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DEVELOPMENT OF A COMBINED INSECT TRAP FOR WHITEFLY (*Bemisia tabaci)* AND TOMATO LEAF MINER (*Tuta absoluta*) MANAGEMENT

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1. ABSTRACT

Whitefly *Bemisia tabaci* and tomato leaf miner *Tuta absoluta* are two important insects that are causing serious damage to crops in protected vegetable cultivation. There is an international call from scientists to find a non-chemical way to manage those pests. This study tested the effect of a new combined light trap with different colors, named GLT trap, on the management of whiteflies and tomato leaf miners in protected vegetable cultivation. The results showed that whiteflies are significantly attracted to the yellow light traps (828 insects) compared to (73 insects) on white traps which captured the least number of insects. Although whitefly is diurnal, a higher number of insects were captured by the yellow-light colored traps (910 insects) than both yellow traps without light (302 insects) and light without color (51 insects) in 6 days. This showed the superiority of GLT trap over the yellow traps by about three times and about 20 times more than light traps without colors. In addition, a higher mean number of leaf miners were captured by yellow traps (14.33), and the lowest number of insects (3.5) was captured on violate traps. The new GLT trap is a promising IPM mean to manage those important insects in greenhouses in both developed and developing countries. It is an inexpensive, effective, and homemade way to control whiteflies and tomato leaf miners without negative consequences.

KEYWORDS: Insect trap, Whitefly, Tuta absoluta, Leaf miner, Tomato, Broccoli, GLT trap.
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2. INTRODUCTION

Pests are the main limiting factors in cultivation of vegetables under controlled conditions (Mutwiwa & Tantau, 2005). Among those pests, two important insects are causing serious damage to crops, whiteflies (Berlinger, 1980; Gillespie & Quiring, 1987; Gillespie & Quiring, 1992; C. Chu & Henneberry, 1998; Chen *et al*., 2004; Hamza, 2017; Varga *et al*., 2018) and tomato leaf miner (Al-Jboory *et al*., 2012; Garzia *et al*., 2012; Abbas, 2014; Pezhman & Saeidi, 2018; Varga *et al*., 2018).

Whiteflies attack the plants either directly by sucking the cell sap or indirectly by providing good environment for sooty mold (Berlinger, 1980; Webb *et al*., 1985; Varga *et al*., 2018). Intensive studies have been conducted to control or manage this important insect (Macdowall, 1972; Gillespie & Quiring, 1987; Gillespie & Quiring, 1992; C.-C. Chu & Henneberry, 1999; Ashfaq *et al*., 2005; Mwangi, 2015; Perdikis *et al*., 2016; Varga *et al*., 2018). The aim was to provide a non-chemical mean to manage whiteflies. Biological control of whiteflies has been investigated by Mwangi (2015); yet it was reported that it is not very successful due to several limitations (Gillespie & Quiring, 1987). Light traps have also been used by Ashfaq *et al.* (2005) to capture insects. Macdowall (1972) suggested to use light traps for managing whiteflies as an alternative for pesticides. In addition, based on previous studies, Mutwiwa & Tantau, (2005) used UV lamp with yellow sticky traps for trapping whiteflies in greenhouses in Germany. Moreover, colored traps have been used to attract this insect (C.-C. Chu & Henneberry, 1999; Mwangi, 2015). Mwangi (2015) reported that traps with yellow and blue colors are more attractive to pest than the no-color traps; however, traps treated with pesticides provided better results (Mwangi, 2015). According to the literature (Webb *et al*., 1985; Kitterman, 1997; Steiner *et al*., 1999; Lu et al. 2012; Perdikis *et al*., 2016), yellow tricky traps and yellow color based traps have been used intensively as an IPM mean to manage whiteflies in greenhouses. Furthermore, C. Chu & Henneberry (1998) compared a trap called "CC" traps to yellow sticky traps, and the later provided better results. Although yellow traps

are minimizing the population density of whiteflies, they can generally be used for monitoring the pest (Gillespie & Quiring, 1987; Gillespie & Quiring, 1992), or as an additional mean to help other management strategies. Previous studies varied in reporting the successfulness and the failure of yellow traps in managing whiteflies (Webb *et al*., 1985). Accordingly, the need to develop another type of management rather than pesticides became crucial.

