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Prediction of Citrus Wax Scale, *Ceroplastes floridensis* Comstock (Hemiptera: Coccidae) Populations Using the Two IPCC's SRES Scenarios (A2 and B2) for 2050 and 2100 Years

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Authors' contributions

This study was carried out in collaboration between the authors. All authors managed the literature searches, read and approved the final manuscript.

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ABSTRACT

The present work deals with the prediction of the populations of citrus wax scale, *Ceroplastes floridensis* during 2050 and 2100 years compared with the pest populations of 2012 as well as the different effect of temperature on populations of 2000 and 2012 years in Sharkia governorate . The results indicated the existent of a relationship between mean temperature and nymph numbers of *C. floridensis* with a good fit to the data and a co-efficient of determination of R^2= 0.908 and 0.957 for 2000 and 2012 years, respectively. Also, the existent of a relationship between mean temperature and adult numbers with a good fit to the data and the co-efficient of determination of R^2=0.934 and 0.956 for 2000 and 2012 years, respectively. The nymph numbers for *C. floridensis* under two different climate change Scenario (A2 and B2) were also estimated. The results indicated that the increased in nymph numbers in 2012s & 2050s and 2012s & 2100s under A2, with average yearly increased, were 20.4% and 60.0%, respectively. While under B2 were 23.1% and 42.6%, respectively. Estimated adult numbers for *C. floridensis* under the two different climate change Scenario (A2 and B2). The results showed that the increased between nymph numbers in 2012s & 2050s and 2012s & 2100s under A2 with

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average yearly increased were 32.6 % and 103.0%, respectively. While under B2 were 37.9% and 72.5%, respectively. It is concluded that the increased temperatures during 2050 and 2100 will increased the population actively of *C. floridensis* in Egypt.

Keywords: Ceroplastes floridensis; Coccidae; prediction; temperature; climate change.

1. INTRODUCTION

The citrus wax scale, *Ceroplastes floridensis* Comstock (Hemiptera: Coccidae) is dangerous pest species in Egypt [1]. This pest attacks different host plants including citrus in Egypt [2, 3,4]. The severity of damage caused by soft scales is graded according to the level of infestation. At the lowest level, sucking the sap is the only damage. This is followed by the appearance of honey few on the leaves, resulting in spread of sooty mould. Then, more serious symptoms appear, such as the fall of leaves extending gradually to an almost complete defoliation and entire branches dryness on the tree. Severe infestation does not result in the tree death, but cause the reduction or even absence of yield for a number of years [5]. This pest had two annual generations during the two seasons on mandarine trees at Qaliobia governorate [6]. Populations of *C. floridensis* increased during late summer and were smallest during winter [7].

Changes in climatic conditions could profoundly affect the population dynamics and the status of insect pests of crops [8]. These effects could either be direct, or through the influence of changes in weather that may have affect the insects' physiology and behavior [9]. In temperate regions, most insects have their growth period during the warmer part of the year. Due to this, species whose niche space is defined by climatic regime will respond more predictably to climate change, while those in which the niche is limited by other abiotic or biotic factors will be less predictable [10]. In the first case, the general prediction is that if global temperatures increase, the species will shift their geographical ranges closer to the poles or to higher elevations, and increase their population size [11].

The aim of this study was to predict the populations of the citrus wax scale, *C. floridensis* during 2050 and 2100 years compared with the pest populations of 2012 as well as the different effect of temperature on populations of 2000 and 2012 years.

2. MATERAIL AND METHODS

Field experiments were carried out in citrus farm located in Sharkia (Kafr El-Hammam - Zagazig). This study was continued during 2012 year. Usual agricultural practices were carried out on the plantation, and no chemical control methods were applied. The study was conducted in an area of about one feddan (1.038 acres) for citrus variety, *Citrus sinensis cv* Baladi. Fifteen trees were selected and labeled. These trees were nearly similar in size, age and vegetation. For sampling, thirty leaves were picked up at random, from different directions and levels, twice a month. The samples were put in polyethylene bags and transferred to the laboratory for inspection. Samples were examined the same day, using a stereomicroscope, for different stages of, the citrus wax scale, *C. floridensis,* in Plant Protection Research Institute, Scale Insect Division. The data of 2000 season adopted from Abd El-Razak [2].

