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Effects of kaolin-based particle film on physiological, nutritional, nutraceuticals parameters and *Ceratitis capitata* infestations in peach fruit at harvest and after storage

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Abstract: The Mediterranean fruit fly (*Ceratitis capitata* Wiedemann) is a worldwide pest of economic importance because attacks a large number of agricultural crops and for the extent of the damage it causes. Among the alternative control strategies to the use of sprays with synthetic insecticides, a very important role can be played by powders obtained from rocks whose activity arise from the ability to form a film of white powder, which acts as a repellent and irritant to insects. This film can also interfere with plants' physiology and affect quality of fruit. In this study the efficacy of a commercial kaolin-based formulation to control medfly infestations was compared to synthetic insecticides commonly used against this pest (phosmet, alfa-cypermethrin, deltamethrin). The results showed a significant reduction of medfly attacks in fruits treated with insecticides (1.5% damaged fruit) or with kaolin (0.5% damaged fruits) compared to the untreated sample (10% damaged fruits), while physiological and quality parameters did not show relevant differences between treatments and control fruit. Overall results highlight how the use of kaolin represents a valid alternative to treatments with synthetic insecticides to control *C. capitata* attacks on peaches, while not affecting fruits' quality.

1. Introduction

Ceratitis capitata (Diptera Tephritidae), also known as the Mediterranean fruit fly is one of the most harmful insect pests to several fruit crops of the Mediterranean countries. It is a polyphagousic phytophagous that is considered highly invasive for the wide of host species and the high tolerance to low temperatures, compared to other fruit flies (Malacrida *et al.*, 2007). The fruits can be attacked early or close to harvesting: in the first case, the fly may sting the fruit several times for the oviposition and the developing larvae cause rottenness, early ripeness and fruit drop. In case of late stings, the eggs laid shortly before harvesting, hatch during storage. Yet, even in case eggs would not hatch, wounds caused by stings could favor growth of decay causing fungi (D'Aquino *et al*., 2011). Given the extent of the damage caused by this fly, early monitoring is required, when fruits are not yet ripe. In Italy the control strategy against *C. capitata* is mainly carried out with traps for adult specimens or with chemical sprays, whose use is increasingly discouraged after the European Directive 2009/128/EC. Moreover, the development of resistant strains to conventional pesticides (Sparks and Nauen, 2015) has stimulated studies for alternative and biological methods based on low toxicity and environmentally friendly plant extracts and mineral products. One of these mineral products is the kaolin clay, a fine powder, mainly composed of kaolinite, which, sprayed onto trees as a water suspension, forms a white and thin particle film on leaves and fruit surface (Glenn *et al*., 1999; Mazor and Erez, 2004). Different mechanisms seem to be involved in contrasting medfly attacks on fruit. The particle film beside masking the colour of leaves, stems and fruits, making long-distance host recognition difficult (Saour and Makee, 2004), renders the host less attractive for the white color of the film, which is the least attractive colour for ovipositing females of *C. capitata* (Katsoyannos, 1987). Moreover, the hard and irritating surface of kaolin film exerts at some extent a repellent effect on several insects, included medfly (Saour and Makee, 2004; Salerno *et al*., 2019).

However, if the positive effect of kaolin to control several pests is well documented and consistent, its impact on physiological response of plants and fruit quality is contradictory, depending on several factors such as the commercial formulations of the powder, the climate conditions, the intensity and quality of solar radiation, and environmental temperature. Several studies show that kaolin particle films do not reduce photosynthesis and plant growth but mitigate water stress and photorespiration caused by intense solar radiation (Kerns and Wright, 2000; Glenn *et al*., 2002; Jifon and Syvertsen, 2003). Kaolin treatments were also reported to reduce leaf temperature and increase water use efficiency in artichoke (Basnizki and Evenari, 1975) and to decrease the rate of CO_2 absorption (presumably due to a partial block of stomata opening) in sorghum and cotton (Stanhill *et al*., 1976; Moreshet *et al*., 1979).

The aim of this study was to evaluate the effectiveness of kaolin versus synthetic insecticides to control medfly infestation and quality in stone fruit at harvest and during a simulated marketing conditions (SMC) of 7 days.

