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Evaluation of the effectiveness of different trap designs for the monitoring of *Drosophila suzukii* (Matsumura, 1931) (Diptera: Drosophilidae) in blackberry crop

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Spotted Wing Drosophila (SWD), *Drosophila suzukii* is one of the most important pests in berry crops around the world. In this study, different models of traps were evaluated for monitoring adult SWD. The study was conducted in a commercial blackberry orchard of the cultivar Chester, in the municipality of Vacaria, RS, Brazil in May 2016. The treatments consisted of three trap designs, namely the European model (Hemitrap®), American model (plastic pot with 750 ml of capacity), and Brazilian model (red dyed, and colorless polyethylene terephthalate (PET) bottle of 250 ml of capacity). A total of 1,572 adults of SWD were captured, as 867 males and 705 females. The mean sexual ratio was of 0.56 ± 0.03 with no difference among trap models. The trap Hemitrap® showed the highest capture values for SWD adults as well as for other Drosophilidae. The American model did not show good results being surpassed by the PET bottle trap. When considering the number of entrapped insects per milliliter of attractant, per area of entrance, per evaporative surface, and per selectivity, the colorless PET trap (Brazilian model) is the most effective.

Key words: Spotted wing drosophila, berry crops, South America, traps.

INTRODUCTION

Blackberry crop is cultivated mostly by small-hold farmers due to the low investment cost and its high profitability (Pagot and Hoffmann, 2003; Poltronieri, 2003). Although blackberry has favorable characteristics for production in family agriculture, pest attack has been limiting the expansion and profitability of the crop, due to the struggle of controlling the pests as well as the rejection of whole fruit lots by the industry when detecting the presence of

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alive insects in the fruits.

The recent registry in Brazil of *Drosophila suzukii* (Matsumura, 1931) (Diptera, Drosophilidae), a pest known worldwide as Spotted Wing Drosophila (SWD) has caused concern among producers and technicians due to the significant damage it causes to the crops, which may reach 100%. SWD is currently expanding worldwide, attacking several host crops: blackberry, strawberry, blueberry and raspberry (Lee et al., 2011; Walsh et al., 2011). In Brazil, the pest was reported in the South of the country in strawberry crops, causing damage of around 30% of the production (Santos, 2014). Due to the high potential of dissemination, rapid population growth and high number of host plants, full attention should be given to SWD in host crops (Teixeira and Rego, 2011).

The establishment of SWD monitoring strategies is an initial step for pest detection in the crops and to back decision making of strategies to control the dissemination. Santos (2014) suggested the use of attractant traps, made with polyethylene terephthalate (PET) bottles (250 ml) to monitor SWD, although, no data regarding the efficiency of this model of trap in the field was presented. In the USA it is common to use traps made with transparent plastic pots for monitoring *D. suzukii* (Lee et al., 2012). In Europe, the use of a commercially available trap (Hemitrap®) has been recommended for monitoring as well as mass control of SWD due to its high efficiency (Probodelt, 2015). It is agreed that the different types of traps, that is, different colors, shapes and number of holes, will affect the rate of insects captured. For example, the external color of the trap has been pointed out as an important factor for SWD, with superior results using yellow, red or black color (Basoalto et al., 2013; Lee et al., 2013). The trap shape is also a characteristic to be analyzed, since the volume of attractant inside the trap influences the amount of volatiles released to the field, and consequently the capture rate of the pests (Lee et al., 2013).

Because it is a recently introduced pest in Brazil, there are still few studies that provide robust knowledge for the monitoring and management of *D. suzukii* in host crops. Thus, the present study aimed to evaluate SWD capture with different trap designs in a commercial blackberry orchard.

MATERIALS AND METHODS

The experiment was conducted in a commercial orchard of blackberry cv. Chester, located in the municipality of Vacaria, State of Rio Grande do Sul, in Southern Brazil (28° 28'40.18 "S and 50° 58'7.40" W) during the month of May, 2016. The experimental design was of randomized complete blocks with four treatments (trap designs) and five replications. The traps were filled with attractant based on biological yeast, sugar and water (Santos, 2016) in the recommended amount for each trap model.

