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RESEARCH ARTICLE

Impact of certain weather factors and plant ages on population density of *Aphis craccivora* (Koch) on faba bean plants in Luxor Governorate, Egypt.

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Abstract

Field studies were done on faba bean plants at the El-Mattana Agricultural Research Station in Luxor Governorate, Egypt, throughout two successive growing seasons (2019/20 and 2020/21) to investigate the seasonal activity of the cowpea aphid, *Aphis craccivora* (Koch) (Hemiptera: Aphididae) (Giza 843 cultivar). As well, estimate the effects of some climatic conditions and plant ages on the seasonal abundance of *A. craccivora*. In this study, two insect expressions were used, *i.e.*, insect numbers and incidence of infestation, which articulated the population of this pest. Results indicated that *A. craccivora* infested faba bean plants from 21st November 2019 to 12th March 2020 during the first growing season and from 22nd November 2020 to 13th March 2021 through the second one. For the two growing seasons, the cumulative counts of *A. craccivora* were 321.48 and 340.66 individuals each season, respectively. Furthermore, the overall mean of *A. craccivora* population was 18.91 ± 0.92 and 20.04 ± 1.52 individuals per 10 plants, during the first and second growing seasons, respectively. As well, the general average of the percentages of abundance was 66.73 ± 1.60 and 58.43 ± 2.28 for the two seasons, respectively. Climatic conditions of weekly inspection dates were more favourable for *A. craccivora* to increase its population in November, January and February for the two seasons. Additionally, in two consecutive growing seasons, the number of *A. craccivora* disappeared during the faba bean maturation stage in end March. According to the findings, the combined impacts of environmental conditions and plant ages can explain changes in *A. craccivora* population density. The results revealed that the effects of weather conditions and plant ages on population density and infestation incidence percentages by *A. craccivora* were highly significant during the two seasons studied, and that these parameters varied from season to season. Also, the dew point and mean daily minimum temperature were the most effective variable for the changes in the insect population and the percentages of infestation incidences under the studied seasons. These information can aid in the development of an aphid IPM program for faba bean plants.

Keywords: *Aphis craccivora*; Seasonal abundance; Faba bean plants; Environmental conditions; Plant age

1. Introduction

Faba bean, *Vicia faba* L. (Family: Fabaceae) is one of the most important leguminous crops in Egypt, as it is consumed fresh, dried, or as a vegetable (Mohamed, 2003). The faba bean is a meat alternative (Ebadah *et al.*, 2006) and is considered the main source of plant protein for human feeding (Yassin *et al.*, 2015). Faba bean plants at different growth stages are attacked by dangerous insect pest species, with aphids being the most destructive, resulting in a drop in seed yield of 12.79 to 61.07% (El-Defrawi and El-Harty, 2009).

The cowpea aphid, *A. craccivora* causes direct damage by sucking the plant sap followed by deformation and excreting large amount of honeydew that encourages the growth of sooty mould. Subsequently photosynthesis and vegetative growth of the infested plants decreased, which may induce plant deformation

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and indirect damage caused by transmission of viral diseases ability (Aly, 2014; El- Sarand *et al*., 2019; El-Defrawi *et al*., 2000 and Khodeir *et al*., 2020).

It is essential to understand bio-ecology for *A. craccivora*, including population dynamics under various climatic conditions, affecting the varied phenological stages, in order to design an effective integrated pest management program against it. The rate of growth and insect activity are both influenced by temperature (Lamb, 1992).

Furthermore, such climate changes could have a significant impact on the population dynamics and situation of crop insect pests (Woiwod, 1997). The population density of *A. craccivora* began to appear in the field with the beginning of the vegetative stage and reached its maximum during the pod developmental stage and diminished during the harvest stage (El-Defrawi *et al*., 2000). The density of *A. craccivora* varied on faba bean plants changed depending on the plant age, the season, and maybe other plant physiology parameters (Hamzah and Megahed, 2021).

Plant phenology (As plant age) can have a big impact on aphid infestation. For example, phenology determines at which growth stage the crop is likely to be invaded by aphids (Williams and Dixon, 2007).

The purpose of this study was to determine the impact of different weather factors and plant ages on the seasonal abundance of *A. craccivora* infesting faba bean plants over the two successive growing seasons, in order to develop an efficient management program against of aphid.

2. Materials and Methods

Many authors used different insect expressions, which articulated the population density of this pest. In this study, two insect expressions were utilized, *i.e*., insect numbers and the percentages of infestation incidence.

