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Implementing of RCPs scenarios to estimate the population density of parlatoria date scale insect, *Parlatoria blanchardii* (Targioni-Tozzetti) (Hemiptera: Diaspididae) infesting date palm trees in Luxor Governorate, Egypt

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Abstract

The present work was carried out to study the effect of some climatic factors on the population density of the white date palm scale insect, *Parlatoria blanchardii* on date palm 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 from 2009 to 2013 years) at Esna district, Luxor Governorate, Egypt. Results showed that monthly observations of total population of *P. blanchardii* had three to four peaks of seasonal activity per year. The mean minimum temperature was the most effective variable in population changes by 18.9, 20.9 and 19.9% for nymphs, adult females and total population of *P. blanchardii* during the base year data, respectively. The obtained results revealed the all expected values for number 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 (2041-2070) and (2011-2040) under the scenarios of (RCP 4.5, RCP 6 and RCP 8.5). Also, the time series of (2071-2100) exhibited the highest percentage of decreasing of the number of nymphs, adult females and total population with an average of (25.84, 23.76 and 24.91%) as compared to the time series of 2040-2071 (24.68, 22.44 and 23.68%) and the time series of 2011-2040 (10.43, 10.17 and 10.31%), respectively. Furthermore, the RCP 8.5 scenario exhibit the highest population density of nymphs, adult females and total population *P. blanchardii* and the lowest decreasing percentage of population density of *P. blanchardii* as compared with the different RCPs during all different time series.

Key words: *RCPs*, *Parlatoria blanchardii*, seasonal activity, climate change scenarios and date palm.

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Introduction

Date palm trees (*Phoenix dactylifera* L.) are subjected to infestation by different pests. Among these pests, the parlatoria date scale insect, *P. blanchardii* is considered one of the most destructive pests. Adults and nymphs feed on leaves sap, sucking great amount of sap which contain macro- and micro-elements. At high level of infestation remarkable damage occurs, resulting in early leaves drop and yield reduction (El-Said, 2000). Great damages occurred by this scale insect by sucking the plant sap that give low rates of photosynthesis and respiration which leads to curling, yellowing and dropping to leaves. The subsequent damage leads to considerable quality and quantity yield losses and also marketing value of the fruits. A characteristic symptom of infestation by *P. blanchardii* is the appearance and accumulation of its scales on attacked palm parts (El-Said, 2000; El-Sherif et al., 2001; Blumberg, 2008). To develop an effective control against *P. blanchardii*, it is essential to know its bio-ecology including population dynamics and climatic factors influencing the 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. Climate change has become one of the major challenges for mankind and the natural environment. Rise 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 (Salem & Hamdy, 1985; Bale et al., 2002; Walther et al., 2002; Samways, 2005; Merrill et al., 2008). Climate change scenario development is a rapidly evolving field. Although these advances are clearly important, they 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). AR5 uses four Representative Concentration Pathway (RCP) scenarios with widely differing emissions pathways, reflecting different levels of ambition in tackling climate change. The lowest, RCP 2.6 is a very strong mitigation scenario, with CO_2 levels peaking by 2050 at ~443 ppmv. RCP 4.5 has a continuing rise in CO_2 concentrations to the end of the century, when they reach ~538 ppmv. RCP 6.0, increase CO_2 concentrations to reach ~670 ppmv by 2100. RCP 8.5 increase CO_2 concentration reaching 936 ppmv by 2100 (IPCC, 2013). The RCP 8.5 was developed using the MESSAGE model and the IIASA Integrated Assessment Framework by the International Institute for Applied Systems Analysis (IIASA), Austria. This RCP is characterized by increasing greenhouse gas emissions over time, representative of scenarios in the literature that lead to high greenhouse gas concentration levels (Riahi et al., 2007). Whereas, RCP 6.0 was developed by the AIM modeling team at the National Institute for Environmental Studies (NIES) in Japan. It is a stabilization scenario in which total radiative forcing is stabilized shortly after 2100, without overshoot, by the application of a range of technologies and strategies for reducing greenhouse gas emissions (Fujino et al., 2006; Hijioka et al., 2008). While, RCP 4.5 was developed by the GCAM modeling team at the Pacific Northwest National Laboratory's Joint Global Change Research Institute (JGCRI) in the United States. It is a stabilization scenario in which total radiative forcing is stabilized shortly after 2100, without overshooting the long-run radiative forcing target level (Smith & Wigley, 2006; Clarke et al., 2007). Furthermore, RCP 2.6 was developed by the IMAGE modeling Assessment Agency. The emission pathway is representative of scenarios in the literature that lead to very low greenhouse gas concentration levels. It is a "peak-and-decline" scenario; its irradiative forcing level first reaches a value of around 3.1 W/m^2 by mid-century, and returns to 2.6 W/m^2 by 2100. In order to reach such radiative forcing levels, greenhouse gas emissions (and indirectly emissions of air pollutants) are reduced substantially, over time (Van Vuuren et al., 2007).

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 the parlatoria date scale insect, *P. blanchardii* 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) compared with the current population of pest (average of population density from 2009 to 2013 years). As well as, the effect of maximum temperature, minimum temperature and solar radiation on the current pest population.

Materials and methods

The population fluctuations of parlatoria date scale, *P. blanchardii* which infest date palm trees were carried out at half-monthly intervals at Esna district, Luxor Governorate during five successive years from 2009 to 2013. An orchard about one feddan was selected for sampling during the studied period. Ten palm trees of White variety of almost similar and as uniform as possible in size, age (5 years), shape, height, vegetative growth were selected. These palm trees were randomly chosen and left without pruning the fronds, as well as they were not exposed for any chemical control measures before and during the period of investigation. The sample size (10 leaflets) was taken from different directions and levels of palm trees. 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 date palm trees leaflets were individually sorted into immature stages (nymphs) and mature stages (adult females) and then were counted and recorded together opposite to each inspected date.