Sharkia (Kafr El-Hammam - Zagazig) weather station were used for collecting climate data (maximum and minimum air temperatures) for 2000 and 2012s. The altitude, latitude and longitude of this weather station were 9 m, 30.61ºN and 31.51ºE, respectively. The climate change data were conducted by MAGICC/SCENGEN tool to extract the projection changes in air temperature (L1 air temp) under the two IPCC's SRES scenarios (A2 and B2) that are described in Table 1. HadCM3 climate model was the base model under the two scenarios.

Each experiment extracted monthly L1 air-temp, for one of the two scenarios, for the coming years 2050s and 2100s. The resulted data from MAGICC/SCENGEN were in 5ºX 5º coordination grid. The future L1 air temp data were down scaled by simple statistical approach, according to the Egyptian coordinates and added to the Ismailia air temperature data 2012s, to produce the future temperature data of 2050 and 2100.

Table 1. Description of IPCC Special Report on Emissions Scenarios (SRES)

Scenario	Storylines
A2	Heterogeneous world, self-reliance and local identities preserved, high population growth, regionally-specific economic growth, fragmented economic and technological development. Temperature increased 2.0 - 5.4ºC
B2	Divergent world with emphasis on local solutions to economic, social and environmental sustainability, moderate population growth, intermediate levels of economic growth, less rapid technological change Temperature increased 1.4 - 3.8ºC

The SAS program was used for statistical analysis. The t-test was used to establish whether a significant difference exist between the insect population in 2012 and the estimated populations of 2050 and 2100 under 0.05 level [12].

3. RESULTS

The mean monthly temperature from Sharkia weather station of the 2012 year was higher than the 2000 year (Fig. 1). In June and July 2012 the mean temperature increased with 2.9ºC than 2000. The mean temperature in January increased with 0.6ºC than 2000, Fig. 2 presented the mean monthly temperature from Sharkia weather station of the 2012 year compared with the estimated temperatures of 2050 and 2100 years under A2 climate change Scenario HadCM3 climate model. The mean temperature was 20.8ºC, 22.3ºC and 24.6ºC in 2012, 2050 and 2100, respectively. The mean monthly temperature in 2050 increased from 0.82ºC to 2.15ºC than 2012 year. In addition, the mean monthly temperature in 2100 increased from 2.71ºC to 5.49ºC than 2012 year. Fig. 3 presented the mean monthly temperature from Sharkia weather station of the 2012 year compared with the estimated temperatures of 2050, 2100 years under B2 climate change Scenario HadCM3 climate model. The mean temperature was 20.8ºC, 22.4ºC and 23.8ºC in 2012, 2050 and 2100, respectively. The estimated mean monthly temperatures in 2050 and in 2100 increased from 0.83ºC to 2.73ºC and from 1.85ºC to 4.25ºC than 2012 year, respectively.

As shown in Fig. 4, the peak numbers of the citrus wax scale nymphs, were in mid July and mid August during 2000 and 2012, respectively. While, the peak numbers of the adults (Fig. 5) during the same two years were in mid August and first week of September, respectively. Highest temperature means were in mid August and mid July, during 2000 and 2012, respectively.

3.1 Relationship between Mean Temperature and Nymph Numbers of *C. floridensis*

When the data on mean monthly temperature in 2000 and 2012 years were regressed against the nymph numbers of *C. floridensis,* a polynomial relationship was obtained between them. **It** was evident from Figs. 6 and 7 that the equations (1and 2).

$y = 0.007x^3 - 0.409x^2 + 7.542x - 29.37$ (eq1) for 2000 year
$y = 0.031x^3 - 1.819x^2 + 38.60x - 245.0$ (eq2) for 2012 year

where (y) was the predicted nymph numbers of *C. floridensis* and (X) was the mean temperature.

The relationship gave a good fit to the data and the co-efficient of determination were $R^2 = 0.908$ for 2000 year and $R^2 = 0.957$ for 2012 year. R showed that the increase in nymph numbers of *C. floridensis* occurred due to the increase in mean monthly temperature. The strong relationship was found in 2012 year with $R^2 = 0.957$.

