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Monitoring the carpenter worm *Paropta paradoxa* (Lepidoptera:Cossidae) infesting apple orchards in Egypt

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Abstract:

In apple orchards, the carpenter worm *Paropta paradoxa* (Herrich-Schäffer) (Lepidoptera:Cossidae) became recently a serious pest in Egypt. Monitoring the population fluctuation was conducted at Nobaria district, Beheira Governorate during the two successive years (2017 and 2018). The rate of infestation approximated 14% (11.5 – 16.5% infested trees), while the degree of infestation reached 1.235 (1.47 – 2.47) moths per tree. The seasonal abundance of the adult moths prevailed from early or late March to early or late November, with mostly two or three flight peaks. The major moths ' flight period was in summer months (July-September) (1.10 moths in 2017 to 1.46 moths / tree in 2018), while spring months (April-June) recorded moderate numbers, being 0.79 to 1.01 moths /tree. Autumn was the minor (0.12 to 0.16 moths/tree), however winter was scant (0.02 – 0.04 moths / tree). The total numbers per year were 2.05 and 2.33 moths / tree during 2017 and 2018, respectively. There was two brood of moths' activity in 2017, but three broods in 2018. There were 8.5 months of moths' activity each year. Effect of weather factors on the moths' activity was mostly positive and significant with daily maximum, daily minimum and daily mean temperatures but mostly negative and insignificant with daily mean relative humidity. Infestation was much doubled during only one year, thus needed urgent integrated control.

Introduction

Apple plantations (*Pyrus malus*, Rosaceae) in Egypt, became profitable cash crop. The area under cultivation extended through the old Delta and valley lands as well as new reclaimed lands. Frequent field observations allover the Governorates of Egypt , in both old valley lands and new reclaimed desert lands , indicated that in addition to *Paropta paradoxa* (Herrich-Schäffer) (Lepidoptera: Cossidae) (Kinawy *et al.,* 1991), the other major lepidopteran stem boring insect pests in apple orchards were, *Zeuzera pyrina* (Linnaeus) (Lepidoptera :Cossidae) (Tadros *et al.,* 2003) and *Synanthedon myopaeformis*

Borkhausen (Lepidoptera :Sessidae) (Tadros *et al.,* 2004).

In addition to apple, *P. paradoxa* is a dangerous pest in Egypt in fig orchards (Willcocks, 1937), apple orchards (Kinawy *et al*., 1991), grape vineyards (Tadros, 1982) and mandarin trees (El-Assal *et al*., 2008).

Young larvae *P. paradoxa* bore directly into twigs, branches and main trunks immediately after hatching. Young larvae bored sapwood, while old larvae bored heartwood. Larval tunnels that might reach 8 mm. in diameter were always kept open and enlarged gradually. Mature larvae lined their tunnels with loose dim silky webbing. Pupation occurred at the end of the tunnels and the pupal skins partially protruded from the opening after moth emergence (Kinawy, 1981). Moths started flight in fig orchard at Alexandria Governorate, from mid-April / late May until late October / late November resulting in two peaks of activity during early July and late August / early September (Mesbah *et al.*, 1993).

Successful integrated pest control depends largely on monitoring studies especially the seasonal fluctuation in the target pest population, the progress of infestation, the seasonal cycle and the effect of the main weather factors on the target pest. In an attempt to contribute to such a gap in the knowledge, the present comparative ecological studies are aimed. The broad objective of investigation is to add new information that may help in planning of rather effective "Integrated Control Programs" for the management of *P. paradoxa* in apple orchards.

Materials and methods

Monitoring studies of *P. paradoxa* were conducted in apple orchards located in the reclaimed lands, at Nobaria district, Beheira Governorate. Monitoring studies extended during two successive years form early January, 2017 until late December, 2018. Only specific safe control treatments were applied in the selected areas throughout the studies.

