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Full Length Research Paper

Mineral oil as a repellent in comparison with other control methods for citrus brown snail, *Caucasotachea lencoranea*

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The efficacy of mineral oil and snail copper repellent tape for the control of the citrus brown snail *Caucasotachea lencoranea* Musson were compared with chemical bait molluscides, iron phosphate and methaldehyde، in a commercial citrus orchard in Northern Iran. The number of snails on citrus trees was monitored 10 days after the application of treatments at an interval of 9 to 10 day up to harvest time. Analysis of variance among the treatments in the first experiment showed that there were significant differences between treatments and control. The mineral oil and copper barrier with 17.27 and 26.66% of the counted snail on trees respectively were more effective rather than methaldehyde and iron phosphate with 47.39 and 52.2%, correspondingly. In a second experiment, the average population of snails on 300 trees treated with mineral oil and methaldehyde were 3.05 and 9.12 snails, respectively. On the contrary, this number in control plants was approximately 15.5 snails per each tree. Analysis of data by dunett T3 test shows significance difference between the treatments. The control efficacies of the mineral oil and methaldehyde were 80.34 and 41.2%, respectively, 60 days post treatments. Results were discussed in terms of a sustainable, integrated pest management system.

Key words: *Caucasotachea lencoranea*, iron phosphate, copper tape, ferricole, mineral oil.

INTRODUCTION

Snails are considered as one of the most important agricultural pest in humid regions of the world (Kiss et al., 2002). According to Sakovich (1999), citrus brown snail (CBS) *Caucasotachea lencoranea* (Musson) is considered as the main pest of citrus orchards in countries such as Azerbayjan and Tajikestan. Issel (1866) reported for the first time in Iran, the subjected specie from Northern provinces of the country (Mirzaei, 1971).

Suitable climatic condition of the north made it as the one of the main species of the pests in this region. The indirect damage of CBS consists of feeding on leave and seedlings sprouts that causes more severe damages. The direct ones consists of fruit feeding, while this fruits lost their quality in the market and on the other hand, could not be store in the ware house.

The shell of *C. lencoranea* reaches about 32 mm in diameter and has 5 whorls, with dark brown 5 spiral tapes. The adults overwinter under the soil or trees gaps and have 1 generation in each 2 years (Mirzaei, 1971). *C. lencoranea* feeds during nights and rest during days in cooler parts of trees and over branches. In this manner, shell aperture had closed by dry gelatin material (Esmaili, 1983). Based on Gimingham (1940), methaldehyde has been the most effective chemical control for slugs and snails since introduction as molluscicides bait in 1934. Mesurol® (methiocarb), a banned use pesticide is another popular molluscicide which often considered more effective and longer lasting under field conditions than

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Figure 1. A barrier cone-like tied on the tree trunk.

methaldehyde (Mutze and Hubbard, 2000). Mazandaran, northern province of Iran has about 112000 ha citrus orchards. In 2010, 30 tonne sevin and 40 tonne methaldehyde used to control CBS in citrus orchards in the mentioned region (personal communication, Zaghi¸ 2010). On the other hand, with having humid climate which provides great condition for CBS activity, every year it allocates the most level under cultivation of pest control in citrus orchards.

Pesticides residue from irregular application of pesticides in most citrus orchards of Mazandaran caused pests resistance, natural enemies' disruption, environmental imbalance, and outbreak of secondary pests (Damavandian, 2007). Many soil-inhabitant insects such as Carabid beetles are the main predator of snails (Helyer et al., 2003). Due to soil pollution, their activity destructed and finally could lead to snail's outbreak. Therefore, regarding to implied problems, severe environmental pollution and endangered residents health made it necessary to replace un-chemical methods in mentioned area. Oil spraying is a very important alternative of chemical pesticides for controlling some pests in organic citrus orchards (Kiss et al., 2005).

The current study was conducted in Mazandaran, Iran, to compare the effectiveness of mineral oil with other conventional methods to improve Integrated Pest Management (IPM) of *C. lencoranea* which seeks to minimize pesticides use through application of alternative strategies. Our main goal is to introduce a novel alternative non-chemical method for controlling citrus snails instead of commercial chemical pesticides.