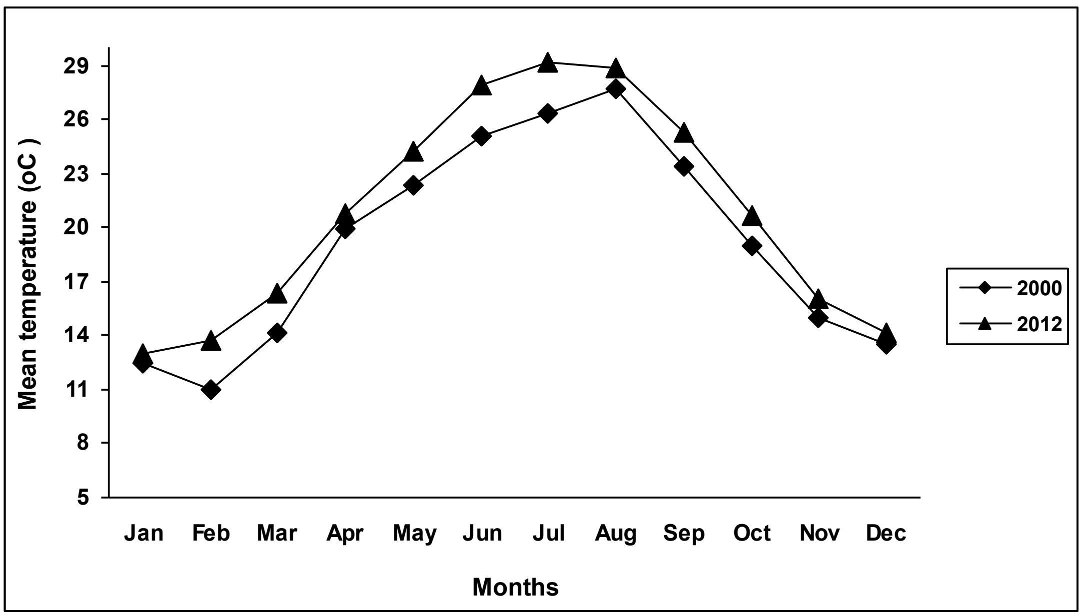

Fig. 1. Mean temperature (ºC) at Sharkia weather station in 2000 and 2012 years

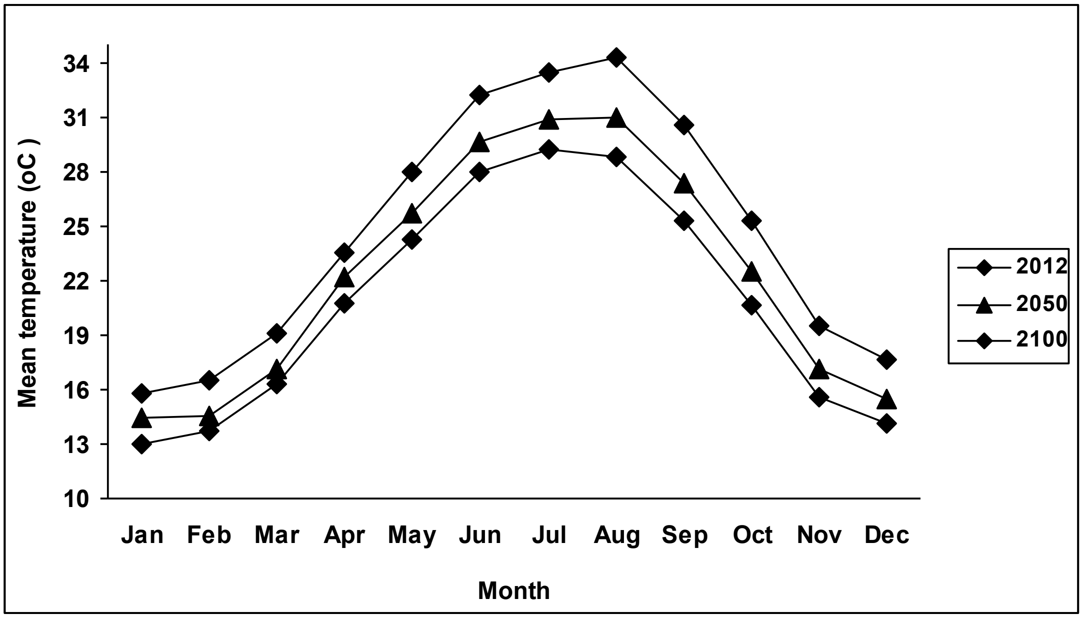

Fig. 2. Mean temperature (ºC) at Sharkia weather station in 2012 year and 2050, 2100 years under A2 Scenario

