medium for the growth of sooty moulds (Cloutier and Chagnon 1990). *Myzus persicae* is difficult to control because of its high multiplication rate and because it feeds under the leaves and into leaf axils (Edelson *et al.* 1993). Females can deposit three to four nymphs per day and larval development includes four instars (Boiteau 1994).

Chinese cabbages var. Monument (Norseco Inc., Laval, QC, Canada) were grown individually in 15 cm diam pots filled with Pro-Mix® under controlled conditions (20 ± 2°C, 80% ± 10% RH and L16: D8). The plants were allowed to grow for 5 wk before being transferred to aphid rearing cages. Plants were not treated with chemicals, but predacious bugs, *Orius insidiosus* (Say) [Hemiptera: Anthocoridae], were released when thrips infestation occurred.

Myzus persicae specimens used in this study were initially collected in a greenhouse at the Horticulture Research and Development Centre (HRDC) of Agriculture and Agri-Food Canada (Saint-Jean-sur-Richelieu, QC, Canada) on plants that had not received any insecticidal treatment. The colony was maintained on Chinese cabbages under controlled conditions (23 ± 2°C, 80 ± 10% RH and L16: D8). The plants were watered and fertilized every other day with water-soluble fertilizers (20-8-20 and 14-0-14, Plant Products Co. Ltd, Canada). Every 2 wk, infested leaves from the old plants were used to infest new cabbage plants. Tested aphids (first and second instars) were obtained by isolating adult aphids from the rearing colonies and allowing them to produce nymphs for 48 h on cabbage leaf disks. Likewise, third and fourth instars and adults were obtained by isolating first and second instars and third and fourth instars, respectively.

The insecticidal soap used in these experiments, newly formulated and provided by PronateX Inc., was prepared with saponified olive and neem oils at a ratio of 1.5/10. During saponification, all limonoids contained in the neem oil used in this soap formulation, such as azadirachtin, were destroyed by alkali

(KOH) (Zanno *et al.* 1975). Ethanol and methanol (75%/25% v/v) as well as distilled water were used to dilute the mixture to reach a concentration of 40% fatty acids. The soap solution was diluted with distilled water prior to its application to obtain the concentrations needed for the bioassays (g L⁻¹).

Both topical toxicity and sublethal toxicity bioassays were performed following the same procedure. Soap was sprayed with a modified paintbrush (BADGER 100) at a pressure of 41.4 kPa. Petri dishes containing aphids were sprayed with 300 µL of soap solution or distilled water (control). The Petri dishes had pierced lids covered with nylon mesh to allow aeration. After drying for 1 h, they were sealed with Parafilm® to prevent aphids from escaping. The Petri dishes were kept in a plastic container that had a wet sponge at the bottom to maintain humidity. The container was incubated at 25 ± 2°C, 40 ± 10% RH and L16: D8. Each Petri dish constituted a replicate.

Topical bioassays were conducted to determine the lethal concentration causing 50% mortality in the population (LC₅₀). Twenty-five young nymphs (first and second instars), old nymphs (third and fourth instars) or adults were transferred to a Petri dish (2.5 cm diam) containing a fresh cabbage leaf disk (2.5 cm diam) and a moistened filter paper at the bottom (2.5 cm diam). The Petri dishes were kept closed until the beginning of the experiment. Four Petri dishes were used per concentration (unit of replication). Seven different concentrations were tested against each aphid age group, with each concentration applied to four Petri dishes. Tested concentrations ranged from 0.25 to 37.50 g L⁻¹ for young nymphs, and from 1.25 to 37.50 g L⁻¹ for old nymphs and adults. Distilled water was used as a control. Aphid mortality was assessed 24 and 48 h after treatment. Aphids not showing any movement when lightly touched with a brush were considered dead. The experiment was repeated three times (four replicates per experiment; 300 aphids per concentration).