MATERIALS AND METHODS

Study site

This study has been conducted in a 40 ha citrus orchard, located in babolsar (36° 33N ¸ 52° 42E)¸ Mazandaran province. Citrus trees were 12-year-old of Thomson navel on *citrus aurantium* root stock with an inter-row distance of approximately 7 m and the distance between trees within a row about 4 m. The average height of trees was 3.5 m. Two experiments were conducted in adjacent blocks with 1 and 1.5 ha in mentioned area.

A completely randomized design was used for both experiments. All snails were removed from trees before applying treatments. There were five treatments:

(1) Untreated control
(2) Mineral oil: Cone-like plastic sheet which mounted around the tree trunk with about 20 cm distances from the ground level. In order to fix it, its upper part is (end of the cone) tied to the tree trunk with plastic brace and about 10 to 15 cm of external upper border of plastic barrier sheet smeared with mineral oil (Tehran oil company®) that has very sharp oily smell (Figure 1).
(3) Methaldehyde pellets (partonar company®) (weight/m^2), according to manufacturer company should apply with any time of raining.

Table 1. Average numbers of counted snails in 80 trees during 6 sampling dates.

Treatment	Snail average for each tree	Standard deviation	Minimum counted snails	Maximum counted snails
Control group	15.19	3.12	8	23
Mineral oil	2.62	1.44	0	6
Copper tape	4.05	1.58	0	7
Methaldehyde	7.2	3.19	2	13
Ferricole	8.69	3.12	2	15

Table 2. Analysis of variance results for equity test of treatments averages in 6 sampling date.

Date	Df	F	p
29.09.2010	4.75	49.09	0.000
10.10.2010	4.75	50.34	0.000
20.10.2010	4.75	56.68	0.000
5.11.2010	4.75	60.1	0.000
15.11.2010	4.75	71.58	0.000
25.11.2010	4.75	73.93	0.000

(4) Ferricole pellets (Kimia sabzavar company®) (10 mg/m^2) consists of iron phosphate with anti-feeding material and should apply with any two or three times of raining.
(5) Copper tape (kimia sabzavar company®): This tape with 5 to 6 cm width and 10 to 20 cm height from the ground level tied to tree's trunk. There are linear groove over lower edge that bend upward after tie the tape, while sharp edges of the tape placed parallel to the ground with right angle to the tree's trunk.

Experiment 1

Citrus orchard selected for this experiment had 390 trees in 13 rows. Treatments applied in this experiment consisted of mineral oil, methaldehyde, ferricole, copper tape and untreated control. In this experiment for each treatment 4 replication and in each replication 4 trees have been considered. Each replicate was separated with two rows buffer zone in order to preventing of treatment impacts on each other which no treating was conducted during experiment term. After treatment, the number of snails over branches was counted in 80 trees under study, every 10 days and totally in 6 different time courses until harvest. It is necessary to say that in each sampling stage, counted snails removed from trees, therefore, the number of existing snails indicated new ones among two sampling date those could pass through the barriers and reach branches and leave of trees.

Experiment 2

Selected citrus orchard block considered about 1.5 ha consisted of 15 rows of trees containing 30 trees in each row, and one row was used for each replication. Totally, 450 trees were sampled during experiment. There were three treatments: (1) untreated control, (2) mineral oil, and (3) methaldehyde pellets (7 mg/m^2).

The most common chemical mulluscicide for controlling *C. lencoranea* in this region is methaldehyde and mineral oil treatment. Since mineral oil is safe for the environment, in the second experiment just methaldehyde and mineral oil treatments were applied. In this experiment for each treatment, there were 5 replications and each replication includes 30 trees. In each sampling date, 5 trees in each row and totally 25 trees were sampled for each treatment. First, tree was sampled randomly in each row, then in the next time course, next tree was sampled. In this experiment, existing snails over trees counted only one time, therefore, results of sampling date had no effects on the next sampling date.

