Use of mineral particle film to protect 'Okitsu' tangerine and 'Valencia' orange against *Anastrepha fraterculus* and the effect on fruit quality[1]

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ABSTRACT

The particle film technology has been reported as a promising tool in pest control. The objective of this work was to evaluate the efficiency of kaolin-based products against the oviposition of South American fruit fly, *Anastrepha fraterculus* (Dip.:Tephritidae), and its effect on the quality of citrus fruits. The experiment was conducted in orchards of 'Okitsu' tangerine and 'Valencia' orange trees in the 2017, 2018 and 2019 harvests. The treatments were as follows: 1) kaolin 10% + 0.1% Break-Thru® adjuvant; 2) Surround® 5% WP; 3) 0.15% phosmet (Imidan® 500 WP), 75 g. a.i.; 4) without application (control). The sprays were performed every 21 days. At harvest, fruits were individually packed in a greenhouse for inspection after 25 days and infestation was recorded. Fruit samples were evaluated for average diameter, average mass, soluble solids, titratable acidity and peel colorimetry. Infestation of *A. fraterculus* in tangerines was reduced in plants treated with the two kaolin-based products in the 2017 harvest. In the 2017 and 2019 crops, Surround® WP reduced the infestation and the number of puparium/fruits in oranges. The mineral films did not alter the physicochemical characteristics of the fruits, representing a promising alternative for the management of *A. fraterculus*.

Keywords: citrus; kaolin; South American fruit fly; Surround®.

INTRODUCTION

As the studies relating to the use of pesticides with diseases and environmental damage have increased, the consumer market has become increasingly demanding regarding food safety (Jardim *et al*., 2009). In addition, the presence of chemical residues in food also affects commercial transactions, since importing countries impose strict sanitary barriers on Brazilian products, with restrictions on the use of certain active ingredients (Choudhury & Costa, 2002).

In fruit growing, one of the categories of pesticides responsible for chemical residues is the synthetic insecticides, which are still widely used to control various pests. This is the current situation of the South American fruit fly, *Anastrepha fraterculus* (Wied.) (Diptera: Tephritidae), one of the main pest insects in fruit growing in southern Brazil. This species causes great losses in the production of several fruit trees (Nava & Botton, 2010; Botton *et al*., 2012; Santos *et al*., 2015). In citrus, a crop in which Brazil is the world's greatest exponent (FAO, 2018), *A. fraterculus* is a key pest, which can cause changes in the peel and pulp of the fruits, impairing exports and preventing the sale of fresh fruits (Raga & Galdino, 2017).

Mineral particle film technology has emerged as an alternative to the use of synthetic insecticides. In this technology, kaolin, an inert clay, is used ground and processed in the form of a white powder, which is applied dispersed in water to plants (Glenn & Puterka, 2005).

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Kaolin forms a thin, white film of particles on leaves and fruits, which makes the plant's surface irritating (Glenn *et al*., 1999) or makes it difficult for the insect to recognize the host (Saour & Makee, 2004). The processed kaolin has been successfully tested against numerous species of insects (Glenn & Puterka, 2005). In 1999, kaolin was considered by the Environmental Protection Agency in America, as not harmful to non-target organisms. Studies indicate no adverse effects either on spiders and honeybees or on aquatic organisms (EPA, 1999).

The effectiveness of this technology has been evidenced for species of tephritid flies, such as *Ceratitis capitata* (Wied.), in nectarine, apple and kaki (Mazor & Erez, 2004; Braham *et al*., 2007) and *Bactrocera oleae* (Gmelin) in olive (Saour & Makee, 2004; Caleca & Rizzo, 2007). Furthermore, it could be a tool for the control of the South American fruit fly. There are few studies on the effect of kaolin-based products on *A. fraterculus*, but they indicate a reduction in oviposition, as in oranges in field tests (Ourique *et al*., 2018).

For their utilization in fruit growing, pest control techniques cannot affect the physicochemical characteristics of the fruits. Mineral films were efficient in controlling *B. oleae* in olive trees, without interfering with the quality of nutritional and sensory parameters of virgin olive oil (Perri *et al*., 2005). The increase in weight and reduction in the surface temperature of fruits covered with Surround® WP (product formulated based on kaolin), without altering the content of soluble solids and the amount of starch, in apples were also observed (Glenn & Puterka, 2007). Studies have also pointed to other uses of this technology, such as protection against sunburn (Chabbal *et al*., 2014) and disease control (Glenn *et al*., 2001; Tubajika *et al*., 2007). In addition, the use of kaolin may promote the agronomic performance of citrus plants, in hot climates with a high incidence of radiation, through the increase of net CO_2 assimilation and water use efficiency (Syvertsen, 2017; Gullo *et al*., 2020).

Thus, the objective of this work was to evaluate the efficiency of products based on kaolin in the field, in the protection of oranges and tangerines against the oviposition of *A. fraterculus,* and the effect on the physicochemical characteristics of the fruits.

MATERIAL AND METHODS

The experiments were carried out at the Experimental Agronomic Station (EEA) at Universidade Federal do Rio Grande do Sul (UFRGS) in Eldorado do Sul, Rio Grande do Sul State, in two orchards, one of 'Valencia' orange (*Citrus sinensis* (L.) Osbeck) (Rutaceae) (30°07'03.28" S; 51°39'54.57" W, 58 m altitude) and another of 'Okitsu' tangerine (*Citrus unshiu* Marcovitch) (Rutaceae) (30°06'46.13"S; 51°39'53.04" W; 37 m altitude). This municipality has slightly undulating topography, with soils classified as Dystrophic Red Argisol (Streck *et al*., 2002). The average annual temperature is 18.8 °C, with abundant and well-distributed rainfall (1,455 mm/year) (Bergamaschi *et al*., 2013). Data on rainfall and minimum, average and maximum temperatures were collected from the EEA weather station.

The experiment was carried out in 2017, 2018, and 2019 crops, in a randomized block design. Were used as treatments, Surround® WP, a commercial formulation of kaolin with adhesive spreader, recommended for insect control at 5% concentration and another product is an industrial kaolin, from a different source, which had never been tested for the purpose of insect control. The treatments consisted of the following: 1) kaolin 10% diluted in water + 0.1% Break Thru® adhesive spreader; 2) Surround® WP, 5% diluted in water; 3) phosmet (WP) 75g a.i. 100 L^{-1} diluted in water and 4) without application (control). Phosmet was used as a positive control because it is one of the most used products by citrus growers in the region where this study was conducted. The sprays were carried out every 21 days or after rainfall with an intensity greater than 30 mm, starting during the fruit growth phase, until the harvest period. No other phytosanitary treatments were performed during the experiment.

During the experiment, a McPhail-type trap was installed in each of the orchards, baited with approximately 600 mL of hydrolyzed Cera Trap® protein (BioIbérica S.A., Barcelona, Spain). These were inspected weekly to calculate the FTD index (number of flies/trap/day). The bait was replaced whenever necessary.

