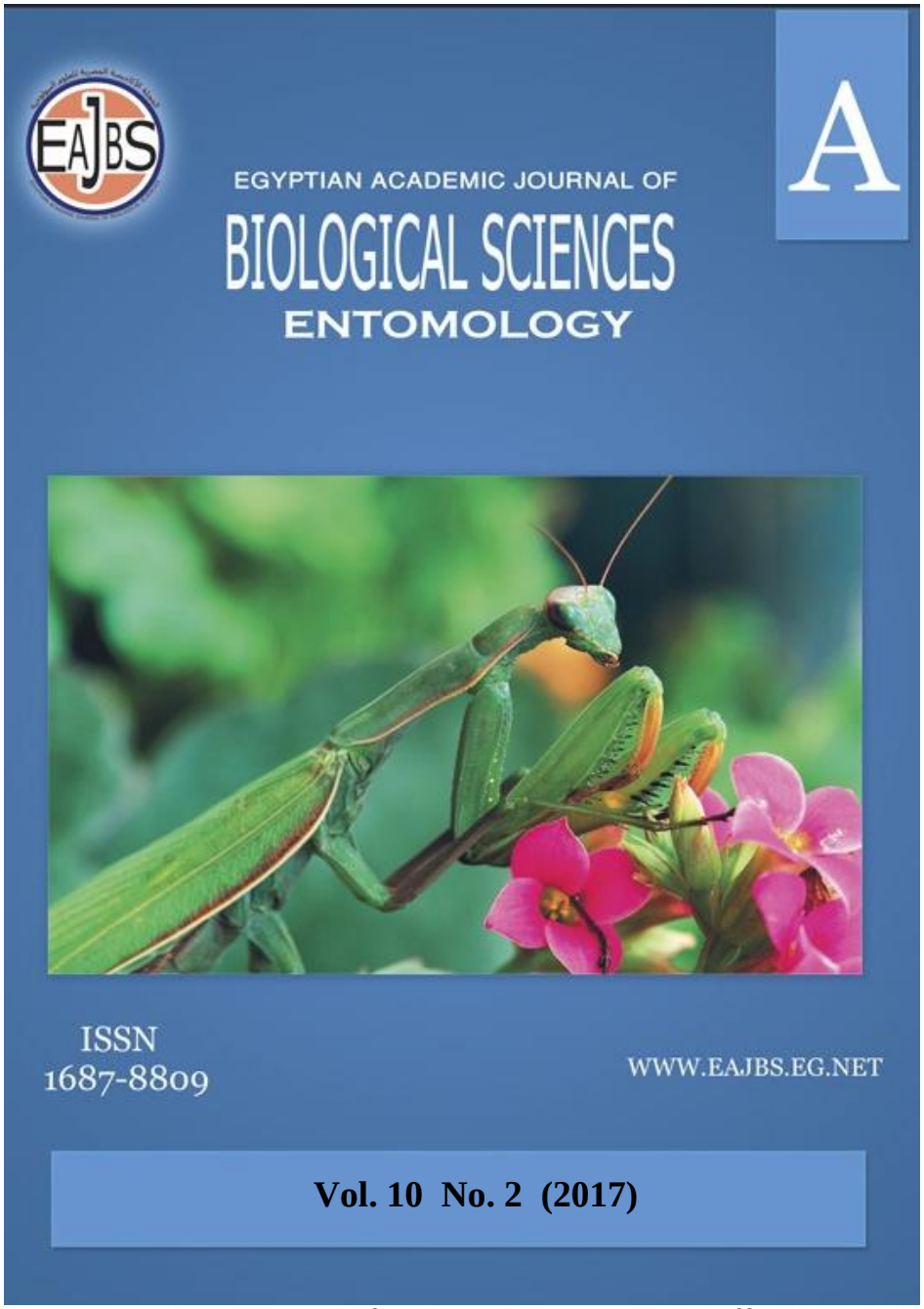

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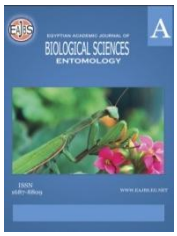

Yield losses caused to potato plants by potato tuber worm, *Phthorimaea operculella* (Zeller) and its economic levels at Qalyubyia Governorate

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ABSTRACT

The present investigation was carried out at Qalyubyia Governorate, Egypt during 2015 and 2016 summer plantations to estimate the losses in potato yield due to the infestation with *Phthorimaea operculella* (Zeller) and calculate the economic levels for its infestation. Results revealed that percentage of infested tubers was the most effective variable on potato yield than either number of larvae or number of holes/tuber. The correlation between these three variables and the yield was negatively highly significant. The explained variance values ranged between 89.08 and 92.35% for both years of study, respectively. The calculated economic threshold level (ETL) ranged between 15.68 and 21.50%; while the economic injury level (EIL) ranged between 24.97 and 26.61%.