Tomato leaf miner is also considered one of the most important pest in greenhouses planted with tomato due to the production loss that estimated by up to 90% (Tsisia *et al*., 2016) to even 100% (Lazgeen *et* al., 2013; Pezhman & Saeidi, 2018) without proper management (Roda *et al*., 2015; Hamza, 2017; Wafula *et al*., 2018). This is because this insect is causing damage to leaves, stems, buds and fruits of tomato plants (Garzia *et al*., 2012; Pezhman & Saeidi, 2018). Garzia *et al.* (2012) listed the distribution of this pest in details. They reported that it was observed first in Iraq in 2010. According to the literature (Korycinska et al., 2009; Al-Jboory *et al*., 2012; Cocco et al., 2013; Pezhman & Saeidi, 2018), and our observation in the field, even with using pesticides, it is hard to control this extremely challenging pest (Mutwiwa & Tantau, 2005; Wafula *et al*., 2018). Therefore, scientists searched for IPM means to manage this pest (Wafula et al., 2018). One of those means included biological control (Torres et al., 2002; González-Cabrera et al., 2011; Abbas, 2014; Tsisia *et al*., 2016); yet, this method has several limitations. For example, in a recent investigation, some strains of nematodes were used to control this pest (Husin & Ali, 2017); yet, it is hard for farmers to access those strains in developing countries. In addition, they may increase the production costs. The limitation of this type of management is discussed by Abbas (2014) in details. Moreover, pheromone traps (Vacas et al., 2011; Lazgeen, *et al*., 2013; Aksoy & Kovanci, 2016; Berxolli & Sh, 2017); and light traps (Aksoy & Kovanci, 2016; Pezhman & Saeidi, 2018) have also been used to manage this insects. Due to the unsatisfied results in managing this pest, scientists tried to combine different types of traps and ways for controlling purposes. The combination of light traps with pheromone has improved trapping of this pest (Ettaib *et al*., 2016; Pezhman & Saeidi, 2018). Moreover, yellow (Tsisia *et al*., 2016), blue, green, white and red traps (Mahmoud *et al.*, 2014) with pheromone have been combined for the same purpose. However, Abbas (2014) and Abbes & Chermiti (2012) discussed many reasons of why mass trapping by pheromone and biological control are not successful means to control this pest.

Accordingly, the pest resistance issue; the environmental issues; the people desire of pest and pesticides free products; and the insufficient efficiency of above mentioned methods to control pests are suggesting to provide a new and more effective method to control these two pests (Mutwiwa & Tantau, 2005). In addition, we used different chemical and non-chemical methods to manage this pest; yet, the pest was increasing in population density and causing more damage, even with taking into account all suggestions provided in the literature. Therefore, we developed a test trap combining colors with light, and the primary results were surprising (Figure 1).

This study examines a new non-chemical method to manage two greenhouse pests, whiteflies and tomato leaf miner. Particularly, it tests the hypotheses that: (i) Different color will attract whiteflies and tomato leaf miner variously; (ii) Insects will respond to the light colored traps. (iii) The combined (colored-light) traps will trap more insects than light or color only. (iiii) the traps can be used for insect management inside greenhouses.

Fig. (1): The test colored-light traps showing a high number of captured leaf miner.

