International Journal of Research in Agricultural Sciences
Volume 7, Issue 3, ISSN (Online): 2348 – 3997

Climate Change Impact on the Population Size of *Parlatoria oleae* (Colvee) (Hemiptera: Diaspididae) using RCP Scenarios

Moustafa M.S. Bakry [1*], Lamiaa H.Y. Mohamed [1] and Shimaa Y.E. Shakal [2]
[1] Scale Insects and Mealybugs research Dept., Plant Protection research Institute, A.R.C, Dokii, Giza, Egypt.
[2] Plant Prot. Dept., Fac. of Agric. and Natural resources, Aswan Univ., Aswan, Egypt.
*Corresponding author email id: md.md_sabry@yahoo.com

Date of publication (dd/mm/yyyy): 09/06/2020

***Abstract* – The present study was carried out to predict the population densities of the plum scale insect, *Parlatoria oleae* (Colvee) on mango trees during three time series (2011 - 2040, 2041 - 2070 and 2071 - 2100) under four Representative Concentration Pathway (RCP) scenarios (2.6, 4.5, 6.0 and 8.5) as compared with the current population of the pest (average of population density for two years of 2017 and 2018) at Esna district, Luxor Governorate, Egypt. Monthly estimations of total *P. oleae* population indicated the presence of three peaks of insect activity per year. The means of minimum air temperature were entirely under the optimum range for activities of nymphs, adult females and total population of *P. oleae* and this climatic factor was the most effective variables in population changes by 35.99, 36.00 and 36.30% for nymphs, adult females and total population of *P. oleae* during the base year data, respectively. The percentages of explained variance (E.V.%) indicated that the combined effect of these climatic factors viz., maximum temperature, minimum temperature and solar radiation were responsible for 78.75, 77.15 and 78.66 % of the population changes of nymphs, adult females and total population of this scale insect, respectively. The obtained results revealed the all expected values for numbers of nymphs, adult females and total population of insect during the all different time series under all different RCPs scenarios were smaller in comparison to the current population of insect. Expected total population of insect will be smaller at time series of (2071-2100) as compared with the two time series of (2011-2040) and (2041-2070) under the scenarios of RCPs (2.6, 4.5, 6 and 8.5). Also, the time series of (2071-2100) exhibited higher percentages of decreasing of the number of nymphs, adult females and total population with averages of (55.12, 57.26 and 56.08%, respectively) as compared to the time series of 2041-2070 (53.26, 55.34 and 54.20%) and the time series of 2011-2040 (50.91, 52.92 and 51.81%, respectively). Furthermore, the RCP 8.5 scenario exhibited the lowest population density of nymphs, adult females and total population *P. oleae* and the highest decreasing percentage for population density of different stages of *P. oleae* as compared with the other RCPs during all different time series.**

***Keywords* – *Parlatoria oleae*, RCPs, Seasonal Abundance, Climate Change Scenarios, Mango.**

I. INTRODUCTION

Mango trees are subjected to infestation by different pests. Among several pests, infesting mango trees, *P. oleae* is considered one of the most main destructive pests of mango trees (**Bakr *et al.*, 2009**). This pest injures the shoots, twigs, leaves, branches and fruits by sucking the plant sap with the mouth parts, causing thereafter 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 where it causes conspicuous pink blemishes around the feeding sites of the scales. A characteristic symptom of infestation by pest is the appearance and accumulation of its scales on attacked mango parts (**El-Amir, 2002 and Hassan *et al.*, 2009**).

To develop an effective control against *P. oleae*, it is necessary to know its bio-ecology including population dynamics and climatic factors influencing its life span and the densities of different phonological stages. Temperature has a direct influence on insect activity and rate of development. According to **Zalom and Wilson**

(1982) the rate of development is based on the accumulation of heat measured in physiological rather than chronological time. **Dent (1991)** stated that the seasonal phenology of insect numbers, the number of generations, and the level of insect abundance at any location are influenced by the environmental factors at that location.

Climatic changes have become one of the major challenges for mankind and the natural environment. Rise upraises in temperature and increased incidence of extreme weather events can directly influence insects by affecting their rate of development, reproduction, distribution, migration and adaptation. In addition, indirect effects can occur through the influence of climate on the insect's host plants, natural enemies and interspecific interactions with other insects **(Bale *et al*., 2002; Walther *et al*., 2002; Samways, 2005; Merrill *et al*., 2008).**

Climatic changes scenario development is a rapidly evolving field, but those are less significant than the fundamental change in climate change modeling (including socioeconomic) brought about by the shift from using IPCC SRES scenarios to representative concentration pathways (RCPs) that "will provide a framework for modeling in the next stages of scenario-based research" **(Moss *et al*., 2010).**

In addition, such changes in climatic conditions could profoundly affect the population dynamics and the status of insect pests of crops **(Woiwod, 1997).** These effects could either be direct, through the influence that weather may have on the insects physiology and behavior **(Parmesan, 2007; Merrill *et al*. 2008),** or may be mediated by host plants, competitors or natural enemies **(Bale *et al*. 2002).**

The objective of this study is to predict the populations of *P. oleae* under four Representative Concentration Pathway (RCP) scenarios (RCP 2.6 – RCP 4.5 – RCP 6.0 and RCP 8.5) during three time series (2011-2040, 2041-2070 and 2071-2100 years) as compared with the current population of pest (average of population density for two years 2017 and 2018). As well, the effect of climatic factors viz., means of maximum temperature, minimum temperature and solar radiation on the current pest population of *P. oleae*.

II. MATERIALS AND METHODS

The population fluctuations of plum scale insect, *P. oleae* on mango trees were carried out at half-monthly intervals at Esna district, Luxor Governorate during two successive years from January, 2017 to December, 2018. An orchard of about a feddan was selected for sampling during the studied period. Ten mango trees of Balady variety similar in age and as uniform as possible in size, shape, height, vegetative growth were selected. Regular half-monthly samples were picked up to randomly from different directions and stratums of tree with rate of 60 leaves per tree. The total number of picked leaves was from 19200 leaves *i.e.* (10 trees x 4 directions x 10 leaves x 48 dates) over the two-years period was taken from the terminal shoots of the tree. The samples were collected regularly and immediately transferred to laboratory in polyethylene bags for inspection using a stereo-microscope. Numbers of alive insects on upper and lower surfaces of mango leaves were individually sorted into immature stages (pre-adults) and mature stages (adult females) and then were counted and recorded together opposite to each inspected date.

Monthly mean numbers of *P. oleae* per leaf were calculated during the two years of study to express the current population size of pest. The monthly counts of maximum and minimum air temperatures and solar radiation at Luxor governorate during 2017 and 2018 years were obtained from the Egypt Weather Underground, https:// www.wunderground.com/global/EG.html.

The altitude, latitude and longitude of this weather region of Luxor were 99 m, 25.67ºN and 32.71ºE, respectively.

Representative Concentration Pathway (RCP) Scenarios:

Clima Scope is a data visualization engine providing maps and data on projected climate changes for a range of global greenhouse gas emission scenarios. Outputs are stamped with metadata on which GCM was used, which carbon cycle was used, which emission scenario was used, and the source of data in order to provide traceability (Table, 1). Data came from peer-reviewed models linked together within the Community Integrated Assessment System (CIAS) developed at the Tyndall Centre for climate change's research within the School of Environmental Sciences at the University of East Anglia **(Warren *et al.* 2008; Mitchell and Jones, 2005; Osborn, 2009).** Data of maximum and minimum air temperatures and solar radiation during three time series (2011-2040, 2041-2070 and 2071-2100) under different RCPs scenarios (2.6, 4.5, 6.0 and 8.5) were obtained from the Clima Scope internet website (http: //climascope.tyndall.ac.uk/)

Statistical analysis of data was carried out with Computer system using **(MSTATC Program software, 1980)** and **SPSS (1999)**. The data obtained were statistically analyzed by using different models of correlation and regression to find out the relationships between different stages of *P. oleae* population (dependent variable) and climatic factors (independent variable). As well as, the percentage of explained variance (% E.V.) was calculated to study the combined effect of these climatic factors on population density of different stages of *P. oleae*. Also, the t-test was used to establish whether a significant difference exists between the current insect population (average of both years of 2017 and 2018) and the expected populations during three time series (2011-2040, 2041-2070 and 2071–2100 years) under different RCPs scenarios (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5) at $P \leq 0.05$ were estimated.

