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Research Article

Early Results of Kaolin Clay Applications in the Dominican Republic

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Abstract

Sustainable approaches for fruit fly control are desirable to reduce resistance development and ease the entry of the commercial fruit to international markets. Kaolin clay foliar applications ares a suitable option for sustainable insect control in agriculture. Kaolin clay has shown to reduce plant stress and increase yield under high-temperature conditions. Adequate kaolin clay treatment could mitigate detrimental effects of high temperatures on guava flowering and fruiting while reducing fruit losses due to Caribbean fruit fly. However, the efficiency of kaolin clay may be affected by the rate and time of application as well as growing conditions and plant morphology. The objective of this study was to evaluate the effect of three kaolin clay rates in combination with three frequencies of application on fruit fly control and guava yield. Kaolin clay was applied to the foliage of guava trees using 19, 38, and 57 kg/ha, and were reapplied either weekly, biweekly, or monthly. Additionally, one control treatment was maintained with no kaolin clay application. Fruit yield, larvae infestation, and foliage temperature were recorded. Guava marketable fruit number was influenced by the kaolin clay compared to the control, although no increase in the overall yield was recorded. Weekly and biweekly applications of kaolin clay reduced fruit fly infestation by 69%, compared to monthly applications. Additionally, application rates of 57 kg/ha reduced larvae infestation by 59%, compared to 19 kg/ha. Biweekly applications of 57 kg/ha reduced fruit fly larvae infestation in guava fruit in 95.5%, compared to the untreated control. This technology showed potential as a sustainable tool for management of Caribbean fruit flies in guava when the recommended field rate (57 kg/ha) is used at least every two weeks.

Keywords: *Caribbean Fruit Fly; Fruit Quality; Psidium Guajava; Rate; Time of Application; Leaf Temperature*

Abbreviations

CFF: Caribbean Fruit Fly

Introduction

Guava (*Psidium guajava* L., Myrtaceae) orchards are native from Southern Mexico and Northern South America [1,2]. In the Dominican Republic, guava orchards can be found in both humid and dry areas across the country and production is traditionally destined for internal consumption. Since 2010, its production has been progressively increasing due to intensifying government programs aimed to promote its production and incentivize exports to Asian markets. However, there is little information regarding appropiate growth conditions and insect management techniques for guava production in the Dominican Republic, since most growers establish their orchards based on land availability and personal perception of future markets. In other regions, guava flowering and fruiting has been reported to be adequate in temperatures ranging between 23°C and 28°C [3,4]. However, common production areas in the Dominican Republic have maximum daily temperatures of 34°C, with minimum temperatures of 22°C [5]. In addition, the Caribbean fruit fly (CFF) (*Anstrepha suspensa* Loew, Diptera: Tephritidae) is a common pest of guava, that causes direct damage to the fruit. The CFF has nearly 100 reported hosts, although it has been reported to have a preference for guava fruits. Females of the CFF feed and oviposit on developing fruit making it unmarketable due to larvae borrowing through the interior of the fruit as they feed [6-10].

Chemical control and sterile insect release are the two most common techniques for tephritid management at a local and regional level [11,12]. Common broad-spectrum insecticides include organochlorines, organophosphates, carbamates, pyrethroids, and spinosins [9,10]. However, continued exposure to chemical products has resulted in insecticide resistance development in several species of tephritids [14-16], as well as the resilience of insecticide residues in fruits, soil and water contamination, and the reduction of beneficial organisms [17,18]. Thus, sustainable approaches for fruit fly control are desirable to reduce potential resistance development and ease the entry of guava produce to international markets [12,17,19].

Sustainable techniques for fruit fly management include the removal of weeds and wild hosts, the elimination of crop residue, physical exclusion from host plants using nets [13,20], and the use of kaolin clay [21-26]. The kaolin clay particle [Al4Si4O10(OH)8] is a white, hydrophilic, non-abrasive matter that serves as a repellent against Lepidoptera, soft-bodied insects and insect larvae [27]. Saour and Makke (2004), reported no differences in between the application of kaolin clay and dimethoate in 14-day application intervals for control of olive fruit flies (*Bactrocera oleae* Rossi, Diptera: Tephritidae) in olive production [25]. Similarly, Verde., *et al.* (2011), reported a significant reduction on fruit damage in citrus caused by Mediterranean fruit flies (*Ceratitis capitate* Wiedemann, Diptera: Tephritidae) after kaolin clay applications using 5 kg/100 L [24]. There is little information on the effect of kaolin clay on guava production and its potential use for CFF control. Additionally, depending on local growing and environmental conditions, rate and frequency of application the efficiency of kaolin clay vary. Appropiate kaolin clay treatments could help reduced fruit losses due to CFF infestations while reducing potential detrimental effects of high temperatures on guava flowering and fruiting. The objective of this study was the evaluate the effect of kaolin clay rates and timing of application on guava yield and CFF control.