'Okitsu' tangerine orchard

The orchard had 96 plants grafted on *Poncirus trifoliata* (L.) Raf. (Rutaceae), distributed in three lines, with a spacing between the lines of 6 m and 3 m between the plants. They are on average, 1.80 m tall. The orchard borders a 'Nadorcott' tangerine orchard at the south; approximately 70 m to the southeast, there is a loquat orchard; to the north, a field area, to the northeast, a wetland, and to the southwest, native forest (Appendix 1). Five blocks were delimited in this orchard, with 3 plants per experimental unit. The plants were sprayed with a backpack-sprayer (Jacto®) with a capacity of 18 L (Appendix 2 A) and a cone-type nozzle up to runoff, in an average volume of 1 L of spray volume per plant. A total of five, six, and three sprays were carried out in the 2017, 2018 and 2019 harvests, respectively. At the base of the canopy of one of the three plants in each plot, four stakes were installed to which a shading meshes was attached, approximately 25 cm from the ground, and covering the entire projection of the plant's canopy (Appendix 2 B). The shading meshes was used to collect, and count fallen fruits.

At the harvest in the experiment, 10 fruits from each plant that did not contain the shading meshes (20 fruits per experimental unit, 100 fruits per treatment) were individually packed over a layer (± 1 cm) of sterilized sand deposited in plastic containers (1 L), and identified according to the treatment and the block, covered with voile fabric, kept in a greenhouse without controlled conditions. After 25 days, fruits and sand were inspected to record puparium and/or larvae. On the same occasion, all the fruits of the plants that contained the shade cloth support were harvested, counted, and examined for visual damage caused by fruit flies.

On March 8, 2017, photosynthetic activity was measured with the aid of an LI-6400XT Portable Photosynthesis System (Licor®) equipment on four leaves in the middle third of each plant's canopy, two from each treatment, taken at random. Assessments were made between 10 and 16 hours.

'Valência' orange orchard

It has 72 plants, grafted on the citrange 'Troyer' and citrumelo 'Swingle' or propagated using cuttings, distributed in four lines, with spacing between lines of 6 m and 3 m between plants. They are on average, 4 m tall. To the south and east, the orchard is bordered by another orchard of 'Montenegrina' variety tangerine trees; to the west by two lines of citrus hybrids and a eucalyptus windbreak, and by citrus hybrids to the north (Appendix 3). Eight blocks were delimited, each composed of plants grafted on the same rootstock, using one tree per experimental unit. The plants were sprayed up to runoff with a backpack spray (Stihl SR 450) with a capacity of 14 L, in an average spray volume of 2 L/plant (Appendix 4). Four sprays were performed in each harvest.

During the harvest period, 13 fruits of each plant (104 per treatment) were taken to the laboratory and packed for 25 days, as described for the 'Okitsu' tangerine tree. The fallen fruits under the canopy were counted and removed Weekly. In the 2018 harvest, there was no collection of fallen fruits. During the harvest period, all fruits were harvested, counted, and examined for visible damage caused by fruit flies.

Evaluated parameters

Based on the data obtained from the two orchards, were calculated: proportion of infested fruits (with larvae and/or puparium), the proportion of puparium per fruit, frequency of fallen fruits (number of fallen fruits/ number of harvested fruits + fallen fruits * 100) and the frequency of damaged fruits (number of visually damaged fruits/number of harvested fruits * 100) for each harvest.

Fruit quality

In both orchards in the three harvests, 10 fruits per experimental unit were collected at random in five different blocks for the analyses of the physical-chemical attributes in the Post-harvest Physiology Laboratory at UFRGS. The titratable acidity (TA), expressed as a percentage of citric acid equivalent, was determined by titrating 6 g of juice with 0.1 M NaOH solution up to pH 8.1 and calculated using the equation: TA = [(NaOH volume) * (NaOH concentration) * 0.064 * 100] / (juice mass). Soluble solids (SS) were determined employing refractometry and expressed as a percentage of solids in 100 g of solution. The fruit mass was expressed in grams (g) and the transverse diameter was expressed in millimeters and measured with a caliper in the equatorial region of the fruits. The fruits were measured with a Colorimeter (Konica/Minolta, CR400), obtaining the variables L*, which is the luminosity value, a* and b*, which are chromatic coordinates. The Peel Color Index (PCI) was calculated by the equation PCI = (1000 * a) / (L * b) (Jimenez-Cuesta *et al*., 1981). Negative values of PCI indicate green colors, and positives values, orange colors. Zero corresponds to the yellow color. The 'Okitsu' fruits in 2018 and 'Valencia' fruits in 2019 were not subjected to colorimetry analysis, because the colorimeter was under maintenance.

Statistical analysis

The data obtained in this experiment related to fruit fly infestation and the physicochemical attributes of the fruits were subjected to the homoscedasticity test and compared with each other by the Anova test followed by the test of Tukey, when parametric, or by Kruskal-Wallis followed by Student-Newman-Keuls, when not parametric. The level of significance adopted was 5%. Pearson's correlation test was carried out between the FTD index and accumulated rainfall and temperature averages 7, 15, and 30 days before the trap collection date. All tests were performed using the Bioestat 5.0 software (Ayres *et al*., 2007).

RESULTS

'Okitsu' tangerine tree

In the 2017 harvest, the average percentage of infestation in the fruits treated with the films, kaolin, and Surround® WP was 1% and 4%, respectively, similar to each other ($p > 0.05$). In fruits without application of products (control), the infestation was 42%, similar to those treated with phosmet (24%) ($p > 0.05$). Nevertheless, the average infestation did not differ among the fruits that received the insecticide and those with Surround® WP (Table 1). In the 2018 harvest, no infestation was observed in the fruits treated with Surround® WP, and in the other treatments, kaolin (3%), insecticide (10%), and control (12%), the infestation was similar. In 2019, there was no statistical difference between the average tangerine infestation, in the Surround® WP (2%), kaolin (4%), insecticide (7%), and control (4%) treatments (Table 1).

The average number of puparium + larvae per fruit in the 2017 harvest was higher in the control when compared to that recorded in fruits treated with mineral films, but it did not differ from that observed in those treated with the insecticide. This average was similar between treatments with mineral films; however, in the fruits treated with Surround® WP, it did not differ from those with insecticide (Table 1). In the 2018 and 2019 harvests, no statistical difference was observed between treatments (Table 1).

The average percentage of fallen fruits did not differ between treatments in the three evaluated harvests (Table 2). The average percentage of fruits that showed visible damage caused by *A. fraterculus* at harvest also did not differ between treatments in the three harvests (Table 2).

In the 2017 harvest, the FTD index (fly/trap/day) was always below the control level (0.5 FTD) and only in the two weeks before harvest, 0.57 and 1.28 were recorded (Figure 1 A), respectively, and a negative correlation with the average temperature (Figure 1 B) was found 15 and 30 days before sampling (Table 3). In the 2018 harvest, *A. fraterculus* individuals were not caught in the traps, and in 2019, throughout the experiment, the recorded FTD index was below the control level and showed a negative correlation with the average temperature just 30 days before sampling. In any of the harvests, there was a correlation between the FTD index and accumulated rainfall (Table 3).

The average net assimilation (± standard error) (μmol de CO_2 m^{-2} s^{-1}) was similar among treatments (control - 8.73 ± 0.606; phosmet - 6.40 ± 0.964; kaolin - 6.53 ± 0.727; Surround® WP 6.42 ± 0.659) (H = 5.2244; gl = 3; p = 0.1561) demonstrating that the mineral films did not interfere with gas Exchange.