2.1. Population studies:

2.1.1. Seasonal abundance of *A. craccivora* infesting faba bean plants:

Field experiments were carried out on faba bean plants at El-Mattana Agricultural Research Station, Luxor Governorate during two successive growing seasons (2019/20 and 2020/21). Four replicates (3×3 m = 9 m^2 each) were distributed in complete randomized blocks design and the commercial faba bean cultivar (Giza 843) was sown in optimum sowing date (November, 1^{st} every season). All agricultural practices were followed except pest control. For estimating the population density of *A. craccivora*, 10 plants were sampled randomly in the morning every week, using 10x lenses in the field (Mohamed, 2003 and Awadalla *et al*., 2016). The sample was started when the seedlings grew above ground and continued until crop harvesting. Direct count of aphids sample was conducted on the same day as described by Dewar *et al*. (1982). Numbers of alive insects' (nymphs and apterous individuals) on 10 plants were counted and recorded to represent every inspection date. Identification of aphid was carried out by taxonomy specialists at the Department of Piercing-Sucking insects, Plant Protection Research Institute, Agriculture Research Center at Giza, Egypt.

- Plant phenological characters *i.e.* plant ages (in days).

2.1.2. Determinations of aphid-days numbers:

Aphid-days are cumulative number was used as a term to express the total impact of an ever-changing population over time. They, also, allow better comparisons between treatments, locations and other variations observed during the experiment. The obtained data of aphid population at the two successive growing seasons are used here to calculate the Aphid-days cumulative values according to the following formula (Ruppel, 1983).

Aphid-days $= 3 \times [(a_1+a_2) / 2]$

Where:

a_1= Mean of aphids count per 10 plants before the present inspection date.

a_2= Mean of aphids count per 10 plants at the present inspection date**.**

2.1.3. Determination of cumulative aphid-days

Cumulative aphid-days = Aphid-days from all last inspection + Aphid-days from present inspection, for each sampling date to obtain a running, cumulative total.

2.1.4. Accumulated numbers of aphids' population

Mean numbers of *A. craccivora* per 10 plants of faba bean were counted every week. To facilitate the comparisons of each season and season to each other, the seasonal population density above criteria was expressed in terms of percentage of the estimated numbers in each inspection date from the overall season. It was done by pooling the collected individuals over the inspected periods of each week. Then, the accumulated numbers of aphids per 10 plants in each inspection date were calculated by adding the number of individuals of aphids that accumulate at each sampling date, and the percentages of accumulated numbers relative to the overall season individuals number were calculated during the two successive seasons. Afterward, the percentages of individual numbers were used, to reflect the general trend of the population density (Bakry, 2018).

2.1.5. Infestation incidence percentages

The *A. craccivora* population density was estimated, while its infestation incidence percentages were calculated according to the formula of Facylate (1971):

$$\mathbf{A = (n / N) \times 100.}$$

Where, A = Percentage of infestation incidence.
n = No. of infested plants in which the pest appeared.
N = Total number of picked plants (Uninfested + Infested) in each inspection date.

Furthermore, the rate of weekly variation in the population (R.W.V.P) was calculated as follows**:**

$$\text{R.W.V.P} = \frac{\text{Av. count of insect at a week}}{\text{Av. count given at the preceding week}}$$

2.2. Simultaneous effects of the climatic factors and plant ages on A. craccivora population density infesting faba bean plants

The weekly counts of four climatic weather factors viz., mean daily maximum temperature (X_1), minimum temperature (X_2), mean of % relative humidity (X_3) and mean of dew point (X_4) of Luxor Governorate during two successive growing seasons (2019/20 and 2020/21) were obtained from the Central Laboratory for Agricultural Climate, Agricultural Research Center, Ministry of Agriculture at Giza. The daily records of these factors were recalculated to obtain the daily averages within one week before the sampling date. The altitude, latitude, and longitude of this weather region of Luxor were 99 m, 25.67ºN and 32.71ºE, respectively.
Concerning, the plant phenology as plant age (X_5) were determined during two successive experimental seasons (2019/20 and 2020/21). This relation was presented by the polynomial equation of third-degree (*i.e.* Age, Age^2 and Age^3).
The multiple polynomial equations become $\mathbf{Y= a+ b_1X_5+ b_2X_5^2+ b_3X_5^3}$**.** This method was used by many investigators by Bakry *et al*. (2020) and Hamzah and Megahed (2021).
The data were statistically analyzed by using different models of correlation and regression to find out the relationships between tested main weather factors and plant ages as independent variables on *A. craccivora* population density (dependent variable) according to Fisher (1950). As well as, the percentage of explained variance (E.V.%) was calculated for demonstrating basic information about the amount of variability in the population size under these tested factors. All statistical analysis of the data was carried out by MSTATC Program software, 1980 and SPSS (1999). All data were subjected to calculations and were depicted graphically by Microsoft Excel 2010.