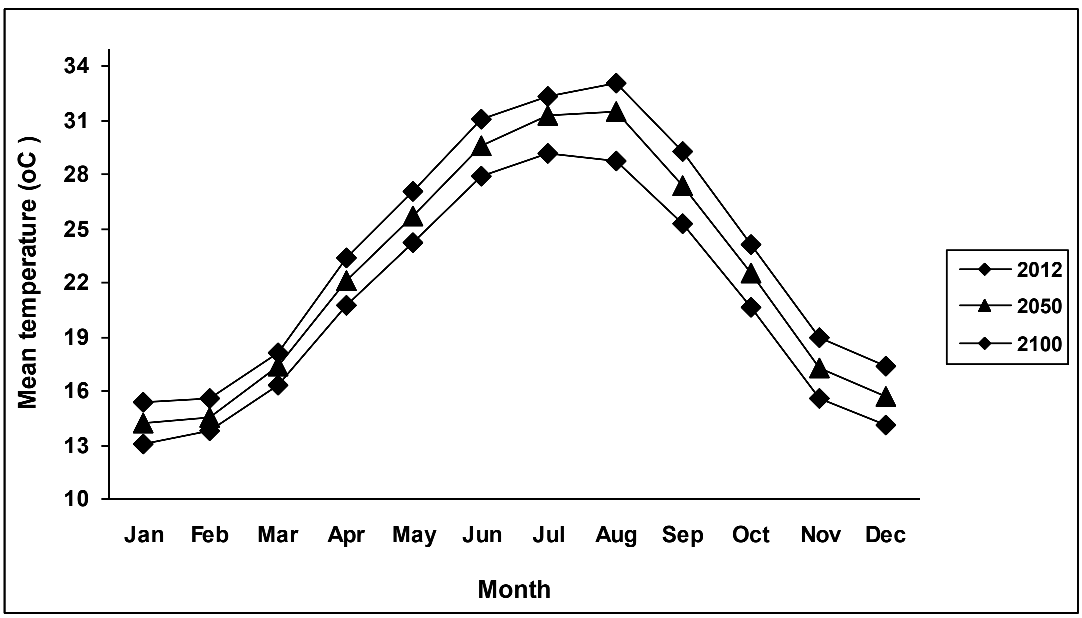

Fig. 3. Mean temperature (ºC) at Sharkia weather station in 2012 year and 2050, 2100 years under B2 Scenario

