Capturing of *Phthorimaea operculella* (Zeller) Male Moths by Sex- Pheromone Traps in Response to Trap Color, Direction and Height at Potato Fields

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ABSTRACT: Potato, *Solanum tuberosum* L., is one of the most important food crops. The potato tuber moth (PTM), *Phthorimaea operculella* (Zeller 1873) (Lepidoptera: Gelechiidae), is a destructive pest of potato in the field, storage and during marketing. The site of the current investigation at Etay El-Baroud Agricultural Research Station (Beheira Governorate) in 2022 summer season, to test the efficiency of sex- pheromone traps in capturing the male moths of *P. operculella*. The impacts of sex- pheromone trap color, trap direction, and trap height on *P. operculella* potato moth captures were evaluated. Every trap had a pheromone capsule as abait. White pheromone traps were the most effective at capturing insects with an average number of male moths (3312.23 ± 169.78 / trap / month), than yellow ones (2216.70 ± 152.63), green traps (1301.00 ± 103.48 male moths / trap per month) or red traps. Depending on the direction of the sex- pheromone trap, there were significant variations in the number of catches. When the traps were positioned in the south (3179.25 ± 150.58 male moths / trap) or center (3109.43 ± 126.15 male moths / trap) of the PTM-infested area, more moths were caught than when they were positioned in the west, east, or north. The ground-resting traps captured more *P. operculella* moths collectively with an average of (3888.50 ± 169.28 individuals / month / trap) than the two other heights (50 and 100 cm above the ground). A statistical analysis of the captures indicated a noteworthy distinction between the 0 cm height (resting on the ground) and the two remaining heights. These findings should be considered while developing a monitoring system for the *P. operculella* trapping system in potato cultivations.

Keywords: Potato tuber moth, Pheromone, Traps, Color, Position, Height

INTRODUCTION

After rice, wheat, and corn, potato (*Solanum tuberosum* L., Solanaceae) is the most significant food crop in the world (**FAOSTAT 2020**). The demand on potato is generally increasing all over the world, particularly in the developing countries to relatively cover the gap in supplies of cereal crops. Thus, all practices and procedures enhancing the potato production are greatly required.

Unfortunately, potato tubers are subject to damage by the potato tuber moth (PTM), *Phthorimaea operculella* (Zeller, Lepidoptera, Gelechiidae) in the field, storage and during marketing. It was found that PTM attacks several solanaceous plants, specially potato in the field and storage resulting in great damage and losses (**Gao *et al* 2019, Li *et al* 2019**). In the field, the larvae of PTM penetrate leaves and stems of the plants, which results in weakness and stunting of the plants. The major damage occurs when the insect pest larvae mine in potato tubers before harvest and during storage (**Rondon 2010**).

Because PTM larvae live inside leaves, stems, or tubers, it has become difficult to monitor and to effectively control this destructive insect pest. In addition, PTM populations have acquired resistance to many insecticides (**Doğramacı and Tingey 2008**).

Some authers (Fetoh 2003 and Abbassy *et al.* 2008) proposed optimizing time to plant potatoes to maximize output because of little PTM infestation, but this was found not satisfactory, as the potato is cultivated throughout the year, particularly in temperate climates.

Chemical control of PTM is not efficient in most cases, due to the internal living of the insect larvae in plant tissues. Furthermore, chemical management has poor results against *P. operculella*, as the insect has become resistant to several conventional pesticides (**Gancheva and Dimitrov 2013**).

Using sex pheromones to manage the insect infestation is a workable and environmentally responsible alternative. A combination of E4, Z7-tridecadenyl acetate (PTM2) was shown to be the female sex pheromone of PTM (Larraín *et al.* 2007). The efficiency of sex- pheromone traps, either for monitoring the insect population fluctuation or for insect management depends on several factors (**Yuan *et al* 2018**). One major advantage of the sex pheromones is that they are safe for non-target organisms because they do not directly kill the captured insects, like the case of conventional insecticides. In addition, they are highly specific because they are a mixture of several specific compounds that attract only the target insect (**Pan *et al* 2022).**

Larvae of PTM, attacking field crops, horticulture, forestry, and stored products were successfully controlled by sex pheromone traps of different designs and types (**Shen *et al* 2020)**

The objectives of the current study were to investigate the efficiency of sex pheromone traps in capturing the males of potato tuber moth, *Phthorimaea operculella*, as affected by trap color, direction, and height above the ground of potato fields.