2. Materials and Methods

Plant material and treatment

The experiment was carried out in a stone fruit orchard located in north-western Sardinia (Lat 39° 50' N, Long 09° 38' E). Seven years old peach trees [*Prunus persica* (L.) Batsch.] cv. O'Henry, highly susceptible to medfly attacks, were chosen for the experiment. Trees were trained to a palmetta system, spaced 3 m along the rows and 4 m between the rows. To evaluate the efficacy of the different treatments, a randomized block design with 3 replicates of 3 trees per treatment was used. Each replicate was separated by the next one by four untreated trees. The following treatments were compared: i) Kaolin (Surround® WP, Geovita, Turin, Italy; dissolved in water at 30 g/L); ii) a sequence of synthetic insecticides representing a local protocol to control medfly, applied in the following order: one treatment with phosmet (Spada® 50 WG, Gowan, Ravenna, Italy, at 1.5 g/L); two treatments with alpha-cypermethrin (Fastac® 10 SC, BASF, Monza e Brianza, Italia, at 0.3 g/L) and two treatments with deltamethrin (Decis® EVO, Bayer Crop Science, Ravenna, Italy, at 0.12 g/L); iii) Untreated control.

Phosmet, an organophosphate insecticide, can penetrate through the plant surface with a limited transport in plant tissues (Agrochemicals Handbook, 1983), while Alpha-cypermethrin and Deltamethrin are synthetic insecticides belonging to the pyrethroid group, that kill insects for contact and are more stable than pyrethrins when exposed to air and sunlight (Worthing and Hance, 1991). All treatments, carried out by spraying the products on the plants to obtain a homogeneous coverage, started 42 d before harvest, when fruits were not susceptible to medfly attacks and repeated at week intervals until 7 d before harvest. This local protocol followed by growers relies on frequent treatments in order to maintain residue levels of insecticides sufficient to kill medfly adults on fruit surface. On the other hand, Kaolin was also sprayed at week intervals to maintain a continuous and even film on fruit surface, whose homogeneity would be reduced and made discontinuous by fruit growth in case less treatments had been done.

Evaluation of medfly damage and storage condition

At harvest, the total number of fruits for each treatment showing visible damage by medfly, confirmed by the presence of larvae after dissecting the fruit, were counted and the percentages of damaged fruit on the total yield of each plant were calculated. The total number of fruit produced by each plant ranged between 278 and 321.

One hundred and twenty sound fruits (divided in replicated of 40 fruits each) for each treatment, free of any visible defect, were selected for storage. The fruits were placed in plastic trays and stored in a ventilated storage room kept at 20°C and 55-60% RH for 7 d. At the end of storage, fruits were inspected for damage by medfly (presence of larvae within the flesh after dissection) or for the presence of molds but with no evident sign of medfly's attack. The percentage of fruit damaged by medfly and that of fruit with the presence of molds were calculated.

Physiological and chemical determinations

Respiratory activity and ethylene production rates were determined after 1, 2, 3, 5 and 7 d of storage at 20°C and 55-60% RH using 10 sound fruit for treatment. Fruit were individually placed in 1 L jars, whose lids were fitted with two silicon septa and closed for 1 h prior CO_2 determination. At sampling time, the headspace air was mixed for 1 min by an electrical fan fixed inside the jar. CO_2 concentrations were determined by a combined CO_2/O_2 analyzer (Combi Check 9800-1, PBI-Dansensor A/S, Rinsted, Denmarck). The analyzer was connected to each jar by two tubes, each one ending with a needle inserted in one of the two septa to form a closed system. Respiration activity, as CO_2 release, was expressed as mL Kg^{-1} h^{-1}.

To determine ethylene concentration a 1-mL sample headspace air from each jar was withdrawn with a gas-tight syringe from the same septa used for CO_2 determination. Ethylene was assessed by a Varian 3300 GC (Australia Ltd., Victoria, Australia) equipped with a flame ionization detector (FID), Carbowax 20M 80/120 mesh Carbograph 1 AW 30 column (Alltech, Italy, Milan), and the column, injector and detector temperatures set at 60°C, 110°C and 180°C, respectively.

Chemical analyses were performed in triplicate at harvest and after 7 d of storage at 20 °C from puree obtained by homogenizing the fruit with a domestic homogenizer. The results of all chemical analyses are the mean values of three replications. According to the type of analysis, detailed procedures of sample preparation are described below.

Titratable acidity (TA), total soluble solid (SST), total phenolic compounds, glucose, fructose, sucrose, antioxidant activity and organic acid were determined on supernatant obtained by centrifugation of the puree at 13,000 x *g* for 20 min and filtered through a 0.45 µm acetate cellulose filter.

TA was measured using an automatic titrator (Metrom 720 SM Tritino, Switzerland) by titrating aliquots (10 g) of samples to an endpoint of pH 8.2 with 0.1N NaOH and expressing the result as g L^{-1} citric acid, while TSS were measured by a digital refractometer (Mod. PR-101, Atago, Tokyo, Japan) and expressed as percentage.

