Current Science International
Volume: 14 | Issue: 01| Jan. - March| 2025

EISSN:2706-7920 ISSN: 2077-4435
DOI: 10.36632/csi/2025.14.1.2
Journal homepage: www.curresweb.com
Pages: 15-25

Impact of Planting Dates and Climate Changes on the Number of Generations of Potato Tuber Moth, *Phthorimaea operculella* Zeller and The Economic Feasibility Study

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Received: 10 Nov. 2024 **Accepted:** 15 Jan. 2025 **Published:** 30 Jan. 2025

ABSTRACT

A Field experiment was applied at El-Ayat district, Giza Egypt, during two successive seasons, 2021&2022 and 2022&2023. The experiment aimed to Impact of planting dates and climate changes on the number of generations of potato tuber moth, *Phthorimaea operculella* Zeller and the economic feasibility study (var. Spunta) four dates were selected for the planting, with a 20-day interval between each: November 21, December 11, January1 and January 21. The statistical analysis indicated that there were significant differences between the different levels of infestations by *P. operculella* according to four different planting dates during two seasons. The highest mean number of *P. operculella* was recorded on the last planting date while the lowest seasonal mean number was recorded on the first planting date. Referring to the effect of different planting dates during the study period, the relationship between the population density of *P. operculella* Zeller larvae and the crop yield of potato was negative and highly significant. Data revealed that the second planting date was the most planting date caused by increasing weight of potato yield with low mean weekly number of the pests during the two successive seasons. Economic evaluation parameters indicate that the second planting date (December 11) achieved the highest return per acre, amounting to 191.2 thousand pounds per acre. According to the study, *P. operculella* matures its life cycle more swiftly at higher temperatures. The current climate (2021–2022) slows down the maturation of all generations. But in the event of future warming: The pest's life cycle shortens at +1.5°C (2021–2040), allowing it to produce more generations annually. Development is further accelerated at +2.0°C (2041–2060), which increases infection frequencies and has a bigger impact on agriculture. According to the tendency, rising temperatures may make insect load on crops worse, necessitating the development of flexible pest management techniques. The findings showed that the Tracer SC (85.15%) was the most effective control in terms of the mean percentage of *Phtorimaea operculella* zeller larva population reduction.

Keywords: *Phtorimaea operculella* zeller, planting dates, climate changes, economic feasibility study, control.

1. Introduction

One of Egypt's most vital food crops, particularly for export, is the potato (*Solanum tuberosum* L.). Potatoes are one of the most affordable sources of protein, vitamins, macro- and micronutrients, polyphenols, carotenoids, and tocopherols in developing countries. As such, they are essential for ensuring food security and generating revenue (Abebe *et al.,* 2017). By adjusting temperature and light, planting dates have a significant effect on potato yield. Long day conditions during growth and short day conditions during tuberization are necessary for the highest yields of potatoes. Chadha (2009). The

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ideal temperature range for photosynthesis and canopy growth is 15–25°C, whereas tuberization needs 20°C. Tuberization is hampered by temperatures above 29°C. (Dahal and others, 2019). Dates of planting have a significant impact on potato growth. (Sandhu *et al.,* 2014, Thongam *et al.,* 2017, Dash *et al.,* 2018 and Meligy *et al.,* 2020). Numerous insect pests can affect potatoes in Egypt, lowering their quantity and quality both in the field and during storage. *Phthorimaea operculella* Zeller, a member of the family Gelechiidae and order Lepidoptera, is a cosmopolitan major pest of potatoes. It attacks a wide range of domesticated solanaceous plants, such as bell pepper, tomato, eggplant, tobacco, and potatoes (*Solanum tubersum*). (Mandour *et al.,* 2012; Schaub & Kroschel 2018; Soliman *et al.,* 2015 and Morey and Khandagle 2020). *P. operculella* causes considerable damage to tubers. The larvae, who often live their whole lives in one of these food sources, are to blame for this. The sole exception to this rule is that the larvae leave the contaminated foliage and look for tubers once it is destroyed. A foliar infection might be so bad that the plant dies. Larvae that mine tubers typically enter through the "eyes" of nearby eggs and create thin, unclean-looking tunnels throughout the tuber. Mounds of droppings near the tunnel exits indicate an infected tuber. In the summer, the field has high levels of tuber infection, and potatoes that are kept can sustain significant damage throughout the year. Because of its great reproductive capability, polyvolatility, and resilience to seasonal weather variations, this species is extremely difficult to control. (Coll *et al.,* 2000; Keller, 2003; Kroschel *et al.,* 2013; Aryal and Jung 2015).