MATERIALS AND METHODS

1. Cultural Practices

Etay El-Baroud Agricultural Research Station (Beheira Governorate), Agricultural Research Center, Egypt served as the site of the current investigation. To encourage the sprout emergence, seed potatoes (Lady Rousetta Cultivar) were moved from the cold storage into a cool, shaded area for 10 days. Sprouted seeds were cultivated on January 5th ,2022 in an area of one feddan divided into three equal parts. The sprouted potatoes were sown as one seed / hill 20 cm apart, with 50 cm rows wide. All recommended agricultural practices for growing potatos were adopted along the growing season, without insecticide applications.

2. Pheromone Trap Type

A plastic container (30×30×50 cm), home-made was prepared, with longitudinal open sides to allow the entrance of attracted male potato tuber moths was used as the body of the trap. The container was half-filled with water provided with a detergent, and the pheromone capsule was fixed in the inner ceiling of the trap.

3. Pheromone Capsules

Sex pheromone capsules, specific for attracting *Phthorimaea operculella* male moths were obtained from Pheromone Production Unit, Plant Protection Research Institute, Dokhi, Cairo, Agricultural Research Center, Egypt. The capsules were kept frozen until use, to conserve the pheromone efficiency. The pheromone capsules were fixed individually in the above-mentioned plastic containers and substituted with fresh ones every two weeks. Also, water and detergent in the containers were removed when needed.

4. Factors Affecting Catch of Pheromone Traps

4.1. Trap Color

Five traps of each color (yellow, white, blue, green, and red) used in this study. The pheromone traps were fixed at 25 cm above the ground. They were randomly distributed among the potato plants (15 m apart). Once a week until crop maturity, the moths captured in each trap were collected and counted and computed as an average number per trap per month.

4.2. Trap Cardinal Direction

The white traps were selected for this test in accordance with the results of the preceding experiment. The white sex- pheromone traps were positioned at a height of 25 cm in the center and in each of the cardinal directions (east, west, north, and south), with five traps per direction spaced 15 meters apart, to cover the entire experimental area. The moths were gathered once a week until harvest.

4.3. Trap Height

Fifteen white traps were set at three heights from the field ground: 0 cm (resting on the ground), 50 cm, and 100 cm. Five pheromone traps were employed for each height. The moths were collected and counted once every week until harvest.

Statistical Analysis

Standard error was calculated for the average of each treatment. Analysis of variance was computed to find out the differences among the means of the above mentioned three treatments. **Duncan's Multiple Range Test (1955)** was used to compare the significance of means.

RESULTS AND DISCUSSION

Factors affecting catch of *Phthorimaea operculella* male moths by sex pheromone traps

1. Trap color

In potato fields during 2022 summer season, sex pheromone traps; red, yellow, white, blue, and green were compared as tools for capturing *P. operculella* male moths (Table 1 and Fig 1).

The white traps captured the highest average number of male moths (3312.23 ± 169.78 / trap / month), followed by yellow ones (2216.70 ± 152.63) and then green traps (1301.00 ± 103.48 male moths / trap per month). These three traps did not significantly differ among each other in their captures. However, these traps had significantly higher captures than those in blue and red colored traps that captured 1403.98 ±

115.48 and 1136.76 ± 147.23 male moths / trap / month, respectively.

In a conclusion, the catches of yellow, white, and green – colored traps are considered significantly the same. Also, the catches of red, yellow, and blue sex pheromone traps did not significantly differ.