Total phenolic content was determined according to the Folin-Ciocalteu colorimetric method (Singleton and Rossi, 1965) and expressed as mg 100^{-1} g^{-1} gallic acid equivalents. Folin-Ciocalteu phenol reagent was from Fluka (Buchs, Switzerland).

Analyses of glucose, fructose and sucrose were performed according to Palma *et al*. (2018). Stock standard solutions of each carbohydrate were prepared in ultrapure water and quantified according to the linear calibration curves of standard compounds. Glucose, fructose, and sucrose were purchased from Sigma-Aldrich Co. (Milan, Italy).

Antioxidant activity was assessed using the free radical DPPH, according to Bondet *et al.* (1997). The mixture containing 3mL of a methanol solution of $6\times10^{-}5$ mol L^{-1} of DPPH and 100 µL samples was allowed to react for 15 min in a cuvette. The decrease of absorbance at 515 nm of DPPH solution added with the sample was measured and the results expressed as Trolox equivalent antioxidant capacity (mmol L^{-1} TEAC). 2,2-diphenyl-1-picrydazyl (DPPH), and Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), a water-soluble analog of vitamin E reagent were from Fluka (Buchs, Switzerland).

Malic and citric acid measurement was performed according to Palma *et al*. (2013).

Total carotenoids were extracted from puree using a mixture of hexane/acetone/ethanol (2:1:1). The homogenized sample (10 g) was weighed into 100 mL glass vials with 50 mL of extranet solution. Samples were kept in constant agitation for 60 min. The solutions were left to separation into a distinct polar layer (35 mL) and non-polar layer (25 mL) containing carotenoids. Total carotenoids were determined by a spectrophotometric method using a UV-Vis spectrophotometer (Cary 50, Varian Australia Ltd., Victoria, Australia). Total carotenoids content was calculated by comparing the absorbance of the carotenoids hexane solution with a calibration curve obtained using different concentrations of standard carotene at 451 nm (Kopec *et al*., 2012). carotene was from Sigma-Aldrich Co. (Milan, Italy).

Firmness measurements were carried out by a testing machine (Mod. DO-FB 0.5 TS, Zwick Roell, Ulm, Germany) recording the highest resistance (F Max) opposed to the penetration of an 8-mm-diameter flat faced cylindrical plunger to a depth of 10 mm and moving at a speed of 3.3 mm s^{-1} and the deformation of the fruit surface at the highest resistance opposed before penetration (L at F max). The two parameters, F Max and L at F Max, were expressed as newton (N) and mm respectively. Ten fruits were used for each treatment.

Mass loss, expressed as percentage, was determined on 30 fruits for treatment, individually weighed at harvest and at the end of the storage period.

Statistical analysis

Statistical analysis was performed using Statgraphics Centurion software (Herndon, VA, USA), version XV Professional statistical program. Analysis of variance (ANOVA) was carried out according to a single-factor design, after testing (Skewness and Kurtosis) data normality assumptions. Appropriate data transformations were carried out when violations of normality assumptions were met. The number of replications differed depending on the type of analysis performed. Mean comparisons were performed using Duncan's multiple range test at $P \leq 0.05$.

3. Results

Evaluation of medfly damage at harvest and after storage

At harvest, kaolin and insecticides reduced the percentage of peaches with visible damage~~s~~ by medfly to 0.5 and 1.5%, respectively compared to 10% of untreated fruit (data not shown).

At the end of storage, fruit with visible damage and the presence of larvae within the flesh, observed after cutting the fruit, were 0.5±1% and 3±1.6% in kaolin and insecticide treatments, respectively, while in control fruit the infested fruits were approximately 16±2.1% (Fig. 1). Decay incidence due to the presence of molds was 7.5±2 % in kaolin treated fruit, 13±3% in those treated with insecticides and 19±5.2% in untreated ones. Consequently, the total loss was 8±3 % in kaolin treated fruit, 16±4.1 % in those treated with the insecticides and 35±7.3% in control ones (Fig. 1).

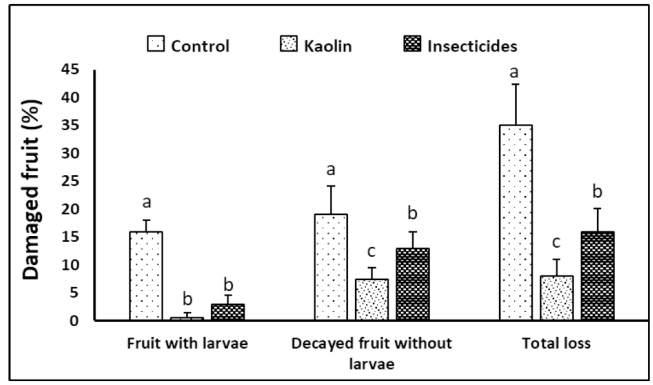

Fig. 1 - Incidence of fruit damaged by *Ceratitis capitata* in 'O'Henry' peach after 7 d of storage. Columns with different letters are significantly different at P≤0.05 according to Duncan's multiple range test. Vertical bars represent standard deviation (n=4).

