THE EFFECT OF KAOLIN TREATMENTS ON PHYTOPHAGOUS AND PREDATORY ARTHROPODS IN THE CANOPIES OF APPLE TREES

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(Received October 10, 2005/Accepted March 3, 2006)

ABSTRACT

The effect of a kaolin-based particle film formulation on apple pests and their natural enemies was investigated in an experimental apple orchard in the Netherlands. Each plot chosen for the experiment was planted with 260 trees of 'Golden Delicious', 'James Grieve' and 'Cox's O.P'. Four 0.2-hectare plots were divided into two parts. One part was treated with kaolin particle film, while the other part served as the control. Kaolin was applied in the form of hydrophobic kaolin M96-018, which was applied at a rate of 45 kilograms per hectare in a suspension of 30 grams kaolin M96-018 and 40 ml methanol per liter of water. The treatments were applied about every ten days twelve times between March 25 and August 5. Beating-tray samples were collected nine times by tapping the entire canopies of ten trees per treatment. Data recorded included the number of aphid colonies, communal caterpillar webs, and leaf mines, and the population densities of *Hoplocampa testudinea* and *Eriosoma lanigerum.* All the samples were collected from the cultivar James Grieve. The kaolin treatment reduced the population density of *Aphis pomi, Anthonomus pomorum,* and *Empoasca vitis,* and the number of communal caterpillar webs. The proportion of fruits infested with *H. testudinea* was 9.31% on the treated plots and 35.7% on the control plots. On the other hand, there were more mines formed by *Lyonetia clerkella*, *Phyllonorycter blancardella* and *Phytomyza heringiana* on the treated plots than on the control plots. Kaolin particle films also increased the population density of *Eriosoma lanigerum* so that, by the end of

the season, the treated plots were severely infested. In spite of the higher prey density, the numbers of the most important predators, *Forficula auricularia*, *Allothrombium fuliginosum* and *Exochomus quadripustulatus,* were significantly lower on the kaolin treated plots. This also was the case for the spiders.

Key words: kaolin particle film, apple, pests, natural enemies

INTRODUCTION

Kaolin particle films protect plants by forming a layer of refined kaolin particles on the surface of the leaves and fruits. This reduces heat stress while allowing photosynthetically active light to pass. Kaolin is negligibly toxic to humans (Glenn and Puterka, 2005). The development of kaolin-based particle film technology was initiated by the Engelhard Corporation and the Agricultural Research Service of the US Department of Agriculture in 1996. Initially, hydrophobic films were produced with the hope that they could be used in controlling diseases in plants. After the first open field trials, hydrophobic kaolin was replaced by hydrophilic kaolin, which is easier to mix and spray with water and is about as effective in controlling arthropod pests as hydrophobic kaolin (Glenn and Puterka, 2005). Although kaolin particle film has been effective in controlling some diseases, emphasis has shifted towards using it to control pests, reduce sunburn, and heat stress. In 2000, the Engelhard Corporation began to market kaolin film technology in the United States under the brand name "Surround® WP Crop Protectant", which has been available in some European countries since 2004.

The fine white kaolin particles form a physical barrier on the surface of the plants which repels various pest species. Kaolin particle film has been used to control numerous pests in apple orchards, including:

- the two-spotted spider mite (*Tetranychus urticae*) (Glenn et al., 1999);
- the spirea aphid (*Aphis spireacola*) (Glenn et al., 1999);
- the white apple leafhopper (*Typhlocyba pomaria*) (Knight et al., 2000);
- the potato leafhopper (*Empoasca fabae*) (Glenn et al., 1999);
- the plum curculio (*Conotrachelus nenuphar*) (Thomas et al., 2004);
- the codling moth (*Cydia pomonella*) (Unruh et al., 2000);
- the oblique-banded leafroller *(Choristoneura rosaceana)* (Knight et al., 2000);
- the red-banded leafroller (*Argyrotaenia velutinana*) (Thomas et al., 2004);
- the fruit-tree leafroller (*Archips argyrospilus*) (Knight et al., 2001); and
- the Mediterranean fruit fly (*Ceratitis capitata*) (Mazor and Erez, 2003).