Table (1): Monthly average numbers of *Phthorimaea operculella* male moths captured by colored sex pheromone traps, during 2022 summer season

Month	Av. No. of *Phthorimaea operculella* male moths / trap					Monthly average
	Red trap	Yellow trap	White trap	Blue trap	Green trap	
June	462.60 ± 54.80	494.50 ± 25.50	489.60 ± 56.90	443.20 ± 63.50	411.20 ± 58.70	460.22 c
July	1319.50 ± 204.00	1828.11 ± 179.00	2640.80 ± 204.00	1508.70 ± 135.10	1424.00 ± 134.10	1744.22 b
August	1895.30 ± 256.00	3692.00 ± 278.00	5134.40 ± 309.00	1928.70 ± 199.10	2201.10 ± 175.20	2970.30 a
September	869.70 ± 75.10	2852.20 ± 102.00	4984.10 ± 112.20	1735.30 ± 65.20	1167.70 ± 46.00	2321.80 ab
Average ± SE	1136.76 ± 147.23 b	2216.70 ± 152.63 ab	3312.23 ± 169.78 a	1403.98 ± 115.48 b	1301.00 ± 103.48 b	

Averages followed by the same letter are not significantly different at the 5% level of probability.

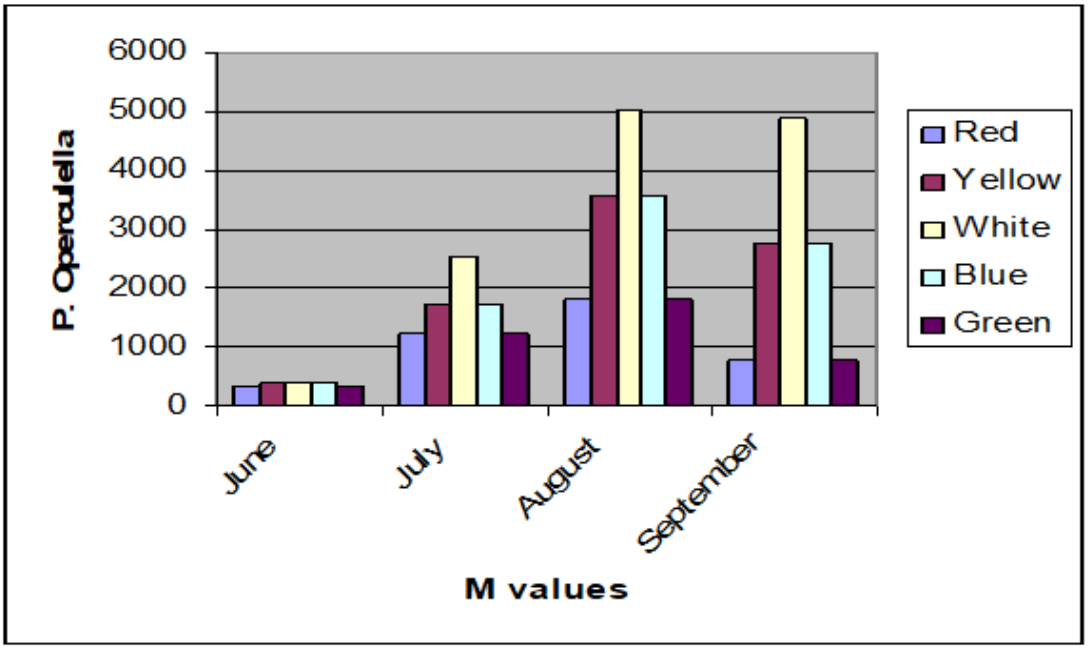

Fig. (1): Monthly average numbers of *Phthorimaea operculella* male moths captured by colored sex pheromone traps, during 2022 summer season

An insect's physiological response to a specific color might be affected by the color's spectrum reflection. We integrate our findings with those of Christos et al. (2004) on jasmine moth, *Palpita unionalis*, who reported that the white and yellow traps were the most efficient colors. On the other hand, pheromone traps with reduced spectral reflectance, collected a considerably higher population of codling moths than those white traps with high levels of reflectance **(Knight and Miliczy, 2003)**. Most of the moths were caught by the trap with a wavelength of 612.1 nm, which opposes the results obtained from studies on the tomato leaf miner, *Tuta absoluta* **(Taha et al., 2012).** More green and yellow pheromone-baited traps are preferred by male grab root borer (GRB) moths than white traps or blue ones **(Craig and Oscar, 2008)**. The majority of *Spodoptera littoralis* moths were drawn to yellow pheromone traps, whereas red pheromone traps were highly effective in collecting *Helicoverpa armigera*, and *Plutella xylostella* male moths **(Kumar, 2009)**. To understand why Potato tuber moth are more

attracted to white and yellow traps compared to the other colors, more investigation is necessary.