Monthly mean numbers of *P. blanchardii* per date palm leaflet from 2009 to 2013 years was considered in this study as current population of pest. The half-monthly of maximum, minimum air temperatures and solar radiation at Luxor governorate from 2009 to 2013 years were obtained from the Central Laboratory for Agricultural Climate, Agriculture Research Center, Ministry of Agriculture in Giza. The altitude, latitude and longitude of this weather region of Luxor were 99 m, 25.67ºN and 32.71ºE, respectively.

Representative Concentration Pathway (RCPs) 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 the data in order to provide traceability (Table 1). The data come from peer-reviewed models linked together within the Community Integrated Assessment System (CIAS) developed at the Tyndall Centre for climate change research within the School of Environmental Sciences at the University of East Anglia (Mitchell and Jones, 2005; Warren et al. 2008;Osborn, 2009). Data of maximum, 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 in the present work was carried out with Computer using MSTATC Program software, 1980, (a microcomputer program of the design management and analysis of agronomic research experiments. Michigan State University, USA) and SPSS (1999) program base 9.0 user's guide, Chicago, IL. The data obtained were statistically analyzed by using different models of correlation and regression to investigate the relationships between different stages of *P. blanchardii* 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. blanchardii*. Also, the t-test was used to establish whether a significant difference exists between the current insect population (average from 2009 to 2013 years) 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 $P \leq 0.05$.

The decrement in numbers of insect was calculated as formula:

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

Where, A= Current population,

B= Expected population, Averages of different stages of insect population and climatic factors was calculated by using Excel sheets and shown graphically.

Table 2: Description of IPCC representative concentration pathway (RCP) up to 2100 compared to the average data from 2009 to 2013 years.

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	6.0	850	3.0	Stabilization without
8.5	8.5	1370	4.9	Rising

Results and Discussion

Trend of climatic factors from 2009 to 2013 years in Luxor region

Maximum air temperature: the means of the monthly maximum temperature were recorded from January, 2009 till December, 2013 (Figure 1). The highest monthly mean maximum temperature values were recorded in July, August and September months during all studied years. While, the lowest during January, February and March months (Figure 1). The highest average annual maximum temperature value (35.94 ºC) was recorded at 2013, followed by 2011, 2010 and 2012 years (33.52, 33.15 and 33.02 ºC), respectively, and the lowest average maximum temperature was recorded in 2009 year (31.99 ºC).

Minimum air temperature: 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 in July, August and September months (Figure 1). The highest average annual minimum temperature value (19.97 ºC) was recorded at 2013, followed by 2012, 2011 and 2010 years (18.88, 18.79 and 18.64 ºC), respectively. Whereas, the lowest average was recorded in 2009 year (18.35 ºC).

Solar radiation: the highest monthly mean solar radiation values were recorded during the summer months (June, July and August) during all studied years. While, the winter months (December, January and February) had the lowest values of solar radiation (Figure 1). The highest average annual solar radiation value (19.41 MJ/m^2) was recorded at 2013, followed by 2012, 2011 and 2010 years (18.35, 18.25 and 18.22 MJ/m^2), respectively. Whereas, the lowest average solar radiation was recorded in 2009 year (17.73 MJ/m^2).

Trend of current and future climatic conditions

Maximum air temperature: results in Figure 2, show the average annual trend of the mean maximum air temperature under current climate (average from 2009 to 2013 years) 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 between different scenarios during three time series. The results also indicated that the range of annual maximum air temperature values was 36.05°C under RCP 2.6 at 2011-2040 to 39.05°C under RCP8.5 at (2071-2100). Also, the difference between RCPs scenarios was less than 0.9°C during the short term time series (2011-2040), while the differences increased during the long term time series (2071-2100) about 2.05°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: Figure 2, shows the average annually trend of minimum air temperature under current (2009-2013) and 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 were ranged between 19.47°C under RCP 2.6 at 2011-2040 and 22.32°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 2.1°C during the short term time series (2011-2040), while the differences increased during the long term time series (2071-2100) about 2.42°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 the Upper Egypt had the highest average annual minimum air temperature, under current (1971-2000) and future conditions (2011-2040, 2041-2070 and 2071-2100).

Solar radiation: Figure (2), shows the average monthly trend of the mean solar radiation under current climate (average of solar radiation from 2009 to 2013 years) and future conditions (2011-2040, 2041-2070 and 2071-2100 years). 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 annual solar radiation value was found under the RCP

2.6 scenario. The results also indicated that the annual maximum 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) about 0.49 MJ/m^2 (difference between RCP 2.6 and RCP 8.5 at 2071-2100).