3. Result and Discussion

3.1. Population studies

3.1.1. Seasonal abundance of A. craccivora

The weekly counts of *A. craccivora* that infested faba bean plants and the percentages of infestation incidence by pest were recorded through the two successive growing seasons (2019/20 and 2020/21). As well, weekly mean records of climatic weather factors and plant phenology for faba bean plants during the two growing seasons of investigation were tabulated in Tables (1 and 2) and Figs. (1 and 2). The effects of the climatic factors and plant ages of faba bean plants on the seasonal activity of *A. craccivora* were estimated.

A- The first growing season (2019/20)

The population density of *A. craccivora* appeared in few numbers on faba bean plants on November 21st and then it highly increased to reach the first peak of abundance on November 28th, with mean counts of 33.78 ± 6.50 individuals per 10 plants under field conditions (30.00 °C, Max. temp.; 14.05°C Min. temp.; 42.81% R.H. and 7.74°C dew pint) and the plant age, was 21 days (Table, 1 and Fig. 1). The population decreased on December 5th and then increased gradually to reach the second peak on December 19th (14.33 ± 1.59 individuals per 10 plants) at (23.81°C, Max. temp.; 9.68°C Min. temp.; 53.84% R.H. and 6.61°C dew point) and the plant age, 42 days. Then, the population decreased on December 26th and then increased to reach the third peak on January 2nd (26.00 ± 4.23 individuals per 10 plants) under field conditions at (21.11 °C, Max. temp.; 7.30°C Min. temp.; 54.64% R.H. and 4.65°C dew point) when the plant age was 56 days. Afterward, the population decreased successively until it reached to January 16th. Another increase in population took place on January 23rd to reach the fourth peak in January 30th (31.89 ± 4.60 individuals per 10 plants) at 22.38 °C, Max. temp.; 6.19°C Min. temp.; 55.07% R.H and 4.40°C dew point and the plant age, 84 days. The population re-increased with increasing the temperature. Moreover, the population decreased on February 6th and then increased to reach the fifth peak on February 13th (29.56 ± 2.36 individuals per 10 plants) at (21.43°C, Max. temp.; 8.65°C Min. temp.; 50.65% R.H. and 4.40°C dew point) and the plant age, 98 days. Then, the population decreased on February 20th and then increased to reach the sixth peak on February 27th (28.11 ± 1.56 individuals per 10 plants) under field conditions at (22.06 °C, Max. temp.; 9.68°C Min. temp.; 53.64% R.H. and 6.13°C dew point), when the plant age was 112 days. After that, the population of aphids decreased gradually until March 12th till the disappearance of any aphid infestation during the period maturation of yield (Table, 1 and Fig., 1).

A similar trend in the seasonal fluctuation of the percentages of infestation incidences was observed. Six peaks were recorded in November 28th, December 19th, January 9th, January 23rd, February 13th and February 27th when the percentages of abundance were 62.22 ± 5.72, 68.89 ± 5.88, 81.11 ± 4.23, 81.11 ± 6.11, 90.00 ± 1.67 and 81.11 ± 2.00 %, respectively in Tables (1) and illustrated in Fig. (1).

B- The second growing season (2020/21)

Results obtained in (Table, 2) and illustrated in Fig. (2), indicated that *A. craccivora* appeared in few numbers on faba bean plants on November 22nd (14.99 ± 1.82 individuals per 10 plants), then its population increased until reach to the first peak of activity on November 29th, with mean counts of 40.67 ± 8.99 individuals per 10 plants under field conditions (29.27 °C, Max. temp.; 12.82°C Min. temp.; 34.54% R.H. and 7.18°C dew pint) and the plant age, was 21 days (Table, 2 and Fig. 2). After that, the population decreased on December 6th and then increased gradually to reach the second peak on December 20th (14.00 ± 3.46 individuals per 10 plants) at (23.23°C, Max. temp.; 8.84°C Min. temp.; 43.43% R.H. and 6.14°C dew point) and the plant age, 42 days. Thereafter, the population decreased on December 27th and then re-increased gradual and continuously to reach the third peak on January 31st (37.67 ± 4.26 individuals per 10 plants) under field conditions at (21.84 °C, Max. temp.; 5.65°C

Min. temp.; 44.42% R.H. and 4.09°C dew point) when the plant age was 84 days. Moreover, the population decreased on February 7th and then increased to reach the fourth peak in February 14th (32.67 ± 1.76 individuals per 10 plants) at (20.91°C, Max. temp.; 7.89°C Min. temp.; 40.78% R.H. and 4.09°C dew point) and the plant age, 98 days. Afterward, the population of aphids decreased gradually until March 13th till the disappearance of any aphid infestation during the period maturation of yield (Table, 2 and Fig., 2).