However, kaolin particle films have been reported to increase population density in the rosy apple aphid (*Dysaphis plantaginea*), San Jose scale

(*Quadraspidiotus perniciosus*), and the western tentiform leaf miner (*Phyllonorycter elmaella*) (Knight et al., 2000; 2001; Kahn et al., 2001). Kaolin particle film treatments also repelled some natural enemies of apple pests. Kaolin particle film treatments reduced the rate of parasitism on the western tentiform leaf miner by *Pnigalio flavipes,* and also reduced populations of spiders (Knight et al., 2001; Kahn et al., 2001). In one study conducted in an apple orchard, ladybird beetle larvae and earwigs (*Forficula auricularia*) were also less numerous on kaolin treated plots than on untreated control plots (Knight et al., 2001)

MATERIAL AND METHODS

The trials were carried out at the De Schuilenburg Experimental Apple Orchard in Kesteren, the Netherlands in 1997. Each plot chosen for the experiment was planted with 260 trees of 'Golden Delicious', 'James Grieve' and 'Cox's O.P'. Four 0.2-hectare plots were divided into two parts. One part was treated with kaolin particle film, while the other part served as the control.

Kaolin was applied in the form of hydrophobic kaolin M96-018 (Engelhard Corporation, Iselin, New Jersey), which was applied at a rate of 45 kilograms per hectare in a suspension of 30 grams kaolin M96-018 and 40 ml methanol per liter of water. The treatments were applied about every ten days twelve times between March 25 and August 5.

Between May 3 and September 17, beating-tray samples were collected nine times by tapping the entire canopies of ten trees per treatment.

On June 15, aphid colonies and communal caterpillar webs were counted on fifty shoots per plot. The caterpillar webs were probably made by the apple ermine moth (*Yponomeuta malinellus*).

On August 11, leaf mines were counted on 200 shoots per plot.

On July 22, the level of infestation by the woolly apple aphid (*Eriosoma lanigerum*) was assessed on a scale from 0 to 8, where 0 equals no infestation and 8 equals infestation of more than 25% of the shoots (Stäubli and Chapuis, 1987).

On June 14, 125 fruits per plot, all of the cultivar 'James Grieve', were examined to determine the amount of damage caused by the apple sawfly (*Hoplocampa testudinea*). Data on sawfly damage were compared using Welch's d-test. Data on the number of aphid colonies and communal caterpillar webs were compared using one-way comparison of related samples with Johnson's modified t-test. Data on the population densities of leafhoppers, *Allothrombium fuliginosum* and *Exochomus quadripustulatus* and the level of infestation by leafminers were compared using Welch's modified t-test.

RESULTS

Pests

The most important pest species collected by beating was the apple blossom weevil (*Anthonomus pomorum*). It was always present in higher numbers in the control plots at all sampling times. However, the difference between the treated and control plots was statistically significant only on June 16, when 3.5 times as many individuals were collected on the control plots that on the treated plots (Fig. 1).

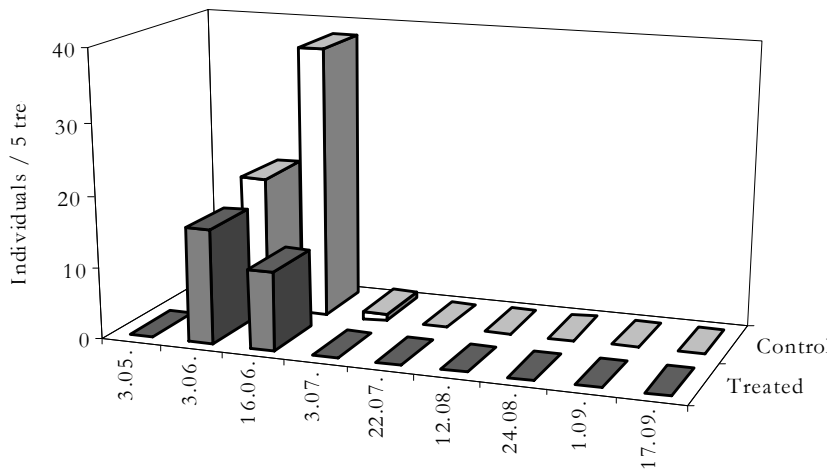

Figure 1. Number of blossom weevils (*Anthonomus pomorum*) collected during the season

Table 1. Mean number of aphid colonies and communal webs of caterpillars per 25 trees (standard deviation) on 15 June, n = 6

	Control	Kaolin	Johnson's modified t-test
Aphis pomi	32.83 (20.95)	2.67 (3.50)	J(5) = 6.757 **
Dysaphis plantaginea	6.33 (15.51)	8.83 (13.06)	J(5) = -0.376 n.s.
Dysaphis devecta	0.00 (0.00)	1.33 (3.27)	J(5) = -1.500 n.s.
Webs of caterpillars	6.00 (3.95)	0.00 (0.00)	J(5) = 3.778 *

n.s. non significant, * $p<0.05$, ** $p<0.01$

The mean amount of damage caused by the apple sawfly damage was 9.31% ±0.04% on the treated plots and 35.7% ±0.12% on the control plots.