The data were analyzed using a one-way analysis of variance after log(x+1) transformation to stabilize the variance, and analysis of variance (ANOVA) (dunnett t3). Means of each treatment in different sampling dates were compared using repeated measure comparisons.

RESULTS

Experiment 1

There were significant differences among the numbers of *C. lencoranea* in the different treatments (P<0.00; df=4, 475; F=336.481). Average number of counted snails in the trees during 6 sampling dates showed that the greatest efficiency was associated with mineral oil, copper barrier tape, methaldehyde and ferricole, respectively (Table 1). Variance analysis for average equity test separately in each sampling date shows that there were significant differences among the numbers of live snails in the treatments (Table 2). While all treatments compared with control trees and each other separately, indicated that all treatments with untreated trees had significant difference, average of differences showed that all sampling dates had greatest difference with untreated trees related to mineral oil treatment and the least difference related to Ferricole treatment (Table 3).Result of dunnett t3 test in all 6 sampling dates indicated significant difference between methaldehyde

Table 3. Comparison of counted snail's number over untreated trees and methaldehyde with other treatments.

Date	Treatment	Average difference of control group with all treatment	Comparison of control group with other treatment (P)	Comparison of methaldehyde with other treatment (P)
29.09.2010	Mineral oil	10.75	0.000	0.000
	Copper tape	8.87	0.000	0.023
	Methaldehyde	5.93	0.000	-
	Ferricole	4.68	0.000	0.908
10.10.2010	Mineral oil	12	0.000	0.001
	Copper tape	10.31	0.000	0.087
	Methaldehyde	7.75	0.000	-
	Ferricole	6.31	0.000	0.867
20.10.2010	Mineral oil	12.25	0.000	0.001
	Copper tape	10.75	0.000	0.052
	Methaldehyde	7.87	0.000	-
	Ferricole	6.18	0.000	0.742
5.11.2010	Mineral oil	12.81	0.000	0.001
	Copper tape	11.56	0.000	0.19
	Methaldehyde	8.39	0.000	-
	Ferricole	6.75	0.000	0.863
15.11.2010	Mineral oil	13.56	0.000	0.000
	Copper tape	12.43	0.000	0.000
	Methaldehyde	8.93	0.000	-
	Ferricole	7.43	0.000	0.861
25.11.2010	Mineral oil	14	0.000	0.000
	Copper tape	12.87	0.000	0.000
	Methaldehyde	9.12	0.000	-
	Ferricole	7.62	0.000	0.873

with mineral oil treatment. Methaldehyde with Copper tape in 3 sampling date and with Ferricole in 6 sampling date had no significant difference (Table 3).

Experiment 2

The number of C. *lencoranea* per tree differed significantly in the treated and untreated trees ($F=276.531$; $df=2.44$; $p<0.001$). Regarding to this experiment, 450 trees sampled and the differences between counted snail numbers were obvious in different treatments (Figure 2).

Results of dunnett t3 test in all 6 time course showed significantly between control group with mineral oil and methaldehyde treatments (Table 4). It must be noted that in all sampling dates, the number of counted snail difference between mineral oil and methaldehyde treatments was significant as well ($p\leq0.05$).

DISCUSSION

Comparison of different treatments with untreated trees showed their ability in *C. lencoranea* control, although the rate of controlling of treatments was different from each other. The higher average of counted number of *C. lencoranea* in the trees after 6 sampling dates was related to ferricole (8.69), methaldehyde (7.2), copper tape (4.05), and mineral oil (2.62), respectively (Table 1); that separate analysis of each sampling date between treatments were significant as well (Table 2).