Table 1. Description of IPCC representative concentration pathway (RCP) up to year 2100.

Scenario (RCP)	**Radioactive (Wm^2 before)**	**Atmospheric CO_2 (ppm)**	**Temperature (°C)**	**Pathway**
2.6	3	490	1.5	Peak and decline
4.5	4.5	650	2.4	Stabilization without
6.0	6.0	850	3.0	Stabilization without
8.5	8.5	1370	4.9	Rising

Source: Moss *et al.* (2010).

The percentage of decrease in numbers of insect was calculated as formula: Decrease % = $\frac{A-B}{A}$ X 100

Where, A = Current population, B = Expected population.

All obtained data were calculated and depicted graphically by Microsoft Excel 2010.

III. RESULT AND DISCUSSION

1. *Trend of Current and Future Climatic Conditions in Luxor Region: Maximum Air Temperature*

The means of the monthly maximum temperature were recorded from January, 2017 till December, 2018 (Fig., 1). The highest monthly mean maximum temperature values were recorded from June to September months ranged from (40.13 to 40.83 °C and 36.61 to 41.32°C) during the two studied years, respectively. While, it was the lowest (23.72 - 25.26 °C and 23.58 - 24.60°C) during January and February months for both the two years, respectively (Fig. 1).

Fig. (2), shows the average annual trend of the mean maximum air temperature under current climate (average of 2017 and 2018) and future periods (2011-2040, 2041-2070 and 2071-2100 years). Data showed that the annual maximum temperature increased for all RCPs scenarios under all time series (2011-2040, 2041-2070 and 2071-2100 years) as compared with current annual maximum temperature. The highest annual maximum air temperature values were found under RCP 8.5 scenario during all time series (2011-2040, 2041-2070 and 2071-2100 years). While, the lowest annual maximum air temperature values were found under the RCP 2.6 scenario when the comparison was between different scenarios during three time series. The results indicated also that the range of annual maximum air temperature values ranged from 35.88°C under RCP 2.6 at 2011-2040 to 39.07°C under RCP 8.5 at (2071-2100). Also, the difference between RCPs scenarios was less than 1.06°C during the short term time series (2011-2040), while the differences increased during the long term time series (2071-2100) about 1.99°C (difference between RCP 2.6 and RCP 8.5 at 2071-2100). This result was agreeable with **IPCC (2007)** which reported that the global surface air temperature increased from 1850 to 2005 by 0.76ºC and the linear warming trend over the last 50 years is determined by 0.13ºC per decade.

Minimum Air Temperature

Fig. (1), showed that the lowest monthly mean minimum temperature values were recorded during the winter months (January and February) in all studied years. While, the highest values were recorded from July to September months.

Fig. (2), shows the average annual trend of minimum air temperature under current (average of the two years) and the future conditions (2011-2040, 2041-2070 and 2071-2100) for Luxor Governorate, Egypt. The lowest average annual minimum temperature was found during the current conditions as compared with the future periods. The projected annual minimum air temperature values ranged between 19.47°C under RCP 2.6 at 2011-2040 and 20.96°C under RCP 8.5 at 2071-2100. The highest annual minimum air temperature values were found under RCP 8.5 scenario during all time series (2011-2040, 2041-2070 and 2071-2100). While, the lowest annual minimum air temperature values were found under the RCP 2.6 scenario. Also, the difference between RCPs scenarios was higher than 0.49°C during the short term time series (2011-2040), while the differences increased during the long term time series (2071-2100) being about 0.99°C (difference between RCP 2.6 and RCP 8.5 at 2071-2100). These results are in line with the report of **(IPCC, 2006)** which mentioned that the temperature will increase by uneven values in different climatic regions under climate change. **Abdrabbo *et al*. (2015)** reported that upper Egypt had the highest average annual minimum air temperature, under current (1971-2000) and future (2011-2040, 2041-2070 and 2071-2100) conditions.

Solar Radiation

Fig. (1), indicated that the highest monthly mean solar radiation values were recorded during the summer months (from June to August) during the two years of study. While, the winter months (December - February) had the lowest values of solar radiation. Fig. (2), illustrated the average monthly trend of mean solar radiation under current climate (average of solar radiation during the two years 2017 and 2018) and future conditions

(2011-2040, 2041-2070 and 2071-2100). The annual solar radiation increased for all RCPs scenarios under all time series (2011-2040, 2041-2070 and 2071-2100 years) as compared with current annual solar radiation. Also, the highest annual solar radiation value was found under RCP 8.5 scenario for all time series (2011-2040, 2041-2070 and 2071-2100 years). While, the lowest value was found under the RCP 2.6 scenario. The results also indicated that the annual solar radiation values ranged between 20.31 MJ/m^2 under RCP 2.6 at 2011-2040 and 20.90 MJ/m^2 under RCP 8.5 at (2071-2100). Also, the difference between RCPs scenarios was less than 0.08 MJ/m^2 during the short term time series (2011-2040), while the differences increased lightly during the long term time series (2071-2100) to reach about 0.49 MJ/m^2 (difference between RCP 2.6 and RCP 8.5 during 2071-2100).

2. *Seasonal Fluctuations in Population of P. oleae*

Nymphs Population

The monthly mean numbers of *P. oleae* nymphs on mango leaves at Esna district, Luxor Governorate during the period from January, 2017 to December, 2018 years and current population (average the two years) are graphically illustrated in Fig. (3). The seasonal activity of nymphs population indicated three peaks per year, in April, July and October/November per over the entire year.

Adult Females Population

It could be noticed that the seasonal fluctuation of adult females corresponded with the fluctuation of *P. oleae* nymphs was observed. The adult females had three peaks those were recorded in April, July and October/ November per each year (Fig., 3).

Total Population (Nymphs and Adult Females) of P. oleae

According to data of total mixed population by *P. oleae*, three peaks were recorded in April, July and October/November per over the entire year (Fig., 3). These results were coincided with those obtained by **El-Hakim and Helmy (1982)** in Egypt, mentioned that *P. oleae* had three peaks in Cairo and Fayoum, and two peaks in Alexandria on olive trees. **Asfoor (1997),** in Qalyobia Governorate, Egypt, reported that three generations of *P. oleae* annually on pear trees, but only two generations on plum, pear and apple trees. Also, recorded three annual peaks on Hollywood plum, maribosa plum, apricot and peach these peaks occurred in May, August and October. **Ezz (1997)** in Egypt, indicated three generations on four deciduous trees, the first generation appeared on first May, the second appeared on first August and the third generation appeared on first October.

3. *Impact of the Main Current Climatic Factors on the Current Population Density of Different Stages of P. oleae:*

3.1. *Nymphs Population*

Effect of mean maximum temperature

The results of statistical analysis of simple correlation (Table, 2) showed significantly positive correlation between the mean maximum temperature and nymphs population of *P. oleae*, r value was (+0.58). The unit effect regression coefficient (b) indicates that an increase of 1°C in the mean maximum temperature, would incr-

-ease the population by 1.62 individuals per leaf for the current year.

Concerning, the partial regression value, data represented in Table (2), emphasized an significantly negative relation (-4.75). As well, the partial correlation value was (-0.63) and t-test value was (-2.31) when the minimum temperature and solar radiation become around their means, during the current year. The obtained results revealed that, mean maximum temperature was above the optimum range of nymphs population of *P. oleae*, and this climate factor was responsible for certain changes in the insect population by 14.11% during the current year.

Effect of Mean Minimum Temperature

The effect of mean minimum temperature on nymphs activity was significantly positive (r = +0.66) for the current year (Table 2). The calculated regression coefficient for the unit effect of this factor indicated that for every 1˚C increase in the mean minimum temperature, the population density would increase by 1.77 individuals per leaf for the current year. The precise effect of the mean minimum temperature on the nymphs population showed that, it was highly significantly positive (P. reg. value was +7.91). Also, the partial correlation value was (+0.79) and t-test value was (+3.68) when the maximum temperature and solar radiation become around their means, during the current year. The obtained results revealed that, mean minimum temperature was entirely under the optimum range of nymphs population and this climate factor was the most effective variable in population changes of nymphs by 35.99% during the current year.