Therefore, the present study focused on Impact of planting dates and climate changes on the number of generations of potato tuber moth, *Phthorimaea operculella* Zeller and the economic feasibility study

2. Material and Methods

2.1. Field experiment

El-Ayat district in the Giza governorate, Egypt, was the site of the field tests in two consecutive seasons (2021&2022, 2022&2023). The first experiment aimed to determine how the infestation rate potato tuber moth was affected by the timing of potato plant planting (var. Spunta). Four dates were selected for the planting, with a 20-day interval between each: November 21, December 11, January1 and January 21. This agricultural season is dedicated to export. The approximately 12 Kerate (2100 m2) experimental area was selected, split into four equal plots, and each plot had three replicates. The duplicate space was 166.5 m^2. Without the use of pesticides, all farming practices were altered as advised. After forty-five days from the date of planting till harvest, the sampling process began. From each copy of these plants, weekly samples of potato leaves were selected at random. These thirty-leaf samples were selected from every plot. Using binoculars, each sample was carried in a paper bag to the lab for examination on the same day of the inspection. The unit effect of infestation with:

2.2. Determination of degree-days units (DDU)

Determination of degree-days units (DDU) Daily maximum and minimum temperatures recorded and obtained from Center Laboratory for Agriculture Climate (CLAC) were transformed to heat units using Threshold of development (t) and accumulated heats (k) for According to Abd El-Wahab *et al.* (2009), the entire preimaginal development of *P. operculella* Zeller was determined to be 4.9 ºC and 741.7 degree-days (DD`s) for generation and the lower Degree-days units (DDU) were calculated by applying the Richmond *et al.,* (1983) .

2.3. Influence of current climatic change on *P. operculella* Zeller

These experiments were performed on *Ph. operculella* Zeller, at El-Ayat district, Giza governorate, Egypt, during January to December for successive seasons 2021&2022 and 2021&2022. Average temperatures (daily maximum and minimum) were calculated according to the data recorded and obtained from CLAC, Egypt.

2.4. Effect of expected future climatic change on *P. operculella* Zeller

This study was performed to predicate the numbers and durations of generations and DDU (accumulated thermal heat units) in expected future climatic change 2040s and 2060s. The future climatic data have been obtained based on the GHG emissions scenarios (SSP-4.5), increase the temperature (1.5 °C) near term 2021- 2040 (2.0 °C) med term 2041-2060 (IPCC 2021).

2.5. Data on Temperatures

Table 1, showed that potato plants in the Giza Governorate study site are impacted by extremely low temperatures. Winter time characteristic readings show an average rise in maximum and minimum temperatures, which are thought to be factors that negatively impact plant growth, quality, traits, and insect pests. As a result, research was done to find out how pests' presence affected potato crop productivity as a result of climate change.

Table 1: Monthly the maximum and minimum air temperatures during growth potato plant in the two seasons 2021&2022 and 2022&2023.

Month	First season 2021&2022		Second season 2022&2023	
	Air temperature (˚C)		Air temperature (˚C)	
	Max.	Min.	Max.	Min.
November	25.62	13.36	26.73	14.92
December	23.0	11.14	22.38	11.50
January	20.45	8.19	20.99	8.78
February	18.83	6.44	19.90	7.23
March	25.47	10.74	26.44	11.20
April	29.59	13.35	30.56	14.35
May	33.68	17.16	34.40	18.00
Means	25.23	11.48	25.91	12.28

Data issued by the Central Climate Laboratory, Agricultural Research Center, Giza, Egypt.

The second experiment was developed in season 2022&2023 to evaluate the efficiency of insecticide (Table, 2).