Catching of *P. operculella* male moths in different months of 2022, regardless of trap color was considered. The least catch was found as 460.22 male moths / trap during June, followed by that during July (1744.22 moths / trap), and that during September (2321.80 male moth / trap). However, the highest catch was that collected during August, with 2970.30 male moths / trap. Significant differences were found among the catches recorded during the abovementioned four months.

2. Trap cardinal directions

The highest catch (3179.25 ± 150.58 male moths / trap) was that of the trap fixed in the south direction (Table 2 and Fig. 2), followed by that of traps fixed in the center of the field (3109.43 ± 126.15 male moths / trap) throughout the season. The third and fourth ranks were those of traps fixed in east (1283.53 ± 146.78 male moths / trap), and west (965.73 ± 143.33 male moths / trap), while the least catch was that in traps positioned in the north direction (913.28 ± 150.73 male moths / trap).

Table (2): Average numbers of *Phthorimaea operculella* male moths captured by white sex-pheromone traps fixed at cardinal directions and center of potato field, during 2022 summer season

Month	Av. No. of *Phthorimaea operculella* male moths / trap (Different directions)				
	West	East	North	South	Center
June	415.20 ± 46.70	324.60 ± 53.80	858.60 ± 60.90	393.40 ± 65.40	208.40 ± 60.40
July	1189.80 ±188.10	1398.33±168.20	655.40 ± 199.30	3440.50 ± 154.20	1018.80 ± 129.20
August	1408.30 ± 250.20	2120.50 ± 259.20	598.60 ± 229.20	5445.30 ± 208.30	5775.70 ± 170.20
September	849.60 ± 85.60	1290.70 ± 106.20	1540.50 ± 115.60	3437.80 ± 175.30	5434.80 ± 146.30
average ± SE	965.73 ± 143.33 c	1283.53 ± 146.78 bc	913.28 ± 150.73 c	3179.25 ± 150.58 a	3109.43 ± 126.15 ab

Averages followed by the same letter are not significantly different at the 5% level of probability.

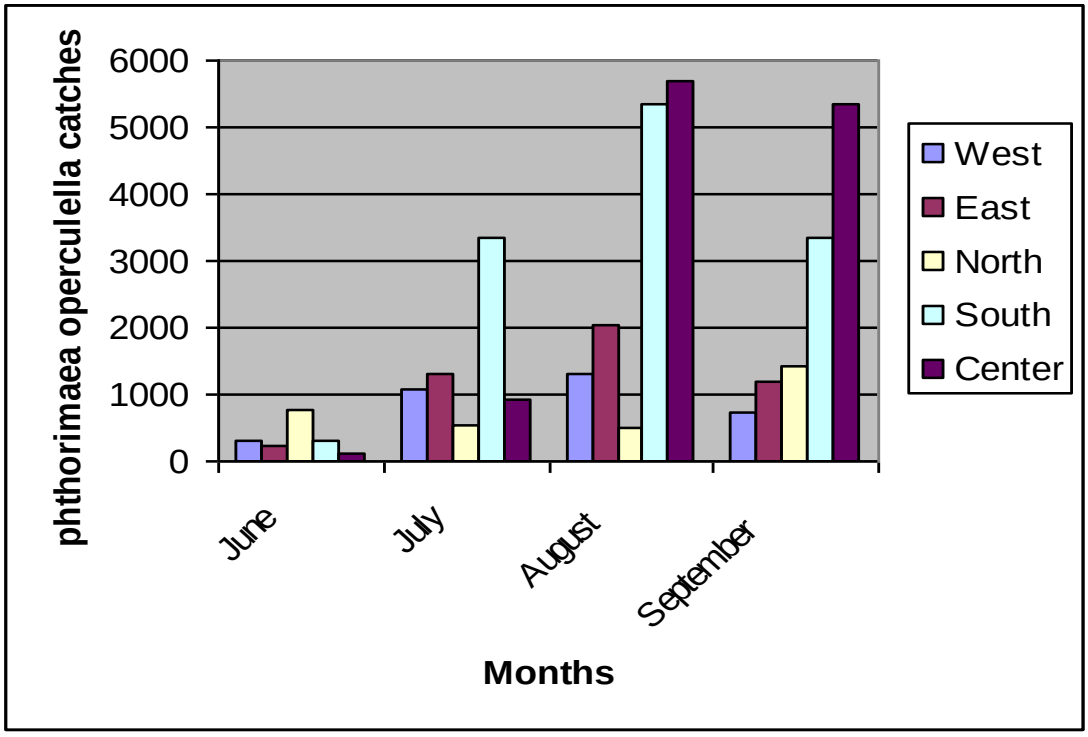

Fig. (2): Average numbers of *Phthorimaea Operculella* male moths captured by white sex pheromone traps fixed at cardinal direction and center of potato field, during 2022 summer season