Materials and Methods

A field study was conducted between Dec. 23rd, 2019 and May 09th, 2020 at Goya Santo Domingo (lat. 18°42'N, long. - 70°10'E), a commercial guava farm in San Cristobal, Dominican Republic. A guava orchard planted in 2001, with a reported history of *A. suspensa* infestations was used for the experiments. Guava trees of the cultivar 'Ruby' were established 3-m apart between plants and 6-m apart between rows, for a plant density of 555 trees/ha. Two drip irrigation lines supplied water throughout the year. Drip emitters were 0.5 - m apart, with an average flow of 3.2 L/h. Irrigation was provided three times per week for periods ranging between 1 and 1.5 hours per irrigation event. Trees received an average flow of 4.7 m^3/year of water, assuming a full water film coverage under the canopy with 8 emitters per tree. Guava trees received approximately 300 kg/ha of nitrogen, 135 kg/ha of P2O5, and 570 kg/ha of K2O per year.

On Dec. 09th, 2019, the orchard was fumigated with Aval® 20SP (acetamiprid) at a rate of 2.5 L/ha, and Amistar® (azoxystrobin and pifenoconazole) at a rate of 1.5 L/ha. Additionally, on Jan. 14th, 2020, plants were fumigated with Exalt® 6SC (spinosyn J and spinosyn L) and Mastercop® (copper sulfate pentahydydrate) at rates of 2 and 4 L/ha, respectively.

Experimental design

The experimental site was approximately 0.86 ha. Treatments were established in a randomized complete block design, with four replications. A row of guava trees represented one block. One experimental plot consisted of three full grown trees and each plot within a block was separated (9 - m apart) by three untreated trees used as buffer zone, while blocks were spaced at 12 - m (2 rows). Treatments consisted of the combination of three kaolin clay (Surround® WP; Ferquido, Santo Domingo, Dominican Republic) rates (19, 38, and 57 kg/ha) and three frequencies of application (weekly, biweekly, or monthly). Additionally, a control treatment was maintained with no kaolin clay application.

Kaolin clay was applied to the foliage of the guava trees using a 20 L backpack sprayer (Guarany; Ferquido, Santo Domingo, Dominican Republic), with a dilution rate of 946 L/ha. Applications were made directly to the tree foliage, from ~ 0.5 m above ground to the top of the trees, covering branches and fruits. Kaolin clay cumulative rate varied per experimental unit, as the number of applications within the evaluation period changed according to treatment (Table 1).

No.	Kaolin clay rate	Time of application	No. of applications during evaluation period1	Kaolin clay cumulative application
1	19 kg/ha	Weekly	20	380 kg/ha
2	38 kg/ha	Weekly	20	760 kg/ha
3	57 kg/ha	Weekly	20	1140 kg/ha
4	19 kg/ha	Biweekly	10	190 kg/ha
5	38 kg/ha	Biweekly	10	380 kg/ha
6	57 kg/ha	Biweekly	10	570 kg/ha
7	19 kg/ha	Monthly	5	95 kg/ha
8	38 kg/ha	Monthly	5	190 kg/ha
9	57 kg/ha	Monthly	5	285 kg/ha
10	Control	-	-	-

Table 1: *Cumulative kaolin clay rates applied per treatment in guava production in San Cristobal, Dominican Republic, 2020.*
1Evalution period started from 23 Dec. 2019 to 09 May 2020.

Sampling

Three fruits per treatment were collected weekly, isolated front each other in 1.5 L plastic containers sealed with a 40 - mesh net, and stored under laboratory conditions with 16 h of light and at 29°C. Sampled fruits stayed in each container for four weeks to allow larvae development. After the incubation period, fruit fly adults and remaining larvae were identified and counted.

Fruit harvests started on March 05th, 2020 with fruit picking twice per week for six weeks. Fruits were classified as marketable and unmarketable. Marketable fruit was defined as guava fruit with a minimum fresh weight of 50 g or above, without visible blemishes or deformation. Marketable yield was defined as the cumulative marketable weight of all harvest until April 18th, 2020. Additionally, unmarketable fruit number and weight was recorded. Average fruit weight for both marketable and unmarketable fruits was determined by dividing the total yield of each treatment by its corresponding fruit number.