Differently, the percentages of infestation incidence occurred five peaks were recorded in November 29th, January 3rd, January 24th, February 14th and February 28th when the percentages of abundance were 73.33 ± 3.33, 66.67 ± 8.82, 76.67 ± 3.33, 76.67 ± 3.33 and 66.67 ± 8.82% respectively, Tables (2) and illustrated in Fig. (2).

The present results agree with those of Rizk *et al.* (2012) reported that *A. craccivora* started early on bean plants in winter plantation (about 16th November). Shalaby *et al.* (2012) however with different plant host species, also stated that *A. craccivora* reached its maximum by the end of February and disappeared from broad bean field by the end of March. Mousa and Metwally (2014) stated that, *A. craccivora* is considered a destructive pest that invades broad bean plant causing serious damage throughout the different stages. Mahmoud *et al.* (2015) at El-Menofeyia Governorate, Egypt, who recorded that *A. craccivora* reached the peak at the end of Nov. to half of Dec. on faba bean plants. Salman *et al.* (2015) in Aswan Governorate, Egypt, who mentioned that population fluctuations of *A. craccivora* on faba bean are probably due to climatic condition. Hassan *et al.* (2016) in Egypt, observed that the population abundance of *A. craccivora* started to appear in the 2nd half of February, whereas, the measured number of the aphids started to grow up as temperature increased.

On the contrary, Helal *et al.* (1996) in Egypt, observed that the cowpea aphid, *A. craccivora* was recorded three peaks of abundance during January, February and March on faba bean plants in both seasons. El-Defrawi *et al*. (2000) recorded that, the population density of *A. craccivora* had two main periods of activity, with highest counts during the third week of December and February in (1995-96), and during the fourth week of December and third week of March in (1996-97). Abdel-Samad and Ahmed (2006) in Egypt, recorded that the most important months for the increase rate of infestation by *A. craccivora* were February and March months. Ali *et al.* (2013), in Egypt, stated that the cowpea aphid, *A. craccivora* had three peaks on faba bean.

The obtained results cleared that the total population density of *A. craccivora* during the first growing season (2019/20) was smaller than the subsequent growing season (2020/21). The mean total *A. craccivora* population through the whole season was 18.91 ± 0.92 and 20.04 ± 1.52 individuals per 10 plants over the first and second growing seasons, respectively. As well, the cumulative numbers of *A. craccivora* were 321.48 and 340.66 individuals per season for the two growing seasons, respectively. This may be due to the influence of environmental factors in this region as recorded in Tables (1 and 2) and illustrated in Fig. (1 and 2). These results were coincided with those obtained by Dent (1991) explained that the rate of insect population abundance at any given area is determined at the environmental factors at that location. Also, Mahmoud *et al.* (2015) in Egypt, reported that there were significant differences in infestation levelbetween the two faba bean planting seasons (2011/2012 and 2012/2013), where thefirst season harbored more aphids, *A. craccivora* than the second one.

It was noticed that the population density of *A. craccivora* was re-increased with increasing the temperature during the two growing seasons. The same findings were noticed by (Hamzah and Megahed, 2021). As well, during the two faba bean growing seasons, there was no evidence of *A. craccivora* infestation on faba bean plants from mid-March until crop harvesting. This could be related to environmental factors (low relative humidity) and plant sap dryness during these times. The same findings were noticed by Yassin *et al*. (2015) at Nubaria, Beheria Governorate, Egypt, reported that the numbers of aphids were very few during flowering and maturity stages of faba bean plants.

3.1.2. Weekly incidence of A. craccivora population, its accumulation and their percentages in relation to the seasonal total

The seasonal population density of the above criteria, expressed in percentage of counted numbers in each inspected week relative to the overall season grand total of the insect population, was expressed in terms of percentage of counted numbers in each inspected week to facilitate comparisons within each season compared to another. In addition, the percentages of accumulated counts for each week were compared to the overall seasonal number to depict the general trend of population density as shown in Tables (1 and 2) and Figs. (1 and 2). This technique was applied by Bakry *et al*. (2020).