Pheromone trap direction is one of the factors affecting the capture of insects **(Athanassion *et al.*, 2002).** Numerous studies have also examined the effect of trap placement on lepidopterous insect attraction. Contrary to the findings of the current investigation, more male moths of *Palpita unionalis* was collected in pheromone traps in the borders of the groves than the middle ones **(Christos, 2004)**. Traps placed on the canopy's edge yielded significantly more codling male moths than those inside the canopy and encircled by foliage. In this way, pheromone traps near fruits captured a notably higher number of male moths than pheromone traps farther away from the fruit **(Alan and Douglas, 2005)**.

3. Trap height

Effect of pheromone trap height is displayed in Table (3) and Fig (3). Throughout the four months of study, the traps settled just at the soil surface captured the highest *P. operculella* male moths with an average of 3888.50 ± 169.28 individuals / month / trap. The second rank was occupied by the those fixed at the height of 50 cm from the ground surface (2739.03 ± 146.46 moths / month / trap). However, the least catch was that in the traps fixed 100 cm above the ground surface (1851.73 ± 129.50 male moths / month / trap).

Table (3): Average numbers of *Phthorimaea operculella* male moths collecting by sex- pheromone traps fixed at different heights above the ground in potato field, during 2022 summer season

Month	Av. No. of *Phthorimaea operculella* male moths / trap (Height above the ground)		
	0 cm	**50 cm**	**100 cm**
June	1270.6 ± 77.60	908.20 ± 65.82	426.00 ± 49.30
July	4068.80 ± 156.50	2544.70 ± 133.00	1667.40 ± 114.50
August	5671.60 ± 242.00	4047.20 ± 201.00	2496.10 ± 188.50
September	4543.00 ± 201.00	3456.00 ± 186.00	2817.40 ± 165.70
Average ± SE	3888.50 ± 169.28 a	2739.03 ± 146.46 b	1851.73 ± 129.50 c

Averages followed by the same letter are not significantly different at the 5% level of probability.