INTRODUCTION

Potato production has been expanded in recent times and *Solanum tuberosum* is now one of the five most important food crops (Oerke, 2006). Insect pests in agricultural systems are one of the major causes of damage to crop production and storage (Thomas, 1999). In tropical countries, these pests are believed to cause losses approaching 60–70%, principally in stored products (Nwilene *et al.*, 2008). The potato tuberworm, *Phthorimaea operculella* (Zeller) is considered as one of the most important potato pests worldwide because of its closed relationship with its host, high adaptability to daily and seasonal changes, high reproductive potential and economic damage (Haines, 1977; Foot, 1979; Briese, 1986 and Herman *et al*., 2005). It is most active during the period from April to August. In the Middle East, *P. operculella* infestation can range between 1 and 65% in the field and storage (Fadli *et al*., 1974; Al-Ali *et al.*, 1975 and Farag, 1998). Little authors were interested in estimating the economic threshold for this serious pest (Ibrahim, 2000; Konar and Mohsain (2004); Basavaraju *et al*. (2009), Giri *et al*. 2013; Tsedaley, 2015). On the other hand, many authors estimated the economic losses of this dangerous pest (Sileshi and Teriessa (2001); Randon *et al.*, 2007; Doğramaci and Tingey, 2008). Global warming has changed the environment surrounding the insect species dramatically in certain areas of the world. This change affected the insect's pests population either in the open field or in storage places.

The aim of the present experiment was to re-estimate the losses in potato yield due to the infestation with *P. operculella* and re-calculate the economic levels for its infestation which helps in making proper management decision.

MATERIALS AND METHODS

An area of about half a feddan was cultivated with potato variety Spunta during the last week of February 2015 and 2016 at the Agricultural Experimental Station belongs to the Faculty of Agriculture, Ain Shams University, Shalakan, Qalyubyia Governorate. The chosen area was divided into 10 experimental plots each about 200 m^2 contained 16 lines. All agricultural practices recommended for cultivation was applied. By the end of the season; i.e. about four months later, the produce of 12 plants per plot was harvested in paper bags. The bags were left opened in the laboratory for drying in two days. After about one week of harvest the following procedures were taken place for assessing yield losses due to *Phthorimaea operculella* Zeller infestation: no. and weight of tubers/plant, no. of infested tubers/plant, no. of holes/tuber, larval content/tuber and accordingly the percentage of infestation was calculated. Finally the economic injury level and economic threshold levels were estimated by applying the (χ^2) procedures and formulae proposed by Steel and Torri (1980).

Yield weight gm/plant	% of infestation (a)	Sample size (R)	P (a/R)	a P
↓	a_1	R_1	P_1	a_1P_1
	a_2	R_2	P_2	a_2P_2
	a_i	R_i	P_i	a_iP_i
Total	C_1	G	$\bar{P}$	$\Sigma a_i P_i$

$\bar{P} = C_1/G \qquad \bar{q} = 1 - \bar{P}$

$\chi^2 = \Sigma a_i P_i - \{C_1 \bar{P}\} / \bar{P} * \bar{q}$

To estimate the relationship between the different infestation levels of *P. operculella* and the corresponding yield, the infestation parameters were taken as independent variables; i.e. infestation % as X_1, no. of larvae as X_2 and no. of holes/tuber as X_3 against the plant yield (g) as dependent variable (Y). The correlation between each of these independent variables and the resulting yield was calculated and accordingly the partial regression termed "C" multiplier (Fisher, 1950) was applied to obtain the combined effect of these three independent variables on the yield (Explained Variance %). The significance of this effect was expressed by the "F" value.

RESULTS AND DISCUSSION

Yield loss assessment

Data from laboratory examination of the tubers collected by the end of the experiment in 2015 season show that as infestation with *Phthorimaea operculella* increases from 0 to 52.0; the larval content from 0 to 7 and the number of holes/tuber from 0 to 9, the corresponding yield decreases from 1510 to 300 (g/ plant). The same results were confirmed in 2016 season since increasing the infestation from 0 to 60.2; the larval content from 0 to 8 and the number of holes/tuber from 0 to 12 had led to a reduction in the corresponding yield from 849 to 111 (g/ plant), (original data not shown here).