Effect of treatments on physiological and chemical properties

Compared to harvest time, respiration rate almost doubled at the end of storage, but significant differences could not be detected among treatments (Fig. 2).

In contrast, overall ethylene production showed a decreasing trend during the first 2 d and then gradually increased with final values significantly higher than those recorded at harvest time (Fig. 3). Although significant differences were not detected among treatments, presumably due to the relatively high variability occurring among the fruit of the same treatment, fruit treated with insecticides showed constantly higher rates than the other two treatments (Fig. 3).

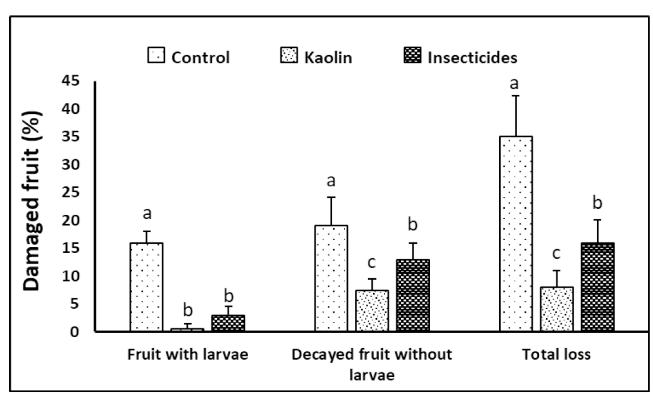

Fig. 2 - Respiratory activity as carbon dioxide release in 'O'Henry' peach as affected by pre-harvest treatments with kaolin or insecticides stored at 20°C. Columns with different letters are significantly different at P≤0.05 according to Duncan's multiple range test. Vertical bars represent standard deviation (n=10).

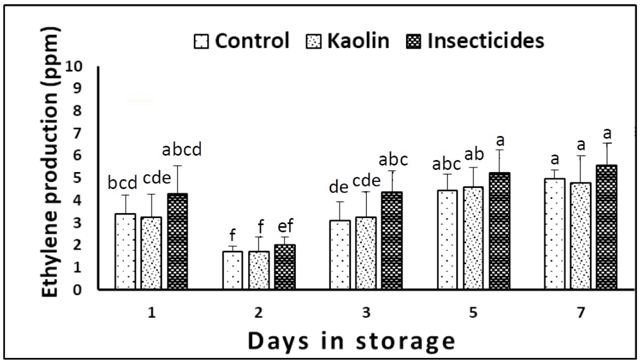

Fig. 3 - Ethylene production rates in 'O'Henry' peach as affected by pre-harvest treatments with kaolin or insecticides stored at 20°C. Columns with different letters are significantly different at P≤0.05 according to Duncan's multiple range test. Vertical bars represent the standard deviation (n=10).

In Table 1 are reported data concerning the chemical composition of peaches at harvest and after 7 d storage. TA showed an overall significant decline of about 9% (p= 0.024) after 7 d of storage, but differences among treatments were not significant neither at harvest time (p=0.720) nor at the end of storage (p=0.982). SST, differently than TA, showed an overall increase of about 6 % over storage (p=0.012). Values of individual treatments were slightly but significantly lower in kaolin treated fruit at harvest (p=0.042), while no significant difference could be detected among treatments after 7 d of storage (p=0.532).

Glucose, fructose and sucrose content did not show any difference among treatments neither at harvest time (p=0.952, p=0.914, p=0.241, respectively) nor at the end of storage (p=0.412, p=0.119, p=0.264, respectively), but while overall fructose levels increased with storage (p=0.018), sucrose decreased (p=0.041).

Regarding the other compounds, negligible variations occurred over storage in citric acid (p=0.048), total carotenoids (p=0.084) and malic acid (p=0.253) levels, while total phenols and antioxidant activity increased with final values of about 129 mg 100^{-1} g^{-1} gallic acid equivalents (p=0.001) and 1.8 mmol L^{-1} TEAC (p=0.001), respectively. However, both total phenols (p=0.240) and antioxidant activity did not show any significant difference neither at harvest time (p=0.291, p=0.183, respectively) nor after 7 d of storage (p=0.571, p=0.982, respectively).

Fruit firmness was affected by storage time but not by treatments (Table 2). In particular, F max and Lat F max decreased during storage with final values about 90 % lower than harvest time.