3. MATERIALS AND METHODS

The study was conducted inside greenhouses in Domiz camp of refugees, Duhok, Kurdistan Region of Iraq. Four planted and slightly infected greenhouses were selected for the study. Homemade traps were developed using the following materials: transparent plastic containers (volume 10 L), six colored fabric (white, green, yellow, red, violet and blue), transparent tarpaulin, sticker glue which is used for mice and rats trapping, plastic rope and rechargeable lights (type; KHHY, Chinese made KH-9077) that can be charged by electricity and solar. The materials were put together by covering the transparent plastic containers with the fabric, then one layer of transparent tarpaulin was covered by the sticker glue and then covered over the fabric (Figure 2). The rechargeable lights were fixed inside the containers. Finally, the traps were distributed randomly in the both sides of the greenhouses as the population intensity of the insects is higher in the sides than in the middle of the greenhouses. The six colored traps were used at night for approximately 5 hours. Three replications were used for leaf miner insect in two greenhouses planted with tomato; whereas, four replications for whitefly insect were used in two greenhouses planted with broccoli. After identifying the most attracted color for whiteflies, three types of traps were installed (yellow traps without lights, light without color and light with yellow color). For this part of the study, three replications were used in different greenhouses to determine the effect of each type trap. The number of whiteflies were also counted every day for 6 days. The data were collected by counting the number of insects every day for six days. The results were compared, and the differences between different colored traps were provided using GenSTAT software 15th edition (VSN International Ltd, UK), and Microsoft excel 2016.

Fig. (2): The preparation of colored-light traps including their parts.

4. RESULTS AND DISCUSSION

The results supported the first hypothesis that different color will attract whiteflies and tomato leaf miner variously. The results showed that there are high significant differences in capturing both insects in terms of color of traps, different days as well as the interaction of trap color and the days (Table 1). This means that leaf miners and whiteflies responded differently to various colors in different days. It is known that tomato leaf miner is a nocturnal insect (Garzia, *et al*, 2012); however, whiteflies are diurnal insects (Ekbom, 1982). Interestingly, the results provided crucial information about the activity of whiteflies at night. While there was no sources of light rather than light-traps, whiteflies attracted to colored-light traps significantly.

Table (1): Analysis of variance for the studied traits

Source of variance	Probability of significance	
	NO. Tomato leaf miner	NO. White fly
Colors	<.001	<.001
Days	<.001	<.001
Colors * Days	0.767	<.002

4.1. WHITEFLY

It was reported that whiteflies are attracted to yellow (Berlinger, 1980; Webb *et al*., 1985; Kitterman, 1997; C.-C. Chu & Henneberry, 1999; Mwangi, 2015; Perdikis *et al*., 2016) and green colors(YANo, 1987). YANo (1987) mentioned a number of combined means of whitefly management including yellow sticky traps. They used yellow sticky traps with biological control; however, yellow traps

provided better results (YANo, 1987). The results of this study accepted with YANo (1987) in terms of color attraction. Whiteflies were significantly attracted to yellow and green colors compared to the other colors (Figure 3, and Table 2). It can be noticed from Figure 3 that the number of insects captured by the traps is dramatically increasing at the beginning, and then the curve starts to become steady at the end of the study. This is because the insect population was decreased. After finalizing this study, the traps were renewed and installed inside the greenhouses without using pesticides, the insect was totally controlled.