Rate and degree of infestation:

Assessment of the rate of infestation was calculated as the percentage of numbers of randomly distributed infested trees with *P. paradoxa* in two apple orchards each year. The degree of infestation was estimated by the mean number of adult moths per tree (indicated by the newly protruding pupal skins) that completed their life cycle and emerged from apple trees each year. Estimation of rate and degree of infestation was carried out in 100 random trees.

1. Population fluctuation of *Paropta paradoxa*:

1.1. Seasonal abundance:

The seasonal abundance of *P. paradoxa* was carried out in apple orchards, about 5 feddans in area with trees approximately 12 years old located at Nobaria district, Beheira Governorate. Monitoring *P. paradoxa* covered two successive years (2017 and 2018).

During December 2016, the old pupal skins were removed and from January 1st , 2017 until December 31, 2018, the newly protruding pupal skins indicating emergence of moths of *P. paradoxa* were counted at half monthly intervals on the 15th and last day of every month. To avoid repeated counting newly protruding pupal skins were immediately removed after counting.

1.2. Progress of infestation and seasonal cycles:

Data of the seasonal abundance were accumulated from January 1st , 2017 until December 31, 2018 for each half monthly interval. The total numbers of moths (pupal skins) represented the accumulated number for the two years together. The presented Figures indicated the periods of the seasonal cycles of moths' activity and inactivity. Progress of infestation also indicated the rate of increase in the borer infestation year after another.

2. Effect of weather factors on the activity of *Paropta paradoxa*:

Four main weather factors, the day maximum temperature (DMxT), day minimum temperature (DMnT), day mean temperature (DMT) and day mean relative humidity (DMRH) were considered in this study. Necessary weather data were obtained from the Central Laboratory of Climate and Meteorology, Agricultural Research Centre, Giza. Population data of *P. paradoxa* taken into account and the meteorological data, both at half monthly intervals, were presented. The relationship between the four weather factors and the moths' population data during the activity season was investigated for two successive years (from January 2017 until December 2018) in the two apple orchards.

To determine the direct effect of each weather factor on the borer activity, population counts were plotted against the corresponding weather data. The simple correlation coefficients "r" for the relationship between each weather factor and *P. paradoxa* population was then worked out according to Snedecor and Cochran (1990).

Results and discussion

1. Rate and degree of *Paropta paradoxa* infestation:

Data in Table (1) clarified that *P. paradoxa* infestation markedly increased in apple orchards year after another. In two apple orchards at Nobaria district, Beheira Governorate, the percentages rate of infestation increased in the 1st orchard from 12% in December 2017 to 21% in December 2018 (mean, 16.5%), but in the 2nd orchard the percentages rate of infestation increased from 7% in December 2017 to 16% in December (mean, 11.5%). The approximated grant mean rate of infestation was 14%.

Although the number of larvae completed their development and emerged per tree (indicated by the pupal exuvia protruding on trees) in the 2nd orchard was only 0.67 (0.43 – 0.91), yet it was 1.80 (1.57 – 2.03) in the 1st orchard. The grand mean degree of *P. paradoxa* infestation approximated 1.235 (1.00 – 1.47) moths per apple tree. This is a serious parameter of the progress of the rate and degree of *P. paradoxa* infestation in apple orchards in Egypt.

Table (1): Rate and degree of *Paropta paradoxa* infestation in apple orchards at Nobaria district, Beheira Governorate during 2017 and 2018 activity seasons.

Year		**2017**	**2018**	**Total**	**Mean**
Rate of infestation (%)	1st orchard	12	21	33	16.5%
	2nd orchard	7	16	23	11.5%
	Grand Mean	**9.5**	**18.5**	**28**	**14%**
Degree of infestation (number of pupal skins /tree)	1st orchard	1.57	2.03	3.60	1.80
	2nd orchard	0.43	0.91	1.34	0.67
	Grand Mean	**1.00**	**1.47**	**2.47**	**1.235**

2. Population fluctuation of *Paropta paradoxa*:

2.1. Seasonal abundance:

As shown in Tables (2 and 3) and Figure (1), the moth's activity of *P. paradoxa* prevailed during the period from early or late March to early or late November in apple orchards at Nobaria district, Beheira Governorate during the two years of study (2017 and 2018 seasons).