Mass loss, which on average was around 3 and 6%

Table 2 - Evolution of firmness as F Max (maximum force to penetration) and L at F Max (deformation of the fruit surface at F Max) and changes in weight loss (% reduction of the initial weight) in 'O'Henry' peaches as affected by pre-harvest treatments with kaolin or insecticides at harvest or after 3 or 7 d of storage at 20°C

Treatment	F Max (N)	L at F max (mm)	Weight loss (%)
	Harvest		*3 days*
Control	46.97 a	4.79 a	4.23 a
Kaolin	53.83 a	5.49 a	4.04 a
Chemical	49.71 a	5.07 a	4.13 a
	7 Days		*7 days*
Control	4.60 b	0.47 b	6.36 b
Kaolin	5.88 b	0.60 b	5.97 b
Chemical	4.80 b	0.49 b	6.04 b

Values in column for each storage time not followed by the same letter are significantly different at P≤0.05 according to Duncan's multiple range test.

Table 1 - Changes in chemical parameters in 'O'Henry' peaches as affected by pre-harvest treatments with kaolin or insecticides at harvest or after 7 d storage at 20°C

Chemical parameter or compound	Treatments					
	Harvest			7 days at 20°C		
	Control	Kaolin	Insecticides	Control	Kaolin	Insecticides
TA (%)	1.02 ± 0.05 a	1.02 ± 0.03 a	1.01 ± 0.01 a	0.92 ± 0.06 b	0.92 ± 0.05 b	0.92 ± 0.04 b
SST (°Brix)	14.7 ± 0.17 b	14.2 ± 0.25 c	14.7 ± 0.17 b	15.3 ± 0.30 a	15.1 ± 0.05 a	15.4 ± 0.30 a
Glucose (g 100 mL^{-1})	1.16 ± 0.10 a	1.16 ± 0.10 a	1.18 ± 0.04 a	1.20 ± 0.03 a	1.23 ± 0.01 a	1.24 ± 0.05 a
Fructose (g 100 mL^{-1})	1.61 ± 0.14 b	1.61 ± 0.14 b	1.57 ± 0.03 b	1.91 ± 0.01 a	1.95 ± 0.07 a	1.82 ± 0.07 a
Sucrose (g 100 mL^{-1})	9.51 ± 0.27 a	9.53 ± 0.56 a	9.03 ± 0.16 a	8.12 ± 0.07 b	8.12 ± 0.07 b	7.97 ± 0.17 b
Total phenols (g 100 mL^{-1})	121.7 ± 31.8 b	125.1 ± 49.5 ab	119.7 ± 31.0 b	128.8 ± 27.8 a	130.9 ± 29.4 a	129.5 ± 11.0 a
Tot carotenoids (g 100 mL^{-1})	7.60 ± 0.58 a	7.25 ± 0.50 a	6.81 ± 0.29 a	7.19 ± 0.44 a	7.36 ± 0.21 a	7.08 ± 0.76 a
Antioxidant (mmol L^{-1} TEAC)	1.76 ± 0.01 b	1.77 ± 0.01 b	1.77 ± 0.01 b	1.82 ± 0.01 a	1.86 ± 0.03 a	1.82 ± 0.01 a
Malic acid (g 100 mL^{-1})	1.23 ± 0.05 a	1.24 ± 0.05 a	1.24 ± 0.03 a	1.16 ± 0.13 a	1.14 ± 0.04 a	1.20 ± 0.05 a
Citric acid (g 100 mL^{-1})	0.23 ± 0.01 c	0.26 ± 0.02 ab	0.23 ± 0.03 bc	0.27 ± 0.03 ab	0.29 ± 0.01 a	0.27 ± 0.02 ab

Values within rows for each parameter not followed by the same letters are significantly different at P ≤0.05 according to Duncan's multiple range test. Each mean is followed by the standard deviation (n=3).

after 3 and 6 d, respectively, was not affected by treatments (Table 2).

4. Discussion and Conclusions

Different field as well as laboratory studies demonstrated the efficacy of kaolin treatments in reducing medfly punctures on fruit of different species (Mazor and Erez, 2004; D'Aquino *et al*., 2011; Lo Verde *et al*., 2011) and its higher efficacy when compared to traditional (organophosphates, pyrethroids) or novel insecticides, despite the excellent laboratory results of the last ones. For example, the high activity of spinosad (Adan *et al*., 1996; Vargas *et al*., 2002; Mangan *et al*., 2006), was not confirmed in field experiments to control medfly in citrus fruit, while kaolin tested in the same experiment, resulted very effective (Braham *et al*., 2007). Indeed, in contrast to traditional insecticides, whose efficiency may be affected by medfly developmental stage, population density, mode of action and environmental factors (ligth, temperature, rain) that can shorten their persistance (Braham *et al*., 2007), kaolin efficiency seems stable over time, provided a uniform coverage of fruit surface and absence of abundant rains (Mazor and Erez, 2004; Lo Verde *et al*., 2011). D'Aquino *et al*. (2011) found a significant lower percentage of damaged fruit at harvest in peaches and nectarines treated with kaolin compared to those subjected to a conventional treatment with organophosphates trichlorfon and fenthion, although the kaolin protective activity was higher in peaches rather than in nectarines owing to the lower adherence of the particles on nectarines surface and the difficulty to form a uniform film.