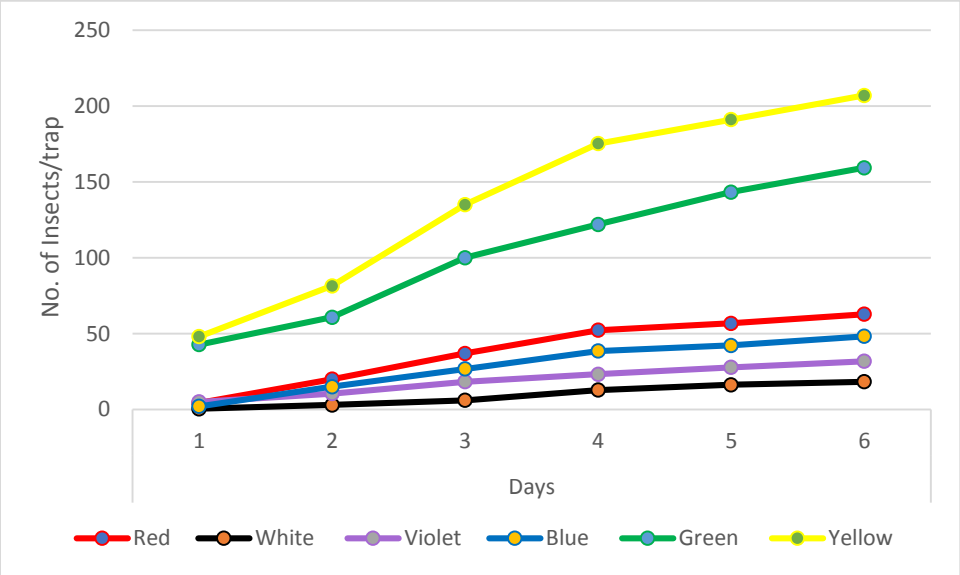

Fig. (3): The mean number of whiteflies captured by the different colored-traps in 6 days in 4 replications.

Overall, the response of whiteflies to different colored-traps in 6 days varied in a way that yellow color attracted more insects (828 insects), followed by green (637 insects), red (251 insects), blue (193 insects), violet (127 insects) and white which captured the least number of insects (73 insects) (Table 2 and Figure 3).

Table (2): Effect of colors, days and their interactions on the number of whitefly insect on broccoli.

	Colors						
Days	**Blue**	**Green**	**Red**	**Violet**	**White**	**Yellow**	**Means of days**
1	2.0	42.8	4.2	5.0	0.5	48.0	17.1
2	15.0	60.7	20.0	10.5	3.0	81.5	31.8
3	26.7	100.0	37.0	18.2	6.0	135.0	53.8
4	38.5	122.0	52.2	23.2	12.7	175.2	70.7
5	42.2	143.2	56.7	27.7	16.2	191.0	79.5
6	48.2	159.2	62.7	31.7	18.2	207.0	87.9
Mean of colors	28.8	104.7	38.8	19.4	9.5	139.6	

LSD values: Colors: 16.82, Days:16.82, Colors*Days:41.20

After determining the most attracted color to capture the whiteflies, it was crucial to investigate whether the color only, the light only or combining both color and light is attracting the insect (Figure 4). The results supported the third hypothesis that the combined (colored-light) traps will trap more insects than light or color only. The results showed that a higher number of whiteflies were captured by the light-yellow colored traps (910 insects) than both yellow traps without light (302 insects) and light without color (51 insects) in 6 days (Figure 5). Although whiteflies are diurnal insects (Mutwiwa & Tantau, 2005), this study showed that they are active and have response to colored-light even when there is another source of light (Figure 5). A special UV traps were used by Mutwiwa & Tantau (2005) to capture whiteflies inside greenhouses in northern Germany; yet, they captured the nocturnal insects. Although they increased the intensity of UV light, the number of captured whiteflies was not significant to depend on such trap as a management mean (Mutwiwa & Tantau, 2005). However, this study showed that whiteflies can be captured by the yellow-light traps about 20 times more than light traps without color, and 3 times more than yellow traps.

