Journal of Phytopathology and Pest Management 5(3): 14-28, 2018
pISSN:2356-8577 eISSN: 2356-6507
Journal homepage: http://ppmj.net/

Relationship between the population density of the white mango scale insect, *Aulacaspis tubercularis* (Newstead) (Hemiptera: Diaspididae) and the yield loss of mango trees in Luxor Governorate, Egypt

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Abstract

The main objective of this work is to estimate the relationship between the pest population, *Aulacaspis tubercularis* (Newstead), infestation through pest activity peaks in September, November, April and June on the yield loss of Goleck mango trees at the district of Esna, Luxor Governorate through two seasons (2016/2017 and 2017/2018). The results revealed that the increment of population density and incidence infestation by the pest gradually decreased the yield of mango, consequently increased the percentage of the yield loss when the data of the yield were colligated with the pest population peaks and its infestation incidence in September, November, April and June months through 2016/2017 and 2017/2018 seasons.Increasing one individual of pest per leaf caused a reduction of the mango yield by 2.14, 1.56, 2.05 and 4.28 kg/tree and 2.08, 1.42, 2.46 and 1.31 kg/tree through the peaks of the two seasons, respectively. Subsequently, increased the yield loss percentages by 1.52, 1.12, 1.47 and 3.06% and 1.44, 0.98, 1.70 and 0.90% when the yield data were correlated with the population density of the pest in September, November, April and June peaks during the two connective seasons (2016/2017 and 2017/2018), respectively. These results confirmed that the pest population and the percentages of infestation incidence of *A. tubercularis* during the peak of April caused the least expected values in the yield of mango and the greatest loss in mango yield. On contrary, the peak during November was less effective, causing the highest expected values in mango yield and the lowest reduction in the yield of mango during the seasons of 2016/2017 and 2017/2018. Generally, the reduction in the yield of mango was a summation of different factors (time, level and variety ability to infestation).

Keywords: *Aulacaspis tubercularis*, pset population, mango, yield reduction.

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Introduction

Mango trees are subjected to infestation by different pests. Among these pests, the white mango scale insect, *Aulacaspis tubercularis* (Newstead) (Heimptera: Diaspididae), which is considered one of the most destructive pests of mango trees. It is now widespread in many mango-growing countries. This pest injures the shoots, twigs, leaves, branches and fruits (sucking plant sap, causing deformations, defoliation, drying up of young twigs, dieback, poor blossoming, death of twig by the action of the toxic saliva) and so affecting the commercial value of fruits and their export potential especially to late cultivars where it causes conspicuous pink blemishes around the feeding sites of the scales (Nabil et al., 2012; Sayed, 2012). In nurseries, a severe early stage infestation retards growth. Young trees are particularly vulnerable to excessive leaf loss and death of twigs during the hot dry weather (El-Metwally et al., 2011). The heavily infested premature fruits dropped while the mature fruits became smaller in size with lacking of juice and unfit for use. The total death of the plant can become evident if infestation occurs as of nursery stage (Abo-Shanab, 2012; Bakr et al., 2009). In Egypt, *A. tubercularis* was one of the most serious scale insect pests on mango trees. It recorded 27.5% of the scale insects on mango trees at Qaliobiya Governorate, Egypt (Bakr et al., 2009). This investigation aimed to evaluate the relationship between the insect population and the infestation incidence percentages of *A. tubercularis* during four peaks of its seasonal activity (independent factors) on percentage of mango yield loss (dependent factor) during two seasons (2016/2017 and 2017/2018).

Materials and methods

This investigation was carried out on mango trees in a private orchard situated at Esna, Luxor Governorate, Egypt during the period from August, 2016 to July, 2018, to clarify the effect of the infestation levels by *A. tubercularis* on the yield of Goleck mango variety. The samples consisted of fifteen Goleck mango trees (Five uninfested and ten infested trees, homogeneous in their infestation with this scale, were selected from different parts of the orchard). The selected trees (infested and uninfested) were approximately the same in age, height (6-7 m) and received the same horticultural practices. The infested mango trees which were selected for carrying out this experiment were not exposed to any chemical control measures before and during the period of investigation. Regular bimonthly samples consisted of 20 leaves/tree were chosen in random from different directions and levels of the mango trees then transferred to the laboratory in polyethylene bags for inspection using a stereo-microscope. Total numbers of alive insects on upper and lower surfaces of mango leaves were counted in each inspection date. The monthly mean numbers of the total population of *A. tubercularis* per leaf was considered in this study to express the population size of pest. The yield of each uninfested and infested mango trees was assessed. In this investigation, used different insect expressions, which articulated the population density of this pest. Two insect expressions were utilized, *i.e.*, insect population and incidence of infestation.

The infestation incidence or relative abundance or the percentage of infested leaves by pest was calculated according to the formula described by Facylate (1971):

$$A = (n\ /\ N) \times 100$$

Where, A = the percentage of infestation incidence or the percentage of infested leaves. n = No. of infested leaves in which the pest appeared. N = Total number of leaves (Uninfested + Infested) taken of each inspection date.

Simple regression was used to elucidate the variability of yield loss that could be caused by the pest during the four peaks of seasonal activity. Partial regression was used to find out the simultaneous effects of insect activity peaks in September, November, April and June on mango yield. The equation of linear regression was calculated according to the following formula of Fischer (1950) and Hosny et al. (1972):

$$Y\ = a \pm bx$$

Where: Y = Prediction value (Dependent variable). a = Constant (y - intercept). b = Regression coefficient. x = Independent variable.