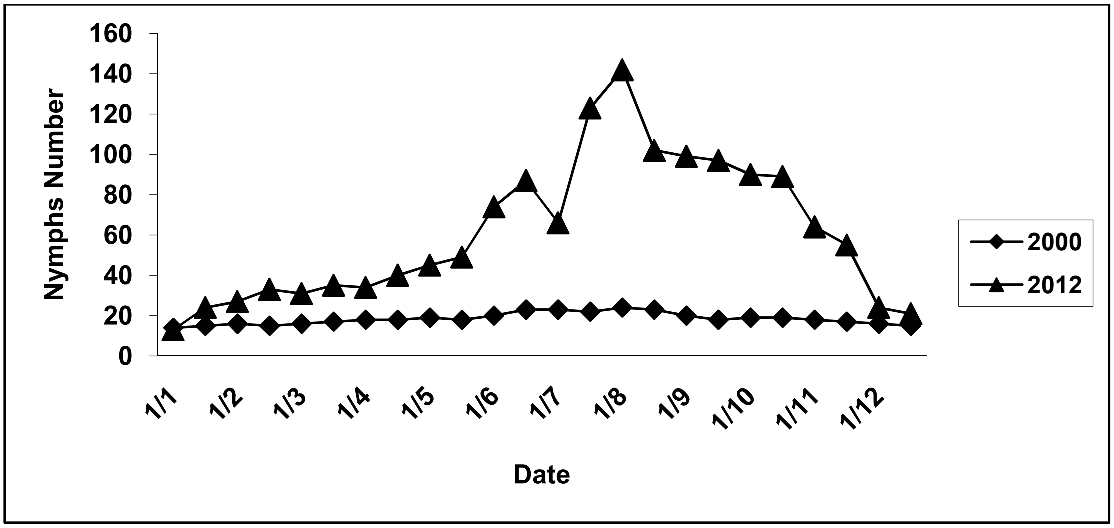

Fig. 4. Nymph numbers of *C. floridensis* in 2000 and 2012 years

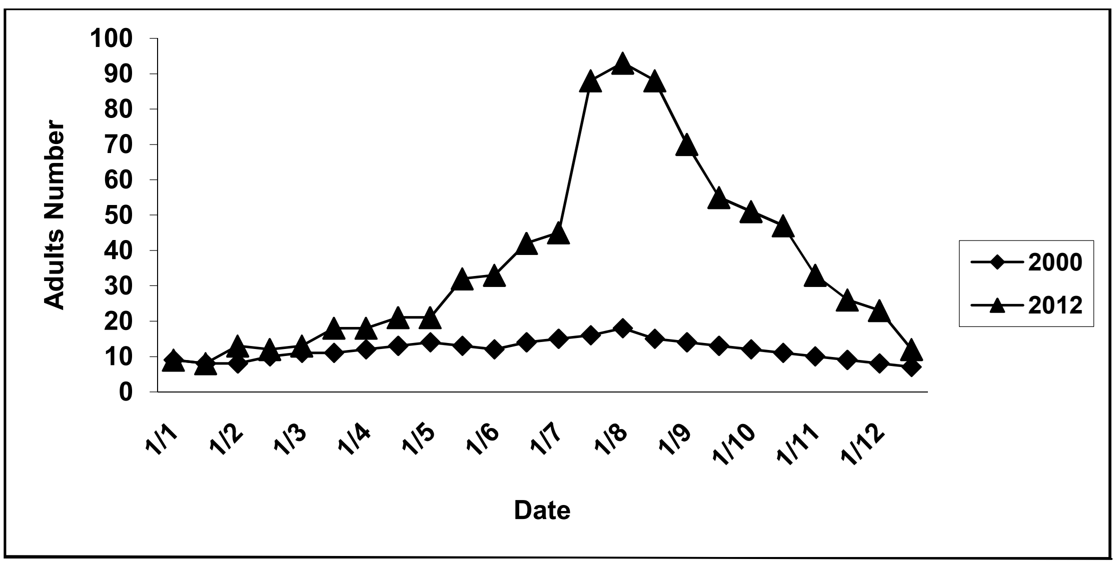

Fig. 5. Adult numbers of *C. floridensis* in 2000 and 2012 years

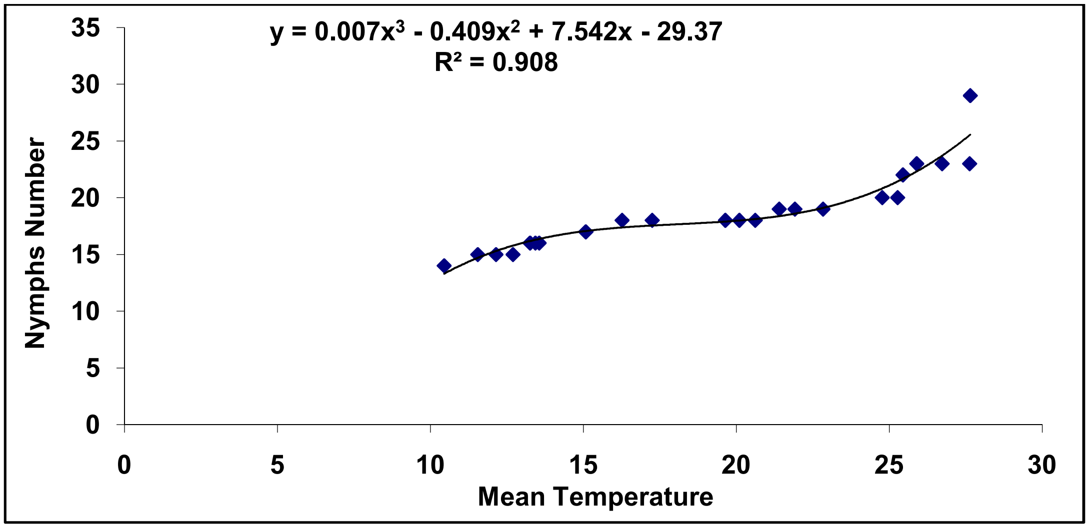

Fig. 6. Relationship between mean temperature in 2000 year and nymph numbers of *C. floridensis*