'Valencia' Orange tree

The average percentage of *A. fraterculus* infestation in the 2017 harvest, only differed between the control fruits (28%) and those treated with Surround® WP (11%). Those treated with insecticide (23%) and kaolin (13%) showed similarity to both the control and the Surround® WP (Table 4). In 2018, there was no statistical difference in the average infestation of oranges between treatments (control - 1%; insecticide - 1%; kaolin - 3%; Surround®WP - 5%) (Table 4). In the 2019 harvest, the lowest infestation was in the fruits treated with

Table 1: Proportion of infested fruits (± SE) and average number of *Anastrepha fraterculus* puparium + larvae/fruit (± SE) (100 fruits/treatment) at harvest in 'Okitsu' tangerines, subjected to kaolin 10%, Surround® WP 5%, phosmet (75 g. i.a.100 L^{-1}) and control in the 2017, 2018 and 2019 harvests, Eldorado do Sul, RS

	Proportion of infested fruits (± SE)			Average number of puparium + larvae/fruit (±SE)		
	2017	2018	2019	2017	2018	2019
Control	0.42 ± 0.09 a	0.12 ± 0.06	0.04 ± 0.02	1.03 ± 0.38 a	0.25 ± 0.15	0.10 ± 0.07
Insecticide	0.24 ± 0.09 ab	0.10 ± 0.03	0.07 ± 0.02	0.98 ± 0.66 ab	0.15 ± 0.05	0.09 ± 0.03
Kaolin	0.01 ± 0.01 c	0.03 ± 0.02	0.04 ± 0.02	0.01 ± 0.01 c	0.03 ± 0.02	0.04 ± 0.02
Surround®WP	0.04 ± 0.02 bc	0	0.02 ± 0.01	0.09 ± 0.07 bc	0	0.01 ± 0.01
p-value	0.0043	0.1515	0.2903	0.0065	0.1451	0.1704

Means followed by the same letter in the column are not different from each other by the test of Student-Newman-Keuls, at the 5% probability level; SE = Standard error.

Table 2: Frequency of fallen fruits (± SE) during harvest and damaged fruits at harvest in 'Okitsu' tangerines submitted to kaolin 10%, Surround® WP 5%, phosmet (75 g. a.i. 100 L^{-1}) and control in the 2017, 2018 and 2019 harvests, Eldorado do Sul, RS

	% Fallen fruits (± SE) during harvest			% Damaged fruits (± SE)		
	2017	2018	2019	2017	2018	2019
Control	5.5 ± 1.39	3.9 ± 0.79	3.1 ± 1.32	0.8 ± 0.45	0.6 ± 0.22	2.6 ± 2.08
Insecticide	10.1 ± 4.91	3.2 ± 1.06	1.2 ± 0.50	0.9 ± 1.06	0.6 ± 0.26	0.7 ± 0.25
Kaolin	3.6 ± 1.83	2.6 ± 1.02	2.2 ± 0.57	0.5 ± 0.54	0.4 ± 0.16	0.3 ± 0.09
Surround®WP	1.1 ± 0.34	1.7 ± 0.43	2.0 ± 0.60	0.4 ± 0.44	0.3 ± 0.11	0.4 ± 0.14
p-value	0.2053	0.2735	0.4032	0.5011	0.5511	0.2896

Means analyzed by the Kruskal-Wallis test at the level of 5% of probability; SE = Standard error

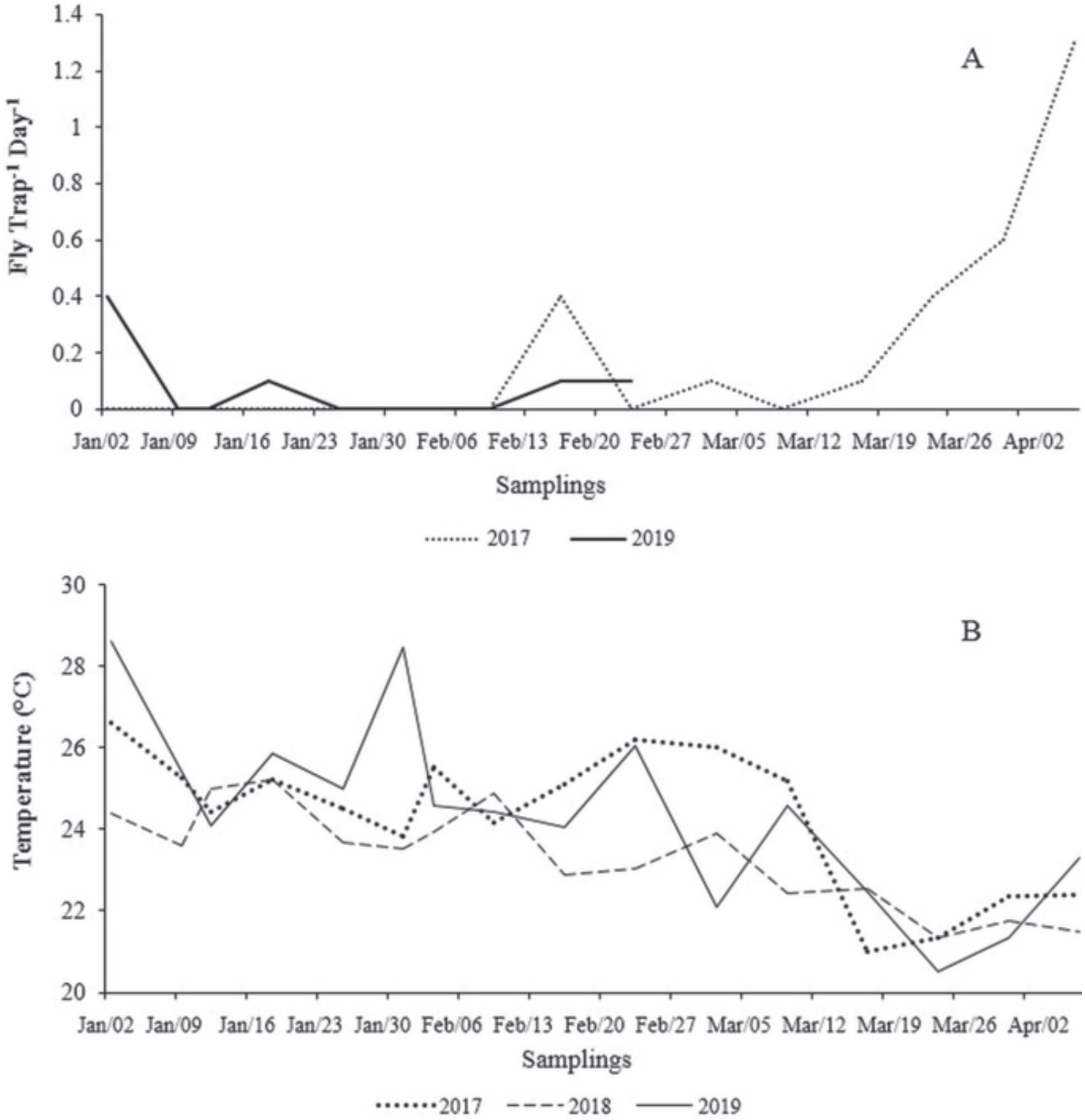

Figure 1: A) *A. fraterculus* fly/trap/day index recorded in 'Okitsu' tangerine orchard in 2017 and 2019 harvests, Eldorado do Sul, RS. B) Average temperature recorded over the experiment in the 2017, 2018 and 2019 harvests; Eldorado do Sul, RS.