The difference was statistically significant (Welch's d test, d(11) = -6.393, p < 0.01).

Twelve times as many green apple aphids (*Aphis pomi*) were found on the control plots than on the treated plots. The difference was statistically significant (Tab. 1).

Relatively few rosy apple aphids (*Dysaphis plantaginea*) and rosy leaf-curling aphids (D*ysaphis devecta*) were found on the 'James Grieve' trees. There were no significant differences between the treated plots and the control plots for either species (Fig.1).

Significantly fewer caterpillar webs were found on the treated plots than on the control plots (Tab. 1).

The most common leafhopper detected on September 28 was the vine leafhopper (*Empoasca vitis*), which was present at an average density of 81.00 ±23.30 individuals per tree on the control plots, and 23.50 ±22.56 individuals per tree on treated plots. The difference was statistically significant (Welch's modified t-test: W(8) = -4.050, p < 0.01).

T a b l e 2. Mean number of mines per shoot (standard deviation) on 11 August, n = 200

	Control	Kaolin	Welch's modified t-test
Phyllonorycter blancardella	0.07 (0.28)	0.61 (0.71)	W(221) = 2.735**
Lyonetia clerkella	0.01 (0.07)	0.07 (0.30)	W(257) = 9.977**
Phytomyza heringiana	0.13 (0.41)	0.30 (0.61)	W(247) = -3.957**

**p < 0.01

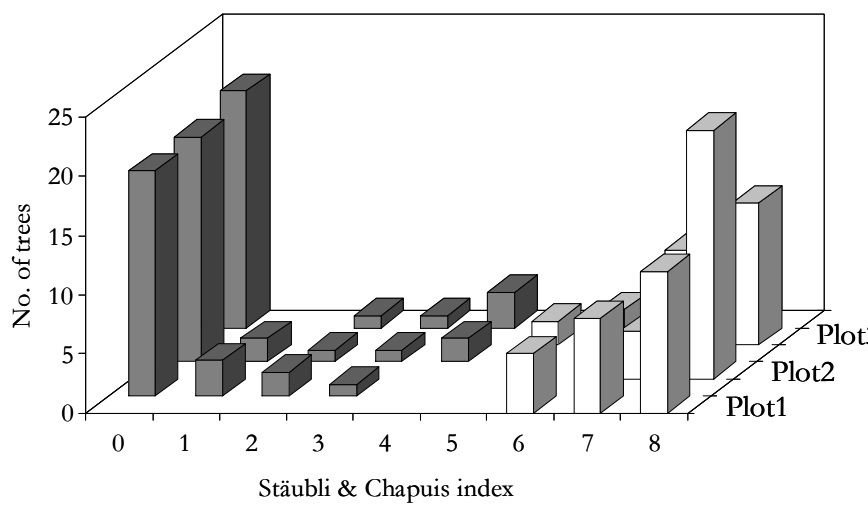

Figure 2. Woolly apple aphids (*Eriosoma lanigerum*) infestation in the treated (grey columns) and control (white columns) parts of the plots (number of trees in the different infestation groups, n = 25 trees) on 22 July; Stäubli and Chapuis (1987) index

Few leafminer mines were counted. Mines of six species were found, mainly the spotted tentiform leafminer (*Phyllonorycter blancardella*), the apple leafminer (*Lyonetia clerkella*), and the agromyzid fly, *Phytomyza heringiana*. Significantly more mines were found on the treated plots than on the control plots (Tab. 2).

Many more woolly apple aphids were found on the treated plots than on the control plots. On average, twenty of the twenty-five trees examined on the control plots received a score of 0, while fifteen of the twenty-five trees examined on the treated plots received a score of 8 (Fig. 2). On the treated plots, the level of infestation was severe and much higher than the economic threshold level.