Results represented in Tables (1 and 2) and in Figs. (1 and 2), indicating that the highest percentages of *A. craccivora* numbers occurred during the first growing season (2019/20), it being (10.51, 8.09, 9.92, 9.19 and 8.74% from the grand total), occurred in Nov., 28th, Jan., 2nd, Jan., 30th, Feb., 13th and Feb., 27th, respectively, may be linked to the favorable climatic circumstances that prevailed during these times. While, during the second growing season (2020/21), those were (11.94, 8.81, 11.06 and 9.59%) found during Nov., 29th, Jan., 24th, Jan., 31st and Feb., 14th, respectively. On the contrary, the lowest percentages of numbers were 1.95% took place on December 5th, 2019 through the first season and 2.05% recorded on December 6th, 2020 during the second season. The percentages of accumulated numbers of *A. craccivora* in each inspected week increased with increasing the periods the inspection during the growing season.

3.1.3. Cumulative Aphid-Days

Data represented in Tables (1 and 2) and illustrated in Fig. (1), presented the aphid-days and the cumulative aphid-days for *A. craccivora* on faba bean plants to express the total impact of an ever-changing population over time. These present results indicated that the impact of *A. craccivora* population on faba bean plants was smaller at the first growing season (948.94 cumulative aphid-days) as compared to the second one (1000.97 cumulative aphid-days). The cumulative aphid-days method was used to express the total impact of an ever-changing population over time in the field by El-Fatih (2006) that used the same technique for cereal aphids on barely.

1.4- Rate of weekly variation in *A. craccivora* population (R.W.V.P.):

The weekly variation rates in the population of *A. craccivora* on faba bean plants were calculated (Table, 3). The rate of monthly variation in the population is considered an indicator of the favorable week for insect activity expressed as the week of higher increase of this insect population through the year. When R.W.V.P. was > 1, that meant more activity, < 1 means lower activity and = 1 means no change in the insect activity (Bakry *et al*., 2020).

As shown as recorded in Table (3), the favourable months of annual increase for *A. craccivora* population appeared to be in Nov., 28th, Dec., 12th, Dec., 19th, Jan., 2nd, Jan., 23rd, Jan., 30th, Feb., 13th and Feb., 27th during the first growing season (2019/20), when the rates of weekly variation were 2.92, 1.58, 1.45, 2.19, 1.82, 1.46, 1.71 and 1.89, respectively. While, the infestation incidence percentages was take place in Nov., 28th, Dec., 19th, Jan., 2nd, Jan., 9th, Jan., 23rd, Feb., 13th and Feb., 27th, when the rates of weekly variation were 1.19, 1.41, 1.16, 1.11, 1.35, 1.35 and 1.46 respectively (Table, 3).

As for the second growing season (2020/21), the favorable times of annual increase for total *A. craccivora* population occurred to be in [Nov., 29th, Dec., 13th, Dec., 20th, (Jan., 3rd, 10th, 17th, 24th, 31st) and Feb., 14th], when the rates of monthly variation were (2.71, 1.29, 1.56, 1.72, 1.09, 1.02, 1.88, 1.26 and 2.09, respectively; Table, 3). As well, the rates of weekly variation for the infestation incidence percentages were higher in Nov., 29th, Dec., 20th, Dec., 27th, Jan., 3rd, Jan., 24th, Feb., 14th and Feb., 28th, when the rates of weekly variation were 1.69, 1.33, 1.06, 1.18, 1.53, 1.44 and 1.18, respectively (Table, 3).

Generally, it was clear that R.W.V.P. for the population density and infestation incidences during weekly inspection dates, which bigger from 1, as considered an indicator that the climatic factors were more favorable for the insect multiplication and build up. As well, the favourable periods for insect activity varied according to tested seasons of the study.

3.2. Effect of the weather factors and plant ages on seasonal abundance of A. craccivora infesting faba bean plants

3.2.1. Effect on independent variables [four climatic factors (X_1, X_2, X_3 and X_4) and plant ages (X_5)] on [population density (Y_1) and infestation incidences (Y_2) by A. craccivora (as dependent variables)

3.2.1.1. Effect on population density (Y_1)

A- Effect of daily mean maximum temperature (X_1):

As shown in Table (4) showed that the simple correlation (r) between the daily mean maximum temperature and the total insect population of *A. craccivora* was insignificantly negative and feeble (-0.22 and -0.01) for the first and second growing seasons, respectively. As well as, the simple regression coefficient indicated that a 1˚C increase in the daily mean maximum temperature, would decrease the population by 0.58 and 0.05 individuals per 10 plants for the two growing seasons, respectively (Table, 4).