The relationship between the three infestation parameters and the corresponding

yield was studied through the correlation between each separate parameter and the yield from one hand and the partial regression for the combined effect of these three parameters on the yield from the other (Table 1).

Data in Table (1) reveal that the yield of potato plant was negatively correlated with each of infestation%, larval content and number of holes due to the presence of *P. operculella*. These three factors collectively were responsible for 89.08% in 2015 and 92.35% in 2016 of the variability in potato yield. The analysis of variance was also highly significant (F = 315.29 in 2015 and 466.69 in 2016).

Table 1: Simple correlation and partial regression values for the relationship between infestation parameters with *Phthorimaea operculella* and potato yield during 2015 & 2016 summer seasons, Qalyubyia Governorate

Season	Tested	Simple Correlation			Partial Regression			
	Variable	" r "	Prob.	" b "	s.e.	" t "	Prob.	
2015	Infestation %	-0.889	0.000	-24.51	13.98	0.265	0.791	E.V. = 89.08%
	No. of larvae	-0.939	0.000	-125.15	16.69	4.639	0.009	"F" Value
	No. of holes	-0.923	0.000	-99.38	14.14	2.980	0.003	315.29
2016	Infestation %	-0.928	0.000	-10.76	1.07	2.419	0.017	E.V. = 92.35%
	No. of larvae	-0.935	0.000	-53.40	6.09	1.782	0.077	"F" Value
	No. of holes	-0.959	0.000	-45.94	8.17	3.202	0.002	466.69

The relationship between the actual yield of 120 plants harvested in each season and the corresponding percentages of infestation is shown in Figs. (1 & 2) along with the corrected yield calculated on logarithmic basis.

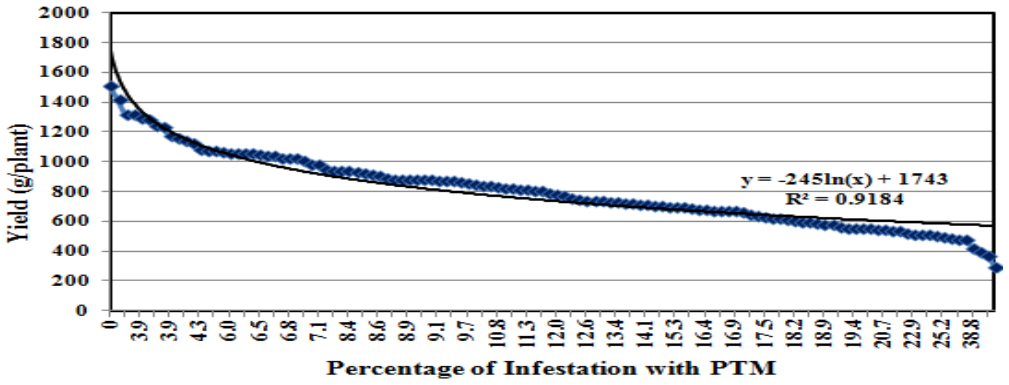

Fig. 1: The corrected yield of potato (Y) per unit change in potato tuber moth infestation during 2015 season, Qalyubyia Governorate

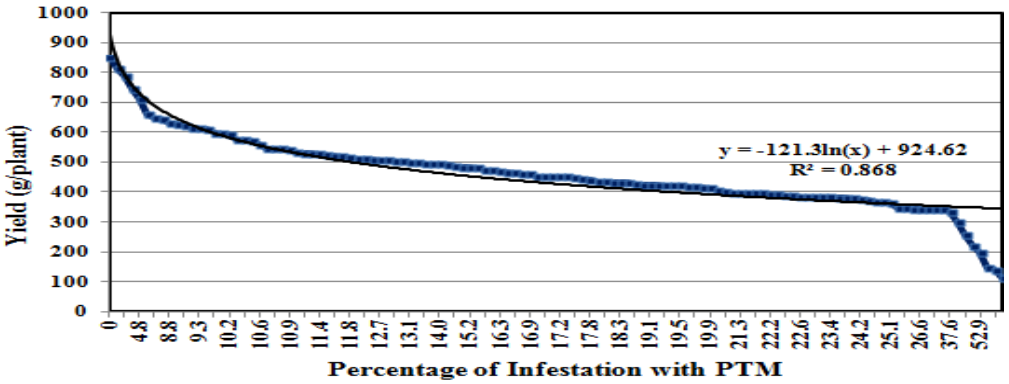

Fig. 2: The corrected yield of potato (Y) per unit change in potato tuber moth infestation during 2016 season, Qalyubyia Governorate