Natural enemies

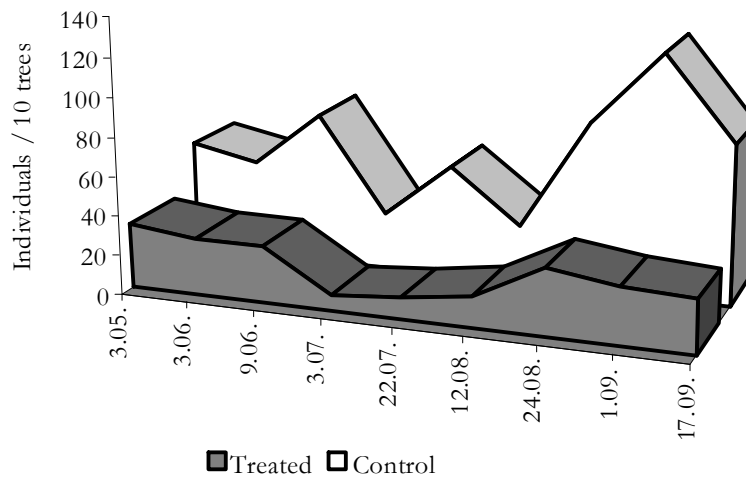

Figure 3. Number of spiders collected during the season

The most common predators encountered were spiders, followed by the common earwig (*Forficula auricularia*). Throughout the growing season, they were less numerous on treated plots than on control plots (Fig. 3 and 4).

Between May 5 and August 24, significantly fewer individuals of the predatory mite *Allothrombium fuliginosum* were found on the treated plots than on the control plots. An average of 0.30 ±0.45 individuals per tree were found on the treated plots, while an average of 3.30 ±1.52 individuals per tree were found on the control plots (Welch's modified t-test: (5) = -4.222, $p < 0.01$).

Between May 5 and August 24, significantly fewer individuals of the pine ladybird (*Exochomus quadripustulatus*) were found on the treated plots than on the control plots. An average of 1.30 ±0.75 individuals per tree were found

on the treated plots, while an average of 4.90 ±2.16 individuals per tree were found on the control plots (Welch's modified t-test: $W(5) = -3.513$, $p < 0.05$).

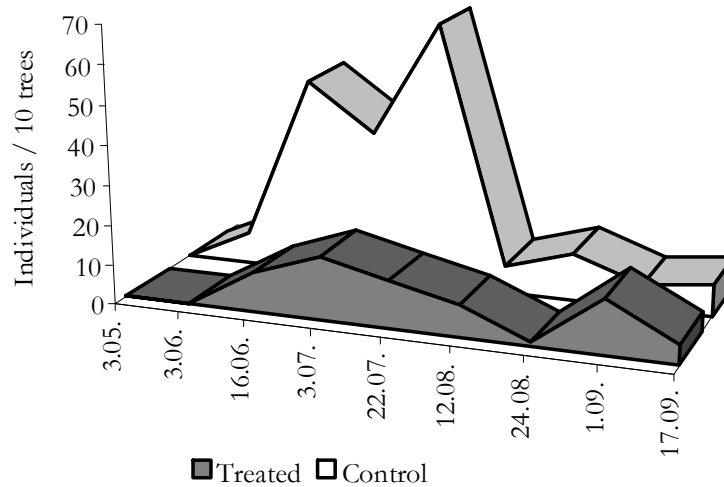

Figure 4. Number of common earwigs (*Forficula auricularia*) collected during the season

After the last treatment on August 5, the population density of *Allothrombium fuliginosum*, *Forficula auricularia* and *Exochomus quadripustulatus* increased on the treated plots.

On the other hand, the population density of spiders was very low on treated plots. Even a month after the last treatment, the population density of spiders was still lower on the treated plots than on the control plots (Fig. 3).

Kaolin particle film technology controls *Anthonomus pomorum, Empoasca vitis*, *Aphis pomi*, *Hoplocampa testudinea* and reduces the number of communal caterpillar webs. However, kaolin particle films were not effective enough in controlling these pests to bring the damage level below the economic threshold level.

Kaolin particle films had no effect on *Dysaphis devecta* and *Dysaphis plantaginea.*

On the other hand, kaolin particle films increased the population density of the leafminers *Phyllonorycter blancardella*, *Lyonetia clerkella* and *Phytomyza heringiana.*

Kaolin particle films also increased the population density of the woolly apple aphid (*Eriosoma lanigerum*) by reducing the population densities of *Forficula auricularia*, *Allothrombium fuliginosum* and *Exochomus quadripustulatus,* which prey on the woolly apple aphid. By the end of the season, the treated plots were severely infested with the woolly apple aphid.

