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Effect Evaluation and Benefit Analysis of Different Trapping Methods for Fruit Flies on Sugar Oranges

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Abstract: Citrus fruit flies are a major kind of quarantine pest that spreads with a potential outbreak in citrus producing areas in Zhaoqing. A variety of fruit flies can be monitored and controlled by physical methods. However, there is a lack of effect evaluation of trapping fruit flies during production. In this study, the effects of different physical trapping methods were tested for bactrocera minax (b. minax) and bactrocera dorsalis (b. dorsalis) in the sugar orange orchards in Zhaoqing. The result showed that in a non-fruiting orchard and fruiting orchard respectively, the numbers of bactrocera dorsalis trapped by sex pheromones were 110 and 32, 25.7 and 6 by food attractants, and 24 and 5 by yellow sticky boards. While the number of bactrocera dorsalis trapped by sex pheromones was significantly higher than that by food attractants and yellow sticky boards, the number of species and quantity of insects trapped by food attractants and yellow sticky boards were, however, higher than by sex pheromones, and bactrocera minax were also trapped. From October to December, there were two peaks of trapped numbers of bactrocera dorsalis, while the number of the bactrocera minax remained stable. In terms of cost per mu, the costs for the first trapping cycle were 55, 40 and 40 yuan per mu by sex pheromones, food attractants and yellow sticky boards respectively, and 15, 40 and 40 yuan per mu after the second trapping cycle. None of the three methods involved contact between lethal chemicals and the fruit. In light of the yearly outbreak due to the life cycles of these two fruit flies, a variety of trapping methods with comprehensive prevention and control measures should be applied starting from the management of non-fruiting orchards, so as to promote pesticide reduction and green plant protection.

Keywords: Sugar Orange Orchid; Citrus Fruit Fly; Physical Trapping; Effect Evaluation

Introduction

Citrus is the largest fruit industry in China. There are five industrial belts, among which the citrus planted in Zhaoqing City is located on the fifth industrial belt. With the development of society and economy, citrus has become one of the economic crops widely planted by farmers in Zhaoqing City, Guangdong Province, China. Among them, the main varieties are sugar oranges and citrus gonggan. The main production areas are concentrated in Deqing County, Fengkai County, Huaiji County and other places. Zhaoqing City is also the largest citrus planting base in Guangdong Province. The citrus planting area reached 960,000 hm^2 during the peak period, and the current planting area is 635,900 hm^2, the output is 782.3 thousand tons, and the output value exceeds 3 billion yuan [1], which has made a significant contribution to the economic income of Zhaoqing City. The shrinking of the area is mainly due to the spread of citrus yellow shoot in recent years, which has led to the destruction of some orchards, and some orchards are out of control or half out of control. This state of out of control and half out of control has led to a trend of spreading and outbreak of other pests and diseases. Among them, the more serious pests are citrus fruit flies and so on. The damage of citrus fruit flies has led to a further decline in citrus production, the decrease of quality and the shortening of shelf life, causing serious economic losses to the majority of orange farmers. Therefore, the prevention and control of citrus fruit flies has become a common concern among orange farmers in Zhaoqing.

Citrus fruit flies beong to insect class (Diptera: Tephritidae) and they are citrus fruit tree pests. Bactrocera minax and bactrocera dorsalis are the main pests of citrus producing areas in China, and they are also important plant quarantine objects.

Bactrocera minax only harms citrus [2], while bactrocera dorsalis not only harms citrus, it also harms loquat, carambola, peach, plum, papaya, lychee, banana, mango, fig, sweet apple, coconut, longan, sapodilla, pear trees and more than 250 kinds of plants. Bactrocera cucurbitae does not harm citrus, but it often appears in the distribution areas of the first two species of fruit flies [3]. Adult fruit flies lay eggs in the fruit, and the larvae feed on the fruit, causing it to rot and fall. Due to their strong reproductive power, short development cycle, and overlapping generations, they are perennially harmful, especially in southern China, which has almost wiped out some fruits and vegetables [4].