This method was helpful in obtaining basic information about the amount of variability in the yield that could be attributed to these peaks of activity, together, which was calculated as percentage of explained variance (E.V.%). The partial regression values indicate the average rate of change in yield due to a unit change in any of the four peaks of insect activity. Statistical analysis in this present work was carried out by MSTATC Program, 1980. All figures were done by Microsoft Excel 2010. The amount of yield losses and damage due to scale insect were calculated according to the following equation:

$$\text{Yield loss } (\%) = \frac{A - B}{A} \times 100$$

Where: A = Yield for uninfested trees. B = Yield for infested trees. *Average yield of mango for uninfested trees were 140 and 145 kg/tree during the first and the second seasons of the study, respectively.

Results and Discussion

Seasonal activity of *A. tubercularis* on mango trees: The half-monthly counts of alive stages of *A. tubercularis* infested Golck mango trees and the infestation incidence by pest at the studied district were recorded during the seasons of 2016/2017 and 2017/2018. Accordingly, it's better to discuss the peaks of seasonal activity on the basis of monthly mean numbers for both of them at the successive sampling dates.

Seasonal activity of *A. tubercularis* total population: Data in Table 1 revealed that the peaks of the total population density of *A. tubercularis* during September, November, April and June, when the general average of the population density were 116.64, 147.71, 80.84 and 90.53 individuals/leaf in the first season and were121.67, 149.57, 88.23 and 92.83 individuals/leaf in the second season, respectively. Furthermore, the population density was varied in the four peaks. The second peak of the pest in November was the biggest ones in size than that of the other peaks, but the lowest was recorded in the third peak in April during the two seasons. Also, the peaks of the total population of the pest through the second season was higher than the first season, which that might be due to the favorable factor influences (*i.e.* environmental conditions,…*etc*.).

Seasonal activity of the infestation incidence percentages: The trends of the infestation incidence percentages and the population density by *A. tubercularis* (peaks) during the investigation period were similar and represented in Table (2). The percentages of infestation incidence have four peaks occurred in September, November, April and June with a general average of 93.83, 95.50, 78.83 and 84.00 % in the first season and of 95.67, 97.00, 82.00 and 84.67% during the second season, respectively. The results showed that the percentages of infestation incidence were varied during the four peaks. The third peak of the pest which occurred in April was the lowest one, whereas the highest one was recorded in the second peak during November in the two seasons. Also, the percentages of infestation incidence through the first season was small comparing to the second season, which might be due to the favorable factor influences (*i.e.* environmental conditions,…*etc*.) (Table 2).

Table 1: Effect of infestation by *A. tubercularis* total population on the yield of Goleck mango variety during four peaks of the seasonal activity of the pest during the two seasons (2016/2017 and 2017/2018).

Season	Inspected trees	Yield (kg)	Yield reduction (%)	Peaks of *A. tubercularis* total population				Average of population density
				Sept.	Nov.	Apr.	Jun.	
2016/2017	1	134	4.29	106.09	141.50	69.86	86.20	100.91
	2	130	7.14	112.77	141.98	76.95	86.77	104.62
	3	126	10.00	114.31	144.09	79.23	89.71	106.83
	4	124	11.43	116.49	144.54	80.09	90.42	107.88
	5	120	14.29	116.64	144.76	80.84	91.16	108.35
	6	118	15.71	116.64	147.71	80.84	91.17	109.09
	7	114	18.57	119.33	147.71	82.69	91.24	110.25
	8	110	21.43	120.16	148.92	84.51	92.07	111.42
	9	104	25.71	121.81	152.63	85.30	93.02	113.19
	10	100	28.57	122.18	163.29	88.13	93.50	116.77
Average		118.00	15.71	116.64	147.71	80.84	90.53	108.93
2017/2018	1	132	8.97	111.34	142.51	80.62	76.23	102.67
	2	128	11.72	118.01	142.58	83.63	89.63	108.46
	3	124	14.48	119.23	146.58	85.01	92.53	110.84
	4	122	15.86	121.67	147.56	86.82	92.55	112.15
	5	118	18.62	121.67	147.81	89.29	92.72	112.87
	6	116	20.00	121.80	149.57	89.69	94.09	113.79
	7	112	22.76	124.31	149.57	90.42	94.73	114.76
	8	108	25.52	125.11	150.16	90.98	94.89	115.29
	9	104	28.28	126.71	153.98	92.22	97.93	117.71
	10	100	31.03	126.82	165.37	93.59	102.94	122.18
Average		116.40	19.72	121.67	149.57	88.23	92.83	113.07

Table 2: Effect of infestation by *A. tubercularis* on the yield of Goleck mango variety during four peaks for infestation incidence with pest in the two seasons (2016/2017 and 2017/2018).

Season	Inspected trees	Yield (kg)	Yield reduction (%)	Peaks of infestation incidence by *A. tubercularis*				Average of infestation incidence
				Sept.	Nov.	Apr.	Jun.	
2016/2017	1	134	4.29	90.00	93.33	71.67	78.33	83.33
	2	130	7.14	90.00	93.33	76.67	80.00	85.00
	3	126	10.00	91.67	93.33	76.67	81.67	85.83
	4	124	11.43	91.67	93.33	76.67	81.67	85.83
	5	120	14.29	93.33	95.00	78.33	83.33	87.50
	6	118	15.71	93.33	95.00	78.33	85.00	87.92
	7	114	18.57	95.00	95.00	81.67	85.00	89.17
	8	110	21.43	96.67	96.67	81.67	86.67	90.42
	9	104	25.71	96.67	100.00	83.33	88.33	92.08
	10	100	28.57	100.00	100.00	83.33	90.00	93.33
Average		118.00	118.00	15.71	93.83	95.50	78.83	84.00
2017/2018	1	132	8.97	93.33	95.00	71.67	76.67	84.17
	2	128	11.72	93.33	95.00	73.33	81.67	85.83
	3	124	14.48	93.33	95.00	80.00	83.33	87.92
	4	122	15.86	95.00	96.67	81.67	83.33	89.17
	5	118	18.62	95.00	96.67	81.67	85.00	89.59
	6	116	20.00	95.00	96.67	83.33	85.00	90.00
	7	112	22.76	96.67	96.67	85.00	86.67	91.25
	8	108	25.52	96.67	98.33	86.67	86.67	92.08
	9	104	28.28	98.33	100.00	86.67	88.33	93.33
	10	100	31.03	100.00	100.00	90.01	90.00	95.00
Average		116.40	116.40	19.72	95.67	97.00	82.00	84.67