The tested insecticides were as shown in Table (2)

The first week of January in 2022 & 2023 planted the potato tubers. The population dynamics of the larvae of the potato tuber moth were followed until the rate of infestation reached 5%. Two pesticide spray treatments per season were applied; the first, 80 days after planting, and the other, 10 days later. The randomized whole block design was employed to distribute the pesticides. Dorsal motor sprayer was utilized for spraying the treatments, and ground water was utilized for dilution of pesticides in the first and second spray. Each treatment was replicated four times, and water alone was sprayed as control. Fifteen leaves were picked at random /replicate /fifteen plants, prior to spray and ten days after 1st and 2nd spray. The leaf samples were placed in a paper bag and brought to the laboratory and observed under binoculars for counting the number of larvae per leaf. The results are expressed as a mean number of larvae per 15 leaves per treatment. The percentage adjusted mortality was calculated by the Henderson and Tilton (1955) modified formula.

Table 2: The tested insecticides.

Trade name	Common name	Formulations	Concentration of A. I.	Rate of application
Protecto	*Bacillus thuringiensis* subap. Kurstaki	WP	9%	300/200L
Voliam flexi	Thiamthoxam+ Chlorantraniliprole	SC	20% + 10%	168/200L
Match	Lufenuron	EC	5%	160/200L
Tracer	Spinosad	SC	24%	30 cm/100LW
Plesiva star	Pymetrozine cyantraniliprole	WG	10%+50%	250/200LW
Control (without any spray)	--	--	--	--

2.6. Economic evaluation parameters.

The follow parameters were calculated as economic evaluations:

Productivity (Kg)**:** productivity = total output/total input.

Price: (pound)/kg.
Total revenue (pound)**:** Total Revenue (TR)= Quantity (Q) x Price (P).
Net return (pound)**:** subtract the purchase price of the investment from its selling price.
Cost benefit ratio (CBR): Calculated by dividing the proposed total cash benefit of a project/ the proposed total cash cost of the project.
Margin over variable costs: refers to the margin results calculated by subtracting variable production costs from revenue.
Pound on return: comparing the difference between its current value and its initial value, and then dividing the result by its initial value.
Added value: Added value = The selling price of a product **-** the cost of bought in materials and component.

2.7. Data Analysis

The SAS software computer was used to perform the statistical analysis of the current data, which included the F-test and L.S.D. value (SAS Institute, 1999).

3. Results and Discussion

Data in Tables (3 & 4) showed the effect of four different planting dates on the infestation of potato by *P. operculella* Zeller, larvae during two seasons, 2021 & 2022 and 2022& 2023 with estimation of the yield.

3.1. Effect of the different planting dates on population density of *P. operculella* Zeller larvae infestation.

Data indicated that in Table (3 and Figures 1,2) Statistical analysis were significant differences between the different level infestation by *P. operculella* according to four different planting dates during 2021 & 2022 and 2022& 2023 seasons. The highest mean number of *P. operculella* was recorded on latest planting date with average of 12.2 larvae /30 leaves.

Table 3: Mean number of pod borer, *P. operculella* Zeller larvae on potato plant at different planting dates during 2021&2022 and 2022&2023 seasons in Giza Governorate.

Sampling data	Mean Number of larvae / 30 potato leaves (± S.D)							
	2021&2022				2022&2023			
	1st Planting November 21th	2nd Planting December 11th	3rd Planting January 1st	4th Planting January 21th	1st Planting November 21th	2nd Planting December 11th	3rd Planting January 1st	4th Planting January 21th
December , 31	-	--	--	--	-	--	--	--
January , 7	-	--	--	--	-	--	--	--
14	-	--	--	--	-	--	--	--
21	-	--	--	--	-	--	--	--
28	-	-	--	--				
February, 5	-	-	--	--	--	--	--	--
12	--	-	--	--	--	--	--	--
19	--	1.2	--	--	0.2	0.8	--	--
26	1.6	1.8	2.4	3.2	0.8	1.6	1.8	--
March, 2	2.8	1.6	2	6.6	2.2	1.8	4.6	4.2
9	2.4	2.2	4.4	8.2	3.6	2.0	6.0	5.8
16	4.2	4.8	6.8	10.8	--	2.6	5.4	7.2
23	--	6.8	6.4	11.2	--	3.8	6.8	9.2
30	--	7.6	7.8	13.6	--	5.6	6.4	14.2
April,7	--	8.8	8.8	14.8	--	--	12.2	14.6
14	--	--	10.8	14.2	--	--	11.4	13.2
21	--	--	11	16.2	--	--	12.8	14.4
28	--	--	--	14.8	--	--	--	15.8
May,5	--	--	--	16.8	--	--	--	15.2
12	--	--	--	15.6	--	--	--	16.2
Means	**2.8d**	**4.4c**	**6.7b**	**12.2a**	**1.7d**	**2.6c**	**7.5b**	**11.8a**
F value	35.41***				18.90***			
L.S.D	0.44				0.79			