Fruit growers have great arbitrariness in the prevention and control of fruit flies, mainly based on the publicity of market products. This paper compares the commonly used fruit fly trapping methods in orchards in Zhaoqing area to provide a scientific basis for local citrus fruit fly prevention and control technology, reduce the citrus loss caused by citrus fruit flies, and ensure the stable development of the citrus industry in Zhaoqing.

1. Materials and methods

1.1 Material source

The fruit fly trapping bottles (hereinafter referred to as the trapping bottles) were purchased from the local agricultural product sales market and were developed by the Guangdong Institute of Entomology. Used with sex pheromones for fruit flies (Methyleugenol for short Me), the special design of the cap of the trapping bottle makes it difficult for fruit flies to crawl out after entering the bottle. At the same time, dichlorvos can be added to speed up the death of trapped pests.

The fruit fly trapping yellow boards (hereinafter referred to as the yellow boards) were purchased from Hebei Yongchang Agricultural Technology Co., Ltd. Fruit fly food trapping boards (hereinafter referred to as trapping boards) were provided by Shengtang Chemical Co., Ltd. of Dongguan City, Guangdong Province. Both the yellow board and the trapping board are composed of a carrier and durable physical glue. The difference is that the carrier of the yellow board is a yellow rubber sheet with a thickness of 1 mm, and the area after unfolding is 38 cm×15 cm, or 570 cm2; while the carrier of the trapping board is a gray cardboard with a thickness of 2 mm, with fruit fly food attractants added. The unfolded area is 48 cm×24 cm, which is 1152 cm^2.

The types, trapping principle, insecticidal principle and sources of citrus fruit fly traps used in this test are shown in Table 1.

Table 1. Different types of citrus fruit fly traps and their trapping principles and sources

Types	Trapping principles	Insecticidal principles	Sources
Fruit fly trapping bottles	Sex pheromones	Dichlorvos poisoning	Guangdong Institute of Entomolog
Fruit fly trapping yellow boards	Pests' habit of liking yellow	Physical viscose killing	Hebei Yongchang Agricultural Technology Co., Ltd.
Fruit fly food trapping boards	Food attractants	Physical viscose killing	Shengtang Chemical Co., Ltd. of Dongguan City, Guangdong Province

1.2 Test location

The experimental orchard is located in the flat sugar orange orchard in the main citrus production area of Zhaoqing City. A two-year-old orchard without fruit, and a five-year-old normal orchard with fruit are chosen. The growth of the trees in the two orchards is in good condition; the planting densities are the same; the production management measures are the same.

1.3 Test methods

A total of 16 trees in 4×4 is used as a test square. Trapping bottle test: In the center of the phalanx, hang the bottle in the shadow of the southwestern part of the canopy of the fruit tree and 1.3 m above the ground, and add sex pheromones and dichlorvos every 3 weeks. Yellow board test: Place 4 yellow boards evenly in a square array, and hang them in the shadow of the southwestern part of the canopy of fruit trees and 1.3 m above the ground. The test method of the trapping board is the same as that of the yellow board.

Each treatment is repeated 3 times, with at least 5 rows of sugar orange trees between the squares.

Count the number of fruits drops before and after trapping, the number and types of trapped fruit flies.

The increase in the number of fruit drops in each experimental square = (the total number of fruit drops after trapping － the total number of fruit drops before trapping) / 16.

2. Results and analysis

2.1 Analysis of the trapping effect of non-fruiting orchards

According to the local fruit farmers' habit of using pesticides to control fruit flies, the statistical period of trapping is set from October to December. In one cycle, the trapping results of non-fruiting orchards are shown in Table 2. The number and species of fruit flies trapped by different trapping methods in each experimental square are different. 110 bactrocera dorsalis were trapped in the trapping bottles. 25.7 bactrocera dorsalis, 13.5 bactrocera minax and 27 other insects were trapped on the yellow boards, with a total of 66.4 insects. 24 bactrocera dorsalis, 16 bactrocera minax and 43 other insects were trapped by trapping boards, and the total number of trapped insects was 83. Most other insects are bactrocera cucurbitae, flies and bees.