The flight commencement of moths started between the 1st half of March (0.01 moths / tree) in 2017, and the 2nd half of March (0.02 moths / tree) in 2018 at Nobaria district, Beheira Governorate. Two or three flight peaks of *P. paradoxa* moths' emergence were recorded at Nobaria district, Beheira Governorate. Table (3) clarified that the first peak of moths' activity mainly fluctuated between the 1st half of March 2018 (0.19 moths / tree) and 2nd half of March 2017 (0.18 moths / tree). A second peak of moths' activity occurred during the 2nd half of June 2018 (0.30 moths / tree). The second peak in 2017 was noticed in the 2nd half of July (0.25 moths / tree). The third peak of moths' activity fluctuated during the same 2nd half of July 2018 (0.35 moths / tree).

At Nobaria district, Beheira Governorate, the last flight of moths was recorded during the 1st half of November in 2017 (0.02 moths / tree) and the 2nd half of November in 2018 (0.01 moths / tree). Tables (2 and 3) further indicated that the maximum *P. paradoxa* moths' flight was during summer months (July - September) showing 1.10 and 1.46 moths / tree in 2017 and 2018 seasons, respectively.

Spring months (April - June) recorded moderate numbers, being 0.79 moths / tree in 2017 and 1.01 moths / tree in 2018 seasons. Autumn months (October - December) showed few numbers, 0.12 and 0.16 moths /tree during 2017 and 2018 seasons, respectively.

Scant numbers of moths' activity was during winter months (January - March), showing 0.04 a nd 2.02moths / tree during 2017 and 2018 seasons, respectively. Moreover, the total numbers of moths emerged during the whole year were 2.05 and 2.33 moths / tree at Nobaria district, Beheira Governorate during 2017 and 2018 seasons, respectively. The respective means per month were 0.171 and 0.194 moths / tree during 2017 and 2018 seasons, respectively.

Data in Table (3) and Figure (1) emphasized that at Nobaria district, Beheira Governorate, *P. paradoxa* had two brood of moths' activity in 2017 or three broods in 2018. In 2017, the first brood prevailed from the 1st half of March to the 1st half of September and the second from the 2nd half of April to the 1st half of November. In 2018, the first brood prevailed from the 2nd half of March to the 1st half of August and the second from the 1st half of May to the 1st half of October and the third brood from the 1st half of June to the 2nd half of November.

Table (2) : Mean number of *Paropta paradoxa* moths in apple orchards at Nobaria district, Beheira Governorate during 2017 and 2018 activity seasons with the corresponding day mean temperature (DMT) and relative humidity (DMRH).