Sublethal effects of the insecticidal soap were based on measures of survival, developmental rate and daily fecundity. We used the number of exuviae produced per 24 h by surviving aphids to express the

Table 1. Corrected survival rate (%) of *Myzus persicae* young nymphs, old nymphs and adults 7 d after treatment with soap at their LC₅₀ concentrations

Days after treatment	Corrected survival rate (%)					
	Young nymphs (1st and 2nd instars)		Old nymphs (3rd and 4th instars)		Adults	
	Control	Treated	Control	Treated	Control	Treated
1	98.7 ± 2.6	100.0	99.7 ± 1.1	100.0	99.0 ± 1.8	100.0
2	97.7 ± 2.7	90.6 ± 9.0**	98.4 ± 1.5	75.8 ± 11.4***	98.3 ± 2.1	92.6 ± 6.1***
3	95.3 ± 6.1	85.6 ± 11.6**	98.4 ± 2.0	72.7 ± 11.5***	94.3 ± 12.4	86.3 ± 8.8***
4	93.7 ± 8.9	79.7 ± 17.8**	97.8 ± 2.6	68.2 ± 11.0***	87.9 ± 14.6	73.6 ± 16.7**
5	89.3 ± 13.0	78.4 ± 17.4	96.5 ± 3.8	66.4 ± 10.4***	77.5 ± 20.4	63.7 ± 15.7
6	82.0 ± 22.7	77.5 ± 17.5	90.3 ± 9.4	65.9 ± 10.0***	64.0 ± 28.2	53.3 ± 20.5
7	73.3 ± 24.7	67.9 ± 17.1	71.2 ± 20.7	60.5 ± 13.4	56.0 ± 31.4	41.5 ± 24.6

** *** Differences from controls according to Mann and Whitney test: ***P* < 0.01, ****P* < 0.001 (n = 4; 300 individuals per treatment).

impact of the insecticidal soap on the capacity of the aphids to develop and, therefore, to molt. Daily fecundity was based on the number of nymphs produced each day by surviving adult aphids to express the effect of the insecticidal soap on the capacity of the aphids to reproduce. Aphids were treated as for the topical toxicity bioassays outlined above, except that treatments consisted of only the LC₅₀ for that age group and distilled water as a control. As only a slight additional direct mortality caused by the insecticidal soap occurred after 24 h (Fig. 1), aphids still surviving 24 h after treatment were used in these experiments. Aphid survival was adjusted to 100% in order to compare survival rates over time with the control (Table 1). For 7 d, mortality, number of exuviae and number of nymphs produced per aphid were recorded daily. Old leaf disks were replaced with fresh ones every 2 d. The nymphs and exuviae were removed daily to facilitate further counting. The experiment was repeated three times (four replicates per experiment; 300 aphids per concentration).

For the topical toxicity bioassay, mortality rates were corrected using Abbott's formula (Abbott 1925). The LC₅₀, slopes and 95% confidence intervals were calculated using a Probit analysis (LeOra software, POLO-PC 1987). Differences between LC₅₀ values for the various age groups were considered to be significant when their 95% confidence intervals did not overlap (Robertson and Preisler 1992). For the sublethal toxicity bioassay, the data were not normally distributed and were thus analyzed using a Mann-Whitney test to compare treated and untreated aphids.

Aphid mortality 24 and 48 h after treatment increased in a concentration-dependent manner (Fig. 1). All regressions were significantly different ($P < 0.05$), indicating that the Probit responses were a linear function of the concentrations for young nymphs, old nymphs and adults (Fig. 1). At soap concentrations higher than 12.50 g L⁻¹, aphid mortality was close to 100%, regardless of the instar (Fig. 1). Mortality rates 24 h and 48 h after treatment were similar (Fig. 1); therefore, only the mortality rate after 24 h was used to calculate the LC₅₀ (Table 2). LC₅₀ values estimated by the Probit analysis were 1.50 g L⁻¹ for young nymphs, 3.25 g L⁻¹ for old nymphs and 5.50 g L⁻¹ for adults of *M. persicae* subjected to direct contact with the soap (Table 2). Aphids that survived a treat-

ment at the LC₅₀ rate had a significantly lower survival rate than the controls up to 5 d following treatment, after which time mortality did not differ (Table 1). Soap application did not affect the developmental rate of nymphs or daily fecundity of *M. persicae* adults. Other than direct mortality during the first 3 d following treatment, treatment with soap did not cause sublethal effects (unpublished data).