Table 2. The trapping results of non-fruiting orchards

Types	Total number of bactrocera dorsalis	Total number of bactrocera minax	Total number of other insects	Total number of trapped insects	Total number of types of trapped insects
Trapping bottles	110^{a}	0^{c}	0^{c}	110^{a}	1^{b}
Yellow boards	25.7^{b}	13.7^{b}	27^{b}	66.4^{c}	8^{a}
Trapping boards	24^{c}	16^{a}	43^{a}	83^{b}	8^{a}

Note: Data in the same column with different upper right letters indicate significant differences ($P<0.05$), and those with the same letters indicate insignificant differences ($P>0.05$).

The number of bactrocera dorsalis trapped by trapping bottles was much greater than that of the yellow boards and the trapping boards. This shows that the sex pheromones ME is more effective than color and food attractants in terms of its attractiveness to bactrocera dorsalis. The trapping bottle only traps bactrocera dorsalis, but not bactrocera minax or other insects. The yellow board and the trapping board can trap not only bactrocera dorsalis, but also bactrocera minax and other kinds of insects. In the trapping amount of bactrocera dorsalis and bactrocera minax, there was no significant difference between the yellow board and the trapping board, but there was a great difference in the trapping amount of other insects, in which the trapping amount of the trapping board was significantly higher than that of the yellow board.

2.2 Analysis of trapping effect of fruiting orchards

The trapping results of the fruiting orchards are shown in Table 3. In each experimental square, the total numbers of bactrocera dorsalis trapped by the trapping bottles, yellow boards and trapping boards were 32, 6 and 5 respectively. Two bactrocera minax and 69 other insects were trapped on the yellow boards, and 4 bactrocera minax and 121 other insects were trapped on the trapping boards. According to the total amount of trapped insects and the types of insects from high (more) to low (less), the sequence is the trap board, the yellow board and the trapping bottle.

The trapping bottle only traps bactrocera dorsalis, and the number is larger than that of the yellow board and the trapping board. The yellow board and trapping board trap more types and numbers of insects than the trapping bottle, and can trap bactrocera minax.

Table 3. The trapping results of fruiting orchards

Types	Total number of bactrocera dorsalis	Total number of bactrocera minax	Total number of other insects	Total number of trapped insects	Total number of types of trapped insects
Trapping bottles	32^{a}	0^{c}	0^{c}	32^{c}	1^{b}
Yellow boards	6^{b}	2^{b}	69^{b}	78^{b}	6^{a}
Trapping boards	5^{b}	4^{a}	121^{a}	130^{a}	5^{a}

Note: Data in the same column with different upper right letters indicate significant differences ($P<0.05$), and those with the same letters indicate insignificant differences ($P>0.05$).