Effect of the total pest population density on the yield: Statistical analysis of data (Table 3) revealed a highly significant negative correlation between the mango yield and the four peaks of the pest population which were -0.93, -0.91, -0.94 and -0.93; and -0.93, -0.89, -0.97 and -0.86 during September, November, April and June peaks during the 1st and 2nd seasons, respectively. The regression coefficient (b) of the unit effect indicated that an increase of one insect per leaf would decrease the yield of mangos by 2.14, 1.56, 2.05 and 4.28 kg. per tree through the first season and 2.08, 1.42, 2.46 and 1.31 kg. per tree during the second season, respectively. The exact relationship between the peaks and the yield of mango was determined by the partial regression coefficient values (Table 3). It was an insignificant negative regression in the first season (-2.93, and -0.94) during the peaks of September and June and was a significant negative regression (-1.03) during the peak of November and an insignificant positive regression (+2.20) during the peak of April. Likewise the partial correlation were -0.68, -0.86, + 0.57 and -0.36 during the peaks of September, November, April and June in the first season, respectively. While, the peaks of the pest activity during the second season (2017/2018) exposed insignificant negative relation (P. reg. = -1.77 and -0.79) during the peaks of September and April, respectively and significant negative effect (P. reg. = -0.73) in November and insignificant positive relation (P. reg. = +0.82) in

June. The values of the partial correlation were -0.69, -0.84, -0.43 and +0.72 during September, November, April and June peaks, respectively.

Table 3: Different models of correlation and regression analyses for describing the relationship between the density of *A. tubercularis* population and the mango yield during the two seasons (2016/2017 and 2017/2018).

Season	Tested counts	Simple correlation and regression values				Partial correlation and regression values				Analysis variance				
		r	b	S.E	t	P. cor.	P. reg.	S.E	t	F values	C.V.	MR	R^2	E.V.%
2016 / 2017	Average no. of individuals/leaf (September)	-0.93 **	-2.14 **	0.30	-7.08 **	-0.68	-2.93	1.41	-2.07	46.24 **	0.02	0.99	0.97	97.37
	Average no. of individuals/leaf (November)	-0.91 **	-1.56 **	0.26	-6.10 **	-0.86 *	-1.03 *	0.27	-3.82 *					
	Average no. of individuals/leaf (April)	-0.94 **	-2.05 **	0.27	-7.49 **	0.57	2.20	1.42	1.55					
	Average no. of individuals/leaf (June)	-0.93 **	-4.28 **	0.59	-7.27 **	-0.36	-0.94	1.09	-0.86					
2017 / 2018	Average no. of individuals/leaf (September)	-0.93 **	-2.08 **	0.29	-7.25 **	-0.69	-1.77	0.83	-2.12	65.41 **	0.02	0.99	0.98	98.12
	Average no. of individuals/leaf (November)	-0.89 **	-1.42 **	0.26	-5.52 **	-0.84 *	-0.73 *	0.21	-3.43 *					
	Average no. of individuals/leaf (April)	-0.97 **	-2.46 **	0.23	-10.80**	-0.43	-0.79	0.76	-1.05					
	Average no. of individuals/leaf (June)	-0.86 **	-1.31 **	0.27	-4.78 **	0.72	0.82	0.35	2.31					

r = Simple correlation; P. cor. = Partial correlation; MR = Multiple correlation; b = Simple regression; P. reg. = Partial regression; C.V. = Coefficient of Variation; R^2= Coefficient of determination; E.V% = Explained variance; S.E = Standard error; * Significant at $P \leq 0.05$; **Highly significant at $P \leq 0.01$.

The calculated partial regression values indicated simultaneously effects of the four peaks of insect population on the mango yield during the two seasons of 2016/2017 and 2017/2018. The results showed that the combined effect of the pest activity peaks on the mango yield during the 1st and 2nd seasons was highly significant (Table 3). The amount of the variability that could be attributed to the combined effect of these peaks on the mango yield was expressed as explained variance percentage (E.V. %), which was 97.37 and 98.12% during the two seasons, respectively. The remaining unexplained variances are assumed to be due to other undetermined factor influences.