The first date recorded the lowest seasonal mean number, with average 2.8 larvae /30 leaves. Sowing on the second and third planting date led to intermediate level infestation, with mean of 4.4 and

6.7 larvae /30 leaves, respectively in the first season. In the second season, results had the same trend as obtained in the first season. The seasonal mean numbers of *P. operculella* found in this season were (1.7, 2.6, 7.5 and 11.8 larvae/30 leaves) on November 21th; December 11**th**; January 1st and January 21th planting date, respectively.

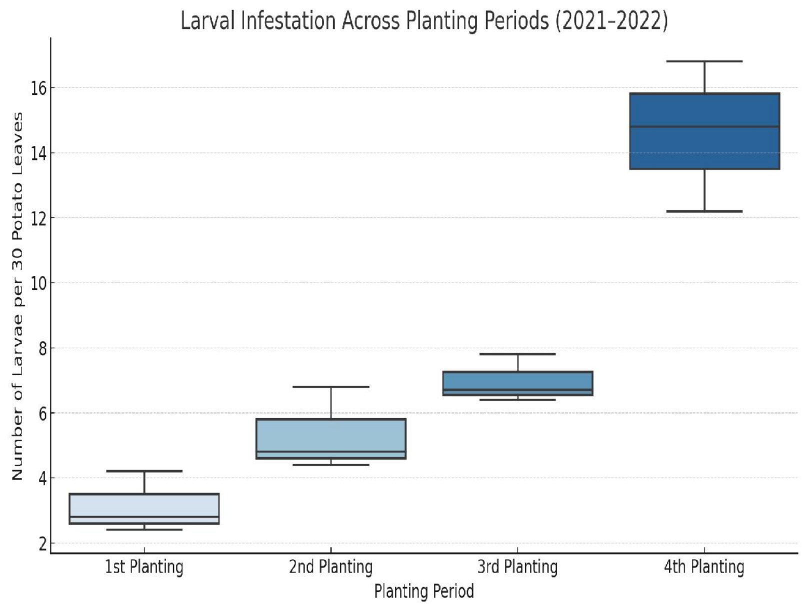

Fig. 1: Mean number of *P. operculella* Zeller larvae on potato at different planting dates during 2021&2022 season in Giza Governorate.

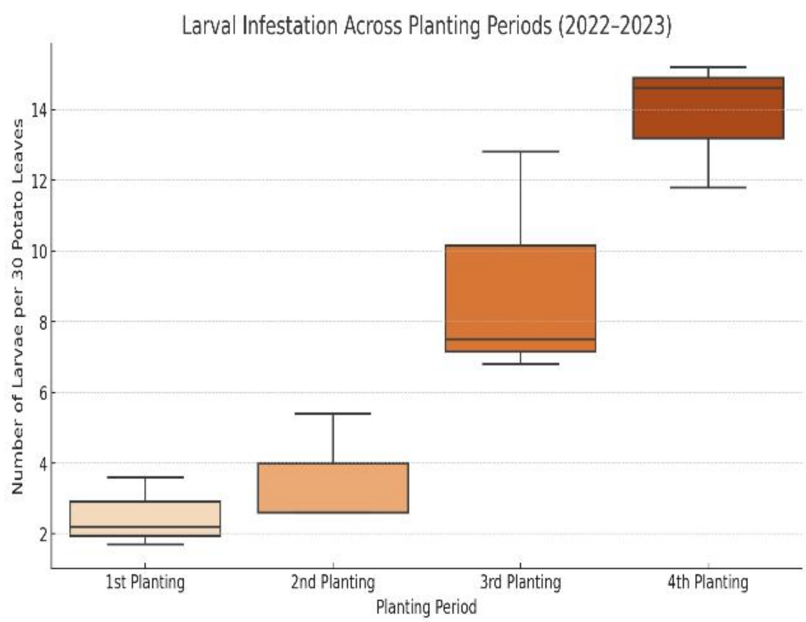

Fig. 2: Mean number of *P. operculella* Zeller larvae on potato at different planting dates during 2022&2023 season in Giza Governorate.