The first treatment consisted of traps made with transparent plastic pots of 14 cm of height by 11 cm in diameter, named as the "American model" (Lee et al., 2013) (Figure 1A). The trap had 11 holes of 4 mm of diameter for the arrival of the insects (138.16 mm^2 of entrance area), located at the upper edge of the trap, near the lid, and filled with 250 ml of attractant. The second treatment consisted of the commercially available yellow color Hemitrap® with 15 cm in height and 12.5 cm of diameter, named as "European model". The trap had 21 holes of 7 mm diameter (807.8 mm^2 of entrance area), arranged in three groups of seven holes each, symmetrically distributed around the trap in its upper third, and filled with 250 ml of the attractant (Figure 1B). The third and fourth treatments consisted of traps made with PET bottles of 250 ml Coca Cola® soda pop, referred to as "Brazilian model". The traps contained five holes with 4 mm of diameter (62.8 mm^2 of entrance area), equidistant 2 cm, in the lower third of the trap which contained 5 cm in diameter. In this trap, a volume of 40 ml of the attractant was used. The difference between treatments three and four was the color of the trap: transparent and red, respectively (Figure 1C and D).

The traps were placed in the field, and arranged in randomized complete blocks (plant rows), equidistant from each other in 6 m, at a height of 1.30 m from the ground level. They were inspected every two days, and the captured insects removed, packed in plastic pots, and taken to the Embrapa Grape and Wine laboratory in Vacaria, RS, for screening. SWD adults were segregated into both sexes and computed under stereomicroscope, along with the number of other Drosophilae adults present in the samples. The analyzed variables were: total number of adults of *D. suzukii* and sexual ratio; total number of other Drosophilidae captured; mean SWD per attractant volume (ml) and mean SWD as a function of the total insect entrance area in each trap model. The total number of holes, total entrance area and evaporation surface of the attractant were considered for each trap.

The data were tabulated and analyzed for normality by the Shapiro-Wilk test and homoscedasticity by Hartley and Bartlett. Treatment averages were compared by the Tukey test at 5% probability using Statistica 6.0 software.

RESULTS AND DISCUSSION

A total of 1.572 adults of *D. suzukii* were collected in the experiment, being 867 males and 705 females. The sexual ratio was approximately 1:1 in all trap models, indicating that the traps did not interfere with the sex-trapping behavior in the evaluated orchard (Table 1). Klesener et al. (2018), in southern Brazil, also found that there are no significant differences in the sexual ratio of SWD in berry crops.

Considering the total entrapment values, the European model (Hemitrap®) was the one that captured the largest number of SWD, followed by the transparent and red color PET bottles traps, whereas the American model was the one with the lowest value (Table 1). In relation to the color, different studies have shown that red color is more attractive to SWD than transparent (Lee et al., 2012; Basoalto et al., 2013; Lee et al., 2013). However, in the study conducted by Mazzetto et al. (2015), it was pointed out that a lower entrapment rate of red color traps in blueberry crops, similarly to the results found in this experiment, where the red color trap did not promote

Figure 1. Trap designs used in the study. (A) Transparent plastic pots (American model); (B) Hemitrap® (European model); (C) Transparent PET bottle; (D) Red color PET bottle (Brazilian model).

Table 1. Total number and sex ratio of adults of *Drosophila suzukii* collected in different trap designs in a commercial orchard of blackberry cv. Chester. Vacaria, RS, May 2016.

Model	Number of trapped insects			
	Male	Female	Total	Sex ratio
Brasilian model Transparent	202	156	358	0.58±0.18
Brasilian model Red	174	122	296	0.58±0.01
European model	394	306	700	0.57±0.04
American model	97	121	218	0.55±0.12
Total	867	705	1.572	0.56±0.03

greater SWD capture in the blackberry orchard.

In relation to the greater entrapment of the European model, some factors are important; for example, the greater volumetric capacity and surface area to release the volatiles of the attractant to the field. Lee et al. (2013), discussed this, and affirmed that there is an increase in the capture of pests as a function of the amount of attractant in the trap, but the increase is not linear, because at a 225% increase in the surface area of the attractant's volatiles release, there was an increase of only 12% in capture rate. For Lee et al. (2012) and Renkema et al. (2014) the greatest capture is related to the entrance area of the insects in the trap (area occupied by holes). This result corroborates the findings of this trial, since it is precisely the European model trap (Hemitrap®) that presented the largest insect entry area

Table 2. Mean (± SE) of adults of *Drosophila suzukii* captured in different trap designs, as a function of the amount of attractant (ml), number of holes, insect entrance area (mm^2) and evaporation surface.