Effect of Mean Solar Radiation

Data in Table (2) showed that the simple correlation (r) between the mean solar radiation and the nymphal activity was insignificantly positive (+0.19). The calculated regression coefficient (b) for the effect of this factor indicated that every 1 MJ/m^2 increase in the mean solar radiation, would increase the population by 0.83 individuals per leaf for the current year. The exactly relationship between this climatic factor and the nymphs activity was determined by the partial regression value (Table 2), which emphasized significantly negative relation (-3.73). As well as, the partial correlation value was (-0.76) and t-test value was (-3.30) when the maximum and minimum temperature become around their means, during the current year. The obtained results revealed that, mean solar radiation was above the optimum range of nymphs population of *P. oleae*, and this climate factor was responsible for certain changes in the insect population by 28.84% during the current year.

The Combined Effect of the Tested Climatic Factors on the Nymphal Activity

The combined effect of these climatic factors on the nymphs population was highly significant where the “F” value, was 9.89 during the current year in Table (2). The influence of these combined climatic factors was expressed as percentage of explained variance which was 78.75% for the current year. The remaining unexplained variances are assumed to be due to the influences of other unconsidered and undetermined factors that were not included in this study in addition to the experimental error.

3.2. *Adult Females’ Population*

Effect of Mean Maximum Temperature

Data presented in Table (2) showed that the simple correlation (r) between the mean maximum temperature and the population density of adult females was insignificantly positive (+0.55) for the current year. As well as, the calculated regression coefficient (b) for the effect of this factor indicated that every 1˚C increase in the mean maximum temperature, would increase the population by 1.27 individuals per leaf for the current year. The precise effect of this factor on the adult females population (Table, 2) showed that it was insignificantly negative relation (P. reg. was -3.91). Also, the partial correlation was (-0.62) and t value was (-2.24) when the minimum temperature and solar radiation become around their means, during the current year. The obtained results revealed that, mean maximum temperature was around the optimum range of adult females population of *P. oleae*, and this climate factor was responsible for certain changes in the insect population by 14.11% during the current year.

Effect of the Mean Minimum Temperature

An significantly positive correlation between this climatic factor and the adult females population was detected (r value was +0.63) for the current year. In the same time, the regression coefficient indicates that an increase of 1˚C in the mean minimum temperature, would increase the population by 1.40 individuals per leaf, for the current year.

The real effect of the mean minimum temperature on the adult females population showed that, it was highly significantly positive (P. reg. value was +6.50). Also, the partial correlation value was (+0.78) and t-test value was (+3.55) when the maximum temperature and solar radiation become around their means, during the current year. The obtained results revealed that, mean minimum temperature was entirely under the optimum range of adult females population and this climate factor was the most effective variable in population changes of nymphs by 35.99% during the current year.

Effect of Mean Solar Radiation

As shown in Table (2), the effect of mean solar radiation on adult females' activity was insignificantly positive (+0.15). The calculated regression coefficient (b) for the effect of this factor indicated that every 1 MJ/m^2 increase in the mean solar radiation, would increase the population by 0.57 individuals per leaf for the current year. The exactly relationship between this climatic factor and the adult females’ activity was determined by the partial regression value (Table 2), which emphasized significantly negative relation (-3.16). As well as, the partial correlation value was (-0.76) and t-test value was (-3.28) when the maximum and minimum temperature become around their means, during the current year. The obtained results revealed that, mean solar radiation was above the optimum range of adult females’ population of *P. oleae*, and this climate factor was responsible for certain changes in the insect population by 30.67% during the current year.

The Combined Effect of the Tested Climatic Factors on the Adult Females

The results showed that the combined effect of these tested factors on the insect population of adult females during the current year was highly significant (“F” value was 9.00) (Table 2). The percentage of variability which could be attributed to the combined effect of these tested factors on the insect population was 77.15% for the current year. The remaining unexplained variances are assumed to be due to the influence of other unconsidered factors which were not included in the present study in addition to the experimental error.

3.3. *Total Population of P. oleae*

Effect of Mean Maximum Temperature

The correlation coefficient (r) between the mean maximum temperature and total population in the current year, was significantly positive (+0.57) (Table 2). The unit effect regression coefficient (b) indicated that an increase of 1°C in the mean maximum temperature, would increase the population by 2.89 individuals per leaf for the current year. The partial regression values emphasized significantly negative relation that was (-8.66). As well as, the partial correlation value was (-0.63) and t-test value was (-2.32) when the minimum temperature and solar radiation become around their means, during the current year. The obtained results revealed that, mean maximum temperature was above the optimum range of total population of *P. oleae*, and this climate factor was responsible for certain changes in the insect population by 14.29% during the current year.

Effect of Mean Minimum Temperature

The correlation coefficient (r) between mean minimum temperature and total population of *P. oleae* was significantly positive ($r = +0.65$) for the current year (Table 2). The calculated regression coefficient for the unit effect of this factor indicated that for every 1˚C increase in the mean minimum temperature, the population density would increase by 3.16 individuals per leaf for the current year. The precise effect of the mean minimum temperature on the total population by pest showed that, it was highly significantly positive relation (P. reg. value was +14.41). Also, the partial correlation value was (+0.79) and t-test value was (+3.69) when the maximum temperature and solar radiation become around their means, during the current year. The obtained results revealed that, mean minimum temperature was entirely under the optimum range of total population and this climate factor was the most effective variable in population changes of nymphs by 36.30% during the current year.

Effect of Mean Solar Radiation

Data in Table (2) showed that, the effect of mean solar radiation on total population activity of *P. oleae* was insignificantly positive (+0.17). The calculated regression coefficient (b) for the effect of this factor indicated that every 1 MJ/m^2 increase in the mean solar radiation, would increase the population by 0.57 individuals per leaf for the current year. The exactly relationship between this climatic factor and the total population activity was determined by the partial regression value (Table 2), which emphasized significantly negative relation (-6.90). As well as, the partial correlation value was (-0.76) and t-test value was (-3.25) when the maximum and minimum temperature become around their means, during the current year. The obtained results revealed that, mean solar radiation was above the optimum range of total population of *P. oleae*, and this climate factor was responsible for certain changes in the insect population by 29.91% during the current year.

The Combined Effect of the Tested Climatic Factors on the Total Population of P. Oleae

The combined effect of these tested factors on the total population of *P. oleae* during the current year was highly significant ("F" value was 9.83, Table 2). The amount of variability that could be attributed to the combined effect of these tested factors on the total population of insect was 78.66% for the current year.

Prediction of Different P. oleae Alive Stages Population Density

The most effective climatic factors, which could be used to predict different alive stages, were maximum air temperature, minimum air temperature and solar radiation. Prediction equation for nymphs, adult females and total population of *P. oleae* were concluded according to the mentioned statistical analysis in Table (3) and pres-

-ented as follow:

For nymphs' population: $Y = 123.27^{**} – 0.63 X_1^{*} + 0.79 X_2^{**} – 0.76 X_3^{*}$, E.V. = 78.75%

For adult females' population: $Y = 102.55^{**} – 0.62 X_1 + 0.78 X_2^{**} – 0.76 X_3^{*}$, E.V. = 77.15%

For total population of pest: $Y = 225.82^{**} – 0.63 X_1^{*} + 0.79 X_2^{**} – 0.76 X_3^{**}$, E.V. = 78.66%

Where, Y = Prediction value; X_1 = Maximum air temperature; X_2 = Minimum air temperature;

X_3 = Solar radiation;* Significant at $P \leq 0.05$; ****** Highly significant at $P \leq 0.01$; E.V. % = Explained variance;

4. *Estimated Population Densities of Different Stages of P. oleae under Different Scenarios of (RCPs) during three Time Series (2011-2040, 2041-2070 and 2071-2100) Compared with the Current Population:*

Numbers of Nymphs

According to prediction equation for nymphs' population and averages of monthly climatic factors under different RCPs scenarios during three time series, *P. oleae* nymph numbers can be estimated. Data in Table (3) and illustrated in Fig. (4), indicated that the expected values for nymphs' population during the different time series (2011-2040, 2041-2070 and 2071-2100) under different RCPs scenarios (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5) were smaller than that for the current population of nymphs. The decreasing percentage of nymph's population under time series 2071-2100 had the highest percentage of decreasing with an average of (55.12%) as compared to 2040-2071 (53.26%) and 2011-2040 (50.91%).