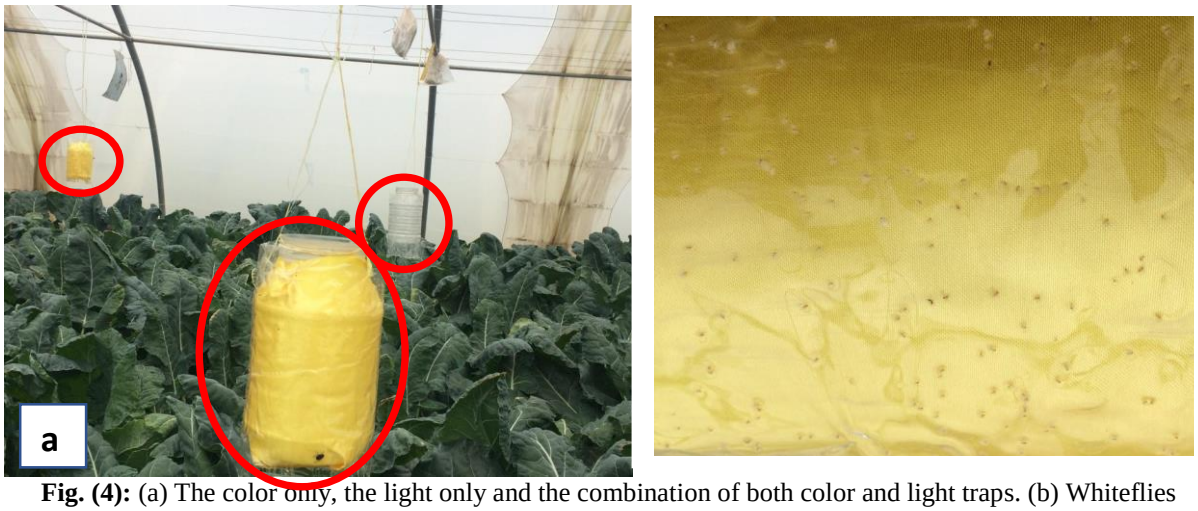

Fig. (4): (a) The color only, the light only and the combination of both color and light traps. (b) Whiteflies captured by the combination of both color and light trap.

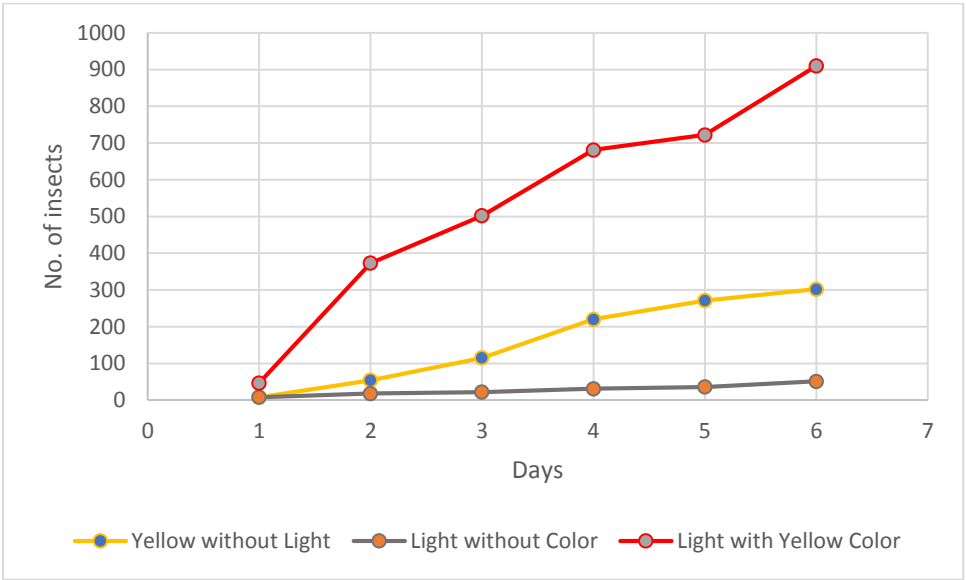

Fig. (5): The number of insects captured by three types of traps (yellow without light, light without color and light with yellow color) in 6 days.

4.2. TOMATO LEAF MINER

Regarding tomato leaf miner, the results showed higher mean number of leaf miners captured by yellow traps (14.33) followed by green traps (4.66), blue traps (4.66), white traps (4.33), red (3.5) and violate (3.5) traps respectively (Figure 6 and Table 3).