The partial regression coefficient values for the effect of daily mean maximum temperature on the total *A. craccivora* population were shown in Table (4). Data revealed that this factor had a significant positive relation with the insect's population (P. reg. value; 3.61) during the first growing season and highly significant positive effect (P. reg. value; 5.73) for the second one. Also, the values of partial correlation were (0.63 and 0.70, respectively), and the t-test values were (2.68 and 3.25, respectively), Table (4). The obtained results revealed that daily mean maximum temperature under the optimum range of total *A. craccivora* population activity during the first growing season and entirely under the optimum range of total population activity during the second growing season. This climate factor was responsible for certain changes in the total *A. craccivora* population by 17.14 and 28.81% for the two successive growing seasons, respectively (Table, 4).

B- Effect of daily mean minimum temperature (X_2)

Data in Table (4), clarified that the simple correlation (Table, 4) showed an insignificantly negative correlations and weakly between the daily mean minimum temperature and the total population of *A. craccivora* (r values; -0.28 and -0.04) during the two growing seasons, respectively. Also, the calculated regression coefficient (b) for the effect of this factor indicated that every 1˚C increase in the mean daily minimum temperature, would decrease the population by 0.79 and 0.16 individuals per 10 plants during the two seasons of study, respectively.

The precise effects of mean minimum temperature on the total insect population of *A. craccivora* are presented in Table (4), those showed highly significantly positive relations (P. reg. values; 8.14 and 11.57) during the two seasons, respectively. Furthermore, the values of partial correlation were (0.79 and 0.80) and the values of the t-test were (4.29 and 4.38) during the two growing seasons, respectively. The obtained results revealed that, mean daily minimum temperature entirely under the optimum range of total *A. craccivora* population during the two growing season. This climatic factor was the most effective variable on total *A. craccivora* population changes by 44.06 and 52.04 % during the first and second growing seasons, respectively (Table, 5).

C- Effect of the mean relative humidity (X_3)

Data presented in Table (4), declared that the correlation between relative humidity and the total population of *A. craccivora* was insignificant negative relations (r values; -0.09 and -0.13) during the two growing seasons, respectively. In the same time, the simple regression coefficient indicated that an increase by 1% in the mean relative humidity, would decrease the population by 0.11 and 0.21 individuals per 10 plants during the first and second seasons, respectively (Table, 4).

The real effect of this factor appeared from the partial regression values which showed that the effect of relative humidity on the total population activity *A. craccivora* was highly significantly positive (P. reg. values; 2.21 and 3.98) during the two growing seasons, respectively. Also, the partial correlation values were (P. cor. values; 0.74 and 0.78) and t-test values were (3.66 and 4.17) for both seasons, respectively. Results revealed that, mean relative humidity was entirely under the optimum range of total population activity during the two seasons. This climatic factor was responsible for certain changes in the total population of *A. craccivora* by 32.02 and 47.31% for the two successive growing seasons, respectively (Table, 4).

D- Effect of mean dew point (X_4)

As seen in Table (4) indicated that, the effect of mean dew point on total population activity was significantly negative (r-value was -0.49) during the first season and insignificantly negative relation (-0.25) through the second season. As well as, the calculated regression coefficient (b) for the effect of this factor indicated that for every 1˚C increase, the population would decrease by 1.80 and 1.18 individuals per 10 plants during the first and second seasons, respectively, Table (4).

The partial regression coefficient values for the effect of mean dew point on total population *A. craccivora* activity are shown in Table (4). Data revealed that this factor had highly significantly negative relations (P. reg. values were -14.69 and -19.29) during the two seasons of study, respectively. The values of the partial correlation were (-0.84 and -0.83) and (t-test) values were (-5.07 and -4.86) during the both the study seasons, respectively. The results revealed that the mean dew point was fully above the optimum range of total population and it was the most effective variable for the changes in the total population of *A. craccivora* by 61.52 and 64.18% during the first and second seasons, respectively in Table (4).

E- Effect of the plant ages (X_5)

The results of statistical analysis of data in Table (4) show the effect of the plant ages on total population of *A. craccivora*. The correlation coefficient (r) was insignificantly positive (r-values; 0.24 and 0.24) for the two growing seasons, respectively. The calculated regression coefficient (b) for the effect of this factor indicated that for everyday increase in the plant age of faba bean, the total population of *A. craccivora* would increase by 0.06 and 0.07 individuals per 10 plants during the two seasons of study, respectively.

The exact relation between the faba bean plant age and total population of *A. craccivora* was determined by the partial regression values (Table, 4), which were insignificant positive (P. reg. value; 0.07) for the first growing season and significantly positive relation (P. reg. value; 0.19) during the second growing season. Also, the partial correlation values were (0.34 and 0.59) and the t-test values (1.20 and 2.44) for the two growing seasons, respectively. Also, the plant ages of faba bean was the least effective variable on the total *A. craccivora* population changes by 3.39 and 16.11% during the second growing season.