Effect of the pest infestation incidence on the yield: Data, in Table (4), showed that the percentages of infestation incidence had a highly significant negative effect on the yield of mango since the correlation coefficient were (-0.98, -0.93, -0.95 and -0.99 and -0.96, -0.94, -0.95 and -0.95) during the peaks of September, November, April and June for the first and second seasons, respectively. The regression coefficient of the unit effect indicates that an increase of 1% in the percentages of infestation incidence would decrease the yield by 3.34, 3.96, 2.86 and 2.97 kg. per tree through the first season and 4.45, 5.21, 1.71 and 2.65 kg. per tree during the second season in September, November, April and June peaks, respectively. The real effect of the infestation incidence appears from the partial regression (P. reg.) values in Table, 4, which showed an insignificant negative effect (P. reg. = -0.81, -0.61 and -0.58) in peaks of September, November and April, respectively, except a significant negative relation in June (P. reg. = -1.35) during the first season. While the second season emphasized insignificant negative relation (P. reg. = -1.27, -1.32, -0.41 and -0.81) during September, November, April and June peaks, respectively. Also, the values of the partial correlation were -0.66, -0.66, -0.70 and -0.78 for the first season and -0.50, -0.48, -0.46 and -0.56 for the second season during September, November, April and June peaks, respectively (Table 4). The results showed that the combined effect of the pest activity peaks on mango yield during the two seasons were highly significant for the two seasons (Table, 4). The combined influence of these peaks of the pest was expressed as E.V.%, which were 99.63 and 98.43 % during the two successive seasons, respectively.

Table 3: Different models of correlation and regression analyses for describing the relationship between the infestation incidence by *A. tubercularis* and the yield of mango during the two seasons (2016/2017 and 2017/2018).

Season	Tested counts	Simple correlation and regression values				Partial correlation and regression values				Analysis variance				
		r	b	S.E	t	P. cor.	P. reg.	S.E	t	F values	C.V.	MR	R^2	E.V.%
2016 / 2017	Average no. of individuals/leaf (September)	-0.98**	-3.34**	0.24	-13.67**	-0.66	-0.81	0.41	-1.98	332.48**	0.01	0.998	0.996	99.63
	Average no. of individuals/leaf (November)	-0.93**	-3.96**	0.53	-7.44**	-0.66	-0.61	0.31	-1.97					
	Average no. of individuals/leaf (April)	-0.95**	-2.86**	0.33	-8.77**	-0.70	-0.58	0.26	-2.22					
	Average no. of individuals/leaf (June)	-0.99**	-2.97**	0.12	-25.04**	-0.78	-1.35 *	0.49	-2.74 *					
2017 / 2018	Average no. of individuals/leaf (September)	-0.96**	-4.45**	0.47	-9.45**	-0.50	-1.27	0.98	-1.29	78.31 **	0.02	0.99	0.98	98.43
	Average no. of individuals/leaf (November)	-0.94**	-5.21**	0.64	-8.11**	-0.48	-1.32	1.08	-1.22					
	Average no. of individuals/leaf (April)	-0.95**	-1.71**	0.19	-8.93**	-0.46	-0.41	0.36	-1.17					
	Average no. of individuals/leaf (June)	-0.95**	-2.65**	0.31	-8.66**	-0.56	-0.81	0.53	-1.52					

r = Simple correlation; P. cor. = Partial correlation; MR = Multiple correlation; b = Simple regression; P. reg. = Partial regression; C.V. = Coefficient of Variation; R^2= Coefficient of determination; E.V% = Explained variance; S.E = Standard error; * Significant at $P \leq 0.05$; **Highly significant at $P \leq 0.01$.

These findings are in a great agreement with those reported by Hernandez et al. (2002). They found a positive correlation between fruit infestation and yield loss at harvest among consecutive seasons, when they studied the relationship between the population densities of *Aonidiella aurantii* (Mask.) and the yield of citrus trees.

Prediction of mango yield and its loss: Prediction equations for the yield of mango and its losses were calculated according to the statistical analysis and presented as follow:

1. The total population density during the four peaks versus the yield of mango: $Y = 448.67^{**} - 3.14\ x_1^{**} - 1.13\ x_2^{**} + 1.85\ x_3^{**} + 0.60\ x_4$; E.V.% = 93.42%
2. The total population density during the four peaks versus the percentages of reduction in mango yield: $Y = -194.34^{**} + 1.62\ x_1^{**} + 0.67\ x_2^{**} - 0.57\ x_3 - 0.35\ x_4$; E.V. %= 95.58%.
3. The infestation incidence of the pest during the four peaks versus the yield of mango: $Y = 408.2^{**} - 0.68\ x_1 - 0.63\ x_2 - 0.05\ x_3 - 1.91\ x_4^{**}$; E.V. %= 96.76%.
4. The infestation incidence of the pest during the four peaks versus the percentages of reduction in mango yield: $Y = -206.4^{**} + 0.92\ x_1^{**} + 0.61\ x_2^{*} + 0.34\ x_3^{**} + 0.61\ x_4^{**}$; E.V. %= 98.97%.

   Where: Y= Prediction value. E.V. % = Explained variance. X_1= peak in September. X_2= peak in November. X_3= peak in June. X_4= peak in April. ***** Significant at $P \leq 0.05$. ****** Highly significant at $P \leq 0.01$.

The aforementioned results on the effect of the four peaks for the pest population or infestation incidence by the pest on the yield of mango and its losses during the two successive seasons emphasize that the effect of these factors varied from season to another which this might be due to many factors *i.e.* environmental conditions (level, time and the ability of variety to infestation).