Table 3: Correlation between weather variables and the number of flies/trap/day (FTD), recorded at seven, 15, and 30 days before sampling, in 'Okitsu' tangerine trees (Eldorado do Sul, RS)

Weather variables	**Days before collection**					
	2017					
	7 days		**15 days**		**30 days**	
	r [1]	**p**	**r**	**p**	**r**	**p**
FTD x rainfall (mm)	-0.3028	0.3146	-0.3528	0.2371	-0.2734	0.3661
FTD x average temperature (°C)	0.5201	0.0684	-0.6532	0.0154	-0.8839	< 0.0001
	2019					
	7 days		**15 days**		**30 days**	
	r	**p**	**r**	**p**	**r**	**p**
FTD x rainfall (mm)	-0.1988	0.637	0.0875	0.8368	-0.3011	0.4687
FTD x average temperature (°C)	0.352	0.3924	-0.3106	0.454	-0.8808	0.0039

r[1] - Pearson's correlation

Surround®WP (4%), which was similar to those treated with kaolin (10%); however different from that observed in the control (22%) and insecticide (26%) (Table 4).

The average number of puparium + larvae/fruit in the kaolin and Surround® WP treatments were similar to each other and inferior to the control in the 2017 harvest (Table 4). In the fruits treated with insecticide, this average did not differ from the control or those treated with the films (Table 4). Puparium averages were similar between treatments in the 2018 harvest. In the 2019 harvest, the average number of puparium + larvae in fruits treated with Surround® WP was lower than that seen in the control and insecticide treatments. In kaolin fruits, this average was similar to that of the other treatments (Table 4). The average percentage of fallen fruits was similar among treatments in the 2017 and 2019 harvests (Table 5).

The average percentage of fruits that showed visible damage caused by *A. fraterculus* in the 2017 harvest was higher in those treated with insecticide than in those in the kaolin and Surround® WP treatments, but it did not differ from the control (Table 5). In the 2018 and 2019 harvests, this percentage did not differ among treatments (Table 5).

The FTD index was greater than the control level throughout the 2017 crop experimental period, ranging from 2.0 to 33.1 (Figure 2 A). Also, there was no correlation between the weather variables (Table 6).

Similarly, in 2018, FTD also remained above the control level, ranging from 0.8 to 7.6. However, a positive correlation was observed with the average temperature at 15 days before sampling. In the 2019 harvest, the FTD variation was 0.0 to 28.6. Only on two occasions was the index below 0.5, both in July, and there was a positive correlation with the average temperature (Figure 2 B) at 7, 15, and 30 days before trap sampling (Table 6). No correlation was observed between the FTD index and the rainfall accumulated in any crop.

Fruit quality

In satsumas, no differences were found among treatments in the three harvests evaluated in relation to the diameter of soluble fruits (mm) in the three harvests and in the Peel Color Index in 2017 and 2019 (Table 7). Regarding the mass, in the 2017 harvest, the control fruits were lighter than those treated with Surround® WP; however, those that received insecticide and kaolin did not differ much from the control as from Surround® WP. In the other harvests, no difference was found in relation to the mass among treatments in the 2018 and 2019 harvests (Table 7). The titratable acidity of the kaolin-treated fruits was higher than those in the insecticide and Surround® WP treatments, but it did not differ from the control in the 2017 harvest. In other crops, the TA of the fruits was similar among treatments (Table 7).

Table 4: Proportion of infested fruits (± SE) and average number of pupariam + larvae/fruit (± SE) (104 fruits/treatment) of *Anastrepha fraterculus* at harvest in 'Valencia' orange trees, subjected to 10% kaolin, Surround® WP 5%, phosmet (75 g a.i. 100 L^{-1}) and control in the 2017, 2018 and 2019 harvests, Eldorado do Sul, RS

	Proportion of infested fruit (± SE)			Average number of puparium + larvae/fruit (± SE)		
	2017	**2018**	**2019**	**2017**	**2018**	**2019**
Control	0.28 ± 0.04 a	0.01 ± 0.01	0.22 ± 0.06 a	0.62 ± 0.14 a	0.01 ± 0.01	0.34 ± 0.10 a
Insecticide	0.23 ± 0.05 ab	0.01 ± 0.01	0.26 ± 0.07 a	0.33 ± 0.07 ab	0.02 ± 0.02	0.44 ± 0.13 a
Kaolin	0.13 ± 0.05 ab	0.03 ± 0.01	0.10 ± 0.03 ab	0.18 ± 0.06 b	0.03 ± 0.01	0.11 ± 0.04 ab
Surround®WP	0.11 ± 0.03 b	0.05 ± 0.02	0.04 ± 0.02 b	0.12 ± 0.03 b	0.07 ± 0.04	0.04 ± 0.02 b
p-value	0.0136	0.4379	0.0077	0.0492	0.4991	0.0173

Means followed by the same letter in the column do not differ by the test of Tukey either by the student-Newman-Keuls test at the 5% probability level; SE = Standard Error

Table 5: Frequency of fallen fruits (± SE) in harvest and damaged fruits in the harvest in 'Valencia' oranges subjected to Kaolin 10%, Surround® WP 5%, phosmet (75 g a.i, 100 L^{-1}) and control in the 2017, 2018 and 2019 harvests, Eldorado do Sul, RS

	% Fallen fruits			% Damaged fruits (± SE)		
	2017	**2018**	**2019**	**2017**	**2018**	**2019**
Control	16.2 ± 1.20	--	16.8 ± 6.22	0.7 ± 0.24 ab	0.1 ± 0.05	1.2 ± 0.32
Insecticide	15.4 ± 3.01	--	17.0 ± 2.41	1.0 ± 0.27 a	0.3 ± 0.12	0.6 ± 0.24
Kaolin	11.8 ± 1.60	--	13.8 ± 2.23	0.2 ± 0.16 b	0.04 ± 0.05	0.4 ± 0.18
Surround®WP	14.2 ± 3.09	--	12.0 ± 2.99	0.3 ± 0.17 b	0.2 ± 0.12	0.4 ± 0.11
p-value	0.3292	-	0.3138	0.0275	0.1689	0.0518

Means followed by the same letter in the column do not differ by the test of Tukey at the level of 5% probability; SE = Standard Error

The physicochemical characteristics of oranges in terms of weight, diameter, soluble solids, titratable acidity, and peel color index were similar among treatments in the three harvests (Table 8).

DISCUSSION

A. fraterculus (puparium + larvae/fruit) infestation in tangerines, as well as in oranges, treated with kaolin-based films was lower in the 2017 harvest in relation to the control. In the 2019 harvest, Surround® WP reduced infestation in oranges, when compared to insecticide-treated and control fruits. These results are corroborate those of Lo Verde *et al*. (2011), D'Aquino *et al*. (2011), and Smaili *et al*. (2016), who reported that kaolin reduced *C. capitata* infestations in citrus orchards. Likewise, Ourique *et al*. (2018) observed that 'Céu' and 'Valencia' cultivar oranges, covered with mineral films were less infested by *A. fraterculus*.