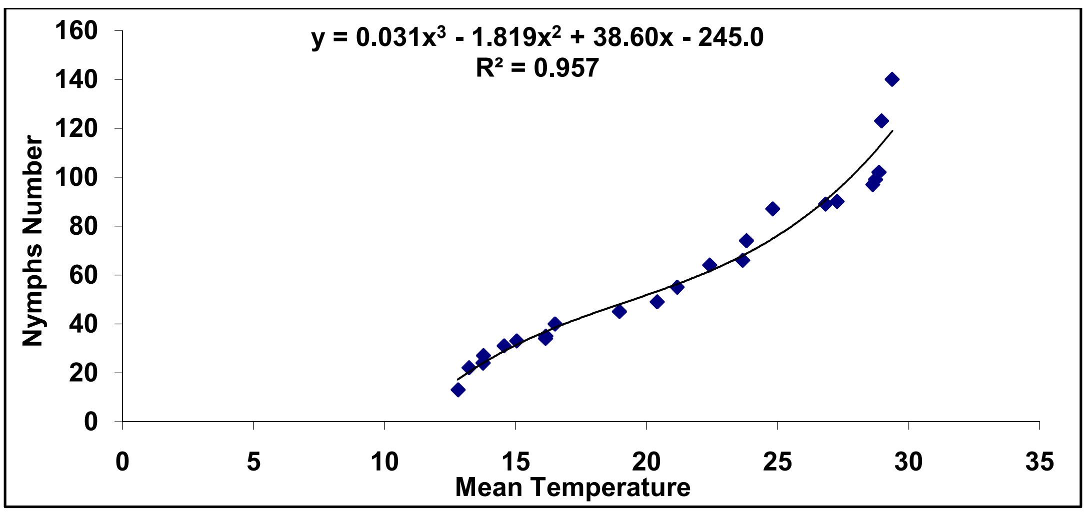

Fig. 7. Relationship between mean temperature in 2012 year and nymph numbers of *C. telekinesis*

3.2 Relationship between mean temperature and adult numbers of *C. floridensis*

When the adult numbers of *C. floridensis* were related to the data of mean monthly temperature in 2000 and 2012 years, a polynomial relationship was obtained (Figs. 8 and 9). The fittness of equations reflect the existant of high significance of relationship:

$y = 0.005x^3 - 0.295x2 + 5.822x - 28.15$ ($R^2 = 0.934$, $p<0.01$) (eq3) - for 2000 year
$y = 0.046x^3 - 2.684x2 + 52.84x - 327.9$ ($R^2 = 0.956$, $p<0.01$) (eq4) - for 2012 year

where (y) was the predicted Adult numbers of *C. floridensis* and (X) was the mean temperature.

This result indicates that the increase in adult numbers of *C. floridensis* occurred due to the increase in mean monthly temperature.

3.3 Estimated Nymph Numbers for *C. floridensis* under the Two Different Climate Change Scenario (A2 and B2)

According to (eq2) and monthly mean temperature under climate change Scenario (A2 and B2) for 2050s and 2100s years we can estimate nymph numbers for *C. floridensis.* Table 2 showed that the increased between nymph numbers in 2012s and 2050s under A2 scenario was from 9.2 to 50.3% and the average yearly increase was 20.4% and the increase between 2012s and 2100s was from 22.4 to 90% and the average yearly increase was 60%. B2 scenario had the same trend. The increase of nymph numbers in 2012s and in 2050s were from 10.3 to 41.2% and the average yearly increase was 23.1%, while the increase between 2012s and 2100s was from 21.2 to 77.3% and the average yearly increase was 43.6%.There were significance deference between Actual nymph numbers in 2012 and estimated nymph numbers in 2050, 2100 under A2 and B2 scenario.

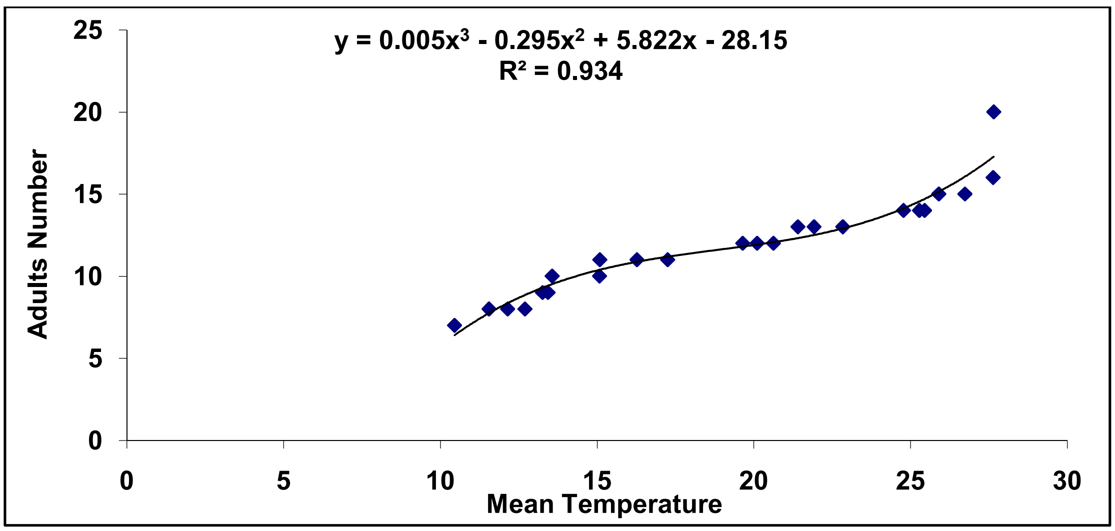

Fig. 8. Relationship between mean temperature in 2000 year and adult numbers of *C. floridensis*