3.2. The relationship between infestation and yield

For two consecutive seasons, Table (4) showed the impact of various planting dates on the overall output of potatoes. Regarding the effect of different planting dates, the relationship between *P. operculella* Zeller larvae population density and potato crop yield was negative and highly significant, with "r" values of -0.92 and "b" values of -0.03 kg during the two consecutive seasons of 2021–2022 and 2022–2023, respectively. Coefficient of determination was 846 throughout two successive seasons, respectively. The results showed that one larvae of *P. operculella* Zeller caused reduction percentage 0.005% (in average) in crop yield of potato. To determine the spate effect of *P. operculella* Zeller "x" on the crop yield "Y", the C-multipliers was used to obtain (Explained Variance "E.V.") this value indicated that the one factor was responsible for 86% during 2021&2022 and 2022&2023, respectively.

According to the data, the second planting date resulted in the highest weight of potato output with the lowest mean weekly number of pests over the course of the two seasons, while the mean crop yield for two consecutive seasons was 3.9 individuals per 30 leaves, weighing 630 kg.

Table 4: Effect of different planting dates on mean number of *P. operculella* Zeller larvae infesting potato plant and crop yield.

Planting date	2021&2022		2022&2023		Means	
	Mean number of *P. perculella*	**Mean yield (kg)**	**Mean number of *P. operculella***	**Mean yield (kg)**	***P. operculella***	**Mean yield (kg)**
1st Planting November 21th	2.8	567	2.2	601	**2.5**	**584.0**
2nd Planting December 11th	4.8	625	2.9	635	**3.9**	**630.0**
3rd Planting January 1st	6.7	448	7.5	433	**7.1**	**440.5**
4th Planting January 21th	12.2	355	11.8	378	**12.0**	**366.5**
Correlation (r)	**-0.88***		**-0.96***		**-0.92***	
Partial regression (b)	**-0.03***		**-0.04***		**-0.03***	
Coefficient of determination "r^2"	**0.774**		**0.921**		**0.846**	
F value	**7.17***		**23.55***		**12.49***	
Expand Variance (E.V%)	**78%**		**92%**		**86%**	

3.3. Economic evaluation parameters.

Table (5), showed that economic evaluation parameters of relationship between population density of *P. operculella* Zeller larvae and crop yield of potato under different planting dates at field conditions. The results indicate that the second planting date (December 11) achieved the highest return per acre, amounting to 191.2 thousand Egyptian pounds per acre, while the lowest return per acre was in the fourth date (January 21) amounting to 111.2 thousand pounds per acre. By calculating the net return, it was found that the second date achieved the best net return, amounting to about 107.7 thousand pounds per acre.

Table 5: Economic evaluation parameters of relationship between population density of *P. operculella* Zeller larvae and crop yield of potato under different planting dates at field conditions.

Planting date	Economic evaluation parameters /fed								
	Productivity (kg)	**Price in pounds/ kg**	**Total costs in pounds/fed**	**Total revenue in pounds/fed**	**Net return in pounds/fed**	**Cost Benefit Ratio (CBR)**	**Margin over variable costs/P/fed**	**Pound on return**	**Added Value/P/fed**
1st Planting November 21th	14776	12	83536	177311	93775	2.12	113775	1.12	125711
December 11th 2nd Planting	15940	12	83536	191277	107742	2.29	127742	1.29	139677
3rd Planting January 1st	11145	12	83536	133742	50207	1.60	70207	0.60	82142
4th Planting January 21th	9273	12	83536	111275	27739	1.33	47739	0.33	59675

The income-to-cost ratio indicator also showed that the second planting date achieved the highest value, amounting to about 2.29, meaning that revenues equal costs by 229%, as the margins over variable costs reached their highest at that date, amounting to about 127.7 pounds per acre. By estimating the return on the invested pound, it became clear from the results that it reached its highest at the second planting date, amounting to about 1.29, meaning that each invested pound achieves a return of 1.29 pounds. From the above, it is clear that the second planting date has better economic feasibility compared to other planting dates, as it achieved the highest added value, estimated at about 139.6 thousand pounds per acre.