Additionally, foliage temperature was collected with an infrared thermometer. Hourly temperature data was collected during the course of two days, with 6 replications per tree, on one tree per treatment. Temperature data was collected 2 - m away from each tree, with an infrared thermometer. Data from both days was averaged per each hour of evaluation.

Statistical analysis

Two analyses of variance were used to identify interactions and treatment main effects. During the first set of analysis, kaolin clay treatments were analyzed without including the control. The combination of between application rate and frequency of application with higher marketable fruit yield and lowest infection rate was compared to the control treatment. In case of significant effect, means were separated by Tukey HSD test. To comply with the analysis of variance assumptions, data was transformed with the function Y = log (X+1).

Results and Discussion

There was no interaction between application rate and frequency of application for any of the measured variables (Table 2). The number of CFF larvae was recorded after exposing the unmarketable fruit samples to a 4-week incubation period showeda significant effect of kaolin clay rates and frequency of application (Figure 1). Weekly and biweekly applications reduced CFF infestation by 69%, compared to monthly applications. Additionally, applications of 57 kg/ha reduced the number of larvae by 59%, compared to 19 kg/ha (Figure 1). Based on individual factor response, biweekly applications of 57 kg/ha was compared to the control treatment. Biweekly applications of 57 kg/ha reduced the number of CFF larvae present on guava fruits by 95.5%, compared to the untreated control (Figure 2).

	Marketable			Unmarketable		
Kaolin clay application	Fruit number (no./ha)	Fruit weight (kg/ha)	Average fruit weight (g/fruit)	Fruit number (no./ha)	Fruit weight (kg/ha)	Average fruit weight (g/fruit)
Rate (R)[2]						
19 kg/ha	7,908	1,036.1	134.3	8,957 a	577.6	125.7
38 kg/ha	7,523	853.5	133.8	1,942 b	247.8	124.4
57 kg/ha	13,582	1,585.4	131.9	6,783 ab	705.5	128.1
Significance[1]	NS	NS	NS	*	NS	NS
Time of application (TA)						
Weekly	11,470	1,293.6	120.9	8,849	559.2	123.4
Biweekly	8,032	973.7	137.2	2,836	360.1	123.8
Monthly	9,512	1,207.6	138.9	5,997	611.6	130.9
Significance	NS	NS	NS	NS	NS	NS
R x TA	NS	NS	NS	NS	NS	NS

***Table 2:** Effect of kaolin clay rate and time of application in guava yield in San Cristobal, Dominican Republic, 2020. 1Values followed by different letters indicate that the means are significantly different (P≤0.05) according to Tukey's honest significant difference test; NS, *Nonsignificant or significant at P≤0.05; 2rate is based on a dilution of 100 gal of water per acre. Field evaluations between 01 Jan. and 30 March. 2020; rates are equivalent to 16, 32, and 48 lb/acre, respectively.*

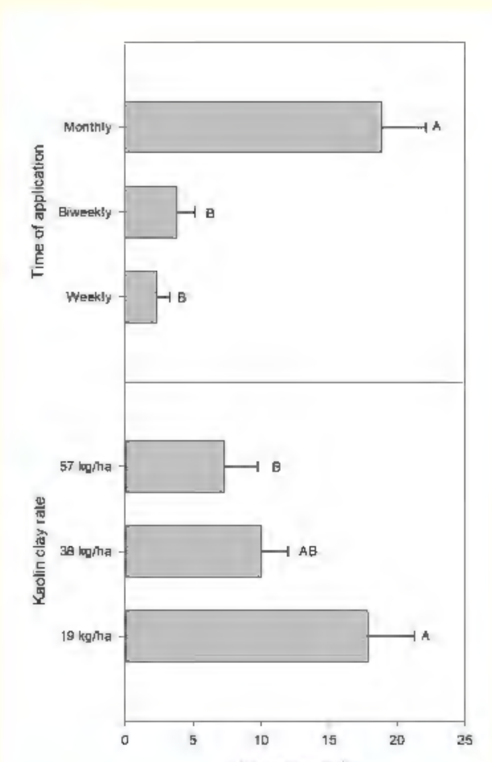

***Figure 1:** Effect of kaolin clay rate and time of application on fruit fly larvae counts on guava fruits under laboratory conditions in San Cristobal, Dominican Republic, 2020.*