The maximum decreasing percentage of nymphs population was expected under RCP 8.5 climate scenario with averages of 51.92, 55.97 and 58.50%; while it the minimum was prospective under RCP 2.6 scenario with averages of 49.52, 51.41 and 52.90% during the time series 2011-2040, 2041-2070 and 2071-2100, respectively. Results indicated also that, all numbers of nymphs population under climate change scenarios was decreased significantly as compared with the current conditions.

Generally, the RCP 2.6 climate scenario is expected to be correlated with the highest population density of nymphs during all different time series, followed by RCP 4.5 and then RCP 6.0; while the lowest population density of nymphs was found under RCP 8.5 scenario.

Numbers of Adult Females

Based on the prediction equation for adult female's population and averages of monthly climatic factors under different RCPs scenarios during three time series, *P. oleae* adult female numbers could be expected. Data in Table (4) and illustrated in Fig. (4), showed that the expected population densities for adult females during the different time series (2011-2040, 2041-2070 and 2071-2100) under different RCPs scenarios (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5) were fewer than that for the current females' population. The decreasing percentage of adult females population under 2011-2040 had the least percentage of decreasing with an average of 52.92% while, the highest percentage of decreasing was recorded under 2071-2100 time series with an average of 57.26%. The highest decreasing percentages of adult females' population were expected under RCP 8.5 with averages of 53.96, 58.14 and 60.76%; while the lowest prospective populations were under RCP 2.6 with decreasing averages of 51.50, 53.43 and 54.96% during the time series 2011-2040, 2041-2070 and 2071-2100, respectively. Results indicated also that, all numbers of adult females' population under climate change scenarios will be decreased significantly as compared with the current conditions.

Generally, the RCP 2.6 scenario is expected to be correlated with the highest population density of adult females during different time series, followed by RCP 4.5 and then RCP 6.0. While, the lowest population density of adult females will be found under RCP 8.5 scenario.

Numbers of Total Population of P. oleae

According to prediction equation for total population numbers of *P. oleae* and means of monthly climatic factors under different RCP scenarios during three time series, the total population numbers for *P. oleae* could be estimated. Data in Table (5) and illustrated in Fig. (4), revealed that the all prospective values for total populations of this scale insect during the different time series (2011-2040, 2041-2070 and 2071-2100) under different RCP scenarios (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5) were smaller than that for the current total population of same species.

The decreasing percentage of *P. oleae* total population under 2071-2100 had the highest percentage of decrease with an average of 56.08% as compared with 2040-2071 (54.20%) and 2011-2040 (51.81%). The highest decreasing percentage of total population was expected under RCP 8.5 with averages of 52.84, 56.94 and 59.52%; while, the lowest were expected under RCP 2.6 with averages of 50.41, 52.32 and 53.82% during the time series (2011-2040, 2041-2070 and 2071-2100, respectively). Results indicated also that, all values of total population under climate change scenarios were decreased significantly as compared with the current population.

Generally, the RCP 2.6 scenario is correlated with the highest population density of total population of *P. oleae* during all different time series, followed by RCP 4.5 and then RCP 6.0. While, RCP 8.5 scenario gave the lowest population density of total population of pest.

From the previously mentioned results, it could be concluded that the monthly observations of total population of *P. oleae* had three peaks of seasonal activity per year. The means of minimum air temperature were entirely under the optimum range for activities of nymphs, adult females and total population of *P. oleae* and this climatic factor was the most effective variables in population changes by 35.99, 36.00 and 36.30% for nymphs, adult females and total population of *P. oleae* during the base year data, respectively. The percentages of explained variance (E.V.%) indicated that the combined effect of these climatic factors viz., maximum temperature, minimum temperature and solar radiation were responsible for 78.75, 77.15 and 78.66 % of the population changes of nymphs, adult females and total population of this scale insect, respectively.

The obtained results revealed the all expected values for numbers of nymphs, adult females and total population of insect during the all different time series under all different RCPs scenarios were smaller in comparison to the current population of insect. Expected total population of insect will be smaller at time series of (2071-2100) as compared with the two time series of (2011-2040) and (2041-2070) under the scenarios of RCPs (2.6, 4.5, 6 and 8.5). Also, the time series of (2071-2100) exhibited higher percentages of decreasing of the number of nymphs, adult females and total population with averages of (55.12, 57.26 and 56.08%, respectively) as compared to the time series of 2041-2070 (53.26, 55.34 and 54.20%) and the time series of 2011-2040 (50.91, 52.92 and 51.81%, respectively). Furthermore, the RCP 8.5 scenario exhibited the lowest population density of nymphs, adult females and total population *P. oleae* and the highest decreasing percentage for population density of different stages of *P. oleae* as compared with the other RCPs during all different time series.

IV. CONCLUSION

The aforementioned results revealed that the means of minimum air temperature were the highest effective variable in *P. oleae* population changes by 35.99, 36.00 and 36.30% for nymphs, adult females and total population compared to during the base year data, respectively. Also, the expected climate changes in Luxor Governorate, Egypt according to the RCP scenarios during three time series will cause a decrease in the population density of *P. oleae*. The decreasing percentages in the total population of *P. oleae* well be between 50.41% to 59.52%, up to the 2011-2100 time series as compared to the current population. The reduction in the population density of *P. oleae* is depending on climate region and climate change scenarios.