3.4. Impact of Climate Change on *P. operculella* Life Cycle

According to the study, *P. operculella* matures its life cycle more swiftly at higher temperatures. The current climate (2021–2022) slows down the maturation of all generations. But in the event of future warming: The pest's life cycle shortens at +1.5°C (2021–2040), allowing it to produce more generations annually. Development is further accelerated at +2.0°C (2041–2060), which increases infection frequencies and has a bigger impact on agriculture. According to the tendency, rising temperatures may make insect load on crops worse, necessitating the development of flexible pest management techniques (Table, 6 and Fig, 3).

Table 6: Degree-days and generation numbers of *Phenacoccus solenopsis* under climate Change on 2021 & 2022 season and Future (2040 and 2060) at Giza Governorate

No. Gen.	**Current climate Normal 2021 & 2022**				**(IPCC) Scenario SSP2-4.5**							
					2021-2040 Normal+1.5 C°				**2041-2060 Normal+ 2.0 C°**			
	Days	**Start**	**End**	**DDUs**	**Days**	**Start**	**End**	**DDUs**	**Days**	**Start**	**End**	**DDUs**
1	101	1/1	11/4	457	91	1/1	1/4	459	68	1/1	9/3	451
2	34	12/4	16/5	463	31	2/4	3/5	453	39	10/3	18/4	450
3	25	17/5	10/6	469	27	4/5	1/6	470	27	19/4	16/5	465
4	24	11/6	4/7	470	22	2/6	24/6	456	22	17/5	8/6	469
5	23	5/7	28/7	466	21	25/6	15/7	451	20	9/6	29/6	472
6	22	29/7	19/8	457	21	16/7	7/8	456	20	30/6	19/7	464
7	22	20/8	11/9	460	21	8/8	29/8	474	19	20/7	7/8	467
8	24	12/9	5/10	459	21	30/8	20/9	455	19	8/8	27/8	468
9									19	28/8	16/9	453
10									20	17/9	7/10	455
Average	34.3			462.6	31.8			459.2	27.3			461.4

Curr. Sci. Int., 14(1): 15-25, 2025
EISSN: 2706-7920 ISSN: 2077-4435 **DOI: 10.36632/csi/2025.14.1.2**

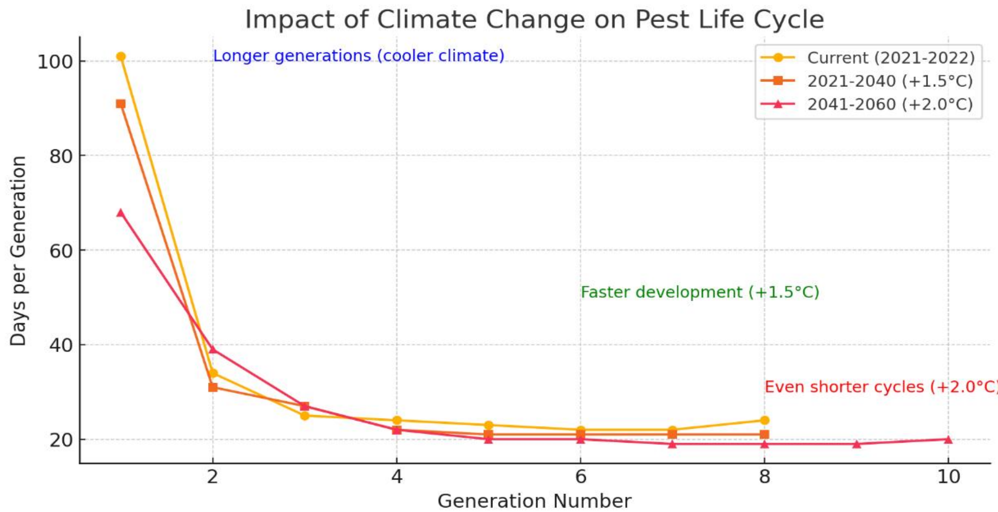

Fig. 3: Generation numbers of *Phenacoccus solenopsis* under climate Change on 2021 & 2022 season and Future (2040 and 2060) at Giza Governorate.