One of the reasons why the infestation can be less with the mineral film is due to its white color that causes the reflection of light, which can disorient the insects, as suggested by Saour & Makee (2004). They can also disguise the color of the fruits, making it difficult for the host to find the fly, an effect pointed out by Mazor & Erez (2004). Further, according to Katsoyannos (1987), the white color is one of the least attractive colors for some Tephritidae. Another related factor is the irritation caused in the tarsi and aculeus by the mineral particles, resulting in a longer cleaning activity in detriment to oviposition was reported by Glenn & Puterka (2005).

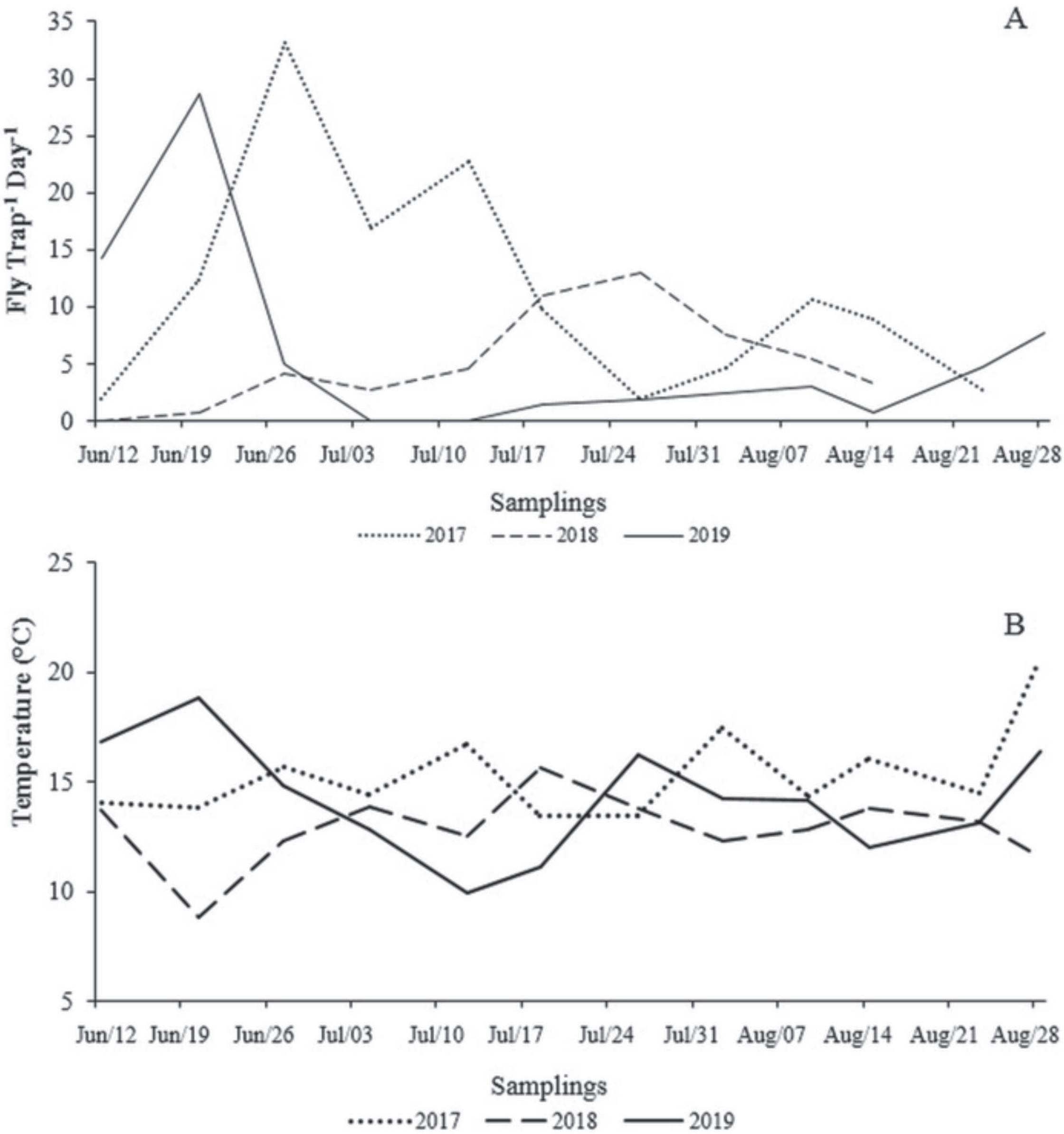

Figure 2: A) *A. fraterculus* Fly/trap/day index recorded in 'Valencia' orange orchard in the 2017, 2018, and 2019 harvests, Eldorado do Sul, RS. B) Average temperature recorded over the experiment in the 2017, 2018, and 2019 harvests, Eldorado do Sul, RS.

In the search for hosts, fruit-flies use chemical signals in addition to visual signals, such as volatiles emitted by plants (Joachim-Bravo *et al*., 2001). Volatiles of different citrus species can even stimulate oviposition, as observed in laboratory tests with *C. capitata* (Ioannou *et al*., 2012). Thus, another possible effect of the films is the covering of oil-secreting glands present in the leaves and in the fruit peel, reducing or altering the released volatiles, which decreases the attractiveness to fruit flies, which may have occurred both in the tangerine and orange orchards.

Table 6: Correlation between weather variables and the number of flies /trap/day (FTD) recorded at seven, 15, and 30 days before sampling in 'Valencia' orange trees (Eldorado do Sul, RS)

Weather variables	Days before collection					
	2017					
	7 days		**15 days**		**30 days**	
	r	**p**	**r**	**p**	**r**	p
FTD x rainfall (mm)	-0.2851	0.4246	-0.3446	0.3295	0.4465	0.1958
FTD x average temperature (°C)	0.2929	0.4114	0.336	0.3424	-0.0457	0.9003
	2018					
	7 days		**15 days**		**30 days**	
	r	**p**	**r**	**p**	**r**	p
FTD x rainfall (mm)	0.689	0.0868	-0.1379	0.7681	-0.1943	0.6763
FTD x average temperature (°C)	0.699	0.0805	0.7946	0.0327	0.603	0.1517
	2019					
	7 days		**15 days**		**30 days**	
	r	**p**	**r**	**p**	**r**	**p**
FTD x rainfall (mm)	-0.0273	0.9365	-0.3546	0.2846	-0.0149	0.9653
FTD x average temperature (°C)	0.8212	0.0019	0.6838	0.0203	0.6462	0.0316

r - Pearson's correlation

Table 7: Mean values (± SE) of mass (g), diameter (mm), total soluble solids (SS) (%), total titrable acidity (TA), Peel Color Index (PCI) in 'Okitsu' tangerines in the harvest period submitted to kaolin 10%, Surround® WP 5%, phosmet (75 g a.i. 100 L^{-1}) and control in the 2017, 2018 and 2019 harvests, Eldorado do Sul, RS. (50 fruits/treatment)