Date of inspection		2017 season		2018 season		2017 Season		2018 Season	
		Actual	Cumulative	Actual	Cumulative	DMT °C	DMRH %	DMT °C	DMRH %
January	1-15	0.0	0.0	0.0	2.05	16.5	72	16.1	70
	16-31	0.0	0.0	0.0	2.05	17.3	70	16.6	71
February	1-15	0.0	0.0	0.0	2.05	19.5	65	17.5	67
	16-28	0.0	0.0	0.0	2.05	20.3	55	22.1	57
March	1-15	0.01	0.01	0.0	2.05	23.5	59	23.5	59
	16-31	0.03	0.04	0.02	2.07	25.6	62	24	61
Winter		**0.04**		**0.02**					
April	1-15	0.06	0.10	0.05	2.12	28.3	52	27	52
	16-30	0.09	0.19	0.10	2.22	29.5	47	30.8	46
May	1-15	0.11	0.30	**0.19**	2.41	31.7	53	28	51
	16-31	**0.18**	0.48	0.16	2.57	33.9	42	30.1	43
June	1-15	0.15	0.63	0.21	2.78	35.3	51	33.6	52
	16-31	0.20	0.83	**0.30**	3.08	35.6	49	34.3	48
Spring		**0.79**		**1.01**					
July	1-15	0.22	1.05	0.26	3.34	36.1	52	35.2	53
	16-31	**0.25**	1.30	**0.35**	3.69	36.5	60	35.5	62
August	1-15	0.21	1.51	0.28	3.97	36.2	60	36.9	60
	16-31	0.19	1.70	0.24	4.21	35.8	63	34.2	63
September	1-15	0.13	1.83	0.20	4.41	33.6	61	32.8	60
	16-30	0.10	1.93	0.13	4.54	32.1	57	30	58
Summer		**1.10**		**1.46**					
October	1-15	0.07	2.00	0.09	4.63	29.1	61	29.3	62
	16-31	0.03	2.03	0.04	4.67	28.2	60	27.6	60
November	1-15	0.02	2.05	0.02	4.69	26.3	62	27.1	63
	16-30	0.0	2.05	0.01	4.70	23.5	59	25.5	58
December	1-15	0.0	2.05	0.0	4.70	21.5	58	22.2	58
	16-31	0.0	2.05	0.0	4.70	19.2	63	20.0	59
Autumn		**0.12**		**0.16**					
Grand Total		**2.05**	**2.05**	**2.33**	**4.70**				
Mean / month		**0.171**		**0.194**					

Table (3): Commencement, peak, last dates and broods of *Paropta paradoxa* moths in apple orchards at Nobaria district, Beheira Governorate during 2017 and 2018 activity seasons.

	2017 season	2018 season
Flight Commencement	1st half of March	2nd half of March
Peaks	2nd half of May	1st half of May
		2nd half of June
	2nd half of July	2nd half of July
Last flight	1st half of November	2nd half of November
Broods	1st half of March to the 1st half of September	2nd half of March to the 1st half of August
		1st half of May to the 1st half of October
	2nd half of April to the 1st half of November	1st half of June to the 2nd half of November

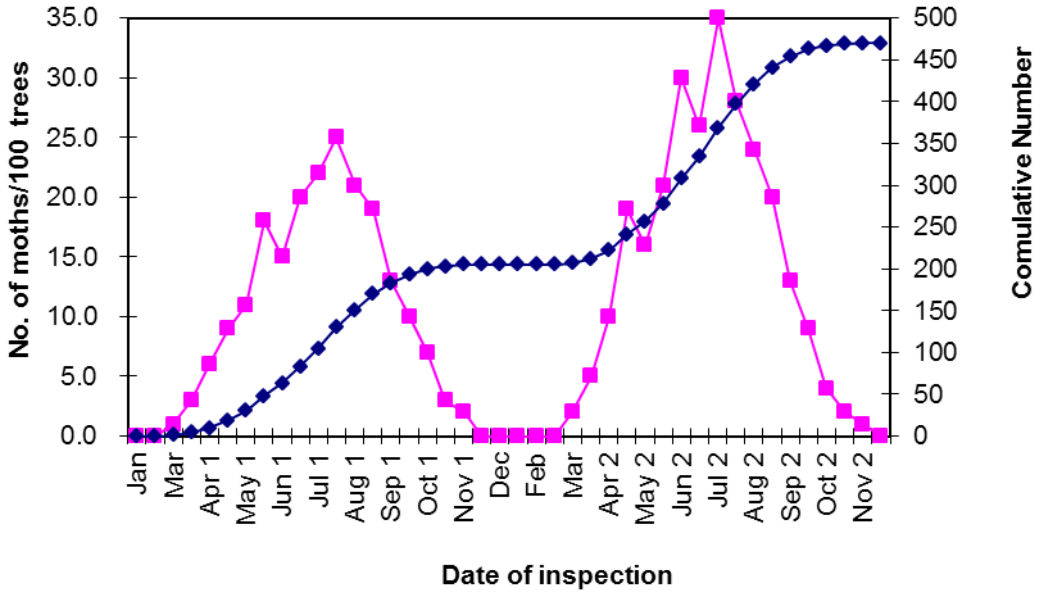

Figure (1): Mean numbers of *Paropta paradoxa* moths in apple orchards at Nobaria, Beheira Governorate during 2017 and 2018.