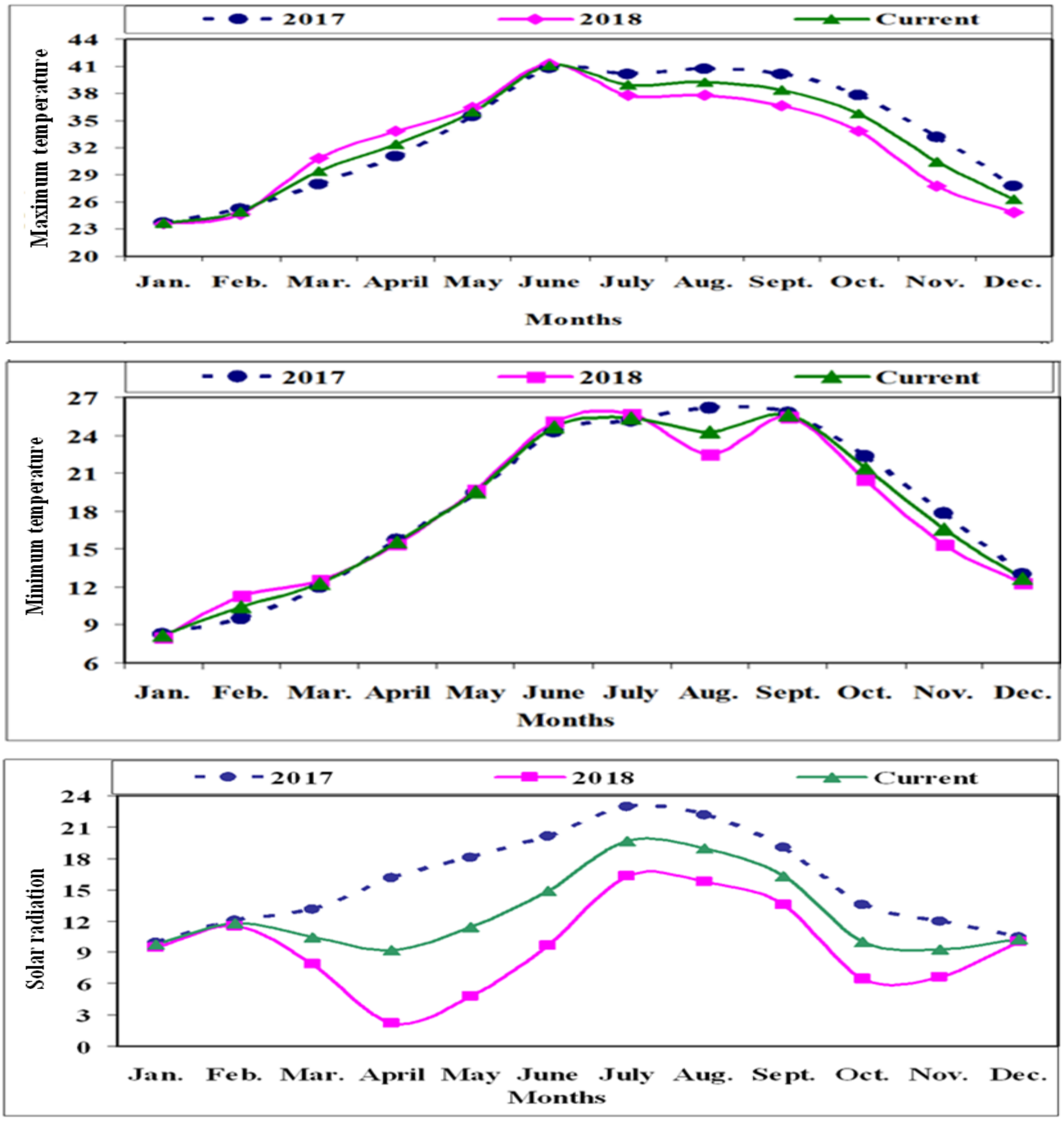


Fig. 1. Means of monthly maximum air temperature, minimum air temperature and solar radiation under climatic conditions at Esna district, Luxor Governorate during the two successive years 2017 and 2018 and the two years average.

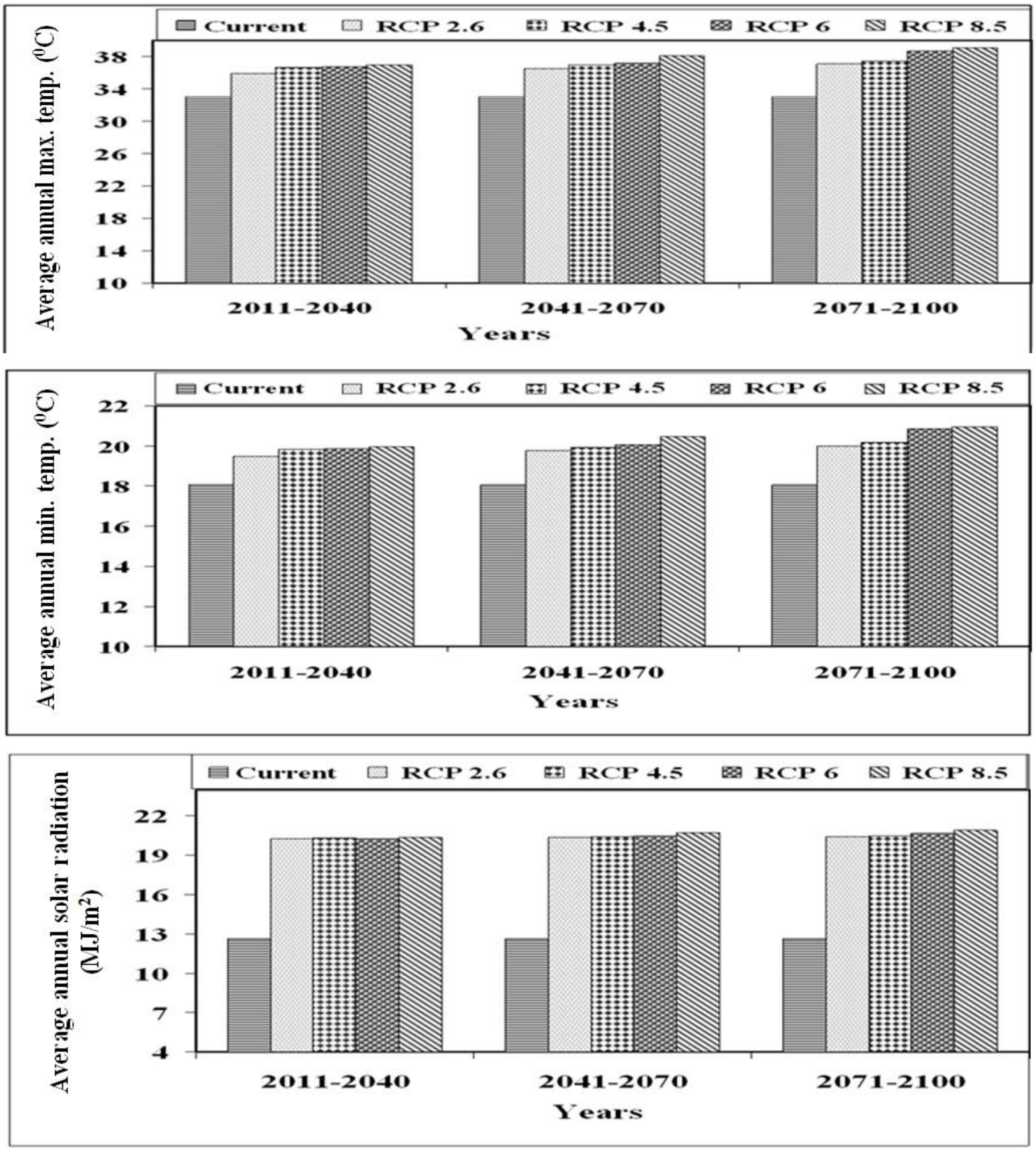
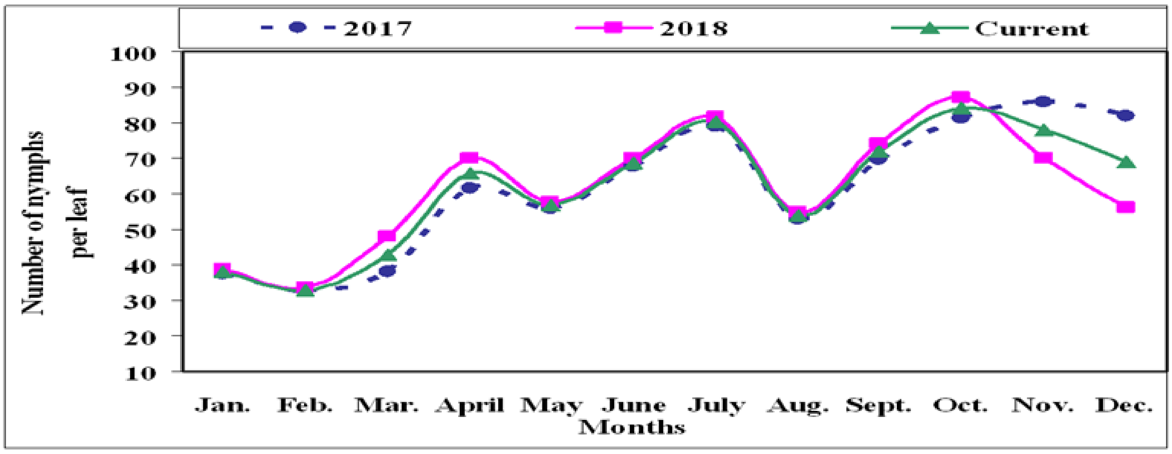


Fig. 2. Means of annual maximum air temperature, minimum air temperature and solar radiation under current and future climatic conditions for different RCP scenarios.