Treatments	Mass (g)	Diameter (mm)	SS (%)	TA (%)	PCI
			2017		
Control	148.3 ± 9.51 a	73.4 ± 1.71	9.2 ± 0.08	0.94 ± 0.08 ab	-0.11 ± 1.17
Insecticide	175.0 ± 4.95 ab	77.1 ± 1.18	9.4 ± 0.15	0.85 ± 0.03 b	-1.23 ± 1.55
Kaolin	153.1 ± 2.70 ab	74.8 ± 0.99	9.5 ± 0.10	1.08 ± 0.05 a	-0.20 ± 0.19
Surround®WP	176.6 ± 4.97 b	77 ± 0.89	9.4 ± 0.06	0.75 ± 0.02 b	-0.39 ± 0.40
p-value	0.0206	0.1736	0.2676	0.0105	0.7634
			2018		
Control	128.1 ± 4.26	67.3 ± 0.62	10.3 ± 0.62	0.87 ± 0.09	-
Insecticide	127.9 ± 7.16	67.7 ± 1.49	10.6 ± 0.18	0.74 ± 0.09	-
Kaolin	138.8 ± 7.38	71.1 ± 1.97	10.7 ± 0.21	0.86 ± 0.06	-
Surround®WP	136.2 ± 4.16	70.1 ± 1.48	11.0 ± 0.25	0.85 ± 0.03	-
p-value	0.3746	0.1485	0.1393	0.5719	-
			2019		
Control	118.9 ± 5.34	67.3 ± 0.51	10.1 ± 0.49	1.33 ± 0.18	0.07 ± 0.75
Insecticide	116.3 ± 10.38	65.3 ± 2.24	10.0 ± 0.17	1.24 ± 0.02	-1.78 ± 1.41
Kaolin	114.4 ± 2.38	66.3 ± 0.67	10.1 ± 0.17	1.17 ± 0.11	-0.48 ± 0.45
Surround®WP	123.7 ± 8.29	68.6 ± 1.26	10.2 ± 0.35	1.32 ± 0.05	-3.18 ± 2.35
p-value	0.7716	0.2900	0.9681	0.6107	0.8095

Means followed by the same letter in the column are not different from each other by the test of Tukey at the 5% probability level; SE = Standard error.

The reduction in citrus fruit drop resulting from the attack of fruit-flies due to the protection exercised by mineral films was observed by Braham *et al*. (2007) and D'Aquino *et al*. (2011). However, in our work, the number of fallen fruits did not differ between treatments, which suggests that the recorded fall may be associated with other biotic factors, such as diseases, or abiotic, such as the action of winds.

In the 2018 and 2019 harvests, *A. fraterculus* infestation on tangerines was similar among treatments. In 2018, no insects were caught in the traps and in 2019, the FTD index was always less than 0.5 fly trap^{-1} day^{-1}, considered control level for the crop (Nava & Botton, 2010). Thus, this result is not due to the lack of efficiency of the products, but rather to the low population recorded in the orchard. In the 2017 harvest, the fruit infestation was higher. Nonetheless, several studies have shown that the population fluctuation of fruit flies does not follow a pattern and varies over the year and among years (Salles, 1995; Garcia *et al*., 2003; Silva *et al*., 2014). One of the factors that explain this behavior is the presence of alternative host fruits around the orchards under evaluation. During the period of fruiting of the tangerine trees, the presence of native fruits, such as Araca, and cultivated, such as peaches, in nearby areas are frequent and they are much more attractive to *A. fraterculus* than the citrus species (Gatelli *et al*., 2008). This fact was also observed by Ourique *et al*. (2018) in 'Céu' orange orchards. Extremely higher or lower temperatures in summer, when the tangerines grow and ripen, could affect the fly population (Salles, 2000). Although, the temperature variation in this season was not atypical in the years when the study was conducted. So, we believe that the temperature was not the cause to low fly infestation in tangerines.

In relation to orange trees, in the 2018 harvest, the infestation was similar between treatments; however, the FTD index throughout the period was greater than 0.5 fly/trap/day. Also, there was a positive correlation between the FTD index and the average temperature 15 days before sampling. Winter in 2018 was unusual, marked by low temperatures that ranged from 1.5 °C to 2.0 °C below the historical average (SEAPI, 2018). Temperatures below 18 °C may decrease the activity of *A. fraterculus* (Salles, 2000). Thus, the insects in the orchard could only be searching for food, in baited traps with attractive food and without reproduction and oviposition activity, which resulted in low infestation in the fruits. In 2019, the average temperature varied throughout the harvest, in general, they were higher than those recorded for the other years (2017 and 2018) until June and lower in July. However, although a correlation with the FTD index was obtained, this did not affect fruit infestation.

Although carbon assimilation in the leaves of tangerine trees was not affected by mineral films, Gullo

Table 8: Mean values (± SE) of mass (g), diameter (mm), total soluble solids (SS) (%), total titratable acidity (TA), Peel Color Index (PCI) in 'Valencia' oranges at harvest, submitted Kaolin 10%, Surround®WP 5%, phosmet (75 g a.i. 100 L^{-1}) and control, in 2017, 2018 and 2019 harvests, Eldorado do Sul, RS. (50 fruits / treatment)

Treatments	Mass (g)	Diameter (mm)	SS (%)	TA (%)	PCI
			2017		
Control	166.7 ± 12.84	69.5 ± 1.68	9.2 ± 0.24	1.66 ± 0.11	4.74 ± 0.26
Insecticide	162.2 ± 5.48	68.3 ± 0.63	9.1 ± 0.17	1.55 ± 0.09	4.84 ± 0.28
Kaolin	177.1 ± 12.29	70.6 ± 1.58	9.2 ± 0.13	1.64 ± 0.05	4.37 ± 0.31
Surround®WP	167.7 ± 7.02	69.8 ± 2.23	9.2 ± 0.09	1.65 ± 0.0	4.59 ± 0.20
p-value	0.7607	0.7914	0.8672	0.8022	0.6375
			2018		
Control	195.7 ± 13.81	74.3 ± 1.70	9.9 ± 0.24	1.52 ± 0.04	4.27 ± 0.32
Insecticide	171.2 ± 9.04	72.6 ± 0.84	9.8 ± 0.19	1.50 ± 0.06	4.39 ± 0.45
Kaolin	197.2 ± 10.32	73.4 ± 0.96	9.8 ± 0.29	1.52 ± 0.07	4.22 ± 0.23
Surround®WP	190.7 ± 5.07	73.8 ± 0.61	9.8 ± 0.11	1.47 ± 0.06	4.77 ± 0.12
p-value	0.3289	0.7926	0.9812	0.9199	0.6417
			2019		
Control	168.4 ± 6.62	70.1 ± 0.81	9.7 ± 0.10	1.46 ± 0.11	-
Insecticide	176.3 ± 7.46	71.1 ± 0.92	9.5 ± 0.31	1.43 ± 0.12	-
Kaolin	173.1 ± 7.50	71.3 ± 1.31	9.4 ± 0.12	1.56 ± 0.14	-
Surround®WP	166.3 ± 5.45	70.1 ± 0.76	9.4 ± 0.37	1.44 ± 0.07	-
p-value	0.6526	0.6512	0.7652	0.7873	-

Means analyzed by the Kruskal-Wallis test at 5% probability level; SE = Standard error.

et al (2020) observed a reduction in the temperature of the 'Navelinas' orange leaves treated with mineral films, which promoted photosynthesis.