The calculated yield: The simple linear regression equations were applied to estimate the expected yield of mango Results in Tables (5 and 6) indicated that the maximum yield (134 kg) was recorded with the lowest values of total density of population and the infestation incidence percentages in the all peaks of seasonal activity through the two seasons. While, the minimum yield (100 kg) was estimated with the highest values of the total density of population and the percentages of infestation incidence in the four peaks of activity during the two seasons (inverted relation). As well as, when the mango yields were correlated with the general average of the total population density of the pest during the four peaks for activity; the yield decreased by 2.44 and 1.90 kg/tree. Also, the infestation incidence of the pest reduced the yield by 3.44 and 3.12 kg/tree during two seasons. Data indicated that the mango yield quantity of the first season (2016/2017) was higher than that recorded in the second one (2017/2018). The differences may be attributed to many factors, e.g. the pest infestation and natural reasons. These results are similar to those obtained by Mohamed and Asfoor (2004), in Egypt, however with different host, they studied the effect of the red scale, *A. aurantii* infestation and the yield loss on citrus trees and found that the reduction in

Valencia orange was higher than that of Navel. As well as, the damage was estimated as % reduction in the yield per tree by 31.14 and 27.15%, respectively.

Table 5: Gradual decrease in yield with the population density increase of the total population of *A. tubercularis* during four peaks for seasonal activity in the two years (2016/2017 and 2017/2018).

Season	Inspected trees	Yield (kg)	September		November		April		June		General average	
			No. of insects / leaf	Calculated yield	No. of insects / leaf	Calculated yield	No. of insects / leaf	Calculated yield	No. of insects / leaf	Calculated yield	No. of insects / leaf	Calculated yield
2016/2017	1	134	106.1	140.5	141.5	127.7	69.9	140.6	86.2	136.5	100.9	137.6
	2	130	112.8	126.3	142.0	127.0	76.9	126.0	86.8	134.1	104.6	128.5
	3	126	114.3	123.0	144.1	123.7	79.2	121.3	89.7	121.5	106.8	123.1
	4	124	116.5	118.3	144.5	122.9	80.1	119.6	90.4	118.5	107.9	120.6
	5	120	116.6	118.0	144.8	122.6	80.8	118.0	91.2	115.3	108.4	119.4
	6	118	116.6	118.0	147.7	118.0	80.8	118.0	91.2	115.2	109.1	117.6
	7	114	119.3	112.3	147.7	118.0	82.7	114.2	91.2	114.9	110.2	114.8
	8	110	120.2	110.5	148.9	116.1	84.5	110.5	92.1	111.4	111.4	111.9
	9	104	121.8	107.0	152.6	110.3	85.3	108.8	93.0	107.3	113.2	107.6
	10	100	122.2	106.2	163.3	93.6	88.1	103.0	93.5	105.3	116.8	98.9
2017/2018	1	132	111.3	137.9	142.5	126.4	80.6	135.1	76.2	138.2	102.7	136.2
	2	128	118.0	124.0	142.6	126.3	83.6	127.7	89.6	120.6	108.5	125.2
	3	124	119.2	121.5	146.6	120.7	85.0	124.3	92.5	116.8	110.8	120.6
	4	122	121.7	116.4	147.6	119.2	86.8	119.9	92.6	116.8	112.2	118.2
	5	118	121.7	116.4	147.8	118.9	89.3	113.8	92.7	116.5	112.9	116.8
	6	116	121.8	116.1	149.6	116.4	89.7	112.8	94.1	114.7	113.8	115.0
	7	112	124.3	110.9	149.6	116.4	90.4	111.0	94.7	113.9	114.8	113.2
	8	108	125.1	109.2	150.2	115.6	91.0	109.6	94.9	113.7	115.3	112.2
	9	104	126.7	105.9	154.0	110.1	92.2	106.6	97.9	109.7	117.7	107.6
	10	100	126.8	105.7	165.4	93.9	93.6	103.2	102.9	103.1	122.2	99.1

The calculated reduction in yield: The simple linear regression equations were used to determine the prospect reduction in yield of mango are represented in Tables (7 and 8). Data in Tables (7 and 8) showed that the least loss percentage in yield (4.3 and 9.0%) was recorded with the lowest levels for the population density or the percentages of infestation incidence in all peaks of the seasonal activity during the two seasons. While, the highest loss percentages in yield (28.6 and 31.0%) was estimated with the highest values of the total population density and the percentages of infestation incidence in the four peaks of the seasonal activity during the two seasons, respectively (positive relation).

Table 6: Gradual decrease in yield with increase of the infestation incidence percentages by *A. tubercularis* during four peaks for seasonal activity in the two years (2016/2017 and 2017/2018).

Season	Inspected trees	Yield (kg)	September		November		April		June		General average	
			% infestation incidence	Calculated yield	% infestation incidence	Calculated yield	% infestation incidence	Calculated yield	% infestation incidence	Calculated yield	% infestation incidence	Calculated yield
2016/2017	1	134	90.0	130.8	93.3	126.6	71.7	138.5	78.3	134.8	83.3	134.2
	2	130	90.0	130.8	93.3	126.6	76.7	124.2	80.0	129.9	85.0	128.5
	3	126	91.7	125.2	93.3	126.6	76.7	124.2	81.7	124.9	85.8	125.6
	4	124	91.7	125.2	93.3	126.6	76.7	124.2	81.7	124.9	85.8	125.6
	5	120	93.3	119.7	95.0	120.0	78.3	119.4	83.3	120.0	87.5	119.9
	6	118	93.3	119.7	95.0	120.0	78.3	119.4	85.0	115.0	87.9	118.4
	7	114	95.0	114.1	95.0	120.0	81.7	109.9	85.0	115.0	89.2	114.1
	8	110	96.7	108.5	96.7	113.4	81.7	109.9	86.7	110.1	90.4	109.8
	9	104	96.7	108.5	100.0	100.2	83.3	105.1	88.3	105.1	92.1	104.1
	10	100	100.0	97.4	100.0	100.2	83.3	105.1	90.0	100.2	93.3	99.8
2017/2018	1	132	93.3	126.8	95.0	126.8	71.7	134.1	76.7	137.6	84.2	134.1
	2	128	93.3	126.8	95.0	126.8	73.3	131.2	81.7	124.3	85.8	128.9
	3	124	93.3	126.8	95.0	126.8	80.0	119.8	83.3	119.9	87.9	122.4
	4	122	95.0	119.4	96.7	118.1	81.7	117.0	83.3	119.9	89.2	118.5
	5	118	95.0	119.4	96.7	118.1	81.7	117.0	85.0	115.5	89.6	117.2
	6	116	95.0	119.4	96.7	118.1	83.3	114.1	85.0	115.5	90.0	115.9
	7	112	96.7	111.9	96.7	118.1	85.0	111.3	86.7	111.1	91.3	112.0
	8	108	96.7	111.9	98.3	109.4	86.7	108.4	86.7	111.1	92.1	109.4
	9	104	98.3	104.5	100.0	100.8	86.7	108.4	88.3	106.7	93.3	105.5
	10	100	100.0	97.1	100.0	100.8	90.0	102.7	90.0	102.3	95.0	100.3