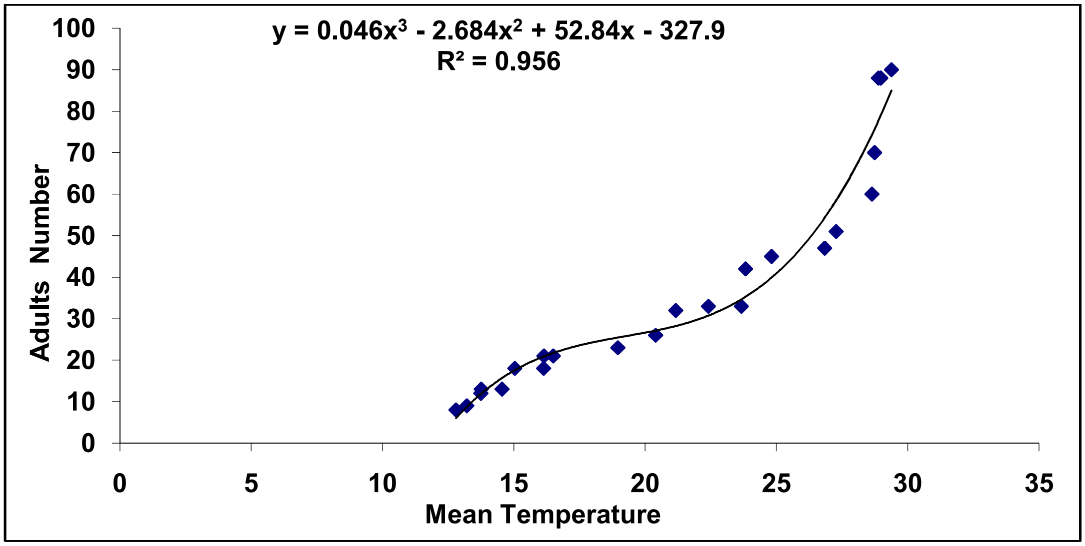

Fig. 9. Relationship between mean temperature in 2012 year and adult numbers of *C. floridensis*

Table 2. Nymph numbers of *C. floridensis* in 2012 year and 2050, 2100 years under two different climate change Scenario A2 and B2

			A2 Scenario		**B2 Scenario**	
Nymphs number	**Month**	**2012**	**2050**	**2100**	**2050**	**2100**
	Jan	18.7	28.1	35.0	26.4	33.1
	Feb	23.8	28.7	38.1	28.8	34.1
	Mar	37.4	40.9	48.2	42.0	44.8
	Apr	54.3	59.9	66.5	59.9	65.8
	May	70.5	80.3	100.9	80.4	91.7
	Jun	100.7	120.9	163.2	121.1	144.3
	Jul	115.1	139.4	189.7	147.6	167.4
	Aug	110.5	141.2	210.0	151.2	181.1
	Sep	77.6	94.9	135.3	95.0	116.6
	Oct	54.0	61.5	77.4	61.5	70.1
	Nov	34.0	40.7	49.6	41.3	47.5
	Dec	26.3	33.7	42.8	34.5	41.7
Mean		60.2	72.5	96.4	74.1	86.5
			*	*	*	*
Increase			20.4%	60.0%	23.1%	43.6%

** Significant at $P < 0.05$*

3.4 Estimated Adult Numbers for *C. floridensis* under Two Different Climate Change Scenario (A2 and B2)

Based on eq4 and monthly mean temperature under climate change Scenarios (A2 and B2) for 2050 and 2100 years on Sharkia Governorate we can estimated adult numbers for *C. floridensis.* Table 3 showed that the increase of adult numbers from 2012 to 2050 under A2 scenario was from 7.7 to 62.1% and the average yearly increase was 32.6%. On the other hand, the increase from 2012s to 2100s was from 23.1 to 161.9% with an average yearly increase of 103.0%. B2 scenario had the same trend of the increase of adult numbers from 2012s to 2050s from 8.8 to 63.6% with an average yearly increased of 37.9% and the increase from 2012s and 2100s was from 14.8 to 113% and the average yearly increased was 72.5%. There were significance deference between actual adult numbers in 2012 and estimated adult numbers in 2050, 2100 under A2 and B2 scenario.