F- The combined effect of four climatic factors (X_1, X_2, X_3 and X_4) and plant ages (X_5)] on the total population of A. craccivora

As shown in Table (4), the combined effect of these tested factors on the *A. craccivora* total population during the two growing seasons was highly significant where the "F" values were 6.17 and 5.17 respectively. The amounts of variability were 73.71 and 70.17% for the two growing seasons, respectively.

3.2.1.2. Effect of plant phenology

A- Plant ages (X_5):

The plant phenology as plant ages (**X_5**) (obtained by three-degree polynomial equation); $\mathbf{Y = a + b_1X_5 + b_2X_5^2 + b_3X_5^3}$ revealed high relation to the variation in the population. E.V. values were 21.90 and 36.78% for two successive growing seasons, respectively (Table, 4). These added values seem to be significant and fully explained the variance in the population density of *A. craccivora*.

Based on this model, the population density of *A. craccivora* on faba bean plants can be predicted by looking for the plant ages. As the plant ages realized the main effect on the population density of *A. craccivora*, regression analysis was performed using the plant age per day (X_5) and the corresponding log of the mean number of *A. craccivora* (Y_1). The regression equation was presented in Fig. (3):

First growing season (2019/20):

$$Y_1 = -0.0001\ X_5^3 + 0.02\ X_5^2 - 1.0483\ X_5 + 30.288 \qquad R^2 = 0.219$$

Second growing season (2020/21):

$$Y_1 = -0.0002\ X_5^3 + 0.037\ X_5^2 - 2.123\ X_5 + 48.784 \qquad R^2 = 0.368$$

Also, the combined effect of these tested factors on *A. craccivora* total population was a insignificant where the "F" values were 1.22 and 2.52 during the two growing seasons, respectively (Table, 4).

3.2.1.3. Effect on independent variables (X_1, X_2, X_3, X_4, X_5, X_5^2 and X_5^3) on total population of A. craccivora (Y_1) (dependent variable)

The Results illustrated that the combined effect of the [abiotic factors (four climatic factors) and plant ages (in days)] on the variation in the population density of *A. craccivora*. The amount of variability, attributed to the combined effect of all these tested factors on the total population density of *A. craccivora* have a significant where the "F" value was 4.90 during the first growing season and insignificant where the "F" value was 3.17 during the second growing season (Table, 4). The multiple regression analysis revealed that the studied variables altogether were responsible for changes in the total population density of *A. craccivora*. The percentages of explained variance (E.V.%) were 79.21 and 71.15% in the two growing seasons, respectively (Table, 4).

The present results do not eliminate the effect of weather factors on the population fluctuations. Under laboratory conditions, these factors may reveal more effects. While under field conditions, these factors first affect the plant growth which makes the plant more palatable for infestation. Therefore, the weather factors and plant ages influenced mathematically on the behavior and activity of *A. craccivora*.

3.2.2.1. Effect on infestation incidence percentages by A. craccivora ***(Y_2)***

A- Effect of daily mean maximum temperature (X_1):

The results of statistical analysis of simple correlation (Table, 5) showed highly significantly negative correlation between the daily mean maximum temperature and the infestation incidence percentages by *A. craccivora* (r value; -0.73) during the first growing season and negatively insignificant relation (r value; -0.45) during the second one, respectively. As well as, the calculated regression coefficient (b) for the effect of this factor appeared that every 1˚C increase in the daily mean maximum temperature, would decrease the infestation incidence percentages by 2.79 and 1.69% during the two seasons of study, respectively.

The accurate effects of daily mean maximum temperature on the infestation incidence percentages by *A. craccivora* are presented in Table (5), those showed insignificantly negative relation for the first season (P. reg. value was -1.02) and insignificantly positive effect (P. reg. value was 2.06) during the second season. In addition, the values of partial correlation were

(-0.22 and 0.40) and the values of t-test were (-0.76 and 1.44) during the two growing seasons, respectively. The obtained results revealed that, daily mean maximum temperature around the optimum range of infestation incidence percentages during the first growing season and within the optimum range of infestation incidence percentages during the second growing season. This climatic factor was the least effective variable for the changes in the infestation incidence percentages by 0.63 and 2.73% for the two successive growing seasons, respectively (Table, 5).

B- Effect of daily mean minimum temperature (X_2)

Data presented in Table (5) emphasized that the simple correlation (r) between the daily mean minimum temperature and the infestation incidence percentages by *A. craccivora* was significantly negative (-0.57) for the first growing season and insignificantly negative relation (-0.37) through the second growing season. In conjunction with, the simple regression coefficient indicated that an increase of 1˚C increase in the daily mean minimum temperature, would decrease the infestation incidence percentages by 2.42 and 1.63% for the two seasons, respectively (Table, 5).