Table 7: Gradual increase in yield loss with the population density increase of the total population of *A. tubercularis* during four peaks for seasonal activity in the two years (2016/2017 and 2017/2018).

Season	Inspected trees	% Yield reduction	September		November		April		June		General average	
			No. of insects / leaf	Calculated reduction	No. of insects / leaf	Calculated reduction	No. of insects / leaf	Calculated reduction	No. of insects / leaf	Calculated reduction	No. of insects / leaf	Calculated reduction
2016/2017	1	4.3	106.1	-0.4	141.5	8.8	69.9	-0.4	86.2	2.49	100.9	1.7
	2	7.1	112.8	9.8	142.0	9.3	76.9	10.0	86.8	4.23	104.6	8.2
	3	10.0	114.3	12.2	144.1	11.7	79.2	13.3	89.7	13.22	106.8	12.1
	4	11.4	116.5	15.5	144.5	12.2	80.1	14.6	90.4	15.40	107.9	13.9
	5	14.3	116.6	15.7	144.8	12.4	80.8	15.7	91.2	17.65	108.4	14.7
	6	15.7	116.6	15.7	147.7	15.7	80.8	15.7	91.2	17.69	109.1	16.0
	7	18.6	119.3	19.8	147.7	15.7	82.7	18.4	91.2	17.91	110.2	18.0
	8	21.4	120.2	21.1	148.9	17.1	84.5	21.1	92.1	20.46	111.4	20.0
	9	25.7	121.8	23.6	152.6	21.2	85.3	22.3	93.0	23.35	113.2	23.1
	10	28.6	122.2	24.2	163.3	33.1	88.1	26.4	93.5	24.81	116.8	29.4
2017/2018	1	9.0	111.3	4.9	142.5	12.8	80.6	6.8	76.2	4.7	102.7	6.1
	2	11.7	118.0	14.5	142.6	12.9	83.6	11.9	89.6	16.8	108.5	13.7
	3	14.5	119.2	16.2	146.6	16.8	85.0	14.3	92.5	19.5	110.8	16.8
	4	15.9	121.7	19.7	147.6	17.8	86.8	17.3	92.6	19.5	112.2	18.5
	5	18.6	121.7	19.7	147.8	18.0	89.3	21.5	92.7	19.6	112.9	19.5
	6	20.0	121.8	19.9	149.6	19.7	89.7	22.2	94.1	20.9	113.8	20.7
	7	22.8	124.3	23.5	149.6	19.7	90.4	23.5	94.7	21.4	114.8	21.9
	8	25.5	125.1	24.7	150.2	20.3	91.0	24.4	94.9	21.6	115.3	22.6
	9	28.3	126.7	27.0	154.0	24.1	92.2	26.5	97.9	24.3	117.7	25.8
	10	31.0	126.8	27.1	165.4	35.2	93.6	28.8	102.9	28.9	122.2	31.7

Furthermore, when the percentages of reduction in mango yield were correlated with the general average of total population density of the pest through the four peaks; the percentages of yield reduction was increased by 1.74 and 1.31%. Also, the percentages of infestation incidence of the pest increased the yield loss by about 2.46 and 2.15% during the two seasons, respectively). These results were coincided with those obtained by Salman and Bakry (2012) in Egypt, however with different insect species and different host, they reported that the increase in population density of the mealybug, *Icerya seychellarum* in population peaks decreased the yield gradually (inverted relation) by 3.6, 6.5 and 4.3 kg/tree and 2.5, 4.1 and 2.3 kg/tree during two successive season, respectively and increased the percentage of the yield loss by 1.47, 2.64 and 1.77 % and 1.47, 1.97 and 1.08 % when the yield data were correlated with the peaks of insect population in October, May and August through the two successive seasons (2010-2012), respectively.

Table 8: Gradual increase in yield loss with increase of the infestation incidence percentages by *A. tubercularis* during four peaks for seasonal activity in the two years (2016/2017 and 2017/2018).