2.3 Analysis of the change of the number of trapped insects at different trapping times

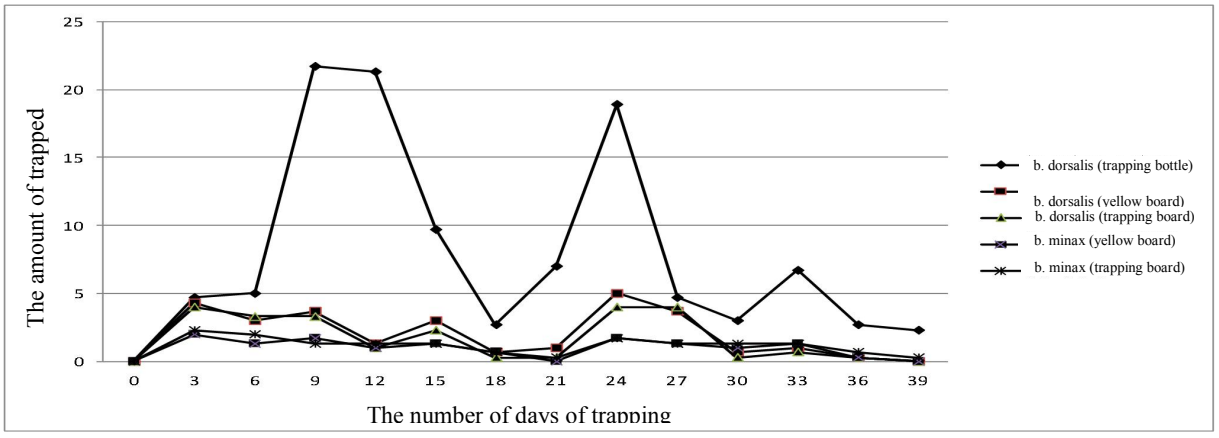

Figure 1. The change of the amount of trapped insects for different trapping times and different trapping methods

Figure 1 shows the changes in the number of bactrocera dorsalis and bactrocera minax trapped by different trapping methods every 3 days. The number of bactrocera dorsalis trapped by the trapping bottle has two peak periods from late

October to early November (October 26 to November 7) and mid-November (November 10 to November 19). The other two trapping methods have only small fluctuations in the trapping amount of bactrocera dorsalis in different periods; the trapping amount of bactrocera minax in different periods has remained relatively stable.

2.4 Analysis of fruit drop

The investigation and statistics of fruit drop before and after trapping fruit flies in fruiting orchards showed that in the experimental square with trapping bottles, the increase of fruit drop base was the smallest (4.69 / plant), followed by trapping boards (7.19 / plant) and yellow boards (10.5 / plant) (12.75 / plant in the control group). It shows that in this growth period, the effect of using trapping bottles to prevent fruit drop is better than that of yellow boards and trapping boards.

2.5 Economic and environmental analysis

In terms of control cost per mu, the first trapping cycle requires 5 traps per mu. The unit price of traps is 8 yuan, the attractant is 3 yuan, and the total cost is 55 yuan per mu. The numbers of the yellow boards and the trapping boards are both 20 sheets per mu, 2 yuan each, and the total cost is 40 yuan per mu. The second trapping cycle and later: because the trapping bottle can be supplemented with attractants in the later stage, the trapping bottle can be recycled. Therefore, except for the first cycle, the cost per cycle is 3*5 yuan = 15 yuan, while the yellow board and trapping board cannot be recycled, so the cost per cycle is the same, 40 yuan per mu.

None of the three methods involved contact between lethal chemicals and the fruit, and the fruit quality would not be adversely affected in the later stage of fruiting and harvest period. The bottle and the trapping core of the trapping bottle can be recycled, with little pollution to the outside world and no pollution to the environment. If the used yellow boards and trapping boards are disposed of properly, they will not cause great pollution to the environment.

3. Results and discussion

Both bactrocera dorsalis and bactrocera minax can be trapped in fruiting orchards and non-fruiting orchards, and the trapping amount of the former orchards is greater than that of the latter. The reason is that local orchard managers generally start to control fruit flies when the fruit trees enter the fruiting period. Therefore, in the cultivation and management of sugar oranges, the prevention and control measures of fruit flies in the non-fruiting stage should be appropriately increased to reduce the density of fruit flies in the orchard, which is conducive to enhancing the comprehensive control effect of fruit flies in the fruiting stage.

The fruit scent from the fruits on the trees and the fallen fruits on the ground in the orchard will have a certain impact on the trapping volume of the trapping board. The other trapped insects are mainly bactrocera cucurbitae and flies, which are related to the planting of other crops around the local orchard and the use of chicken manure in the orchard. Sex pheromones have high requirements on target insects. The insects trapped by the trapping bottle were male bactrocera dorsalis, but no bactrocera minax was trapped, so the target was single. The yellow board and trapping board not only trap male and female bactrocera minax and male and female bactrocera dorsalis, but also trap some other harmful insects, with a wide range of targets [5,6]. Although the yellow board and the trapping board are not as effective as the trapping bottle, they can trap and kill multiple pests at the same time. Therefore, in the large-scale prevention and control of fruit flies in orchards, it is suggested that the trapping bottle can be used in the orchard where cbactrocera dorsalis occurs mainly, and the combination of the trapping bottle and the trapping board (or yellow board) is recommended in the mixed occurrence area of fruit flies.