2.2. Progress of infestation:

The cumulative numbers (seasonal cycle) of emerged moths (Figure, 1) indicated that there was 8.5 months of moths activity at Nobaria, Beheira Governorate followed by 3.5 months of moths inactivity. Infestation was more than doubled each only one year. Infestation / tree / year increased from 2.05 moths at the end of 2017 to 4.70 moths at the end of 2018. This serious parameter imposed urgent need of controlling the pest.

2.3. Effect of temperature and relative humidity on moths activity:

Statistical analysis revealed that the fluctuation in *P. paradoxa* moths' population was significant and positively correlated with the temperature in the two years of study, that day maximum temperature (DMxT) showed "r" from 0.8133 to 0.8271, day minimum temperature (DMnT) resulted in "r" from 0.8065 to 0.8098, and day mean temperature (DMT) calculated "r" from 0.7753 to 0.7949). On the contrary, the

effect of day mean relative humidity (DMRH) on moths' population was insignificant and negative where "r" resulted in -0.1987 to -0.12031. Statistically, there were combined effect of all the weather factors: the DMxT, DMT, DMnT and DMRH on *P. paradoxa* moths' population fluctuation in the studied apple orchards than the effect of each single factor. The combined effect of these weather factors on moths' activity (explained variance "E.V.") ranged between 61.3% and 66.9%. This may be due to the hidden larval and pupal stages inside the wood of the trees not exposed to the direct weather factors. However, these weather factors strongly affect the whole ecosystem of the apple orchards.

Monitoring studies (especially the seasonal fluctuation of the pest population, progress of infestation, seasonal cycle and effect of the main weather factors on the target pest) are essential in planning successful and effective "Integrated Control Programs" for the management of pest. Survey studies indicated that *P. paradoxa* became recently dominant and economically important boring pest in apple orchards. In apple orchards moths' activity started from March and emergence was stopped by November. The activity seasons (8.5 months) were mostly in summer and spring, but few in autumn and late winter season showed scant moths activity. There were two to three broods of the borer activity each year. Infestation was more doubled each one year, thus needed urgent integrated control. Generally, there were positive and significant effects of major weather factors: daily maximum, daily minimum and daily mean temperatures on the borer activity, but this effect was mostly negative and insignificantly with daily mean relative humidity.

Literature is few concerning studies on *P. paradoxa* in apple orchards as well as other fruit hosts, yet in Egypt, researches focused on fig (Kinawy, 1981; Mesbah *et al.*, 1993 and Hashim, 2004), grapevine (Tadros, 1982), mandarine (El-Assal *et al.*, 2008) and apple (Kinawy *et al.*, 1991) trees. Theses researches stated that immediately after egg hatching the young larvae of *P. paradoxa* bore directly into twigs, branches and main trunks. Young larvae bored sapwood, while old ones bored heartwood. Mature larvae lined their tunnels with loose dim silky webbing. Pupation occurred at the end of the tunnels and the pupal skins partially protruded from the opening after moth emergence. Population studies indicated that moths' population fluctuation of *P. paradoxa* on the previous fruit host trees emerge prevailed from the April / May until October / November, with one or two major peacks. Mesbah *et al.* (1993) stated that the life cycle of *P .paradoxa* on fig trees recorded 370 -422 days. They stated that emergence of *P. paradoxa* moths highly affected with the temperature but the relative humidity had less effect. Abroad, Plaut and Tsour (1975) in the Jordan valley and the Shomorn foothills, found that in grapevine yards emergence of *P. paradoxa* adults began during first or second ten days of April, while in the Yizreil valley emergence of adult moths began late April or early May. The main emergence period ended in early July in Jordan valley and in September in the Shomorn foothills.

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