Table 3. Adult numbers of *C. floridensis* in 2012 year and 2050, 2100 years under two different climate change Scenario A2 and B2

			A2 Scenario		B2 Scenario	
Adult number	**Month**	**2012**	**2050**	**2100**	**2050**	**2100**
	Jan	9.4	15.2	19.9	13.9	18.7
	Feb	11.8	15.7	21.5	15.7	19.3
	Mar	21.2	22.8	25.4	23.3	24.3
	Apr	27.3	29.7	33.7	29.7	33.2
	May	36.5	44.7	65.3	44.8	55.6
	Jun	65.1	87.7	138.9	87.9	115.6
	Jul	81.0	109.6	172.4	119.6	144.1
	Aug	75.8	111.8	198.6	124.0	161.5
	Sep	42.3	58.9	104.6	59.0	82.7
	Oct	27.2	30.6	42.1	30.6	36.2
	Nov	19.3	22.8	25.8	23.0	25.2
	Dec	13.8	19.0	23.6	19.5	23.2
Mean		35.7	47.4	72.6	49.3	61.6
			*	*	*	*
Increase			32.6%	103%	37.9%	72.5%

** Significant at P < 0.05*

4. DISCUSSION

The present work deals with the effect of temperature on the population of *C. floridensis and* the prediction of this species population during 2050 and 2100 years, compared with the population of 2012, as well as the different effect of temperature on the populations of 2000 and 2012 years. The ecological studies of *C. floridensis* started with Swailem et al. [7], who found that population of this pest proved to be considerably higher in Alexandria and Beheira than in Sharkia and Gharbeia regions. Salem and Hamdy [8] studied the population dynamics of *C. floridensis* on guava trees in Egypt. The performed counts of the insect at different zones of the trees showed that both heights and directions affect the distribution of the insect in July and August, but not in November. The highest population, however tends to be accumulated on the upper most sunny zones of the trees, versus the lowest population which almost harbours the central caves of the trees and this distribution is mainly a photic response. The economic threshold of *C. floridensis* had been determined during 3 peaks of infestation of the insect. The population density which causes the damage threshold was around 24.4, 26.6-28.4 and 25.1-27 scales per twig in June, October and December, respectively [13]. Helmy et al. [6] confirmed the obtained results of the aformentioned literature. They recorded 3 peaks of *C. floridensis,* mid-April, late-June and early November on mandarin. *C. floridensis* had three peaks on guava [1]. *C. floridensis* occurs in a high population from September to January, then the numbers go down. The insect population relatively increases from June up to August [2].

Results indicated the existant of a relationship between mean temperature and nymph numbers of *C*. *Floridensis which* gave a good fit to the data with a co-efficient of determination of R^2= 0.908 and 0.957 for 2000 and 2012 years, respectively. The relationship between mean temperature and adult numbers of *C. floridensis also* gave a good fit to the data with a coefficient of determination of R^2=0.934 and 0.956 for 2000 and 2012 years, respectively. These data showed a direct proportional between the temperature and the population of *C. floridensis.* Our data also estimated nymph numbers for *C*. *floridensis* under the two different climate change Scenario (A2 and B2). The results indicated that the increased between nymph numbers in 2012s & 2050s and 2012s & 2100s under A2 with average yearly increased were 20.4% and 60.0%, respectively. While under B2 were 23.1% and 42.6%, respectively. Adult number for *C. floridensis was* Estimated under the two different climate change Scenarios (A2 and B2). The results showed that the average yearly increase of nymph numbers from 2012 to 2050 and from 2012 to 2100 under A2 were 32.6% and 103.0%, respectively. While under B2 were 37.9% and 72.5%, respectively. Results here agree with the concepts of the following literatures ex. Climate change has been recognized globally as the most impending and pressing critical issue affecting mankind survival in the 21st century. The last assessment report from the Intergovernmental Panel on Climate Change predicted an increment in mean temperature from 1.1 – 6.4 °C by 2100 [14]. In Egypt, temperature showed a significant effect on the population of such pests including *C*. *floridensis* in Ismailia governorate [15] and also the population density of *C*. *floridensis* was positively correlated with the studied abiotic factor [16].

5. CONCLUSION

It is concluded that the estimated increase in temperatures during years 2050 and 2100 will encourage the increase in population numbers and activity of *C. floridensis* in Egypt.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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