3.5. The efficiency of control agents on *Phtorimaea operculella* zeller larvae infesting potato plant.

Data in (Table, 7 and Fig., 4), indicated that the first week of January in 2022 & 2023 planted the potato tubers. The population dynamics of the larvae of the potato tuber moth were followed until the rate of infestation reached 5%. Two pesticide spray treatments per season were applied; the first, 80 days after planting, and the other, 10 days later. The results showed that the average percentage of reduction in population of *P. operculella* zeller larva, it is clears that the Tracer SC (85.15%) was the most potent one followed by Plesiva star WG (83.6%), Protecto WP (82.15%), Voliam flexi SC (81.55%) and the least potent one was Match EC (80.4%). Three different groups of the evaluated compounds could be determined. According to the percentage of reduction in *P. operculella* zeller larvae (F. value = 20.77 and L.S.D = 1.33%). The results showed that there is a convergence in the reduction ratios these treatments can be used interchangeably during the integrate pest management program so that the insect does not gain resistance.

Table 7: The efficiency of control agents on *Phtorimaea operculella* (zeller) larvae infesting potato plant during 2022&2023 season at Giza Governorate.

Treatments	Mean No. of larvae before spray	First spray No. of larvae after 10 days		Mean No. of larvae before spray	Second spray No. of larvae after 10 days		General mean Reduction %
		No.	%		No.	%	
Protecto WP	20.8	4	**80.5 cd**	11.5	2.3	83.8 b	82.15c
Voliam flexi SC	20	3.8	81.1c	11.8	2.5	82.0 c	81.55 cd
Match EC	18.3	3.8	80.0 d	12.8	2.8	80.8 d	80.4 d
Tracer SC	21.5	3.5	84.3 a	13	2	86.0 a	85.15 a
Plesiva star WG	20.5	3.5	**83.0 b**	12.8	2.4	84.2 b	83.6 b
Control (without any treatments)	20.8	21.5	--	19.3	23	--	--
F value	--	--	31.86***	--	--	53.37***	20.77***
L.S.D	--	--	1.04	--	--	0.91	1.33

Curr. Sci. Int., *14(1): 15-25, 2025*
EISSN: 2706-7920 ISSN: 2077-4435 **DOI: 10.36632/csi/2025.14.1.2**

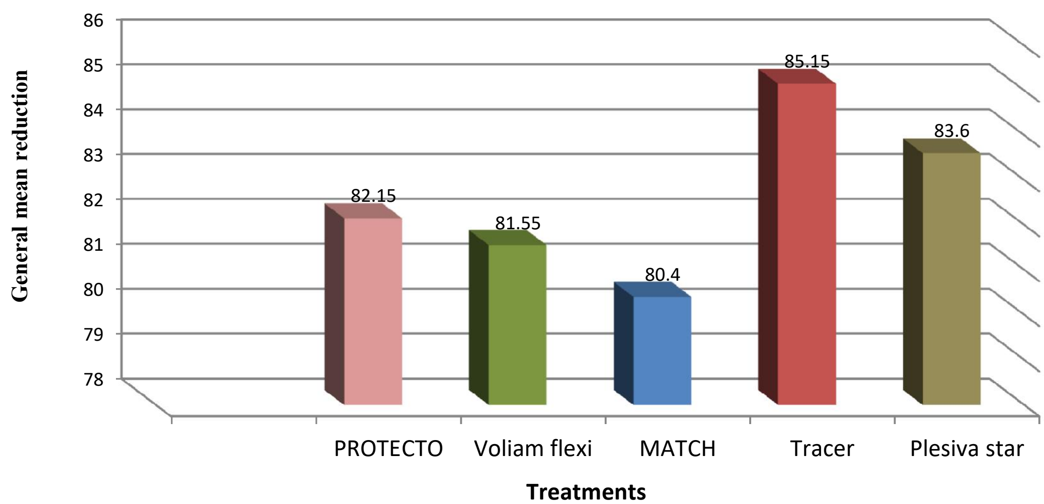

Fig. 4: Efficiency of control agents on *P. operculella* (zeller) larvae infesting potato plant during 2022&2023 season at Giza Governorate.