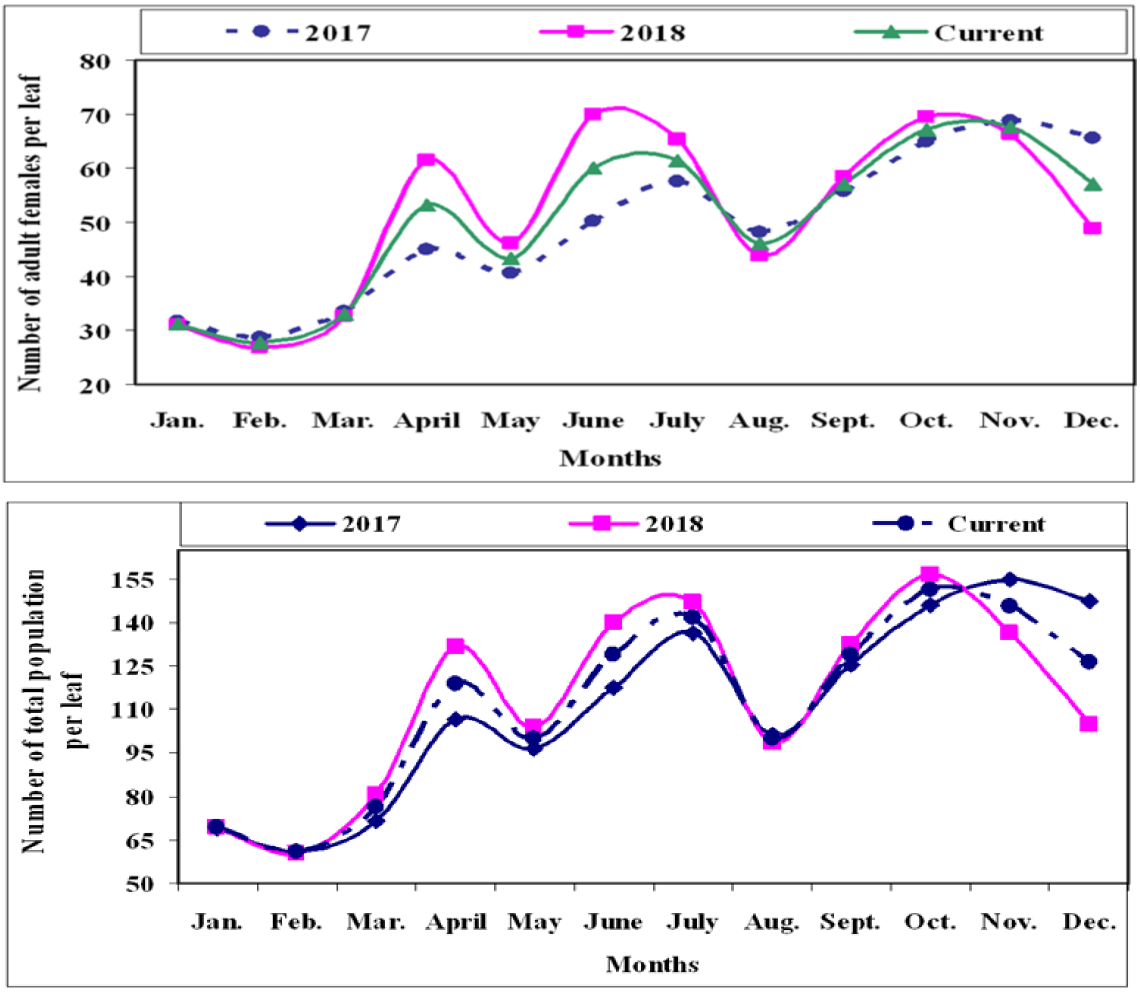


Fig. 3. Monthly mean number of nymphs, adult females and total population of *P. oleae* on mango leaves at Esna district, Luxor Governorate during the two successive years 2017 and 2018 and the two years average.

Table 2. Models of correlation and regression analyses for describing the relationship between the main weather factors on the current.

Tested Parameters		**Simple Correlation and Regression Values**				**Partial Correlation and Regression Values**					**Efficiency %**	**Rank**	**Analysis of Variance**				
		r	**b**	**S.E.**	**t**	**a**	**P. cor.**	**P. reg.**	**S.E.**	**t**			**F Value**	**C.V.**	**MR**	**R^2**	**E.V. %**
Nymphs	Max. Temp.	0.58	1.62	0.72	2.24*	123.27 **	-0.63	-4.75	2.06	-2.31*	14.11	3	9.89 **	0.15	0.89	0.79	78.75
	Min. Temp.	0.66	1.77	0.64	2.74*		0.79	7.91	2.15	3.68**	35.99	1					
	Solar Radiation	0.19	0.83	1.39	0.60		-0.76	-3.73	1.13	-3.30*	28.84	2					
Adult Femals	Max. Temp.	0.55	1.27	0.61	2.10	102.55 **	-0.62	-3.91	1.75	-2.24	14.23	3	9.00 **	0.15	0.88	0.77	77.15
	Min. Temp.	0.63	1.40	0.54	2.56*		0.78	6.50	1.83	3.55*	36.00	1					
	Solar Radiation	0.15	0.57	1.15	0.49		-0.76	-3.16	0.96	-3.28*	30.67	2					

Tested Parameters		Simple Correlation and Regression Values				Partial Correlation and Regression Values					Efficiency %	Rank	Analysis of Variance				
		r	b	S.E.	t	a	P. cor.	P. reg.	S.E.	t			F Value	C.V.	MR	R^2	E.V. %
Total	Max. Temp.	0.57	2.89	1.32	2.19	225.82 **	-0.63	-8.66	3.74	-2.32*	14.29	3	9.83 **	0.15	0.89	0.79	78.66
	Min. Temp.	0.65	3.16	1.18	2.68*		0.79	14.41	3.90	3.69**	36.30	1					
	Solar Radiation	0.17	0.57	1.15	0.49		-0.76	-6.90	2.06	-3.35**	29.91	2					

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

Table 3. Monthly mean numbers of *P. oleae* nymphs under current and future conditions under different RCP scenarios at Esna district, Luxor Governorate, Egypt.

Month	Current	RCP 2.6	RCP 4.5	RCP 6	RCP 8.5	RCP 2.6	RCP 4.5	RCP 6	RCP 8.5	RCP 2.6	RCP 4.5	RCP 6	RCP 8.5
		2011-2040				2041-2070				2071-2100			
Jan.	38.00	28.45	26.72	27.84	27.24	33.50	25.94	25.94	22.50	24.41	23.52	19.86	10.50
Feb.	33.06	17.57	16.91	16.46	16.15	15.14	14.51	15.25	11.37	14.50	14.73	5.40	-4.87
Mar.	43.04	13.90	12.71	12.92	12.04	9.52	10.20	10.82	6.93	10.82	10.41	1.64	-0.02
April	65.73	25.66	15.67	15.95	15.03	16.12	15.53	15.03	12.61	14.66	14.03	9.48	12.60
May	56.79	22.94	23.21	22.44	22.75	22.93	22.41	22.41	21.24	22.79	22.36	21.43	22.54
June	68.78	26.84	32.00	27.26	26.52	26.84	26.48	26.49	25.72	26.86	26.51	25.78	27.02
July	80.46	34.29	34.27	34.33	34.00	34.31	34.02	33.69	32.41	34.23	33.57	32.90	34.02
Aug.	53.92	38.71	38.95	38.81	38.82	38.44	38.47	38.55	37.83	38.66	38.40	37.39	38.34
Sept.	72.03	45.90	46.06	46.08	46.17	46.10	46.09	45.79	45.69	46.16	46.24	45.07	45.81
Oct.	84.16	47.65	47.23	47.61	47.22	47.21	47.22	47.20	46.37	47.20	47.18	47.10	55.87
Nov.	78.04	38.86	38.35	38.31	38.01	38.31	37.83	37.60	35.71	37.97	37.34	67.57	35.14
Dec.	69.04	34.28	33.45	33.24	33.31	32.62	32.47	30.97	28.78	31.71	31.29	16.46	31.40
Average	61.92	31.26	30.46	30.10	29.77	30.09	29.26	29.14	27.26	29.16	28.80	27.51	25.70
$P \leq 0.05$		*	*	*	*	*	*	*	*	*	*	*	*
Decrease (%)		49.52	50.81	51.38	51.92	51.41	52.74	52.93	55.97	52.90	53.49	55.58	58.50
		50.91				53.26				55.12			