According to Amiri (2009), methaldehyde has been the most effective chemical control for snails in Mazandaran¸ Northern Province of Iran. In spite of its increase application, *C. lencoranea* damages were more severe (Ahmadi and Hallaji Sani¸ 2006). Increase damaging by snails regarding to pesticides application rise depends on many reasons. For example, increasingly consumption of synthetic pesticides will lead to snails resistance (Ahmadi

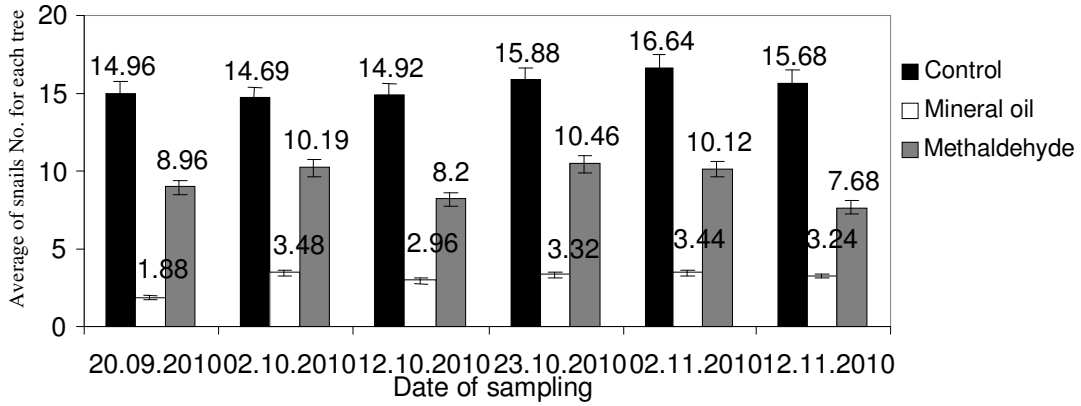

Figure 2. Comparison of average number of snails for each treatment in different dates.

Table 4. Comparison of counted snail's number in the treated and untreated trees.

Date	Treatment	Average difference with control group	Comparison of control group with other treatments (P)
20.09.2010	Mineral oil	13.8	0.000
	Methaldehyde	6	0.008
02.10.2010	Mineral oil	11.48	0.000
	Methaldehyde	5.36	0.005
12.10.2010	Mineral oil	11.96	0.000
	Methaldehyde	6.72	0.000
23.10.2010	Mineral oil	12.56	0.000
	Methaldehyde	5.72	0.004
02.11.2010	Mineral oil	13.2	0.000
	Methaldehyde	6.52	0.000
12.11.2010	Mineral oil	12.44	0.000
	Methaldehyde	8	0.000

and Arbabi, 2000) and reduction in the rate of activities of the natural enemies activities such as carabid beetles and increase of relative humidity caused snails activity (Denny, 1980), and reduction in methaldehyde activities (Ahmadi and Arbabi, 2000). According to Armsworth et al. (2005) snails have been seen less in places that carabid beetles had more activity and made less damages. In addition to make damages on ecosystem, Methaldehyde had not the best results on snail controlling in our study. Methaldehyde control ability in controlling *C. lencoranea* was a little above Ferricole. However, there was no significant difference between them ($p \leq 0.13$) and in comparison with Copper tape and Mineral oil, had less efficiency (Figure 3).

Ferricole with 1% iron phosphate control snails (Jackel, 1999; Koch et al., 2000) has no serious danger for other creatures in the environment (Roberts et al., 1990; Clarks, 1993). It was useful as nutritious material for plants (Rae et al., 2009). According to Speiser and kistler (2002), iron phosphate caused decrease snail's damage over products such as lettuce but in comparison to methaldehyde had fewer effects. In this study, effect of ferricole on *C. lencoranea* activity in comparison to methaldehyde had less impact, but their differences in pest control were not significant (Figure 3).