Our results indicate that the insecticidal soap must be applied at shorter spray intervals and coverage should be thorough to provide direct contact with the aphids. A previous study has shown that the LC₅₀ for adults of *Aphidius colemani*, an aphid parasitoid, was 2.75 g L⁻¹ (Tremblay *et al.* 2008), which is lower than the LC₅₀ of even the most susceptible age group of *M. persicae*. However, the insecticidal soap did not affect the size or fecundity of the parasitoids that survived treatment, two factors that are important for determining the fitness of the parasitoids (Boivin and Lagacé 1999). This suggests that the combined use of both insecticidal soap and parasitoids can be done as long as the soap treatment is not applied in the presence of parasitoid wasps in the crop. Releasing the wasps after the soap treatment could help control the part of the aphid population that survived in microhabitats that protected them from the treatment.

Our results are consistent with previous studies that showed that *M. persicae* is susceptible to insecticidal soap (Edelson *et al.* 2002; Fournier and Brodeur 2000). At a concentration of 12.50 g L⁻¹, all instars of *M. persicae* showed mortality close to 100% after 48 h. The insecticidal soap M-Pede™ at 61.25 g L⁻¹ effectively controlled populations of *M. persicae* on chrysanthemums and *Aphis gossypii* Glov. [Homoptera: Aphididae] on German ivy by reducing the population to zero 3 d after treatment in a greenhouse (Miller and Uetz 1998). Insecticidal soaps are fast-acting insecticides, as 75-90% of the mortality occurred within 24 h after application.

Because insecticidal soaps must be sprayed directly on the insect to be efficient, several factors can limit their efficacy. The structure of the crop is probably a major factor in the capacity of insecticidal soaps to control pests. Plant architecture is known to affect the susceptibility of insects to their natural enemies (Gingras and Boivin 2002; Gingras *et al.* 2003), with larger and more complex plants offering insects more sheltered micro-habitats. In our experiments, aphids

Table 2. Values of LC₅₀ (g L⁻¹), 95% confidence intervals (CI), slopes, intercepts and values of χ^2 for different instars of *Myzus persicae* 24 h after spray application of an insecticidal soap

Instar	LC ₅₀ (g L ⁻¹) ^a (95% CI)	Slope (± SE)	Intercept	χ^2
1st and 2nd	1.50 (1.35-1.83)	42.00 (± 1.75)	50.75	144.20
3rd and 4th	3.25 (3.00-3.75)	51.50 (± 2.13)	45.25	196.05
Adult	5.50 (5.00-6.25)	61.00 (± 2.35)	39.75	226.42

^a LC₅₀ values were significantly different ($P < 0.05$) based on POLO non-overlapping confidence intervals (LeOra Software, POLO-PC 1987) ($n = 4$; 300 individuals per concentration).