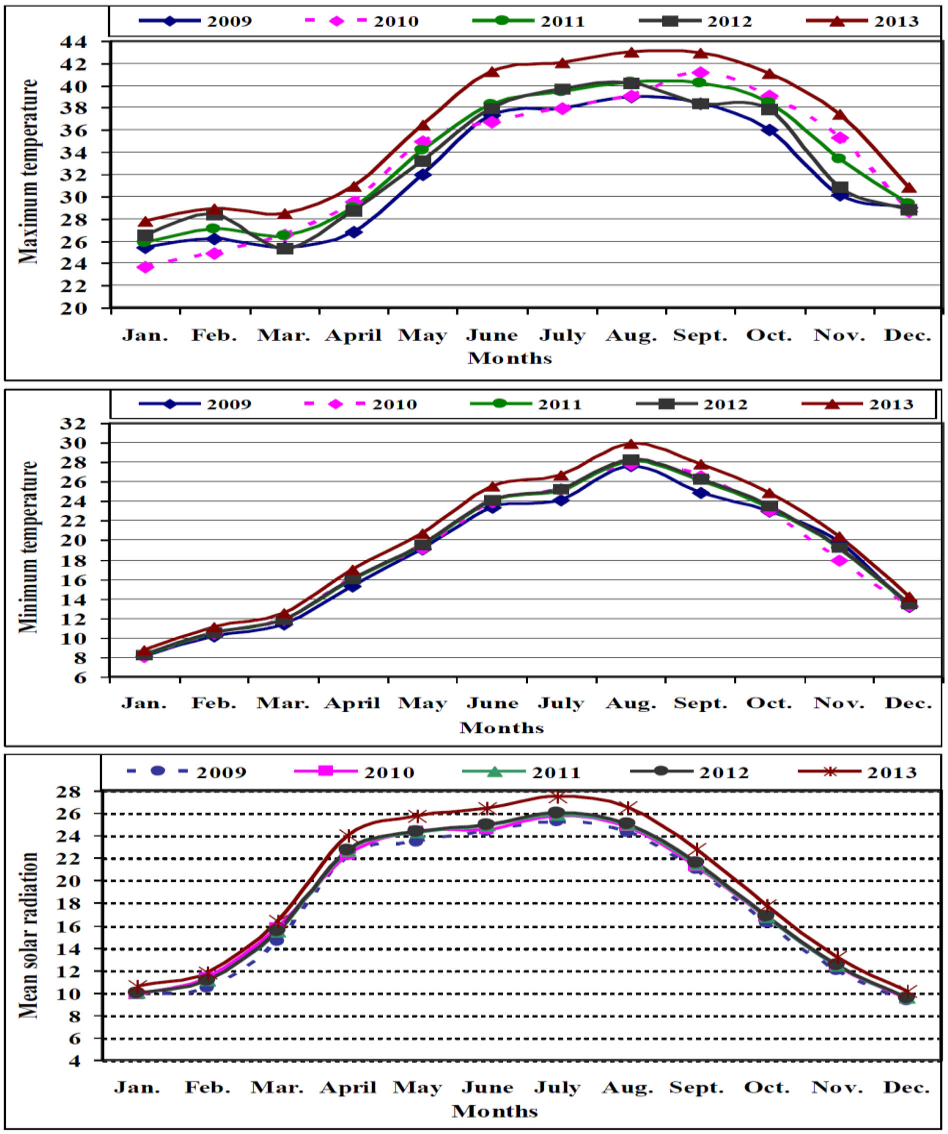

Figure 1. Means of monthly maximum air temperature, minimum air temperature and solar radiation under climatic conditions at Esna district, Luxor Governorate during the period from 2009 to 2013 years.

Seasonal fluctuations in population of *P. blanchardii*

Nymph: the monthly mean number of nymphs of *P. blanchardii* on date palm leaflets at Esna district, Luxor Governorate during the period from 2009 to 2013 years and current population are graphically illustrated in Figure (3). The nymphs of insect had four peaks per year, in April, June, September and November in all studied years and current population expect for 2009 year, where three peaks per year were recorded in April, June and October.

Adult females: as in nymph fluctuation a similar trend in the seasonal fluctuation of adult females of *P. blanchardii* was observed, with different values. The adult females had four peaks that were recorded in April, June, September and November in all studied years and current population (Figure 3).

Total population (nymphs and adult) of *P. blanchardii*: according to data of total population of insect, four peaks were recorded in April, June, September and November in all studied years and current population expect, 2009 year, three peaks per year were recorded in April, June and October (Figure3). Most authors indicated three or four peaks per year for *P. blanchardii* depending on the area, environmental conditions and the host plant world wide. Hussain (1996) at Bahria Oases, Egypt, stated that the population density of *P. blanchardii* on date palms had three peaks in October, March and July. Youssef (2002) at Baltim region, Kafr El- Sheikh Governorate, Egypt, reported that this insect had three peaks during the year, the highest peak was found in October, the second in March and the smallest third one in June. But, many authors in Egypt reported that the *P. blanchardii* had four peaks per year (Eraki, 1998; El-Said, 2000; El-Sherif et al., 2001; Elwan and El-Said, 2009).

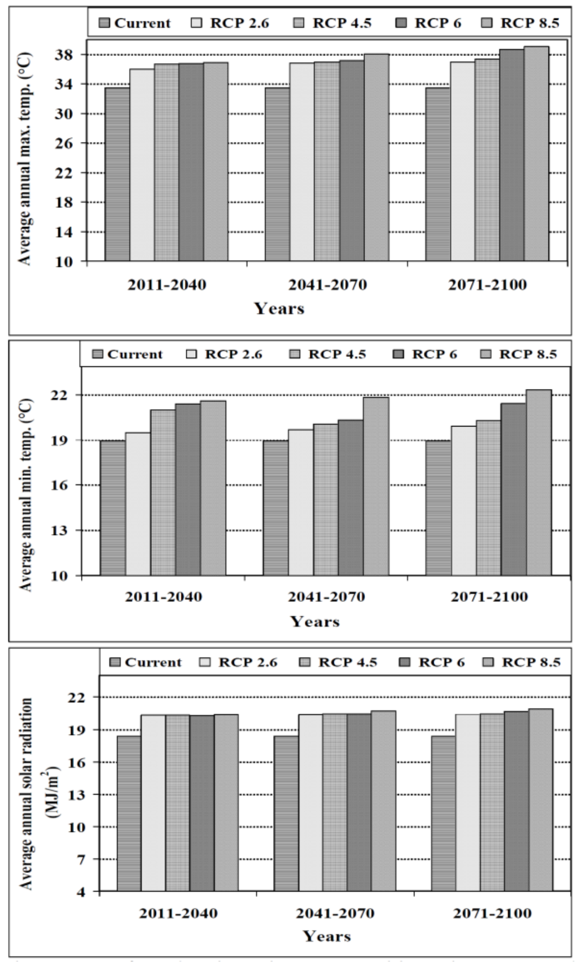

Figure 2. Means of annual maximum air temperature, minimum air temperature and solar radiation under current and future climatic conditions for different RCPs scenarios.