Regarding to results, in the case of chemical control with citrus brown snail, in order to prevent environmental pollution by pesticides, it is suggested that to apply Ferricole, it is a little more expensive in comparison to methaldehyde (Table 5). Preventing snail's movement by barriers of copper tape type is reported by several researchers (Barker, 2002). Schuder et al. (2003) implied

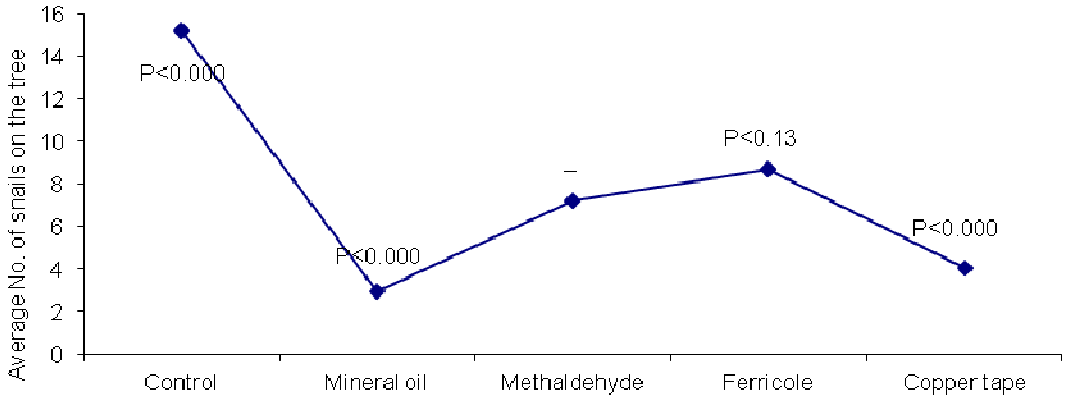

Figure 3. Comparison of average of counted snails for studied treatment (comparison methaldehyde with other treatments).

Table 5. Cost of each treatment during one season per hectare.

Treatment	Amount of application for each tree	Times of application during experiment	Price ($/tree)	Labor ($/ha)	Total cost ($/ha)
Methaldehyde	13.3 g	8	0.03	32	95.7
Ferricole	20 g	8	0.05	32	120
Copper tape	50 cm	1	0.6	12	180
Mineral oil	50 cm of con-like foam	1	0.28	12	84

prevention mechanisms and negative effects of copper tapes on activities and feeding of snails and considered them as an effective factor to limit snail's activity.

In this study, copper tape caused decrease in the number of *C. lencoranea* in all sampling date and in comparison to chemical controls such as methaldehyde and ferricole had more efficiency (Figure 3). Its difference with both mentioned treatments was significant ($p \leq 0.00$). It must be said that some snails could pass through copper tape and after raining, their numbers becomes more. Ryder and Bowen (1977) indicated that copper salts have the ability to be absorbed by snail's body and caused damage. Therefore, snail movement over copper tape after raining may depend on copper salt washing and lower concentration of it by rain. According to Dutoit and Brink (1992), copper tape around the trunk could control *Helix aspersa* muller for more than 7 months.

Barriers which caused prevention of vertical movement of snails could be chemical or physical (Schuder et al., 2003). Plastic sheet of foam type in cone-like shape mounted around the tree trunk. In the first stage, physically prevents snails movement and then by smearing to internal edges of cone to the mineral oil (Tehran oil®) with sharp smell caused snails to quickly withdraw their tentacles when encountering mineral oil and escape (personal observation).

Results in the first and second experiments obtained from 80 and 450 trees¸ respectively¸ showed that mineral oil treatment in comparison to other treatments in all sampling date had more efficiency (Tables 3 and 4). Snail's movement around the trunks and upward the trees during sampling dates were not monotonous and showed significant difference in all 6 sampling date. Various factors are involved in snails' movement and activity but the most important factor that caused reduction in snail activity is cool temperature (Riddle and Miller, 1988; Ansart and Vernoun, 2003; Ansart et al., 2001). In our study, during sampling dates, average temperature was always more than 10°C and in this condition, environmental moisture and raining, probably effects on snails activity. Bedford et al. (1998) believed that *H. aspersa* activity generally become more in raining seasons.

We conclude that this new method based on barrier and mineral oil is a very powerful physico-chemical obstruction for several reasons. The most important ones include the most rate of pest control, the logical cost (Table 5), and less pollution in the environment. Copper tape is due to expensiveness, iron phosphate and Methaldehyde because of less efficiency and environmental pollution, respectively put under next range of control.

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