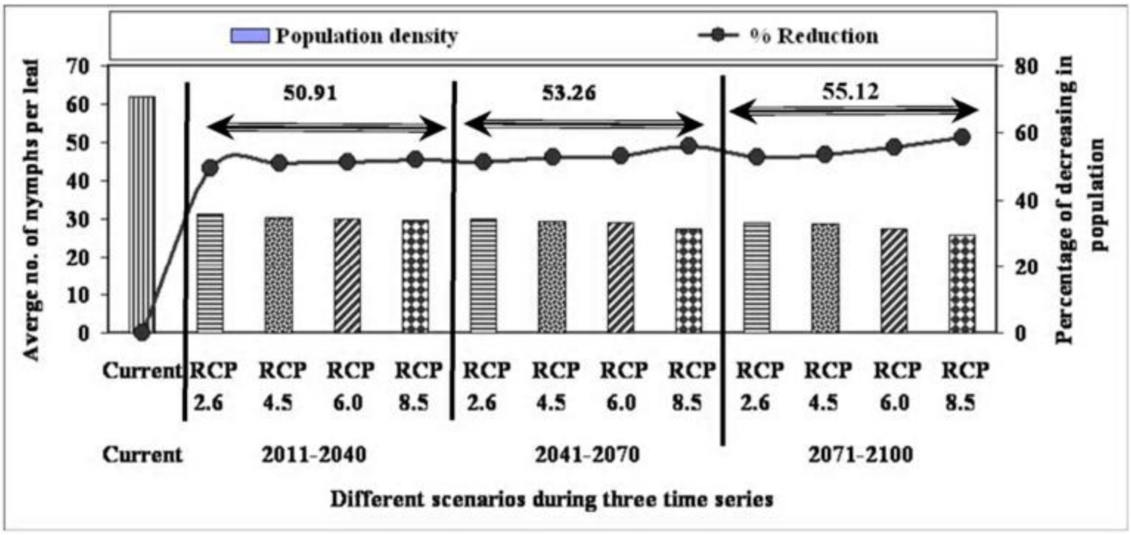
Table 4. Monthly mean numbers of *P. oleae* adult females under current and future conditions under different RCP scenarios at Esna district, Luxor Governorate, Egypt.

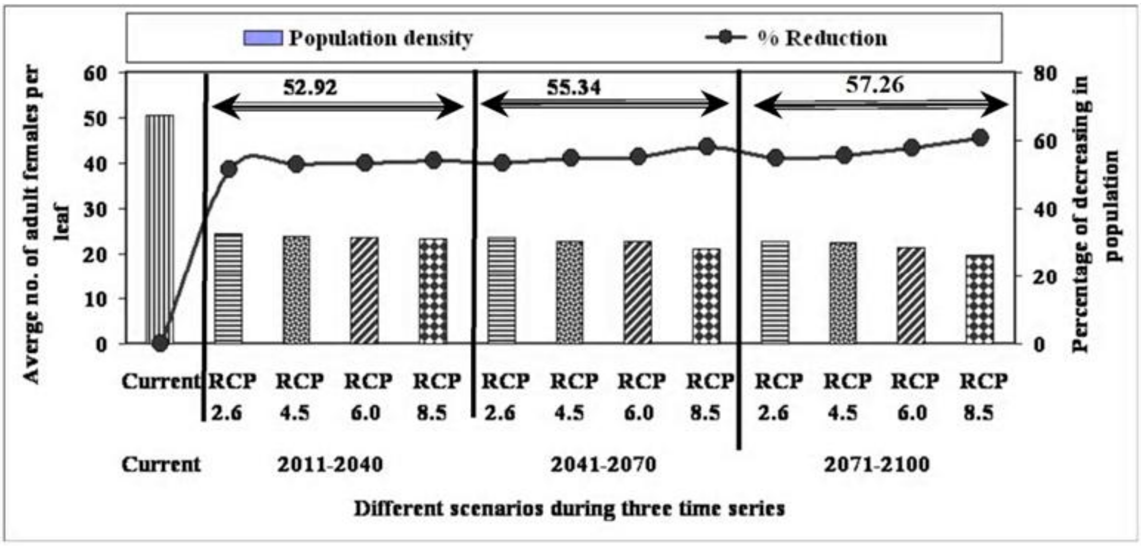
Month	**Current**	**RCP 2.6**	**RCP 4.5**	**RCP 6**	**RCP 8.5**	**RCP 2.6**	**RCP 4.5**	**RCP 6**	**RCP 8.5**	**RCP 2.6**	**RCP 4.5**	**RCP 6**	**RCP 8.5**
		2011-2040				**2041-2070**				**2071-2100**			
Jan.	31.28	23.07	21.61	22.57	22.05	27.24	20.97	20.97	18.10	19.71	18.96	15.92	8.11
Feb.	27.75	13.86	13.32	12.95	12.69	11.86	11.31	11.93	8.69	11.30	11.50	3.75	-4.82
Mar.	33.09	10.43	9.43	9.61	8.86	6.74	7.32	7.84	4.57	7.84	7.50	0.17	-1.25
April	53.23	19.70	11.45	11.69	10.91	11.83	11.34	10.91	8.86	10.59	10.06	6.22	8.77
May	43.40	17.05	17.26	16.60	16.86	17.03	16.58	16.58	15.58	16.90	16.53	15.73	16.64
June	60.02	20.14	24.39	20.48	19.85	20.14	19.83	19.84	19.19	20.15	19.84	19.22	20.25
July	61.43	26.26	26.24	26.29	26.00	26.27	26.02	25.73	24.67	26.21	25.65	25.07	25.99
Aug.	46.00	29.94	30.12	30.02	30.02	29.70	29.72	29.78	29.17	29.90	29.67	28.84	29.65
Sept.	57.09	36.18	36.30	36.31	36.38	36.32	36.32	36.06	35.94	36.38	36.43	35.49	36.15
Oct.	67.14	37.95	37.59	37.91	37.57	37.56	37.57	37.54	36.83	37.54	37.52	37.53	44.77
Nov.	67.54	31.17	30.74	30.71	30.45	30.71	30.30	30.10	28.51	30.42	29.89	54.77	28.00
Dec.	57.17	27.78	27.09	26.92	26.97	26.40	26.27	25.01	23.18	25.64	25.29	12.93	25.18
Average	50.43	24.46	23.79	23.50	23.22	23.48	22.80	22.69	21.11	22.72	22.40	21.30	19.79
P ≤0.05		*	*	*	*	*	*	*	*	*	*	*	*
Decrease (%)		51.50	52.82	53.39	53.96	53.43	54.80	55.00	58.14	54.96	55.57	57.76	60.76
		52.92				55.34				57.26			

Table 5. Monthly mean numbers of *P. oleae* total population under current and future conditions under different RCPs scenarios at Esna district, Luxor Governorate, Egypt.

Month	**Current**	**RCP 2.6**	**RCP 4.5**	**RCP 6**	**RCP 8.5**	**RCP 2.6**	**RCP 4.5**	**RCP 6**	**RCP 8.5**	**RCP 2.6**	**RCP 4.5**	**RCP 6**	**RCP 8.5**
		2011-2040				**2041-2070**				**2071-2100**			
Jan.	69.29	51.52	48.33	50.41	49.29	60.73	46.92	46.92	40.60	44.12	42.49	35.78	18.61
Feb.	60.81	31.44	30.24	29.41	28.84	27.00	25.82	27.18	20.06	25.80	26.23	9.15	-9.69
Mar.	76.13	24.33	22.13	22.53	20.90	16.27	17.51	18.67	11.49	18.67	17.91	1.81	-1.27
April	118.96	45.36	27.11	27.64	25.94	27.95	26.87	25.94	21.47	25.25	24.10	15.70	21.37
May	100.20	39.99	40.47	39.04	39.60	39.97	39.00	39.00	36.83	39.69	38.89	37.16	39.19
June	128.80	46.98	56.38	47.74	46.38	46.99	46.31	46.32	44.91	47.01	46.35	45.00	47.26

Month	Current	RCP 2.6	RCP 4.5	RCP 6	RCP 8.5	RCP 2.6	RCP 4.5	RCP 6	RCP 8.5	RCP 2.6	RCP 4.5	RCP 6	RCP 8.5
		2011-2040				2041-2070				2071-2100			
July	141.89	60.54	60.51	60.61	60.01	60.58	60.04	59.42	57.08	60.45	59.22	57.96	60.01
Aug.	99.92	68.65	69.06	68.83	68.84	68.14	68.19	68.33	67.01	68.57	68.08	66.23	68.00
Sept.	129.13	82.08	82.35	82.39	82.55	82.42	82.41	81.85	81.64	82.54	82.67	80.56	81.96
Oct.	151.30	85.60	84.82	85.52	84.79	84.78	84.79	84.74	83.20	84.74	84.70	84.63	100.64
Nov.	145.58	70.04	69.09	69.02	68.45	69.02	68.12	67.70	64.22	68.39	67.23	122.34	63.13
Dec.	126.21	62.06	60.53	60.16	60.28	59.03	58.74	55.97	51.97	57.35	56.58	29.39	56.57
Average	112.35	55.72	54.25	53.61	52.99	53.57	52.06	51.84	48.37	51.88	51.20	48.81	45.48
P ≤0.05		*	*	*	*	*	*	*	*	*	*	*	*
Decrease (%)		50.41	51.71	52.29	52.84	52.32	53.66	53.86	56.94	53.82	54.43	56.56	59.52
		51.81				54.20				56.08			