Kaolin particle films can also indirectly increase the population density of many other pests by reducing the population density of spiders.

The effectiveness of kaolin particle films as a pest control method was reduced by two factors:

- frequent rainfalls, which washed off the kaolin particle film; and
- the reduction in the number of predators and parasitoids.

Further research is needed in the following areas:

- the efficacy of kaolin treatments early in the season in controlling *Anthonomus pomorum* and other pests in organic apple orchards;
- the negative impact of kaolin particle films on the key natural enemies of the most important apple pests; and
- the potential use of kaolin films in reducing environmental stress and pest damage in organic apple production in regions with a dry and hot climate.

Acknowledgements. Preparation of this paper was supported by the Hungarian National Scientific Research Fund (OTKA), Grant No. T046380.

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EFEKT STOSOWANIA KAOLINU NA WYSTĘPOWANIE ROŚLINOŻERNYCH I DRAPIEŻNYCH STAWONOGÓW W KORONACH DRZEW JABŁONI

Viktor Markó, Leo H.M. Blommers, Sándor Bogya i Herman Helsen

STRESZCZENIE

Wpływ kaolinu na szkodniki jabłoni i ich wrogów naturalnych badano w doświadczalnym sadzie jabłoniowym w Holandii. Każde poletko doświadczalne obejmowało 260 drzew jabłoni odmiany 'Golden Delicious', 'James Grieve' i 'Cox's O.P' Cztery poletka liczące po 0,2 ha podzielono na dwie części. Jedną część traktowano kaolinem, a drugą pozostawiono jako kontrolną. Kaolin stosowano w formie hydrofobowego kaolinu M96-018 w dawce 45 kg/ha jako zawiesinę 30 gram kaolinu M96-018 i 40 ml metanolu w 1 litrze wody. Zabiegi wykonywano mniej więcej co 10 dni, dwanaście razy w okresie od 25 marca do 5 sierpnia. Do oceny występowania stawonogów zastosowano metodę otrząsania całych koron 10 drzew każdej kombinacji. Ponadto rejestrowano: liczbę kolonii mszyc, oprzędów czynionych najprawdopodobniej przez gąsienice namiotnika jabłoniowego (*Yponomenta malinellus*), min na liściach oraz liczebność populacji owocnicy jabłkowej (*Hoplocampa testudinea*) i bawełnicy korówki (*Eriosoma lanigerum*). Wszystkie obserwacje wykonywano na odmianie 'James Grieve'.

Zabiegi kaolinem redukowały liczebność mszycy jabłoniowej (*Aphis pomi*), kwieciaka jabłkowca (*Anthonomus pomorum*), skoczka *Empoasca vitis* oraz oprzędów namiotnika jabłoniowego (*Yponomenta malinellus*).

Liczba owoców uszkodzonych przez *H. testudinea* na drzewach traktowanych kaolinem wynosiła 9,31%, natomiast na drzewach kontrolnych 35,7%. Z kolei liczba min na liściach powstałych w wyniku żerowania larw takich gatunków, jak: *Lyonetia clercella*, *Phyllonorycter blancardella* i *Phytomyea heringiana* była wyższa na drzewach traktowanych kaolinem niż na drzewach kontrolnych. Zabiegi kaolinem spowodowały również wzrost liczebności populacji *Eriosoma lanigerum* tak, iż pod koniec sezonu odnotowano bardzo liczne zasiedlenie drzew. Pomimo większej liczebności ofiar (dostępność pokarmu), liczebność takich ważnych drapieżców, jak *Forficula auricularia*, *Allothrombium fuliginosum* i *Exochomus quadripustulatus*, była znacząco niższa na kwaterach traktowanych kaolinem. Dotyczyło to także liczebności pająków.

Słowa kluczowe: kaolin, stawonogi roślinożerne, stawonogi drapieżne, jabłoń, *Yponomenta malinellus*, *Hoplocampa testudinea, Eriosoma lanigerum, Aphis pomi*, *Anthonomus pomorum*, *Empoasca vitis, Lyonetia clercella*, *Phyllonorycter blancardella, Phytomyea heringiana*, *Forficula auricularia*, *Allothrombium fuliginosum, Exochomus quadripustulatus*