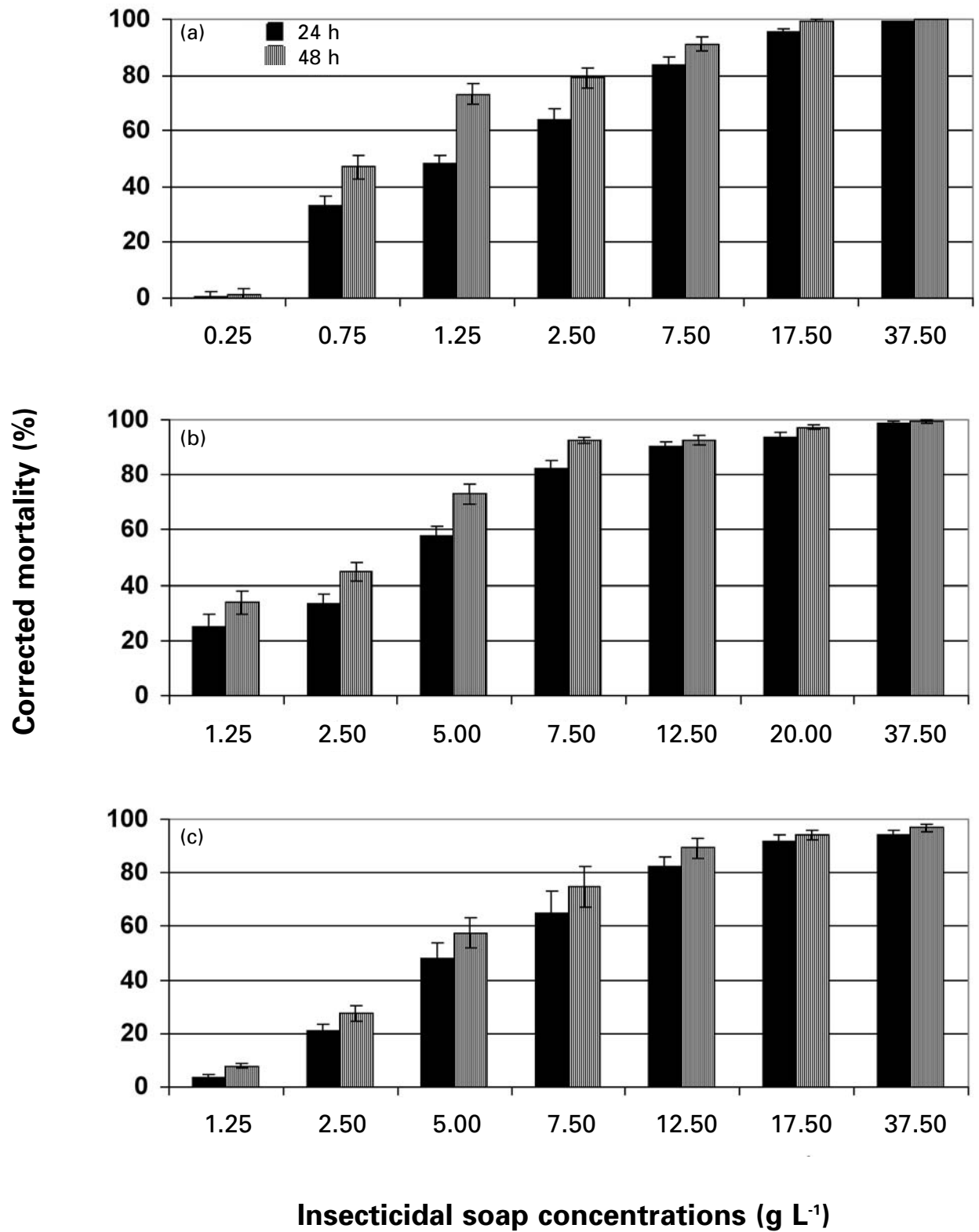


Figure 1. Corrected mean percent mortality (\pm SE) of (a) young nymphs, (b) old nymphs, and (c) adults of *Myzus persicae* 24 and 48 h after spray applications of different soap concentrations (n = 4; 300 individuals per concentration).

on leaf disks were sprayed directly, which would have provided better direct contact than spraying aphids hiding on plants. On lettuce, the LC_{50} was 18.75 (14.50-24.50 g L⁻¹) for third instars of *M. persicae* sprayed with the insecticidal soap Safer's® (Woodstream Canada Corporation, Canada) (Fournier and Brodeur 2000). This corresponds to approximately six times the concentration of insecticidal soap we needed to obtain the LC_{50} (3.25 g L⁻¹). On cabbage leaf disks, Edelson *et al.* (2002) used M-Pede™, an insecticidal soap containing 490 g L⁻¹ of potassium salt of fatty acids, and obtained an LC_{50} of 6,8 g L⁻¹ (6.1 - 7.3 g L⁻¹) for third to fourth instar of *M. persicae*. This is twice the concentration of insecticidal soap we needed to obtain the LC_{50} for similarly aged nymphs. Such variability in the LC_{50} could be due to differences in crop architecture, aphid behaviour and distribution, the methods used to apply the insecticide, and insecticidal soap composition.

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