When using sex pheromones to trap citrus fruit flies, it is best to hang the traps in the shadow of the southwestern part of the canopy to achieve the best prevention and control effect [7]. The hanging height of the trap should be adjusted appropriately according to the height of the fruit tree plant, generally above 1 m. If the tree is tall, it should be hung to no less than 0.5 to 1 m of the average height of the fruit tree [8]. In this test, a trapping bottle was selected at a height of 1.3 m and supplemented with sex pheromones and dichlorvos every 3 weeks. Kuang Shizi et al. conducted research on setting yellow

boards in different directions of fruit trees. Studies have shown that when the yellow board is set in the south direction of the fruit tree, the trapping amount is the largest [9].

The tested orchard used a broad-spectrum insecticide pyrethroid pesticides to control fruit flies in the early stage. However, different numbers of bactrocera dorsalis and bactrocera minax can still be trapped in the trapping square, and the increase in the number of fruits drops in the trapping square is much lower than that of the control group, reaching a very significant level of difference. This shows that the control effect of the chemicals used in the tested orchard is average. Studies have shown that chemical control can kill 88.9% of adult fruit flies [10], and the effect is obvious. The tested orchards in this study may use such pesticides for a long time, leading to increased resistance of pests. Many orchards in the production area have the habit of using chemical control, generally starting from late September to early October. However, other physical prevention and treatment are concentrated in late October or early November before being used. Chemical prevention and control will cause much pollution, so it is recommended that Zhaoqing citrus production areas adopt chemical and physical prevention measures in advance for a certain period of time, in order to effectively prevent, control and reduce the harm of pesticides to fruits.

In Fuchuan County, Guangxi, adults of bactrocera dorsalis began to appear in early May, and entered the first peak period in early August, the middle peak period from mid-August to late October, and the last peak period in early November [11]. There are 3-5 generations of bactrocera dorsalis in Guangdong every year, and adults appear all the year round, with a large number from May to October. Bactrocera minax produces one generation every year. Adults emerge in May. The hatching period of the eggs occurs in early September. From the hatching of the eggs to the third instar larvae, they all feed on the fruit and cause damage [12-14]. The growth and decline law of fruit fly populations may be different in different regions and in different host plants, and the difference in fruit ripening stages has the greatest impact. At the same time, it is affected by the changes of climatic factors in different years, among which temperature and light factors and precipitation have an obvious effect on the occurrence of bactrocera dorsalis adults, followed by soil temperature and humidity [15-18]. However, the life cycle of fruit flies has a similar pattern throughout the year. Although this study did not investigate the annual growth and decline of fruit fly populations in Zhaoqing, according to the results of this article, it can be seen there were two obvious peak periods and one sub-peak period during the period of trapping and killing bactrocera dorsalis through sexual pheromones trapping bottles.

To sum up, for the comprehensive prevention and control of fruit flies in sugar orange orchards in Zhaoqing area, the consciousness of prevention and control in the whole life cycle of trees should be established, and the methods of universal prevention and control throughout the year combined with key prevention and control in the peak period, dominated by physical prevention and control and supplemented by chemical prevention and control should be adopted. Among them, the physical prevention and control is based on the combination of trap bottles and trapping boards (or yellow boards), and at the same time, it combines concentrated burying and burning of yellow fruit damaged by larvae and insect fruit falling under the tree to completely eliminate eggs and larvae. In the winter and spring seasons, measures such as turning the soil to kill worms, destroying the pupae's overwintering sites and affecting the emergence of adults, can effectively reduce the insect population density and promote the economic and green plant protection technology of pesticide reduction and control.

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