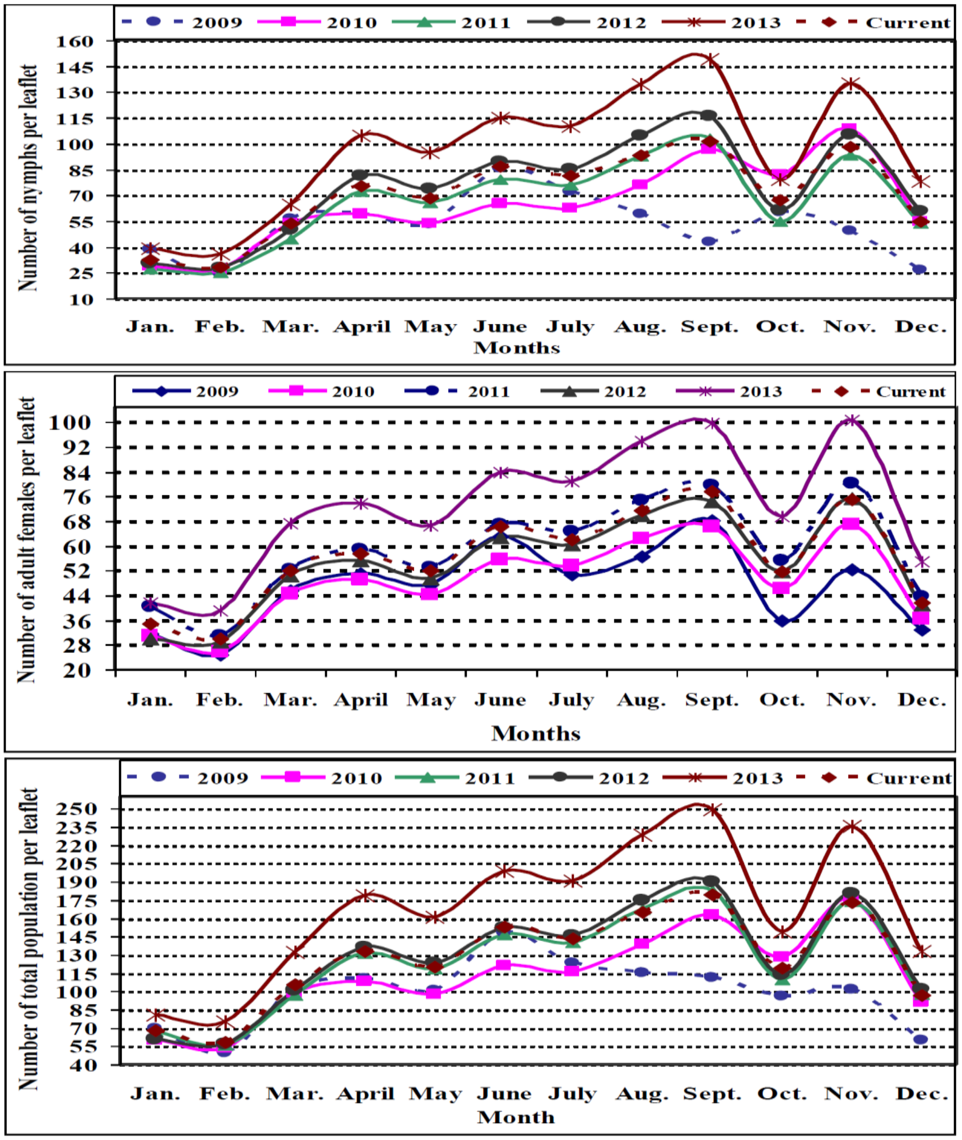

Figure 3. Monthly mean number of nymphs, adult females and total population of *P. blanchardii* on date palm leaflets at Esna district, Luxor Governorate during the period from 2009 to 2013 years and current data.

Impact of the main current climatic factors on the current population density of different stages of *P. blanchardii*

Effect of maximum temperature on nymphs population: The results of statistical analysis of simple correlation (Table 2) showed highly positive significant correlation between the mean maximum temperature and nymphs population of *P. blanchardii*, r value was (+0.79). The unit effect regression coefficient (b) indicates that an increase of 1°C in the mean maximum temperature increased the population by 3.34 individuals per leaflet for the current year. Concerning, the partial regression values are represented in

Table (3), emphasized an insignificant negative relation (-8.23) and (t) value was (-2.16) for the current year, as well as the partial correlation was insignificant negative (-0.61). The obtained results revealed that, mean temperature around the optimum range of nymphs population of *P. blanchardii* activity and was responsible for the certain changes in the insect population by 9.8 % during the current year.

Effect of minimum temperature on nymphs population: The effect of mean minimum temperature on nymphs activity was highly significant positive (r = +0.86) 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 increased by 3.06 individuals per leaflets for the current year. The precise effect of the mean minimum temperature on the population of nymphs showed that, it was significant positive (P.reg value was +10.65) and (t) value was (+2.99) (Table 3). Also, the partial correlation was significant positive (+0.73). The obtained results revealed that, mean minimum temperature under the optimum range of nymphs population and was responsible for the most changes in the insect population by 18.9% during the current year.