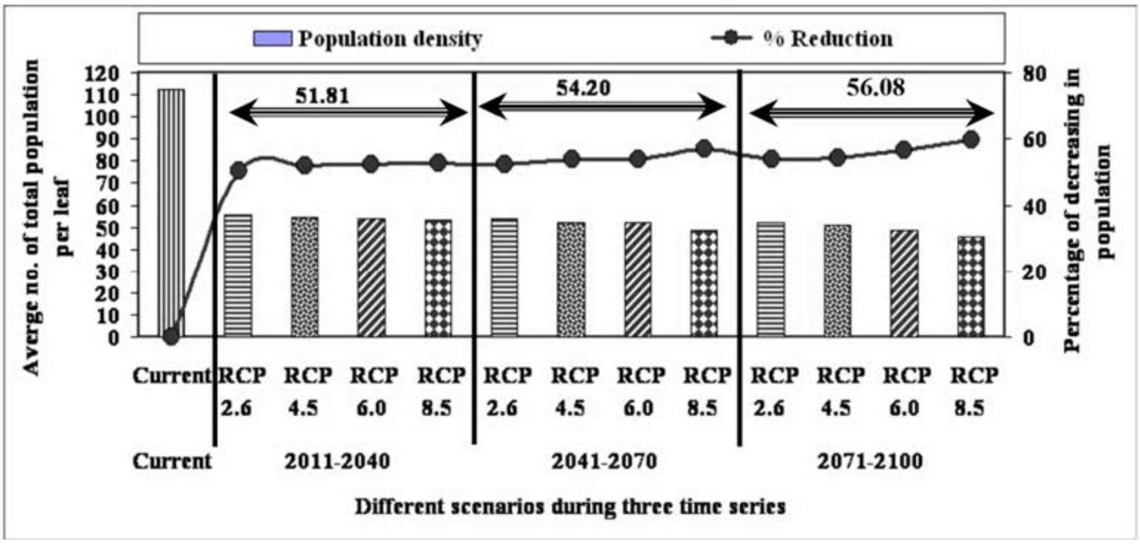


Fig. 4. Mean numbers and decreasing percentages among different stages of *P. oleae* populations under current and future conditions under different RCPs scenarios during three time series at Esna district, Luxor Governorate.

REFERENCES

[1] Abdrabbo, M.A.; A.A. Farag and W.M.S. El-Desokey (2015): Implementing of RCPs Scenarios for the prediction of Evapotranspiration in Egypt. International Journal of Plant & Soil Science. 6(1): 50-63 pp.

[2] Asfoor, M.A. (1997): Seasonal abundance and control of plum scale insect *Parlatoria oleae* (Clovee) on some deciduous trees. Ph.D. Thesis, Fac. Agric., Zagazig Univ., Egypt, 398 pp.

[3] Bakr, R.F.A.; R.M. Badawy; S.F.M. Mousa; L.S. Hamooda and S.A. Atteia (2009): Ecological and taxonomic studies on the scale insects that infest mango trees at governorate Egypt. Acad. J. biolog. Sci., 2 (2): 69- 89 pp.

[4] Bale, J.; G. Masters; I. Hodkinson; C. Awmack; T. Bezemer; V. Brown; J. Butterfield; A. Buse; J. Coulson and J. Farrar (2002): Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. Global Change Biol. 8: 1–16 pp.

[5] Dent, D. (1991): Insect Pest Management. C.A.B. International.

[6] El-Amir, S.M. (2002): Environmentally safe approaches for controlling some scale insects infesting olive trees in new reclaimed areas. M.Sc. Thesis Fac. Agric., Al-Azhar Univ., Egypt, 92 pp.

[7] El-Hakim, A.M. and E.I. Helmy (1982): Survey and population studies on olive leaf pests in Egypt. Bull. Entomol. Soc., Egypt, 64: 213-220 pp.

[8] Ezz, N.A. (1997): Ecological studies on plum scale insect *Parlatoria oleae* and its parasitoid *Aphytis* sp. on deciduous trees. M.Sc. Thesis, Fac. Agric., Cairo Univ., 148 pp.

[9] Hassan, A. SH.; M.M. Mansour and M.A. EI-Deeb (2009): Seasonal abundance of the plum scale insect, *Parlatoria oleae* (Colvee) (Homoptera: Diaspididae) on the olive trees in newly reclaimed areas. Egypt. J. Agric. Res., 87(3): 691-715 pp.

[10] Intergovernmental Panel on Climate Change (IPCC): IPCC Guidelines for National Greenhouse Gas Inventories programme, edited by: Eggleston, H.S.; L. Buendia; K. Miwa; T. Ngara and K. Tanabe (2006): The institute for Global Environmental Strategies (IGES), Hayama. http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

[11] Merrill, R.; D. Gutie´rrez; O. Lewis; J. Gutierrez; S. Diez and R. Wilson, (2008): Combined effects o f climate and biotic interactions on the elevational range of a phytophagous insect. J. Anim. Ecol. 77: 145–155 pp.

[12] Mitchell, TD. And PD. Jones (2005): An improved method of constructing a database of monthly climate observations and associated high-resolution grids. International Journal of Climatology.25: 693-712 pp.

[13] Moss, R.H.; J.A. Edmonds; K.A. Hibbard; M.R. Manning; S.K. Rose; D.P. van Vuuren; T.R. Carter; S. Emori; M. Kainuma; T. Kram; G.A. Meehl; J.F.B. Mitchell; N. Nakicenovic; K. Riahi; S.J. Smith; R.J. Stouffer; A.M. Thomson; J.P Weyant and T.J. Wilbanks (2010): The next generation of scenarios for climate change research and assessment. Nature, 463: 747–756 pp.

[14] MSTATC (1980): A Microcomputer program of the design management and analysis of agronomic research experiments. Michigan State Univ., USA.

[15] Osborn, T.J. (2009): A user guide for Clim Gen: A flexible tool for generating monthly climate data sets and scenarios. Climatic Research Unit, University of East Anglia, Norwich. 17.

[16] Parmesan, C. (2007): Influences of species, latitudes and methodologies on estimates of phenological response to global warming. Glob. Chang. Biol. 13: 1860–1872 pp.

[17] Samways, M. (2005): Insect Diversity Conservation. Cambridge University Press, Cambridge.

[18] SPSS.(1999):SPSS base 9.0 user's guide. SPSS, Chicago, IL

[19] Walther, G.R.; E. Post; P. Convey; A. Menzel; C. Parmesan and T.J.C. Beebee (2002): Ecological responses to recent climate change. Nature. 416: 389-395 pp.

[20] Warren, R.; S. de la Nava Santos; R. Ford; T.J. Osborn and S. Raper (2008): Development of the Community Integrated Assessment System (CIAS), a multi-institutional modular integrated assessment approach for modeling climate change, and of SoftIAM, its supporting software. Environmental Modelling and Software, 23(5): 592-610 pp.

[21] Woiwod, I. (1997): Detecting the effects of climate change on Lepidoptera. J. Insect Conserv. 1: 149–158 pp.

[22] Zalom, F. and T. Wilson (1982). Degree days in relation to an integrated pest management program. Division of Agricultural Sciences, University of California, Davis, CA, USA. 2 pp.

AUTHOR'S PROFILE

First Author
Moustafa M.S. Bakry, Scale Insects and Mealybugs Research Dept., Plant Protection Research Institute, A.R.C, Dokii, Giza, Egypt.

Second Author
Lamiaa H.Y. Mohamed, Scale Insects and Mealybugs Research Dept., Plant Protection Research Institute, A.R.C, Dokii, Giza, Egypt.

Third Author
Shimaa Y.E. Shakal, Plant Prot. Dept., Fac. of Agric. and Natural Resources, Aswan Univ., Aswan, Egypt.