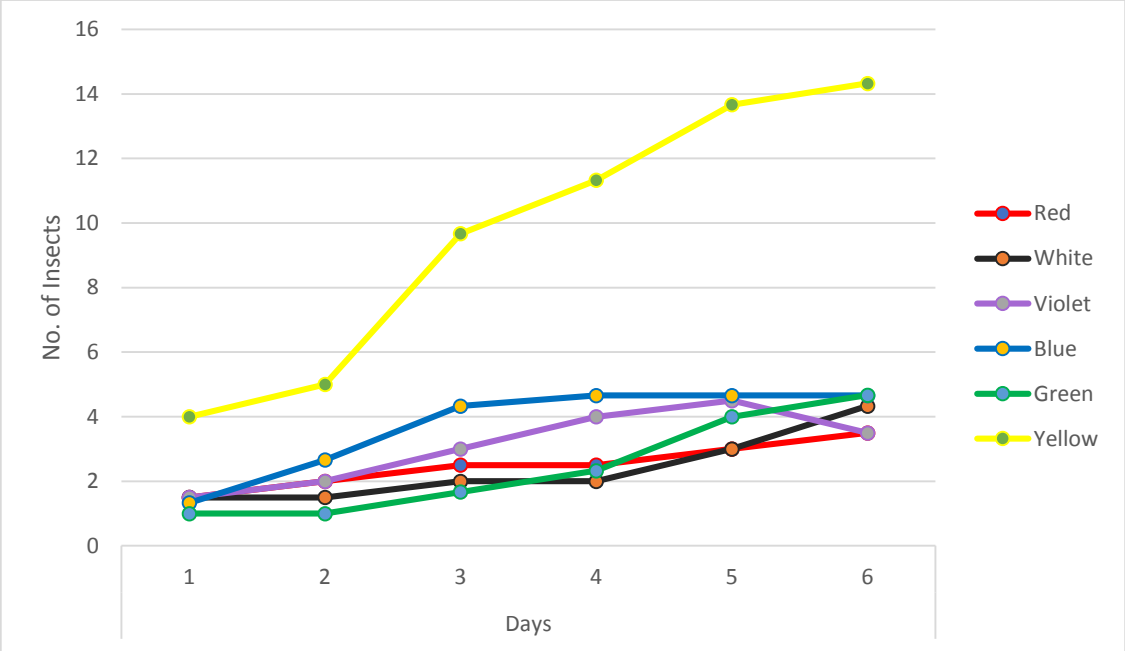

Fig. (6): The mean number of leaf miners captured by the different colored-traps in 6 days.

It was reported that yellow traps and pheromone traps have been used to trap tomato leaf miner in greenhouses (SALAS, 2004; Cabello *et al*., 2012; Cocco *et al*, 2012; 2013 and Tsisia *et al*., 2016). Yet, they were used for monitoring purpose only (Tsisia *et al*., 2016). The limitation of pheromone traps is their ability to attract the male insects mainly. Therefore, this type of trap can generally be used for monitoring purpose. Abbes & Chermiti (2012) discussed many reasons of why mass trapping by pheromone and biological control are not successful means to control this pest. As a nocturnal insects, tomato leaf miner is attracted to light (Mahmoud *et al.*, 2014); therefore, it was logical to combine colors with the lights to trap this insect.

Without proper management, leaf miner causes significant damage and losses in tomato fields (Garzia *et al.*, 2012; Pezhman & Saeidi, 2018; Wafula *et al*., 2018). Our attempts to control this important pest varied, and we used different means of management techniques. Following the literature (Al-Jboory *et al*., 2012; Abbas, 2014; Mahmoud *et al.*, 2014; Berxolli & Sh, 2017; Pezhman & Saeidi, 2018; Wafula *et al*., 2018), in addition to our attempts, the pest is getting resistant to almost all types of insecticides very quickly. Moreover, considering the key points recommended by Pezhman & Saeidi (2018) and Wafula *et al.* (2018), we developed our new trap, and named it Good Luck Tuta (GLT) trap. According to our field experiences and practical work, all means of tomato leaf miner control have their own limitations. All means and techniques were not enough to manage this pest; yet, after using of test GLT trap, the pest was totally controlled. This was the reason of conducting this study after observing the primary results.