Effect of mean solar radiation on nymphs population: Concerning the data in Table (2) showed that the simple correlation (r) between the mean solar radiation and the population density of nymphs was significantly positive (+0.64). The calculated regression coefficient (b) for the effect of this factor indicated that every 1 MJ/m^2 increase in the mean solar radiation increased the population by 2.4 individuals per leaflets for the current year. The exactly relationship between this climatic factor and the activity of the nymphs was determined by the partial regression values (Table, 3), which emphasized insignificant negative relation between solar radiation and the nymphs activity (P.reg was -1.01) and (t) value was (-1.08). Also, the partial correlation was insignificant negative (-0.36). The obtained results revealed that, mean solar radiation around the optimum range of nymphs population and this climate factor was the least effective variable in population changes of the nymphs by 2.4% during the current year (Table 3).

The combined effect of the tested climatic factors on the nymphs' activity: The combined effect of these climatic factors on the nymphs' population was highly significant where the "F" value, was 13.07 during the current year in Table (3). The influence of these combined climatic factors was expressed as percentages of explained variance which were 83.05% 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.

Effect of maximum temperature on adult females' population: Data are presented in Table (2) showed that the simple correlation (r) between the mean maximum temperature and the population density of adult females was highly significant positive (+0.74) 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 increased the population by 1.99 individuals per leaflet for the current year. The precise effect of this factor on the adult females population (Table, 3) showed that it was insignificant negative (P.reg was -5.76) and t value was (-2.06) for the current year. Also, the partial correlation was insignificant negative (-0.59). The obtained results revealed that, mean maximum temperature around the optimum range of adult females' activity and was responsible for the certain changes in the population of adult females by 11.9 % during the current year.

Effect of minimum temperature on adult females' population: As shown in Table (2), it was noticed a highly significant positive correlation between this climatic factor and the adult females population (r value was +0.81) for the current year. In the same time, the regression coefficient indicates that an increase of 1˚C in the mean minimum temperature increased the population by 1.84 individuals per leaflet, for the current year. The real effect of this factor appeared from the partial regression value that, referred to the significant positive effect (+7.12) and (t) value was (+2.73) during the current year (Table 3). As well as, the partial correlation was significant positive (+0.69). Also, the obtained results revealed that, mean minimum temperature under the optimum range of adult females activity and was responsible for the most changes in the insect population by 20.9% during the current year.

Effect of mean solar radiation on adult females' population: Data in Table (2) obtained that, the effect of mean solar radiation on adult females activity was significant positive correlation for current year (r was +0.61). Also, the simple regression coefficient (b) for the effect of this factor indicates that for every 1 MJ/m^2 increase in the mean solar radiation, the population density of this insect increased by 1.46 individuals per leaflet for the current year. The partial regression coefficient for the effect of mean solar radiation on the adult females population are represented in Table (3), revealed that it was negative and insignificant for the current year (P.reg value was -0.66) and (t) value was (-0.96). Also, the partial correlation was insignificant negative (-0.32). The obtained results revealed that, mean solar radiation around the optimum range of adult females activity and was the least effective variable in population changes of the adult females by 2.5% 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 = 9.12) as recorded in Table (3). The percentage of variability that could be attributed to the combined effect of these tested factors on the insect population was 77.5% for the current year. The remaining unexplained variances are assumed to be due to the influence of other unconsidered factors that were not included in this study in addition to the experimental error.

Effect of mean maximum temperature on total population of *P. blanchardii*: In the current year as reported in Table (2), the correlation coefficient (r) between the mean maximum temperature and total population was highly significant positive (+0.78). The unit effect regression coefficient (b) indicates that an increase of 1°C in the mean maximum temperature increased the population by 5.33 individuals per leaflet for the current year. The partial regression values emphasized insignificant negative relation that was (-14.00) and "t value" was (-2.16) for the current year. Also, the partial correlation was insignificant negative (-0.61). The obtained results revealed that, mean maximum temperature around the optimum range of total population activity and was responsible for the certain changes in the total population of insect by 10.7 % during the current year (Table 3).

Effect of mean minimum temperature on total population of *P. blanchardii*: Results in Table (2) revealed that, the effect of this weather factor on total population of *P. blanchardii*. The correlation coefficient (r) between mean minimum temperature and total population was highly significant positive correlation for the current year (r = +0.84). The calculated regression coefficient (b) for the effect of this factor indicated that for every 1˚C increase, the population increased by 4.9 individuals per leaflet for the current year. The real effect of this factor on total population of *P. blanchardii* revealed that, it was significant positive for the partial regression (P.reg. = +17.77) and (t) value was (+2.93) during the current year. Also, the partial correlation was significant positive (+0.72). The obtained results revealed that, mean minimum temperature under the optimum range of total population activity and were responsible for the most changes in the total population of insect by 19.9% during the current year (Table 3).

Effect of mean solar radiation on total population of *P. blanchardii*: Data in Table (2) showed that, the effect of mean solar radiation on total population activity was significant positive for the current year (r was +0.66). As well as, the unit effect (regression coefficient) indicates that for every 1 MJ/m^2 increase in the mean solar radiation, the total population density of insect increased by 3.86 individuals per leaflet for the current year. Partial regression coefficient for the effect of mean solar radiation on the total population of insect revealed that it was insignificant negative for current year (P.reg value was -1.67) and t value was (-1.04). Also, the partial correlation was insignificant negative (-0.359). As well as, the obtained results revealed that, mean solar radiation around the optimum range of total population activity and was the least effective variable in population changes of the adult females by 2.5% during the current year (Table 3).

The combined effect of the tested climatic factors on the total population of *P. blanchardii*: The results in Table 3 showed that, the combined effect of these tested factors on the total population of *P. blanchardii* during the current year was highly significant (F value = 11.74). The amount of variability that could be attributed to the combined effect of these tested factors on the total population of insect was 81.5% for the current year.