Our results showed a marked effect of both kaolin and insecticides in reducing the number of fruit with visible damages at harvest, but after one week of storage at 20°C, decay incidence caused by pathogenic fungi was markedly higher in fruit treated with insecticides than in those treated with kaolin. The lower performance of fruit treated with insecticides compared to those treated with kaolin may depend on the short persistence of pyrethroids: due to their rapid degradation rate, the level of residues on fruit surface after one week might be not sufficient to completely prevent medfly oviposition. As a result, in fruit damaged just before harvest, decay incidence at the end of storage caused by the activity of developing larvae or pathogenic fungi penetrated through stings was higher in insecticides treated fruit than in kaolin ones.

Kaolin sprayed on leaves and fruit surface, depending on particles size and film uniformity may affect the transmission of photosynthetically active, ultraviolet and infrared radiations, resulting in changes in surface temperature, photosynthetic activity, selective production of pigments, chemical composition, susceptibility to decay and physiological disorders (Jifon and Syvertsen, 2003; Lombardini *et al*., 2005; Russo and Díaz-Pérez, 2005; Cantore *et al*., 2009).

Our results showed no difference in respiration and ethylene production rates of kaolin treated fruit compared to control or insecticides treated ones. These results can be explained considering that the size and porosity of the particles deposited on fruit surface would not affect gas exchange and the fruit ripening process.

Kaolin did not affect firmness and mass loss. These results are in contrast with those reported by Ergun (2012) with 'Galaxy' apples, who attributed the reduction of mass loss to the small size of the kaolin particles which by partially blocking stomata and lenticels would have led to a reduction of gases and water vapor exchange with the environment. A reduced transpiration rate of kaolin was also detected in bean leaves (Tworkoski *et al*., 2002), groundnut (Khan and Morey, 1980), and tomatoes (Cantore *et al*., 2009).

Differently, either no or an inconsistent effect of kaolin film on transpiration and stomatal conductance were reported by others (Kerns and Wright, 2000; Glenn *et al*., 2001; Jifon and Syvertsen, 2003; Russo and Díaz-Pérez, 2005; Glenn, 2012; Lobos *et al*., 2015). Genetic variability among species, differences in growth environment, possible kaolin-induced physical skin modifications, kaolin formulations, may be only some among the numerous factors leading to contrasting results (Wand *et al*., 2006; Conde *et al*., 2016).

Although no specific study at our knowledge has been set up to specifically evaluate the effect of kaolin treatments on fruit quality, generally results reported in the literature indicate a positive effect of kaolin on overall quality. These positive effects of kaolin, seems to rely on its ability to reduce organs' surface temperature and to enhance solar radiation reflection, which, while reducing the risk of sunburns improves skin color development, lowers the photorespiration process and increases photosynthetic efficiency (Glenn *et al*., 2002; Wand *et al*., 2006; Glenn, 2009).

In grapevine, kaolin treatments stimulated the phenylpropanoid, flavonoid-flavonol and anthocyanin-pathways thus increasing total phenolics and anthocyanins content in ripe berries, but had no effect on pH, TA and SST (Conde *et al*., 2016). Our results, in agreement with previous findings (Glenn, 2012; Lobos *et al*., 2015; Conde *et al*., 2016), denoted no effect of kaolin on TA and SST, but also on juice antioxidant activity, glucose, fructose, sucrose and organic acids contents both at harvest time and during storage.

Despite kaolin treatment was not able to completely control medfly attacks, its performance was superior to synthetic insecticides in controlling direct damage by medfly due to the presence of larvae but also indirect damage even when larvae did not develop, for the lower incidence of decay caused by wounds pathogens. Therefore, kaolin seems to be a promising alternative to conventional insecticides to manage medfly infestation in peaches. One potential disadvantage of kaolin at commercial level is the fact that the white film persists on fruit surface after harvest and that to be removed fruit should be washed, an operation that normally is not done on peaches intended for fresh consumption. However, the presence of kaolin on fruit surface could be exploited positively commercially by reporting in the label that the white film covering the fruit is a proof that no synthetic insecticides were used in the growing process. On the other hand, in case fruit are destined to the processing industry rinsing the fruit would not be a problem.