Model	Insect/ml	Insect/hole	Insect/entrance area (mm^2)	Insect/evaporation surface (cm^2)
Brasilian model Transparent	1.79±0.61[a]	14.3±4.89[a]	1.14±0.39[a]	3.65±1.24[a]
Brasilian model Red	1.48±0.17[ab]	11.8±1.36[a]	0.94±0.11[ab]	3.02±0.34[ab]
European model	0.56±0.06[bc]	6.6±0.73[ab]	0,17±0.01[c]	1.14±0.12[bc]
American model	0.17±0.04[c]	3.9±0.96[b]	0.31±0.07[bc]	0.45±0.11[c]
Coefficient of variation (%)	14.01	22.2	11.37	18.22

Means followed by the same letter in the column do not differ statistically by the Tukey test at 5% of probability.

Table 3. Number and percentage of *Drosophila suzukii* and other Drosophilidae collected with different trap designs in commercial blackberry orchard cv. Chester. Vacaria, RS, May 2016.

Model	Trapped insects				
	Drosophila suzukii		Other Drosophilidae		Total
	Number	%	Number	%	
Brasilian model Transparent	358	80	89	20	447
Brasilian model Red	296	90	33	10	329
European model	700	68.2	326	31.8	1.026
American model	218	84.2	41	15.8	259
Total	1.572	76.6	489	23.7	2.061

(807.8 mm^2).

Thus, when evaluating the number of SWD captured in relation to the attractant volume, number of holes, insect entrance area and evaporation surface of the attractant, the Brazilian model (transparent) was superior with significantly higher entrapped insects/ml; insects/ entrance area and insects/evaporation surface (Table 2). In this new analysis, the European and American models were similar, without significant differences between them (Table 2).

In this analysis, the "Brazilian model" (transparent) was efficient for the population evaluation of SWD, since with a low amount of attractant (40 ml), it was already possible to measure the population of the pest in the field. The best performance was also observed when analyzing the evaporation surface area of the attractant, since the Brasilian model trap has the smallest area (62.8 mm^2) than the others (Table 2).

Another important aspect of the traps is the location of the holes, which in the Brazilian model are in the lower third and near the surface of the attractant. In addition, the convex shape of the bottle in the region (Coca-Cola®), makes it difficult for the insects to escape from the trap in function of the SWD positive phototropism. This does not occur in the American model because the holes are in the top position of the trap, near the lid of the pot, just where there is more accumulation of insects, which allows them to escape. Comparing the European model, Hemitrap®, with the American model, which contained the same attractant volume (250 ml), the largest capture was determined by the position and number of holes, which in the Hemitrap® model seemed to be more adequate.

Regarding other Drosophilidae, a total of 489 adults were collected in the experiment, representing 23.7% of the total drosophila sampled in this study. This result reflects a certain selectivity of the attractant used and proposed by Santos (2016), since larger percentages of other Drosophilidae are mentioned in studies with SWD, as for example in the use of apple vinegar (Lee et al., 2012). From the traps evaluated, the Brazilian model showed selectivity for SWD collection of 90 and 80%, in red and transparent color, respectively. Close result was obtained with the American model (84.2%), while in the European model the lowest value (68.2%) was recorded (Table 3).

The results obtained in this study showed the possibility of using traps made with PET bottles to monitor SWD in blackberry orchards. This type of trap does not have the highest number of collected insects, an attribute of the European model trap, but when considering other aspects such as proportion of insects per ml of attractant, number of holes and entrance area, the PET trap (Brazilian model) presented statistically superior performance. Another important aspect is to be a reusable material, with low cost for trap confection. In addition, the Brazilian model presented low capture of other Drosophilidae, which simplifies the sorting of collected material. The reduced amount of attractant used in the PET model (Brazilian model) is another favorable point, because it uses only 40 ml, against 250 ml of other traps. It should be noted that the Brazilian model proposal is for use in SWD monitoring to support decision-making control strategies, not for mass collection strategies, where the European model, Hemitrap® trap, would be the most appropriate.

For Lee et al. (2012, 2013), the most efficient trap model for SWD monitoring should be the one with the highest insect capture, suitability to the needs of the producer, ease of handling and acquisition. Thus, traps made with PET bottles proved to be an efficient alternative to use for SWD monitoring in blackberry orchards.

Conclusions

The evaluated traps do not interfere in the capture behavior according to sex in blackberry orchard. The European model, Hemitrap® trap, captures the largest number of SWD adults and other Drosophilidae.

By taking into consideration the number of insects collected per ml of attractant, per entrance area, per hole, per evaporation surface and selectivity, the Brasilian model transparent trap is the most efficient.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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