These results are closely agreed with those obtained by Assem and Abdel-Salam (1972) who reported that damage caused by *P. operculella* in February plantation was 24-27.5% of the tuber weight at harvest. Gugliemetti (1978) in Chile tested 20 potato cultivars against the infestation with *P. operculella*. He found that infestation among these cultivars ranged between 28.7 and 61.6%. Sileshi and Teriessa (2001) in Ethiopia reported that 8.7% of potato tubers were lost due to infestation with *P. operculella*. Based on potato prices at that time, the average loss was estimated to be 321.75 $/ha. Randon *et al*. (2007) reported that potatoes from several fields in the Columbia Basin of Oregon State were rejected for market due to *P. operculella* infestation which caused economic losses of about $2 million in 2003. Doğramaci and Tingey (2008) stated that *P. operculella* can cause 50% yield losses associated with grade-outs when tuber infestation ≥4% and that higher incidence of tuber infestation can render potatoes completely unmarketable in the U.S. Basavaraju *et al*. (2009) in India reported that yield losses due to PTM infestation ranged between 6 and 9% according to the area. Tsedaley (2015) reported that *P. operculella* is the most important constraint of potato production in Ethiopia and it causes up to 42% yield losses in storage.

Estimation of economic levels

Data shown in Table (2) show the calculation of the different economic levels for the infestation with *Phthorimaea operculella* at Shalakan, Qalyubyia Governorate during 2015 season.

Table 2: Chi square (χ^2) analysis for the changes in potato yield due to the increases in infestation with *Phthorimaea operculella* during 2015 summer season, Shalakan, Qalyubyia Governorate.

Calc. χ^2	Category No.	**Yield weight (g/plant)**	**Infestation % (a_i)**	**Sample Size (R)**	**P_i (a/R)**	**a_iP_i**	
3.98	1	1392.75	0.00	100	0.000	0.000	**GEP**
	2	1222.86	3.90	100	0.039	0.152	
	3	1087.80	4.32	100	0.043	0.187	
	4	1046.80	6.46	100	0.065	0.417	
	5	969.83	7.42	100	0.074	0.551	
	6	904.18	8.70	100	0.087	0.757	
	7	866.25	9.38	100	0.094	0.880	
	8	832.25	10.73	100	0.107	1.151	
	9	812.50	11.43	100	0.114	1.306	
	10	761.63	12.38	100	0.124	1.533	
	11	727.50	13.55	100	0.136	1.836	
	12	710.00	14.52	100	0.145	2.108	
23.24	13	695.00	15.68	100	0.157	2.459	**ETL**
	14	676.80	16.62	100	0.166	2.762	
	15	635.71	17.53	100	0.175	3.073	
	16	594.80	18.58	100	0.186	3.452	
	17	563.20	19.34	100	0.193	3.740	
	18	537.43	21.26	100	0.213	4.520	
56.33	19	500.00	24.97	100	0.250	6.235	**EIL**
	20	393.40	41.62	100	0.416	17.322	
	Total		**278.39**	**2000**	**2.784**	**54.442**	

GEP = General Equilibrium Position
ETL = Economic Threshold Level
EIL = Economic Injury Level

These data clearly reveal that the general infestation with the pest was higher than in 2016. The general equilibrium position was reached when the infestation was

below 4%, in this case the plant yield was 1392.75 g. When infestation increased up to 15.86%, the corresponding yield decreased to 695.0 g/plant (χ^2 value was 23.24; the Economic Threshold Level). When the infestation increased again up to 24.97%, the yield was reduced drastically to only 500.0 g/plant (χ^2 value was 56.33; The Economic Injury Level).

Data shown in Table (3) show the calculation of the different economic levels for the infestation with *P. operculella* at Shalakan, Qalyubyia Governorate during 2016 season. These data reveal that less than 7% of PTM infestation causes insignificant reduction in yield and the population of the pest at this point will be in equilibrium position (GEP); the calculated (χ^2) value was 7.21. As the infestation % increased up to 21.5%, the losses in potato yield decreased until it reached 396.83 g/plant (Economic Threshold Level; calculated χ^2 value was 21.71). Increasing the infestation percentage up to 26.61% caused the yield to reach only 342.33 g/plant which was considered as the Economic Injury Level (χ^2 value was 54.76).