Many investigators studied the effect of weather factors on the population of *P. blanchardii*. Laudeho and Benassy (1969) in Mauritania stated that maximum temperature combined with wind and low humidity was very effective for the survival of the crawlers of *P. blanchardii*. Eraki (1998) in Egypt, stated that, the responsibility of four factors combined maximum temperature, minimum temperature, mean of % relative humidity and % parasitism expressed as mount of percentage of explained variance were 72.5, 74.9, 81.5 and 65.2% during 1^{st}, 2^{nd}, 3^{rd} and 4^{th} generations, respectively. In the second year of study, the explained variance was 76.6, 99.6, and 97.3% during 1^{st}, 2^{nd} and 3^{rd} generations, respectively. El-Said (2000) in North Sinai, Egypt, stated that the effect of daily mean relative humidity was insignificant positive for both years of investigation. The simultaneous effect the three considered weather factors on activity was highly significant during both years of investigation. The percentage of variance explained by these factors was 56.5 and 53.6% for the two years.

Table 2: Simple correlation and regression values when the counts of the current climatic factors were plotted versus the current population density nymph, adult and total of P. blanchardii.

Stages	Tested factors	Simple correlation and regression values						C.V.
		Constant	r	B	S.E	t	p	
Nymphs	Max. temp (°C)	-41.63	0.79 **	3.34**	0.81	4.12 **	0.002	0.22
	Min. temp (°C)	12.40	0.86 **	3.06 **	0.58	5.25 **	0.000	0.19
	Solar radiation (MJ/m^2)	26.17	0.64 *	2.40 *	0.91	2.64 *	0.024	0.28
Adult females	Max. temp (°C)	-10.50	0.74 **	1.99 **	0.57	3.50 **	0.005	0.19
	Min. temp (°C)	21.27	0.81 **	1.84 **	0.42	4.39 **	0.001	0.17
	Solar radiation (MJ/m^2)	29.32	0.61 *	1.46 *	0.59	2.45 *	0.03	0.23
Total	Max. temp (°C)	-52.13	0.78 **	5.33 **	1.37	3.90 **	0.003	0.21
	Min. temp (°C)	33.67	0.84 **	4.90 **	0.99	4.95 **	0.000	0.18
	Solar radiation (MJ/m^2)	55.49	0.63 *	3.86 *	1.49	2.59 *	0.03	0.25

r: Simple correlation, b : Simple regression, S.E : Standard error, P: Probability, (*): Significant at $P \leq 0.05$, (**): Highly significant at $P \leq 0.01$, C.V. : Coefficient of Variation.

Prediction of different alive stages of *P. blanchardii*: Furthermore, 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. blanchardii* were concluded according to the mentioned statistical analysis in Table (3) and presented as follow:
$Y = 163.18 – 8.23\ x_1 + 10.65\ x_2 - 1.01\ x_3$ for nymphs population, Y = 126.62 – 5.76

x_1 + 7.12 x_2 - 0.66 x_3 for adult females population, Y = 289.80 – 14.00 x_1 + 17.77 x_2 - 1.67 x_3 for total population. Where is, Y= Prediction value, X_1= Maximum air temperature, X_2= Minimum air temperature, X_3= Solar radiation.

Table 3: Multiple regression and correlation analysis between current climatic factors and the current population density nymph, adult and total of *P. blanchardii*.

Stages	Tested factors	Partial regression values					Partial correlation	Individual role %	Analysis variance				
		Constant	P.reg	S.E	T	p			F values	C.V.	MR	R^2	E.V.%
Nymphs	Max. temp (°C)		-8.23	3.81	-2.16	N.S	-0.61	9.8					
	Min. temp (°C)	163.18*	10.65	3.56	2.99	*	0.73	18.9	13.07**	0.166	0.91	0.8305	83.05
	Solar radiation (MJ/m2)		-1.01	0.94	-1.08	N.S	-0.36	2.4					
Adult females	Max. temp (°C)		-5.76	2.80	-2.06	N.S	-0.59	11.9					
	Min. temp (°C)	126.62*	7.12	2.31	2.73	*	0.69	20.9	9.12**	0.153	0.88	0.775	77.50
	Solar radiation (MJ/m2)		-0.66	0.69	-0.96	N.S	-0.32	2.5					
Total	Max. temp (°C)		-14.00	6.49	-2.16	N.S	-0.61	10.7					
	Min. temp (°C)	289.80*	17.77	6.06	2.93	*	0.72	19.9	11.74**	0.157	0.902	0.815	81.50
	Solar radiation (MJ/m2)		-1.67	1.60	-1.04	N.S	-0.35	2.5					

P.reg: Partial regression, S.E: Standard error, MR: Multiple correlation, R^2: Coefficient of determination, E.V%: Explained variance, C.V.: Coefficient of Variation.

Estimated the population density of different stages of *P. blanchardii* under different scenarios of (RCPs) during three time series (2011-2040, 2041-2070 and 2071-2100) compared with the current population

Number of nymphs: According to prediction equation for nymphs' population and means of monthly climatic factors under different RCPs scenarios during three time series we can estimate nymph's numbers for *P. blanchardii*. Data in Table (4) indicated that the all projected values for nymph's population during the different time series (2011-2040, 2041-2070 and 2071 -2100) under different RCPs scenarios (RCP2.6, RCP4.5, RCP6.0 and RCP8.5) were smaller than that of the current population of nymphs. The decreasing percentage of the nymph's population under 2071-2100 had the highest percentage of decreasing with an average of (25.84%) as compared to 2040-2071 (24.68%) and 2011-2040 (10.43%). The lowest decreasing percentage of nymphs population was expected under RCP 8.5 with an average of 3.25, 13.45 and 17.91%; while the highest was prospective under RCP 2.6 with an average of 24.98, 32.09 and 30.01% during the time series 2011-2040, 2041-2070 and 2071-2100, respectively. Results indicated also that, all numbers of nymph's population under climate change scenarios decreased significantly as compared with the current conditions. Generally, the RCP 8.5 scenario had the highest population density of nymphs during different time series, followed by RCP 6.0 and then RCP 4.5; the lowest population density of nymphs was found under RCP 2.6 scenario.