Season	Inspected trees	% Yield reduction	September		November		April		June		General average	
			% infestation incidence	Calculated reduction	% infestation incidence	Calculated reduction	% infestation incidence	Calculated reduction	% infestation incidence	Calculated reduction	% infestation incidence	Calculated reduction
2016/2017	1	4.3	90.0	6.6	93.3	9.6	71.7	1.1	78.3	3.7	83.3	4.1
	2	7.1	90.0	6.6	93.3	9.6	76.7	11.3	80.0	7.2	85.0	8.2
	3	10.0	91.7	10.5	93.3	9.6	76.7	11.3	81.7	10.8	85.8	10.3
	4	11.4	91.7	10.5	93.3	9.6	76.7	11.3	81.7	10.8	85.8	10.3
	5	14.3	93.3	14.5	95.0	14.3	78.3	14.7	83.3	14.3	87.5	14.4
	6	15.7	93.3	14.5	95.0	14.3	78.3	14.7	85.0	17.8	87.9	15.4
	7	18.6	95.0	18.5	95.0	14.3	81.7	21.5	85.0	17.8	89.2	18.5
	8	21.4	96.7	22.5	96.7	19.0	81.7	21.5	86.7	21.4	90.4	21.5
	9	25.7	96.7	22.5	100.0	28.5	83.3	24.9	88.3	24.9	92.1	25.6
	10	28.6	100.0	30.4	100.0	28.5	83.3	24.9	90.0	28.5	93.3	28.7
2017/2018	1	9.0	93.3	12.6	95.0	12.5	71.7	7.5	76.7	5.1	84.2	7.5
	2	11.7	93.3	12.6	95.0	12.5	73.3	9.5	81.7	14.2	85.8	11.1
	3	14.5	93.3	12.6	95.0	12.5	80.0	17.4	83.3	17.3	87.9	15.6
	4	15.9	95.0	17.7	96.7	18.5	81.7	19.3	83.3	17.3	89.2	18.3
	5	18.6	95.0	17.7	96.7	18.5	81.7	19.3	85.0	20.3	89.6	19.2
	6	20.0	95.0	17.7	96.7	18.5	83.3	21.3	85.0	20.3	90.0	20.1
	7	22.8	96.7	22.8	96.7	18.5	85.0	23.3	86.7	23.4	91.3	22.8
	8	25.5	96.7	22.8	98.3	24.5	86.7	25.2	86.7	23.4	92.1	24.6
	9	28.3	98.3	27.9	100.0	30.5	86.7	25.2	88.3	26.4	93.3	27.3
	10	31.0	100.0	33.0	100.0	30.5	90.0	29.2	90.0	29.5	95.0	30.8

Also, Bakry and Mohamed (2015) mentioned that the increase in the population density in the four peaks of the pest population decreased the yield gradually by 1.37, 1.47, 4.25 and 1.77 kg/treeand 1.45, 1.53, 4.66 and 1.85 kg/tree during two successive seasons, respectively and increased the percentage of the yield loss by 0.55, 0.59, 1.70 and 0.71 % and 0.60, 0.63, 1.90 and 0.76 %; when the yield data were linked with the peaks of the pest population in October, December, April and July through two successive seasons, 2016-2017 and 2017-2018, respectively.

Expected values in the yield and its loss with increasing the pest population or infestation: Concerning, the comparison between the peaks of the pest population or infestation incidence of *A. tubercularis* and their effect on the yield of mango during the two successive seasons (2016/2017 and 2017/2018), was depending on the total number of the pest per leaf for all peaks of the population or the infestation incidence (Tables 9 and 10).

Table 9: Expected values with (decrease or increase) in the yield with increase the rates of infestation by *A. tubercularis* total population during four peaks in the two seasons (2016/2017 and 2017/2018).

Season	No. of insects/ leaf	Calculated yield				% Yield reduction			
		Sept.	Nov.	Apr.	Jun.	Sept.	Nov.	Apr.	Jun.
2016/2017	15	335.01	325.51	253.29	441.63	-139.30	-132.52	-80.92	-215.4
	30	302.98	302.06	222.47	377.35	-116.42	-115.76	-58.91	-169.5
	45	270.96	278.60	191.65	313.08	-93.55	-99.01	-36.89	-123.6
	60	238.93	255.15	160.83	248.81	-70.67	-82.26	-14.88	-77.7
	75	206.91	231.69	130.01	184.53	-47.80	-65.50	7.14	-31.8
	90	174.88	208.24	99.19	120.26	-24.92	-48.75	29.15	14.1
	105	142.86	184.78	68.37	55.99	-2.04	-32.00	51.17	60.0
	120	110.83	161.33	37.55	-8.29	20.83	-15.24	73.18	105.9
	135	78.81	137.87	6.73	-72.56	43.71	1.51	95.20	151.8
	150	46.78	114.42	-24.10	-136.84	66.58	18.27	117.22	197.8
	165	14.76	90.96	-54.92	-201.11	89.46	35.02	139.23	243.7
Mean	90.00	174.88	208.24	99.19	120.26	-24.92	-48.75	29.15	14.11
2017/2018	15	338.46	307.91	296.62	218.39	-133.42	-112.35	-104.57	-50.61
	30	307.24	286.56	259.70	198.74	-111.89	-97.63	-79.11	-37.06
	45	276.01	265.22	222.79	179.08	-90.35	-82.90	-53.65	-23.50
	60	244.78	243.87	185.87	159.42	-68.82	-68.18	-28.19	-9.94
	75	213.56	222.52	148.95	139.76	-47.28	-53.46	-2.72	3.61
	90	182.33	201.17	112.03	120.11	-25.75	-38.74	22.74	17.17
	105	151.10	179.82	75.11	100.45	-4.21	-24.01	48.20	30.73
	120	119.87	158.48	38.20	80.79	17.32	-9.29	73.66	44.29
	135	88.65	137.13	1.28	61.13	38.86	5.43	99.12	57.84
	150	57.42	115.78	-35.64	41.48	60.40	20.16	124.58	71.40
	165	26.19	94.43	-72.56	21.82	81.93	34.88	150.04	84.96
Mean	90.00	182.33	201.17	112.03	120.11	-25.75	-38.74	22.74	17.17

Effect of total population density: The results revealed that the total population density of pest in peak of April was more effective causing the lowest expected values in mango yield with an average of 99.19 and 112.03 kg/tree through the two successive seasons, respectively. While, the peak of total population in November was the least effective causing the highest expected values in mango yield with an average of 208.24 and 201.17 kg/tree during the two successive seasons, respectively (Table 9). As regarding, the prospective values with (increase or decrease) in the percentage of the yield loss with increasing the infestation rates by *A. tubercularis* during the two successive seasons (Table 9). The results showed that the total population density during November peak was least effective causing the least percentages of reduction in mango yield with an average of -48.75 and -38.74% during the two successive seasons, respectively. But, the pest population was more effective during April peak causing the greatest loss in mango yield with an average of 29.15 and 22.74% during the two successive seasons, respectively.