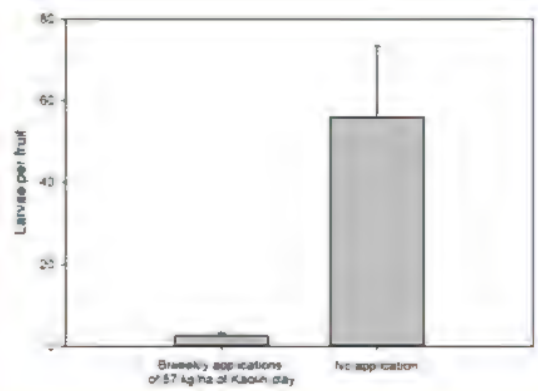

Figure 2: *Effect of biweekly applications of 57 kg/ha of kaolin clay and a control treatment with no application on fruit fly larvae counts on guava fruits under laboratory conditions in San Cristobal, Dominican Republic, 2020.*

General kaolin clay recommendations for tropical trees suggest an application rate of 57 kg/ha, three to four times per season [26], which is equivalent to 230 kg/ha per season. In our experiment, only biweekly applications of 19 kg/ha or monthly applications of 19 or 38 kg/ha resulted in a lower or equal rate than recommended (Table 1). In terms of marketable fruits, there was no significant difference among kaolin clay application rates showing an average of 9,671 fruits per ha across rates. Similarly, there was no apparent effect of kaolin clay rates on total marketable fruit weight and average fruit weight showing an average of 1,158 kg/ha and 133.2 g/fruit, respectively, across rates (Table 2). Similar to the application rates, the frequency of kaolin clay applications did not affect marketable fruit number, weight, or average fruit weight, with averages of 9,671 fruits/ha, 1,157 kg/ha and 132 g/fruit, respectively, across all the frequencies evaluated (Table 2).

Unmarketable fruit number was affected by kaolin clay rate. The lowest number of unmarketable fruit was obtained when a rate of 38 kg/ha was used, while an application rate of 19 kg/ha resulted in a 78% increment in the number of unmarketable fruit (Table 2). However, the total weight of unmarketable fruits and average fruit weight was not significantly different among kaolin clay application rates. The average unmarkable fruit weight and the average unmarketable fruit weight were 510 kg/ha and 126 g/fruit, respectively (Table 2). Moreover, frequency of application did not affect significantly unmarketable fruit number, weight, or average fruit weight (Table 2).

Provided there was no effect of kaolin clay rate or time of application on marketable fruit yield, the average of all kaolin clay treatments was compared to the control. There was a significant effect of kaolin clay on the number of marketable fruits (Table 3). Kaolin clay application rate increased average fruit number by 54%, compared to the control treatment (Table 3). However, marketable fruit weight, average fruit weight, and all unmarketable fruit variables were not different among application rates (Table 3).

	Marketable			**Unmarketable**		
Treatment	Fruit number (no./ha)	Fruit weight (kg/ha)	Average fruit weight (g/fruit)	Fruit number (no./ha)	Fruit weight (kg/ha)	Average fruit weight (g/fruit)
Kaolin application	17,112	2049.3	131.7	10776	881.3	102.9
Control	4,995	757.4	143.6	6,475	1,034.5	153.9
Significance1	NS	NS	NS	NS	NS	NS

Table 3: *Effect of kaolin clay application in guava yield in San Cristobal, Dominican Republic, 2020.*
*1NS, *Nonsignificant or significant at P≤0.05 according to Tukey's honest significant difference test;*
Field evaluations between 01 Jan. and 30 March. 2020.

Additionally, foliage temperature was slightly affected by kaolin clay rates. During the first few hours of the day, the average temperature in the untreated control rapidly increased from 28.5°C to 32.5°C between 8:00 and 9:00 am. However, all kaolin clay treatments maintained a lower temperature during the early hours of the day, ranging from 28.7°C to 31.6°C between 8:00 am and 10:00 am (Figure 3). After 11:00 am, with the increasing radiation of the day, there was no clear difference in temperature among treatments (Figure 3). Nevertheless, all kaolin clay treatments had a higher temperature at 2:00 pm, compared to the control. After 3:00 pm, all treatment gradually reduced their temperature to 29°C. Additionally, foliage, and fruit were checked for phytotoxic effects due to kaolin applications (e.g. leaf burn, fruit bronzing). Visual inspection showed no adverse effects on plant foliage and fruit throughout the experimental field.