Table 4: Monthly mean numbers of nymphs of *P. blanchardii* under current and future conditions under different RCPs scenarios at Esna district, Luxor Governorate, Egypt.

Months	Current	2011-2040				2041-2070				2071-2100			
		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
Jan.	32.90	39.81	42.88	45.16	48.10	31.79	34.70	35.92	31.35	33.97	33.68	24.24	26.62
Feb.	28.20	30.17	34.11	34.16	35.45	18.27	22.44	25.64	21.06	23.12	23.18	27.44	37.14
Mar.	54.02	32.15	38.39	40.39	40.74	20.99	23.76	27.46	25.04	24.30	24.63	36.41	76.71
Apr.	75.40	39.02	48.87	51.91	51.48	30.98	37.08	37.83	41.69	33.38	34.31	51.59	86.36
May	68.28	52.84	66.44	69.47	67.74	54.67	49.97	53.26	70.19	47.82	49.53	61.87	90.24
Jun.	86.95	58.04	72.98	77.21	76.99	60.33	64.01	65.83	92.18	59.96	62.01	76.50	92.73
Jul.	81.27	66.19	90.61	94.11	94.95	68.32	70.75	72.67	102.62	75.08	77.34	79.73	61.26
Aug.	93.52	70.64	86.75	97.10	99.83	70.13	75.30	76.49	99.07	78.76	81.17	65.80	53.03
Sept.	101.64	74.27	88.91	93.40	91.75	67.93	73.74	73.64	82.45	67.93	70.05	59.88	36.32
Oct.	67.67	69.79	82.37	87.71	87.67	62.25	67.84	67.46	74.59	62.30	64.01	42.57	25.68
Nov.	98.30	53.09	61.48	64.60	67.01	48.65	50.94	50.59	51.62	46.93	47.64	31.96	50.49
Dec.	54.90	46.44	51.16	52.37	53.91	38.23	41.80	38.78	37.78	36.47	36.54	56.78	55.47
Average	70.25	52.70	63.75	67.30	67.97	47.71	51.03	52.13	60.80	49.17	50.34	51.23	57.67
$P \leq 0.05$		*	*	*	*	*	*	*	*	*	*	*	*
Decrease (%)		24.98	9.26	4.21	3.25	32.09	27.37	25.80	13.45	30.01	28.34	27.08	17.91
		10.43%				24.68%				25.84%			

Number of adult females: Based on the prediction equation for adult female's population and means of monthly climatic factors under different RCPs scenarios during three time series we can estimate adult female's numbers for *P. blanchardii*. Data in Table (5), showed that the all expected population for adult females during the different time series (2011-2040, 2041-2070 and 2071-2100) under different RCPs scenarios (RCP2.6, RCP4.5, RCP6.0 and RCP8.5) were smaller than that of the current population of adult females. The decreasing percentage of the adult females population under 2011-2040 had the least percentage of decreasing with an average of 10.17% while, the highest percentage of decreasing were recorded under 2071-2100 time series with an average of 23.76%. The lowest decreasing percentage of adult females population was expected under RCP 8.5 with an average of 4.29, 13.38 and 17.58%; while the highest was prospective under RCP 2.6 with an average of 22.12, 28.48 and 26.79% during the time series 2011-2040, 2041-2070 and 2071-2100, respectively. Results indicated also that, all numbers of adult female's population under climate change scenarios decreased significantly as compared with the current conditions. Generally, the RCP

8.5 scenario had the highest population density of adult females during different time series, followed by RCP 6.0 and then RCP 4.5. But, the lowest population density of nymphs was found under RCP 2.6 scenario.

Table 5: Monthly mean numbers of adult females of *P. blanchardii* under current and future conditions under different RCPs scenarios at Esna district, Luxor Governorate, Egypt.

Months	Current	2011-2040				2041-2070				2071-2100			
		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
Jan.	35.00	37.87	39.80	41.32	43.37	32.21	34.20	35.02	31.58	33.71	33.44	26.38	26.72
Feb.	30.00	30.83	33.33	33.30	34.17	22.44	25.32	27.51	24.04	25.82	25.79	27.40	32.36
Mar.	52.12	31.12	35.14	36.44	36.66	23.27	25.11	27.65	25.61	25.52	25.66	32.03	58.49
Apr.	57.68	34.35	40.75	42.76	42.40	28.63	32.79	33.24	35.46	30.25	30.78	41.00	64.75
May	52.23	42.45	51.34	53.32	52.02	43.65	40.19	42.39	53.65	38.74	39.77	47.67	67.10
Jun.	66.52	45.48	55.26	58.06	57.83	46.99	49.40	50.58	68.39	46.63	47.89	57.48	68.81
Jul.	62.17	50.71	67.12	69.40	69.90	52.11	53.63	54.87	75.19	56.75	58.15	59.67	47.55
Aug.	71.54	53.74	64.31	71.39	73.22	53.29	56.73	57.45	72.58	59.24	60.74	50.70	42.76
Sept.	77.75	56.94	66.54	69.53	68.28	52.40	56.30	56.13	61.65	52.30	53.61	47.41	33.07
Oct.	51.77	54.62	62.86	66.45	66.35	49.25	53.02	52.66	57.07	49.19	50.23	37.30	27.42
Nov.	75.20	44.79	50.25	52.32	53.97	41.62	43.11	42.80	43.09	40.34	40.73	31.66	41.63
Dec.	41.81	41.86	44.88	45.65	46.70	36.05	38.49	36.33	35.34	34.78	34.75	45.90	44.67
Average	56.15	43.73	50.97	53.33	53.74	40.16	42.36	43.05	48.64	41.11	41.80	42.05	46.28
$P \leq 0.05$		*	*	*	*	*	*	*	*	*	*	*	*
Decrease (%)		22.12	9.23	5.02	4.29	28.48	24.56	23.32	13.38	26.79	25.56	25.11	17.58
		10.17%				22.44%				23.76%			