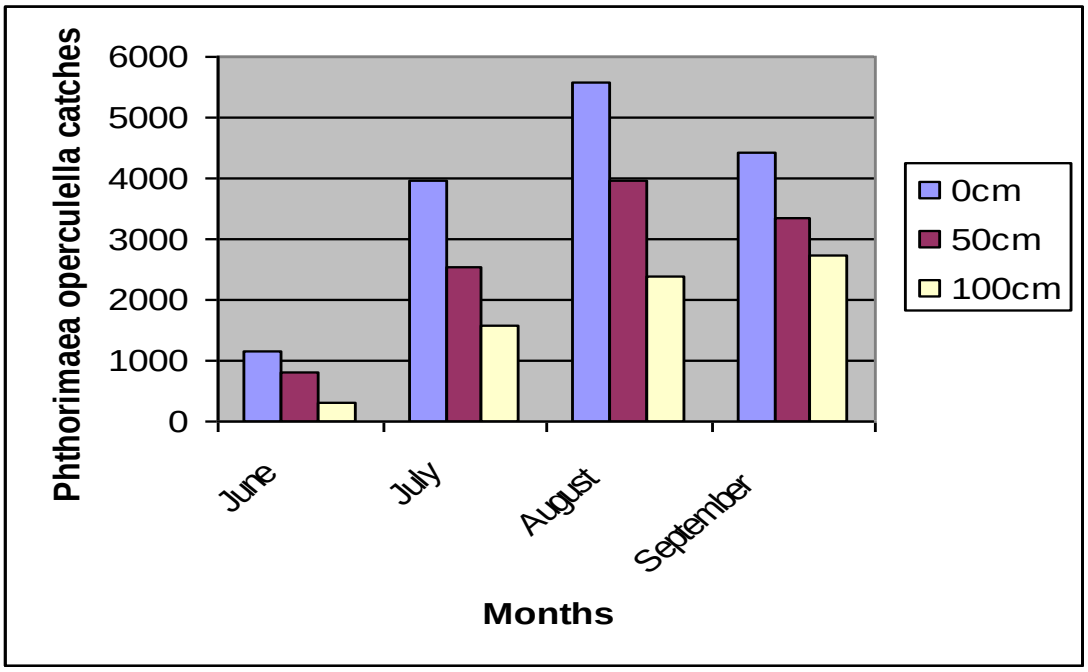

Fig. (3): Average numbers of *Phthorimaea Operculella* male moths collecting by sex- pheromone traps fixed at different heights above the ground of potato field, during 2022 summer season

In line with the current results, more *Phthorimaea operculella* male moths were caught in traps fixed 30 cm above the ground of potato fields than in those 100 cm above the ground **(Kennedy, 1975).** Similar results were obtained by **Edi *et al* (2004)** when they collected greater numbers of *Spodoptera frugipedra* male moths in pheromone traps fixed 1.5 m above the ground than in traps at 2.0 m above the ground. **Herman *et al.* (2005)** discovered, however, that the height of the sex pheromone trap had no significant impact on the catch of male *P. operculella* moths.

CONCLUSIONS

The results of this study provide a long-term monitoring of *Phthorimaea operculella* male moths using pheromone traps. This study shows that *P. operculella* moths response to sex-pheromone baited traps are significantly influenced by the color, orientation, and height of the traps. Compared to other tested trap combinations, the white or yellow trap performed better at capturing the male moths of the insect pest when it was placed in the middle or south of the field and rested on the ground. These findings should be considered when developing a sound potato tuber moth monitoring system.

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الملخص العربي

اصطياد ذكور فراشة درنات البطاطس (Zeller) *Phthorimaea operculella* باستخدام المصائد الفرمونية الجنسيه استجابةً للون المصيدة واتجاهها وارتفاعها في حقول البطاطس

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البطاطس *Solanum tuberosum L*. من أهم المحاصيل الغذائية. وتعتبر فراشة درنات البطاطس (Lepidoptera: Gelechiidae ،PTM)) *Phthorimaea operculella* (Zeller 1873)، من الأفات المدمرة للبطاطس في الحقل والتخزين وأثناء التسويق. أجري البحث بمحطة البحوث الزراعية – مركز إيتاي البارود (محافظة البحيرة) في الموسم الصيفى 2022 لاختبار كفاءة مصائد الفرمون الجنسية في صيد ذكور فراشات *P. operculella*. تم تقييم تأثير لون المصيدة واتجاهها ، وارتفاعها عن سطح الارض على أصطياد فراشة درنات البطاطس *P. operculella* .كانت المصائد الفرمونية البيضاء هي الأكثر فعالية في صيد الحشرات بمتوسط عدد ذكور الفراشة (3312.23 ± 169.78 فراشة / مصيدة / شهر)، مقارنة بالمصائد الصفراء (2216.70 فراشة ± 152.63)، والمصائد الخضراء (1301.00 فراشة ± 103.48) أو المصائد الحمراء. وبالنسبة ، كما كانت هناك فروق معنوية في تاثيراتجاه المصيدة علي صيد الذكور. عندما تم وضع المصائد في الجنوب تم اصطياد (3179.25 ± 150.58 ذكر / مصيدة) وفى الوسط تم اصطياد (3109.43 ± 126.15 ذكر فراشة / مصيدة) . مقارنة بوضعها في الشرق او الغرب أو الشمال. عندما تم وضع المصائد علي سطح الارض مباشرة تم اصطياد عدد أكبر من الفراشات بمتوسط (3888.50 ± 169.28 ذكر / شهر / مصيدة) مقارنة بالارتفاعين الآخرين (50 و 100 سم فوق سطح الأرض). أشار التحليل الإحصائي إلى وجود فروق معنوية بين الارتفاعات. وبناء علي هذا يجب أخذ نتائج هذا البحث في الأعتبار عند اعداد نظام مراقبة لحشره *P. operculella* باستخدام المصائد الفرمونية الجنسية.