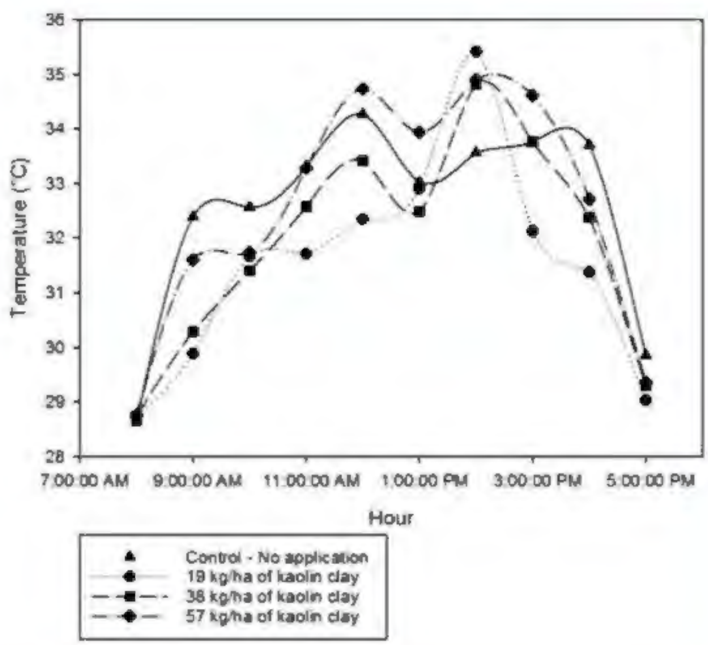

Figure 3: *Effect of kaolin clay rate on folliage temperature on guava production in San Cristobal, Dominican Republic, 2020.*

The number of guava marketable fruit was influenced by the application of kaolin clay, although it did not increase the overall yield. There are two possible explanations for the lack of weight yield response to kaolin clay applications. It was hypothesized that the applications of kaolin clay will result in a reduction in foliage temperature, allowing for a more adequate microclimate conditions for flowering under high-temperature environments. This in turn would result in higher numbers of flowers to be promoted; therefore, an increment in fruit number. However, the temperature effect did not seem to overwrite the source/sync effect of the increased number of fruits. A higher number of fruits require a higher production of photosynthates and carbohydrates, and an increase movement of water towards each fruit. Average fruit weight was not significantly affected by treatment, although the variability of the data and the low P-value suggest that a longer period of harvest could have uncover potential differences in average fruit weight.

Conversely, guava is a tropical fruit with high adaptability to high temperatures. Therefore, it could be possible that *P.guajava* shows little phenological responses to the application of kaolin clay, giving its rapid adaptability to tropical conditions. Further research is necessary to clarify the response of tropical trees such as guava trees to kaolin clay application after long periods of uninterrupted spraying. Additionally, it could be possible that different cultivars under specific growing conditions have different responses to kaolin clay applications.

In terms of its effect on fruit fly management, the applications of kaolin clay clearly reduced CFF infestation compared to the untreated guava trees. Kaolin clay created a barrier film on the surface of the tree leaves and guava fruits that seemed to reduce the attraction of CFF and other Tephritidae species. Several authors had reported the beneficial effects of kaolin clay for insect management in horticultural crops [21-24]. However, more research is necessary to better understand the insect/film-particle dynamics under high temperature and high humidity conditions. Most of the reported kaolin clay research focus in sub-tropical areas and/or temperate crops (e.g. apples, blueberries, grapes, etc) [29,30]. In the Dominican Republic, there is minimal changes in temperature and rainfall year around, and more in-situ research like the evaluations presented in this study are needed to improve the current recommendations for the use of alternativeapproaches for insect management such as kaolin clay. To our knowledge, this is the first reported evaluation of kaolin clay use in guava production in the Dominican Republic.

Conclusion

Biweekly applications of the recommended field rate for kaolin clay reduced larvae infestation by 95.5% in guava fruit production, compared to the untreated control. The applications of kaolin clay increased the average number of commercial guava fruit, despite not increasing the overall commercial yield during the first quarter of the year in the Dominican Republic. This technology showed potential as a sustainable tool for guava crop growers to manage a variety of insect pests as long as recommendations are adapted to specific production areas. Further studies are needed to identify the effects of kaolin clay on guava trees after long periods of applications.

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Conflict of Interest

The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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