Number of total population of *P. blanchardii*: Confirmed to prediction equation for total population numbers of *P. blanchardii* and means of monthly climatic factors under different RCPs scenarios during three time series we can estimate total population numbers for *P. blanchardii*. Data in Table (6), revealed that the all prospective values for total population of insect 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 of the current total population of insect. The decreasing percentage of the total population of *P. blanchardii* under 2071-2100 had the highest percentage of decreasing with an average of 24.91% as compared with 2040-2071 (23.68%) and 2011-2040 (10.31%). The lowest decreasing percentage of total population was expected under RCP 8.5 with an average of 3.71, 13.42 and 17.76%; while the highest was projected under RCP 2.6 with an average of 23.71, 30.48 and 28.58% during the time series (2011-2040, 2041-2070 and 2071-2100), respectively. Results indicated also that, all numbers of total population under climate change scenarios decreased significantly as compared with the current population. Generally, the RCP 8.5 scenario had the highest population density of total population of *P. blanchardii* during different time series, followed by RCP 6.0 and then RCP 4.5. While, RCP 2.6 scenario gave the lowest population density of total population.

From the previously mentioned results, it could be concluded that the monthly observations of total population of *P. blanchardii* had three to four peaks of seasonal activity per year. The mean minimum temperature was under the optimum range for activities of nymphs, adult females and total population of *P. blanchardii* and this climatic factor was the most effective variable in population changes by 18.9, 20.9 and 19.9% for nymphs, adult females and total population of *P. blanchardii* during the base year data, respectively. The obtained results showed that the percentage of explained variance (E.V.%) indicate that the combined effect of these climatic factors viz., maximum temperature, minimum temperature and solar radiation were responsible for 83.05, 77.50 and 81.50% of the population changes of nymphs, adult females and total population of insect, respectively.

Table 6: Monthly mean numbers of total population of *P. blanchardii* under current and future conditions under different RCPs scenarios at Esna district, Luxor Governorate, Egypt.

Months	Current	2011-2040				2041-2070				2071-2100			
		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
Jan.	67.90	77.69	82.68	86.48	91.47	64.00	68.91	70.93	62.92	67.69	67.12	50.62	53.34
Feb.	58.20	61.00	67.44	67.46	69.62	40.71	47.76	53.15	45.10	48.94	48.97	54.83	69.50
Mar.	106.14	63.27	73.52	76.83	77.40	44.26	48.87	55.11	50.65	49.82	50.29	68.44	135.20
Apr.	133.08	73.37	89.62	94.68	93.88	59.61	69.87	71.08	77.16	63.63	65.10	92.59	151.11
May	120.51	95.29	117.78	122.80	119.76	98.32	90.16	95.65	123.83	86.57	89.30	109.54	157.34
Jun.	153.47	103.51	128.25	135.27	134.82	107.32	113.41	116.41	160.57	106.59	109.90	133.98	161.55
Jul.	143.44	116.90	157.73	163.51	164.85	120.44	124.39	127.53	177.81	131.84	135.49	139.40	108.81
Aug.	165.06	124.38	151.07	168.49	173.06	123.41	132.04	133.94	171.65	137.99	141.92	116.49	95.78
Sept.	179.39	131.21	155.46	162.93	160.04	120.32	130.04	129.77	144.10	120.22	123.65	107.29	69.39
Oct.	119.44	124.42	145.23	154.16	154.02	111.50	120.86	120.13	131.66	111.49	114.24	79.87	53.10
Nov.	173.50	97.88	111.73	116.92	120.98	90.27	94.05	93.39	94.71	87.27	88.38	63.62	92.11
Dec.	96.71	88.30	96.03	98.02	100.61	74.27	80.29	75.11	73.12	71.25	71.29	102.69	100.15
Average	126.40	96.44	114.71	120.63	121.71	87.87	93.39	95.18	109.44	90.27	92.14	93.28	103.95
$P \leq 0.05$		*	*	*	*	*	*	*	*	*	*	*	*
Decrease (%)		23.71	9.25	4.57	3.71	30.48	26.12	24.70	13.42	28.58	27.11	26.21	17.76
		10.31%				23.68%				24.91			

The obtained results revealed that, all expected values for number 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 (2041-2070) and (2011-2040) under the scenarios of (RCP 4.5, RCP 6 and RCP 8.5). Also, the time series of (2071-2100) exhibited the highest percentage of decreasing of the numbers of nymphs, adult females and total population with an average of (25.84, 23.76 and 24.91%) as compared to the time series of 2040-2071 (24.68, 22.44 and 23.68%) and the time series of 2011-2040 was (10.43, 10.17 and 10.31%), respectively. Furthermore, the RCP 8.5 scenario gave the highest population density of nymphs, adult females and total population of *P. blanchardii* and was exhibiting the lowest decreasing percentage of population density of insect as compared with the different RCPs during all different time series.

The aforementioned results revealed that the expected climate changes in Luxor Governorate, Egypt according to the RCPs scenarios during three time series will decrease the population density of *P. blanchardii*. The decreasing in the total population of *P. blanchardii* well be between 3.71% and 30.48%, up to the 2011-2100 time series as compared to the current population. The decrement in population density of *P. blanchardii* is depending on climate region and climate change scenarios.

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