References

ADAN A., DEL ESTAL P., BUDIA F., GONZALEZ M., VINUELA E., 1996 - *Laboratory evaluation of the novel naturally derived compound spinosad against* Ceratitis capitata*.* - Pestic. Sci., 48: 261-268.

BASNIZKI J., EVENARI M., 1975 - *The influence of a reflectant on leaf temperature and development of the globe artichoke (*Cynara scolymus *L.)*. - J. Amer. Soc. Hort. Sci., 100: 109-112.

BONDET V., BRAND-WILLIAMS W., BERSET C., 1997 - *Kinetics and mechanism of antioxidant activity using the DPPH free radical method*. - LWT - Food Sci. Technol., 30: 609-615.

BRAHAM M., PASQUALINI E., NCIRA N., 2007 - *Efficacy of kaolin, spinosad and malathion against* Ceratitis capitata *in* Citrus *orchards.* - Bulletin of Insectology, 60(1): 39-47.

CANTORE V., PACEA B., ALBRIZIO R., 2009 - *Kaolin-based particle film technology affects tomato physiology, yield and quality.* - Environ. Exp. Bot., 66: 279-288.

CONDE A., PIMENTEL D., NEVES A., DINIS L.T., BERNARDO S., CORREIA C.M., GERÓS H., MOUTINHO-PEREIRA J., 2016 - *Kaolin foliar application has a stimulatory effect on Phenylpropanoid and flavonoid pathways in grape berries.* - Front. Plant Sci., 7: 1150.

D'AQUINO S., COCCO A., ORTU S., SCHIRRA M., 2011 - *Effects of kaolin-based particle film to control* Ceratitis capitata *(Diptera: Tephritidae) infestations and postharvest decay in citrus and stone fruit.* - Crop Prot., 30: 1079-1086.

ERGUN M., 2012 - *Postharvest quality of 'Galaxy' apple fruit in response to kaolin-based particle film application.* - J. Agr. Sci. Tech., 14: 599-607.

GLENN D.M., 2009 - *particle film mechanisms of action that reduce the effect of environmental stress in 'empire' apple* - J. Amer. Soc. Hort. Sci., 134(3): 314-321.

GLENN D.M., 2012 - *The mechanisms of plant stress mitigation by kaolin-based particle films and applications in horticultural and agricultural crops.* - HortSscience, 47(6): 710-711.

GLENN D.M., PRADO E., EREZ A., McFERSON J., PUTERKA G. J., 2002 - *A reflective, processed-kaolin particle film affects fruit temperature, radiation reflection, and solar injury in apple.* - J. Amer. Soc. Hort. Sci., 127(2): 188-193.

GLENN D.M., PUTERKA G.J., DRAKE S.R., UNRUH T.R., KNIGHT A.L., BAHERLE P., PRADO E., BAUGHER T.A., 2001 - *Particle film application influences apple leaf physiology, fruit yield, and fruit quality.* - J. Amer. Soc. Hort. Sci., 126(2): 175-181.

GLENN D.M., PUTERKA G.J., VAN DER ZWET T., BY R.E., FELDHAKE C., 1999 - *Hydrophobic particle fi lms: a new paradigm for suppression of arthropod pests and plant diseases*. - J. Econ. Entomol., 92: 759-771

JIFON J.L., SYVERTSEN J.P., 2003 - *Kaolin particle film applications can increase photosyntesis and water use efficiency of "Ruby Red" grapefruit leaves.* - HortScience, 128(1): 107-112.

KATSOYANNOS B.I., 1987 - *Response to shape, size and colour,* pp. 307-321. - In: ROBINSON A.S., and G. HOOPER (eds) *Fruit flies: their biology, natural enemies and control.* Elsevier, Amsterdam, The Netherlands, pp. 384.

KERNS D.L., WRIGHT G.C., 2000 - *Protective and yield enhancement qualities of kaolin on lemons*, pp. 14-20. - In: WRIGHT G., and M. KILBY (eds.) *Citrus and deciduous fruit and nut research report*. College of Agriculture and Life Sciences, the University of Arizona, Tucson, Arizona, USA, pp. 123.

KHAN G.Z., MOREY D.K., 1980 - *Influence of kaolin spray on transpiration and water use efficiency of ground nut (*Arachis hypogaea *L.) under different soil moisture regimes.* - J. Maharashtra Agric. Univ., 5: 131-134.