Table 3: Chi square (χ^2) analysis for the changes in potato yield due to the increases in infestation with *Phthorimaea operculella* during 2016 summer season, Shalakan, Qalyubyia Governorate.

Calc. χ^2	Category No.	**Yield weight**	**Infestation %**	**Sample Size**	**P_i**	**a_iP_i**	
		(g/plant)	**(a_i)**	**(R)**	**(a/R)**		
7.21	1	798.00	0.00	100	0.00	0.00	**GEP**
	2	653.00	7.02	100	0.07	0.49	
	3	611.20	9.38	100	0.09	0.88	
	4	564.10	10.53	100	0.11	1.11	
	5	523.33	11.48	100	0.11	1.32	
	6	506.80	12.58	100	0.13	1.58	
	7	497.60	13.18	100	0.13	1.74	
	8	484.43	14.98	100	0.15	2.24	
	9	461.88	16.64	100	0.17	2.77	
	10	443.75	17.51	100	0.18	3.07	
	11	429.20	18.47	100	0.18	3.41	
	12	418.00	19.54	100	0.20	3.82	
21.71	13	396.83	21.50	100	0.22	4.62	**ETL**
	14	387.67	22.52	100	0.23	5.07	
	15	381.33	23.49	100	0.23	5.52	
	16	364.50	24.64	100	0.25	6.07	
54.76	17	342.80	26.61	100	0.27	7.08	**EIL**
	18	322.33	62.76	100	0.63	39.39	
	Total			**2000**	**3.33**	**90.18**	

GEP = General Equilibrium Position
ETL = Economic Threshold Level
EIL = Economic Injury Level

Roux *et al.*, (1992) in Tunisia calculated the action threshold for *P. operculella* infestation at 20% of damaged tubers. Ibrahim (2000) reported the presence of a negative significant correlation between percentage of infestation with *P. operculella*, larval content and number of holes/tuber and potato plant yield. He estimated the damage threshold level at 4% infestation and the EIL at 13%. Konar and Mohsain (2004) in West Bengal found that percentage of damaged tubers in Bionchee area ranged between 5.8 and 17.3%. Randon (2010) in USA reported that the greatest risk of tuber damage due to *P. operculella* infestation occurs immediately before harvest while the crop is left in the field prior to digging and that potatoes that are left in the field for any period of time can become infested. Giri *et al*. (2013) estimated the initial damage due to PTM as less than 5% infestation to foliage or tubers. They also

mentioned that this percentage is enough to spread infestation to all storage conditions.

Finally, It is very important to emphasise that applying these economic levels in the field through the extension services is very helpful from the economic point of view to avoid as possible the great losses in potato yield. In addition, applying other control methods such as agricultural and mechanical methods along with using sex pheromone traps are very important in the IPM of this pest.

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ARABIC SUMMERY

الفاقد في محصول نباتات البطاطس نتيجة الإصابة بدودة درنات البطاطس *Phthorimaea operculella* (Zeller) ومستوياتها الاقتصادية في محافظة القليوبية

يوسف عزالدين يوسف عبد الله
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أجريت التجربة الحالية في محافظة القليوبية ، مصر خلال العروتين الصيفتين لعامي ٢٠١٥ ، ٢٠١٦ لتقدير الفاقد في محصول البطاطس نتيجة الإصابة بحشرة دودة درنات البطاطس *Phthorimaea operculella* (Zeller) ولحساب الحدود الاقتصادية للإصابة. تشير النتائج المتحصل عليها إلى أن نسبة الإصابة بالدرنات هي العامل الأكثر تأثيراً على محصول البطاطس عن أي من عدد اليرقات أو عدد الثقوب / الدرنة، وكان هناك ارتباطاً سالباً شديد المعنوية بين كل من هذه العوامل والمحصول الناتج، وتراوحت نسبة التأثير المشترك لهذه المتغيرات الثلاثة على المحصول الناتج بين ٨٩,٠٨ و ٩٢,٣٥% لعامي الدراسة على التوالي. تراوحت قيمة الحد الاقتصادي للضرر ما بين ١٥,٦٨ ـ ٢١,٥٠% بينما تراوحت قيمة الحد الحرج للإصابة بين ٢٤,٩٧ ـ ٢٦,٦١%.