Table (3): Effect of colors, days and their interactions on the number of Tomato leaf miner insects on tomato.

Days	Colors						
	Blue	Green	Red	Violet	White	Yellow	Means of days
1	1.33	1.00	1.00	0.67	1.00	4.00	1.5
2	2.67	1.00	1.33	1.33	1.00	5.00	2.06
3	4.33	1.67	1.67	2.00	2.00	9.67	3.56
4	4.67	2.33	1.67	2.67	2.00	11.33	4.11
5	4.67	4.00	2.00	3.00	3.00	13.67	5.06
6	4.67	4.67	2.33	3.00	4.33	14.33	5.56
Mean of colors	3.75	2.44	1.67	2.11	2.22	9.67	

LSD values: Colors: 1.902, Days: 1.902, Colors*Days: 4.658

5. CONCLUSION

GLT trap is an environmental friendly, inexpensive, reliable and suited to any place in the world (including developing countries), and an effective way to manage whiteflies and tomato leaf miner. In addition, it is considered an excellent way to overcome the problem of pest resistance to insecticides. Moreover, it may overcome the limitations of the other types of traps. In order to improve this type of trap, a number of points are recommended. First, it can be further improved by providing a better source of light which can be last till morning. Second, it can be recommended to use the GLT trap to manage both diurnal and nocturnal insects. Therefore, further studies are required to examine the effect of GLT trap on other harmful insects. Furthermore, the traps should be placed in between the rows with placing a suitable container under the traps in order to gather the glue that drops from the trap. It is also recommended not to use this type of trap when biological control or pollinators are used in the greenhouses. This is because it captured some other insects as well. Thus, further studies are required to examine its effect on beneficial insects.

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دروست کرنا تەلهەکا مێش ومورا بو ژناڤبرنا پێشکا سپی (Bemisia tabaci) وپەروانا پەلەپێزا تەماتێ (Tuta absoluta)

پوختە

پێشکا سپی Bemisia tabaci و پەروانا پەلەپیزا تەماتێ Tuta absoluta دهێنە هژمارتن ژ گرنکترین مێش و موریّت زیانێت مەزن دگەهینە زەرزەواتی دناف چاندنا نخافتی دا. گازیەکا جیهانی یا هەی دا چارەسەرکرنەکا بێ قرکەر بو ژ ناڤبرنا ڤان هەردوو مێش و موورا بهێتە کرن. تەلهەك هاتە دروست کرن کو روناهی هاتیە کومکرن دگەل هژمارەکا رەنگا ژبو دیارکرنا چالاکی وکارتێکرنا وێ دکونترول و ژ ناڤبرنا پێشکا سپی و پەروانا پەلەپیزا تەماتێ. ئەنجاما دیارکر کو پێشکا سپی بشێوەکێ بەرچاڤ بەرەڤ تەلهێت روناهیێ یێت رەنگێ زەرڤە دچیت (828 پێشک) ول دویڤدا یێت رەنگێ کەسک (637 پێشک) و پاشی یێت رەنگێ سور (251 پێشک) و رەنگێ شین (193 پێشک)و رەنگێ مور(127 پێشک) ول دویڤدا رەنگێ سپی کو نزمترین هژمارا پێشکان گرت (73 پێشک) د ماوێ شەش روژاندا. سەرەرای وێ چەندێ کو پێشکا سپی مێش و مورەکا روژێ یە, مەزنترین هژمارا پێشکا هاتەگرتن ب تەلهێت روناهیێ یێت زەر (910 پێشک) ب بەراورد دگەل تەلهێت رەنگێ زەر بێی روناهی (302 پێشك) و هەروەسا تەلهێت روناهیێ بێی رەنگ (51پێشک). ل ڤێرێ دیاردبیت زالبونا تەلها GLT ب رێژا نێزیکی 3 جارا پتر ژ تەلهێت رەنگێ زەر یێت بێ روناهی ونێزیکیی20 جارا پتر ژ تەلهێت روناهیێ یێت بێ رەنگ دماوێ شەش روژاندا. بلندترین ناڤینێ هژمارتنا پەروانێت پەلەپیزا تەماتێ هاتنە تومارکرن لسەر تەلهێت روناهیێ یێت رەنگێ زەر (14.33) ول دویڤدا ل سەر تەلهێت روناهێێ یێت رەنگێ کەسک و شین (4.66) بو هەر ئێک ژوان تەلها. و ل دویدا تەلهێت سپی (4.33) و تەلهێت سورو مور (3.5) بو هەر ئێک ژوان تەلها. تەلهێت GLT دیارکر کو دەرگەهێ پاشەروژێ یە بو بنبرکرنا هەمەلایەن یا دەردان IPM بو سەرەدەریێ دگەل ڤان هەردوو مێش و موریّت گرنگ د چاندنا نخافتی دا و یا گونجایە بو وەلاتێت پێشکەفتی و پێش نەکەفتی. ژبەرکو ئەڤ جورێ تەلهێ یێ بها ئەرزانە و باندورە و چێکرنا خومالیە بو ژناڤبرنا پێشکا سپی و پەروانا پەلەپیزا تەماتێ و بێی زیانێت تێکدەری.