KOPEC R.E., COOPERSTONE J.L., CICHON M.J., SCHWARTZ

S.J., 2012 - *Analysis methods of carotenoids,* pp. 105-148. - In: XU Z., and L.R. HOWARD (eds.) *Analysis of antioxidant. Rich Phytochemicals.* John Wiley & Sons, Ltd, Oxford, UK, pp. 408.

LO VERDE G., CALECA V., LO VERDE V., 2011 - *The use of kaolin to control* Ceratitis capitata *in organic citrus groves.* - Bulletin of Insectology, 64(1): 127-134.

LOBOS G.A., ACEVEDO-OPAZO C., GUAJARDO-MORENO A., VALDÉS-GÓMEZ H., TAYLOR J.A., LAURIE V.F., 2015 - *Effects of kaolin based particle film and fruit zone netting on Cabernet-Sauvignon grapevine physiology and fruit quality.* - J. Int. Sci. Vigne Vin., 49: 137-144.

LOMBARDINI L., HARRIS M.K., GLENN D.M., 2005 - *Effects of particle film application on leaf gas exchange, water relations, nut yield, and insect populations in mature pecan trees.* - HortScience, 40: 1376-1380.

MALACRIDA A.R., GOMULSKI L.M., BONIZZONI M., BERTIN S., GASPERI G., GUGLIELMINO C.R., 2007 - *Globalization and fruit fly invasion and expansion: the medfly paradigm*. - Genetica, 131: 1-9.

MANGAN R.L., MORENO D.S., THOMPSON G.D., 2006 - *Bait dilution; spinosad concentration, and efficacy of GF-120 based fruit fly sprays.* - Crop Prot., 25(2): 125-133.

MAZOR M., EREZ A., 2004 - *Processed kaolin protects fruits from Mediterranean fruit fly infestations.* - Crop Prot., 23: 47-51.

MORESHET S., COHEN Y., FUCHS M., 1979 - *Effect of increasing foliage reflectance on yield, growth, and physiological behavior of a dry land cotton crop*. - Crop Sci., 19: 863-868.

PALMA A., CONTINELLA A., LA MALFA S., D'AQUINO S., 2018 - *Changes in physiological and some nutritional, nutraceuticals, chemical-physical, microbiological and sensory quality of minimally processed cactus pears cvs. Bianca, Gialla and Rossa stored under passive modified atmosphere.* - J. Sci. Food. Agric., 98: 1839-1849.

PALMA A., D'AQUINO S., VANADIA S., ANGIONI A., SCHIRRA M., 2013 - *Cold quarantine responses of "Tarocco" oranges to short hot water and thiabendazole postharvest dip treatments*. - Postharvest Biol. Tech., 78: 24-33.

RUSSO V.M., DÍAZ-PÉREZ J.C., 2005 - *Kaolin-based particle film has no effect on physiological measurements, disease incidence or yield in peppers.* - HortScience, 40: 98-101.

SALERNO G., REBORA M., KOVALEV A., GORB E., GORB S., 2020 - *Kaolin nano powder effect on insect attachment ability.* - J. Pest Sci., 93: 315-327.

SAOUR G., MAKEE H., 2004 - *A kaolin-based particle film for suppression of olive fruit fly* Bactrocera oleae *Gmelin (Dipt. Tephritidae) in olive trees.* - J. App. Entomol., 128: 28-31.

SINGLETON V.L., ROSSI J.A., 1965 - *Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents*. - Am. J. Enol. Vitic., 16: 144-158.

SPARKS T.C., NAUEN R., 2015 - *IRAC: Mode of action classification and insecticide resistance Management.* - Pestic. Biochem. Phys., 121: 122-128.

STANHILL G., MORESHET M., FUCHS M., 1976 - *Effect of increasing foliage and soil reflectivity on the yield and water use efficiency of grain sorghum.* - Agron. J., 68: 329-332.

TWORKOSKI T.J., GLENN D.M., PUTERKA G.J., 2002 - *Response of bean to applications of hydrophobic mineral particles.* - Can. J. Plant Sci., 82: 217-219.

VARGAS R.I., MILLER N.W., PROKOPY R.J., 2002 - *Attraction and feeding responses of Mediterranean fruit fly and a natural enemy to protein baits with two novel toxins, phloixine B and spinosad.* - Entomol. Exp. App., 102: 273-282.

WAND S.J.E., THERON K.I., ACKERMAN J., MARAIS S.J.S., 2006 - *Harvest and post-harvest apple fruit quality following applications of kaolin particle film in South African orchards.* - Sci. Hortic., 107: 271-276.

WORTHING C.R., HANCE R.J., 1991 - *The Pesticide Manual: A World Compendium.* - 9th edition. British Crop Protection Council, pp. 1200.