Table 10: Expected values (decrease or increase) in the yield with increase of the infestation incidence percentages by *A. tubercularis* during four peaks for seasonal activity in the two seasons (2016/2017 and 2017/2018).

Season	Infestation Incidence (%)	Calculated yield				% Yield reduction			
		Sept.	Nov.	Apr.	Jun.	Sept.	Nov.	Apr.	Jun.
2016/2017	10	398.27	456.90	314.67	338.00	-184.47	-226.36	-124.76	-141.42
	20	364.84	417.26	286.10	308.27	-160.59	-198.04	-104.35	-120.19
	30	331.41	377.63	257.53	278.54	-136.71	-169.73	-83.95	-98.95
	40	297.98	337.99	228.96	248.81	-112.83	-141.42	-63.54	-77.72
	50	264.55	298.35	200.39	219.08	-88.96	-113.11	-43.13	-56.48
	60	231.11	258.71	171.81	189.35	-65.08	-84.79	-22.72	-35.24
	70	197.68	219.07	143.24	159.62	-41.20	-56.48	-2.31	-14.01
	80	164.25	179.44	114.67	129.89	-17.32	-28.17	18.09	7.23
	90	130.82	139.80	86.10	100.16	6.56	0.15	38.50	28.46
	100	97.39	100.16	57.53	70.43	30.44	28.46	58.91	49.70
Mean	55.00	247.83	278.53	186.10	204.22	-77.02	-98.95	-32.93	-45.86
2017/2018	10	497.51	570.00	239.68	314.07	-243.11	-293.10	-65.29	-116.60
	20	453.02	517.86	222.56	287.59	-212.43	-257.15	-53.49	-98.34
	30	408.54	465.73	205.44	261.12	-181.75	-221.19	-41.68	-80.09
	40	364.05	413.59	188.32	234.64	-151.07	-185.23	-29.87	-61.83
	50	319.56	361.45	171.20	208.17	-120.39	-149.28	-18.06	-43.57
	60	275.07	309.31	154.07	181.70	-89.70	-113.32	-6.25	-25.31
	70	230.58	257.17	136.95	155.22	-59.02	-77.36	5.55	-7.05
	80	186.10	205.04	119.83	128.75	-28.34	-41.40	17.36	11.20
	90	141.61	152.90	102.71	102.27	2.34	-5.45	29.17	29.46
	100	97.12	100.76	85.59	75.80	33.02	30.51	40.98	47.72
Mean	55.00	297.32	335.38	162.63	194.93	-105.04	-131.30	-12.16	-34.44

Effect of infestation incidence by pest: A similar trend in the percentages of infestation incidence of the pest on the yield and its reduction was observed and represented in Table (10). The infestation incidence during the peak of November was the least effective causing the highest expected values in mango yield with an average of 278.53 and 335.38 kg/tree during the two successive seasons, respectively. While, the peaks in April was more effective causing the lowest expected values in mango yield with an average of 186.10 and 162.63 kg/tree during the two successive seasons, respectively. Furthermore, the percentages of infestation incidence during April peak was highest effective causing the greatest loss in mango yield with an average of -32.93 and -12.16% during the two successive seasons respectively. But, the peak of infestation incidence in November was the lowest effective causing the least percentages of reduction in mango yield with an average of -98.95 and -131.30% during the two successive seasons respectively (Table 10). Generally, it seems that the population density and infestation incidence by *A. tubercularis* during April peak was the most serious one, during the two seasons, causing the greatest loss in mango yield which that coincided with the newly spring growth cycle for the vegetative growth of mango trees. These results were confirmed by the findings of El-Said (2006) who found that the high infestation levels, the feeding of this pest caused a serious damage resulting in early leaves drop and yield reduction. Bakry (2009) reported that the early season infestation with the Maskell scale insect, *Insulaspis pallidula* during May was more effective than other months causing the greatest loss in mango yield. Also, Salman and Bakry (2012) stated that the early infestation with the mealybug, *Icerya Seychellarum* during May was more effective than other months causing the greatest loss in mango yield. Bakry and Mohamed (2015) reported that the infestation by *Aonidiella aurantii* (Mask.) during April was more effective than other time causing the greatest loss in mango yield. Generally, it could be concluded that the reduction in mango yield was considered as a summation of different factors including level and time of infestation and the ability of variety to infestation. These results are similar to those obtained by Reddy-Seshu (1992) who found a linear relationship between infestation and yield loss, and more increasing in yield loss as a result of the earlier infestation. Also, Selim (2002) studied the effect of Maskell scale insect, *Insulaspis pallidula* (Green) infestation on the yield of mango trees. He stated that the yield decreased gradually with increasing the population density of this pest. He added that the yield decreased gradually with increasing the population density of *Insulaspis pallidula* (Green) in four peaks (September, April, July and August).

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