Mineral films also act as sunscreen and prevent injuries denominated sun damage, which occur in many fruits, including citrus (Barber & Sharpe, 1970; Agustí, 2003). The reduction of these lesions with the use of kaolin has been demonstrated in 'Okitsu' tangerines (Chabbal *et al*., 2014), in 'Balady' (*Citrus reticulata*, Blanco) (Ennab *et al*. 2017), and in 'Rio Re' pomelo trees (*Citrus paradisi* Macf.) (Rodriguez *et al*., 2019). In this work, the fruits did not present any solar damage, but this could be an additional function of mineral films, in addition to pest control, improving the quality of fruits.

Fruit quality measured based on physical-chemical characteristics, both in tangerines and oranges with the application of mineral films were similar to those of the control fruits in this study. This result corroborates those of Mezófi *et al*. (2018), who did not verify the effect of kaolin on the mass and on the concentration of soluble solids in cherries, in addition to finding a reduction in the infestation of *Rhagoletis cerasi* (Linnaeus) (Diptera: Tephritidae) in the cherry orchard. In 'Navelinas' oranges, Gullo *et al*. (2020) also observed the absence of kaolin interference in color, SS, and TA parameters.

Based on the physicochemical characteristics described by Schwarz *et al*. (2018) for 'Okitsu' tangerines, it was found that the treatments did not affect these parameters in this work. Regarding oranges, it was observed that parameters such as diameter, SS, and TA were similar to those recorded by Petry *et al*. (2015) and the average mass followed the values described for the cultivar Valencia (Schwarz *et al*., 2018), so, with no effect of the treatments. Moreover, the PCI, whose minimum export value must be 2 to oranges (Spósito *et al*., 2006), has always remained above 4 in all treatments. Thus, besides reducing the infestation of *A. fraterculus*, the mineral films did not alter important characteristics of the fruits for consumption and commercialization.

Due to their mode of action, mineral films also have the advantage of reaching other pests that may be present in citrus orchards such as *Diaphorina citri* Kuwayama (Hemiptera: Liviidae), as found by Miranda *et al*. (2018).

An important aspect that should be emphasized is that insecticides such as that used in this study (phosmet) do not prevent the damage caused by the fruit fly. Furthermore, are applied only when the control level (0.5 FTD) is reached and its use is limited to a maximum of five applications per harvest, requiring a 10 to 15-day withdrawal period (MAPA, 2020). Conversely, mineral films can be applied preventively, they have a maximum application limit, neither a withdrawal period, as it is an inert material (Glenn & Puterka, 2005). The removal of the fruit films can be easily done with water and a brush system, as in the "packinghouses" processing units (Lo Verde *et al*., 2011). Thus, these products are safe both for those who apply them and for the environment, they also add value and do not face market restrictions for exports.

The adoption of this technology as a tool to control different pests and to reduce the stress caused by heat or radiation, can be important and assist in the phytosanitary management of orchards, decreasing the use of organosynthetic pesticides, production costs, contamination of the environment, besides generating fruits with a high added value.

CONCLUSIONS

The results obtained in this experiment indicate that the use of mineral particle film technology and may be a tool to protect citrus fruits from damages caused by South American fruit fly, therefore maintaining the quality for the consumption of fresh fruits. Kaolin does not have preharvest interval or maximum number of applications allowed, so it is an environmentally safe product.

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REFERENCES

Agustí M (2003) Citricultura. Madrid, Mundi-Prensa. 422p.

Ayres M, Ayres Junior M, Ayres DL, Santos AAS & Ayres LL (2007) BioEstat 5.0: Aplicações estatísticas nas áreas das ciências biológicas e médicas. Belém, Sociedade Civil Mamirauá. 345p.

Barber NH & Sharpe PJH (1970) Genetics and physiology of sunscald of fruits. Agricultural Meteorology, 8:175-191.

Bergamaschi H, Melo RW, Guadagnin MR, Cardoso LS, Silva MIG, Comiram F, Dalsin F, Tessari ML & Brauner PC (2013) Boletins agrometeorológicos da Estação Experimental Agronômica da UFRGS - série histórica 1970 – 2021. Available at: <https://hospedagemphp.ufrgs.br/agronomia/joomla/index.php/eea-pesquisa>. Accessed on: July 14th, 2020.

Botton M, Junior RM, Nava DE & Arioli CJ (2012) Novas alternativas para o monitoramento e controle de *Anastrepha fraterculus* (Wied., 1830) (Diptera: tephritidae) na fruticultura de clima temperado. Available at: <https://ainfo.cnptia.embrapa.br/digital/bitstream/item/69914/1/Dori-Edson-Nava.pdf>. Accessed on June 18th, 2020.

Braham M, Pasqualini E & Ncira N (2007) Efficacy of kaolin, spinosad and malathion against *Ceratitis capitata* in Citrus orchards. Bulletin of Insectology, 60:39-47.

Caleca V & Rizzo R (2007) Tests on the effectiveness of kaolin and copper hydroxide in the control of *Bactrocera oleae* (Gmelin). IOBC/WPRS Bulletin, 30:111-117.

Chabbal MD, Piccoli AB, Martínez GC, Avanza MM, Mazza SM & Rodríguez VA (2014) Kaolin applications to control sunburn in ‘Okitsu’ mandarin. Cultivos Tropicales, 35:50-56.

Choudhury MM & Costa TS (2002) A segurança de produtos hortifrutícolas frescos. Petrolina, Embrapa Semi-Árido. 36p. (Documentos, 181).

D’Aquino A, Cocco S, Ortu M & 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 Protection, 30:1079-1086.

Ennab HA, EL-Sayed SA & Abo EL-Enin MMS (2017) Effect of kaolin applications on fruit sunburn, yield and fruit quality of balady mandarin (*Citrus reticulata* Blanco). Menoufia Journal of Plant Production, 2:129-138.

EPA - Environmental Protection Agency in America (1999) Fact Sheet. Available at: <http://www.epa.gov/pesticides/biopesticides/ingredients/factsheets/factsheet_100104.htm>. Accessed on November 10th, 2021.

FAO - Food and Agriculture Organization of the United Nations (2018) Statistic Division. Available at: <http://www.fao.org/faostat/en/#data/QC/visualize/>. Accessed on: July 14th, 2020.

Garcia FRM, Campos JV & Corseiul E (2003) Flutuação populacional de *Anastrepha fraterculus* (Wiedemann, 1830) (Diptera, Tephritidae) na Região Oeste de Santa Catarina, Brasil. Revista Brasileira de Entomologia, 47:415-420.

Gatelli T, Silva FF, Meirelles RN, Redaelli LR & Dal Soglio FK (2008) Moscas frugívoras associadas a mirtáceas e laranjeira ‘Céu’ na região do Vale do Rio Caí, Rio Grande do Sul, Brasil. Ciência Rural, 38:236-239.

Glenn DM & Puterka GJ (2005) Particle films: a new technology for agriculture. Horticultural Review, 31:01-44.

Glenn DM & Puterka GJ (2007) The use of plastic films and sprayable reflective particle films to increase light penetration in apple canopies and improve apple color and weight. HortScience, 42:91-96.

Glenn DM, Puterka F, Van Der Zwet JT, Byers RE & Feldhake C (1999) Hydrophobic particle films: a new paradigm for suppression of arthropod pests and plant diseases. Journal of Economic Entomology, 92:759-771.