تصميم مصيدة حشرات جديدة لادارة الذبابة البيضاء (*Bemisia tabaci*) و حفار اوراق الطماطة (*Tuta absoluta*)

الخلاصة

تعتبر الذبابة البيضاء *Bemisia tabaci* الى جانب حفار اوراق الطماطة *Tuta absoluta* من اهم الحشرات التي تصيب محاصيل الخضر في البيوت المحمية والتي تحدث ضرر كبير لها. هناك نداء عالمي لايجاد طريقة غير معتمدة على المبيدات لادارة هاتين الافتين. تم تصميم مصيدة تعتمد في الية عملها على الربط ما بين الاضاءة والوان مختلفة لدراسة مدى كفائتها في مكافحة هاتين الحشرتين. اظهرت النتائج ان الذبابة البيضاء تنجذب بشكل كبير الى مصائد الضوء الصفراء اللون

(828 حشرة) تليها الخضراء (637 حشرة) ومن ثم الحمراء (251 حشرة) والزرقاء (193 حشرة) والبنفسجية (127 حشرة) والبيضاء التي اصطادت اقل عدد من الحشرات (73 حشرة) خلال ستة ايام. بالرغم من كون الذبابة البيضاء حشرة نهارية الا انه تم اصياد اكبر عدد من الحشرات بواسطة المصائد الضوئية الصفراء (910 حشرة) مقارنة بالمصائد الصفراء بدون ضوء (302 حشرة) والمصائد الضوئية الشفافة بدون الوان (51 حشرة). وهذا يظهر تفوق مصائد GLT بحوالي ثلاث مرات على المصائد الصفراء بدون ضوء وحوالي 20 مرة اكثر من المصائد الضوئية الشفافة بدون لون خلال ستة ايام. تم تسجيل اعلى متوسط لحافرات اوراق الطماطة في مصائد الضوء الصفراء (14.33) وتليها المصائد الخضراء والزرقاء (4.66) لكل منها. ومن ثم البيضاء (4.33) والحمراء والبنفسجية (3.5) لكل منها. اظهرت مصائد GLT انها وسيلة واداة واعدة في ادارة المكافحة التكاملة (IPM) في ادارة هاتين الحشرتين المهمتين في البيوت المحمية والمناسبة للدول المتقدمة وغير المتقدمة. كون هذه المصيدة غير مكلفة و فعالة و محلية الصنع لادارة الذبابة البيضاء و حفار اوراق الطماطة وبدون ضرار جانبية.