Our results agree with many researches who studied the effect of planting date on potato pests infestation. According to Dash *et al.* (2018), the optimal planting date was November 15th, with a maximum tuber yield of 24.019 t ha-1. Meligy *et al.* (2020) conducted two field trials at the Experimental Farm of Arid Land Agricultural Graduate Studies and Research Institute (ALARI), Faculty of Agriculture, Ain Shams University in Shubra el-Khaimah, Qalyubiah Governorate, over the course of two consecutive seasons, 2014/2015 and 2015/2016. Examining the effects of three planting dates (18 December, 7 January, and 27 January) and their interactions on potato crop productivity was the goal of the current study. The results showed that for both seasons under study, the first planting date (18 December) produced the highest tuber production and Singh and associates (2022) At the Main Experiment Station, Department of Vegetable Science, Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (U.P.), an experiment was carried out to determine the best planting dates for potato cultivation during the Rabi season of 2011–12 and 2012–13. Five dates for planting: October 17, October 27, November 7, November 17, and November 27 According to the results, the highest tuber yield—391.59 quintal in 2011–12 and 404.59 quintal per hectare in 2012–13—was obtained by planting on November 17. Nonetheless, in both study years, the lowest overall tuber yield—282.61 q ha-1 and 291.74 q ha-1—was noted when the plants were planted on November 27. The life cycle of *Phthorimaea operculella*, a significant global potato pest, is predicted to be impacted by climate change (Rondon, 2020). The ideal temperature ranges for *P. operculella* development, survival, and reproduction is between 20 to 30°C (Sporleder *et al.,* 2004). Between 10 to 35°C, the pest can finish its life cycle, and between 28 and 30°C, population growth peaks (Sporleder *et al.,* 2004). The biological patterns of *P. operculella* may be changed by climate variation, which could have an impact on crop-pest connections, population growth rates, and overwintering (Rondon, 2020). The pest's capacity to adapt to different temperatures makes control methods difficult (Rondon, 2010). Because parasitoids like Apanteles subandinus are temperature-dependent, climate change may also affect biological control efforts (Cañedo *et al.,* 2022). It is essential to comprehend these temperature-driven processes in order to create efficient management plans for various agro-ecological zones. Comprehending these temperature-driven dynamics is essential for forecasting possible range expansions under shifting climatic conditions and creating efficient management plans in various agro-ecological zones (Sporleder *et al.,* 2004; Cañedo *et al.,* 2022). The efficiency of control agents on *Phtorimaea operculella* zeller larvae infesting potato plant and According to Omar *et al.* (2011), the amount of PTM larvae was considerably decreased when bioinsecticides were sprayed on potato plants. Insecticides that were the most effective were Spinosad (Tracer 24% SC), Azadirachtin (Achock 15% EC), and soybean oil (Naturals 96% EC). El-din Gamal *et al.* (2016) In the current study, three insecticides—indoxacarb (Avaunt 15% EC), lufenuron (Match 5% EC), and methoxyfenozide (Runner 24% SC)—were tested for their effectiveness against potato tuber moth (PTM), Phthorimaea operculella (Zeller) larvae on two potato varieties (Spunta and Mondial) over the course of two consecutive summer seasons in 2014 and 2015 at Appig village, Kafer El-zyaat center, Gharbia Governorate, Egypt. The pesticides were applied at various intervals of 10 or 15 days after the initial spray. According to the results, all treatments reduced the PTM population in the foliage infestation during the 10-day trials conducted during the 2014 season. The highest values were obtained with Avaunt (46.29% & 41.97%) for the Spunta and Mondial varieties, followed by Runner (34.84% & 28.10%) and Match (34.04% & 26.53%). Additionally, the similar pattern was noted in the 2015 season. All treatments, however, demonstrated a decrease in the PTM population in the foliage infestation during the 15-day trials conducted in the 2014 season. The highest values were obtained with Avaunt (54.46% & 61.41%), followed by Runner (47.01 % & 47.47 %) and Match (41.18% & 44.51%) for the Spunta and Mondial varieties, respectively. Season 2015 similarly showed the same pattern. In general, all treatments reduced the PTM population in the foliage infestation and increased the yield of two kinds of potatoes as compared to the untreated control. Experiments lasting 15 days were more suitable than those lasting 10 days, and the Spunta type was more prone to foliage infestation than the Mondial variety.

4. Conclusion

Climate change is intensifying the threat posed by *P. operculella* through faster reproduction, range expansion, and increased pest pressure. Effective pest management will require climate-resilient strategies, improved forecasting models, and resistant crop varieties to mitigate these impacts.

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