Glenn DM, Van Der Zwet T, Puterka G, Gundrum P & Brown E (2001) Efficacy of kaolin-based particle films to control apple diseases. Plant Health Progress, 10.1094/PHP 2001-0823-01-RS.

Gullo G, Dattola A, Vonella V & Zappia R (2020) Effects of two reflective materials on gas exchange, yield, and fruit quality of sweet orange tree *Citrus* sinensis (L.) Osb. European Journal of Agronomy, 10.1016/j.eja.2020.126071.

Ioannou CS, PapadopouloS NT, Kouloussis NA, Tananaki CI & Katsoyannos BI (2012) Essential oils of citrus fruit stimulate oviposition in the Mediterranean fruit fly *Ceratitis capitata* (Diptera: Tephritidae). Physiological Entomology, 37:330-339.

Jardim ICSF, Andrade JA & Queiroz SCN (2009) Resíduos de agrotóxicos em alimentos: uma preocupação ambiental global – um enfoque às maças. Química Nova, 32:996-1012.

Jimenez-Cuesta M, Cuquerella J & Martinez-Javega JM (1981) Determination of a color index for Citrus fruit degreening. Proceedings of the International Society of Citriculture, 2:750-753.

Joachim-Bravo IS, Guimarães NA & Magalhães TC (2001) Influência de substâncias atrativas no comportamento alimentar e na preferência de oviposição de *Ceratitis capitata* (Diptera, Tephritidae). Sitientibus - Série Ciências Biológicas, 1:60-65.

Katsoyannos BI (1987) Response to shape, size and colour. In: Robinson AS & Hooper G (Eds.) Fruit flies: their biology, natural enemies and control. Amsterdam, Elsevier. p. 307-321.

Lo Verde G, Caleca V & Lo Verde V (2011) The use of kaolin to control *Ceratitis capitata* in organic citrus groves. Bulletin of Insectology, 64:127-134.

MAPA - Ministério da Agricultura, Pecuária e Abastecimento (2020) Agrofit - Sistema de agrotóxicos fitossanitários. Available at: <http://agrofit.agricultura.gov.br/agrofit_ cons/principal_agrofit_cons>. Accessed on: August 06th, 2020.

Mazor M & Erez A (2004) Processed kaolin protects fruits from Mediterranean fruit fly Infestations. Crop Protection, 23:47-51.

Mezófi L, Sipos P, Vétek G, Elek R & Markó V (2018) Evaluation of kaolin and cinnamon essential oil to manage two pests and a fungal disease of sour cherry at different tree canopy levels. Journal of Plant Diseases and Protection, 10.1007/s41348-018-0168-2.

Miranda MP, Zanardi OZ, Tomaseto AF, Volpe HXL, Rafael B, Garcia RB & Prado E (2018) Processed kaolin affects the probing and settling behavior of *Diaphorina citri* (Hemiptera: Lividae). Pest Management Science, 74:1964-1972.

Nava DE & Botton M (2010) Bioecologia e controle de *Anastrepha fraterculus* e *Ceratitis capitata* em pessegueiro. Pelotas, Embrapa Clima Temperado. 29p. (Documento, 315).

Ourique CB, Redaelli LR, Efrom CFS & Pedrini D (2018) Effects of kaolin and limestone on infestation of South American fruit fly in citrus orchards. Biological Agriculture & Horticulture, 10.1080/01448765.2018.1512897.

Perri E, Ianotta N, Muzzalupo I, Russo A, Caravita MA, Pellegrino M, Parise A & Tucci P (2005) Kaolin protects olive fruits from Bactrocera oleae (Gmelin) infestations unaffecting olive oil quality. Available at <https://orgprints.org/id/eprint/10205/1/Perri_et_al_IOBC_Kaolin.pdf>. Accessed on: August 06th, 2020.

Petry HB, Schneideri LA, Silveira Júnior JC, Crizel TM, Flôres SH & Schwarz SF (2015) Avaliação física e química e aceitação pelo consumidor de laranjas ‘Valência’, produzidas sob sistemas de cultivo orgânico e convencional. Ciência Rural, 45:619-625.

Raga A & Galdino LT (2017) Sintomatologia do ataque de moscas-das-frutas (Diptera: Tephritidae) em citros. São Paulo, Instituto Biológico. 17p. (Documento Técnico, nº 33).

Rodriguez J, Anoruo A, Jifon J & Simpson C (2019) Physiological effects of exogenously applied reflectants and anti-transpirants on leaf temperature and fruit sunburn in citrus. Plants, 10.3390/plants8120549.

Salles LA (1995) Bioecologia e controle da mosca-das-frutas sul-americana. Pelotas, Embrapa – CPACT. 58p.

Salles LA (2000) Biologia e ciclo de vida de *Anastrepha fraterculus* (Wied.) In: Malavasi A & Zucchi RA (Eds.) Moscas-das-frutas de importância econômica no Brasil: conhecimento básico e aplicado. Ribeirão Preto, Holos. p.81-86.

Santos JP, Redaelli LR, Sant’Ana J & Hickel ER (2015) Suscetibilidade de genótipos de macieira a *Anastrepha fraterculus* (Diptera: Tephritidae) em diferentes condições de infestação. Revista Brasileira de Fruticultura, 37:90-95.

Saour G & Makee H (2004) A kaolin-based particle film for suppression of olive fruit fly *Bactrocera oleae* Gmelin (Dipt. Tephritidae) in olive trees. Journal of Applied Entomology, 128:28-31.

Schwarz SF, Souza ELS & Oliveira RP (2018) Características das variedades copa. In: Efrom CFS & Souza PVD (Eds.) Citricultura do Rio Grande do Sul: indicações técnicas. Porto Alegre, Secretaria da Agricultura, Pecuária e Irrigação. 289p.

SEAPI - Secretaria da Agricultura, Pecuária e Irrigação (2018) Condições Meteorológicas Ocorridas Rio Grande do Sul - 07 A 13 de Setembro de 2018. Porto Alegre, SEAPRI. 2p. (Boletim Meteorológico Semanal, 36).

Silva FF, Redaelli LR, Meirelles RN & Dal Soglio FK (2014) Danos de moscas-das-frutas (Diptera, Tephritidae) em citros, manejados no sistema orgânico de produção. Revista Ceres, 61:637-642.

Smaili MC, Bakri A, Gaboune F, Bouharroud R & Blenzar A (2016) Comparison of the effect of spinosad, kaolin and protein bait spray on *Ceratitis capitata* (Diptera: Tephritidae) in citrus orchards in the Gharb (Morocco). International Journal of Research in Agricultural Sciences, 3:197-205.

Spósito MB, Julianetti A & Barbasso DV (2006) Determinação do índice de cor mínimo necessário para a colheita de laranja doce Valência a ser submetida ao processo de desverdecimento. Laranja, 27:373-379.

Streck EV, Kämpf N, Dalmolin RSD, Klamt E, Nascimento PC & Schneider P (2002) Solos do Rio Grande do Sul. Porto Alegre, Universidade Federal do Rio Grande do Sul. 127p.

Syvertsen JP (2017) Aspects of stress physiology of citrus. Acta Horticultural, 1177:51-58.

Tubajika KM, Civerolo EL, Puterka GJ, Hashim JM & Luvisi DA (2007) The effects of kaolin, harpin, and imidacloprid on development of Pierce's disease in grape. Crop Protection, 26:92-99.