The partial regression coefficient values for the effect of daily mean minimum temperature on the infestation incidence percentages by *A. craccivora* are shown in Table (5). Data inferred that this factor had highly significantly positive effects (P. reg. values; 9.22 and 13.37) for the two growing season, respectively. Also, the values of partial correlation were (0.83 and 0.88) and the t-test values were (4.91 and 6.21) during the both seasons, respectively, Table (5). The obtained results revealed that, daily mean minimum temperature entirely under the optimum range of the infestation incidence percentages during the two growing seasons. This climatic factor was the most effective variable in changes of infestation incidence percentages by 26.63 and 50.53% during the two growing seasons, respectively (Table, 5).

C- Effect of the mean relative humidity (X_3)

The correlation between relative humidity and the infestation incidence percentages by *A. craccivora* was insignificantly positive (r values; 0.19 and 0.02) for the two growing seasons, respectively. In the same time, the simple regression coefficient indicated that an increase of 1% in the mean relative humidity, would increase the infestation incidence percentages by 0.31 and 0.03% during the two seasons, respectively (Table, 5).

The real effect of this factor appeared from the partial regression values which deduced that the effect of relative humidity on the infestation incidence percentages by *A. craccivora* was significantly positive (P. reg. value; 1.55) for the first growing season and highly significantly positive relation (P. reg. value; 3.09) during the second growing season. Also, the partial correlation values were (P. cor. values; 0.62 and 0.77) and t-test values were (2.58 and 3.97) for both growing seasons, respectively.

Results revealed that, mean relative humidity was under the optimum range of infestation incidence percentages during the first season and entirely under the optimum range during the second one. This climatic factor was responsible for certain changes in the infestation incidence percentages by 7.39 and 20.72% for the two successive growing seasons, respectively (Table, 5). These results in line with the findings of Mahmoud *et al.* (2017) at El-Monofia Governorate, Egypt, reported that humidity positively affected *A. craccivora* population on faba bean plants.

D- Effect of mean dew point (X_4)

Data in Table (5) excreted that the effect of mean dew point on the infestation incidence percentages was highly significantly negative (-0.69) during the first season and significantly negative relation (-0.58) during the second season. In additionally, the calculated regression coefficient (b) for the effect of this factor indicated that for every 1˚C increase, the infestation incidence percentages would decrease by 3.73 and 3.23% during the first and second seasons, respectively, Table (5).

The partial regression coefficient values for the effect of mean dew point on the infestation incidence percentages by *A. craccivora* are shown in Table (5). Data demonstrated that this factor had highly significantly negative effects (P. reg. values were -13.40 and -20.78) during the two seasons of study, respectively. The values of the partial correlation were (-0.82 and -0.89) and (t-test) values were (-4.67 and -6.43) during the two seasons, respectively. The results excreted that the mean dew point was entirely above the optimum range of infestation incidence percentages, and this climatic factor was the most effective variable for the changes in the infestation incidence percentages by *A. craccivora* by 24.16 and 54.23% during the first and second seasons, respectively in Table (5).

E- Effect of the plant ages (X_5)

Data in Table (5) exposed that the effect of the plant age**s** on the infestation incidence percentages by *A. craccivora*. The correlation coefficient (r) was insignificantly positive (r-values; 0.36 and 0.26) for the two growing seasons, respectively. The calculated regression coefficient (b) for the effect of this factor indicated that for everyday increase in the plant age of faba bean, the infestation incidence percentages by *A. craccivora* would increase by 0.13 and 0.09% during the both the study seasons, respectively.

The exactly relationship between the faba bean plant age**s** and total population of *A. craccivora* was determined by the partial regression values (Table, 5), which were insignificantly positive (P. reg. values; 0.05 and 0.05) for the two growing seasons, respectively. Also, the partial correlation values were (P. cor. values; 0.22 and 0.23) and t-test values were (0.75 and 0.80) for the two growing seasons, respectively. Also, the plant age**s** of faba bean was the least effective variable for the changes in the infestation incidence percentages by *A. craccivora* by 0.61 and 0.82% during the first and second growing seasons, respectively, Table (5).

F- The combined effect of four climatic factors (X_1, X_2, X_3 and X_4) and plant ages (X_5)] on the infestation incidence percentages of A. craccivora:

As demonstrated in Table (5), the pooled effect of these tested factors on the infestation incidence percentages by *A. craccivora* during the two growing seasons was highly significant where the "F" values were 15.94 and 13.11 respectively. The amounts of variability were 87.87 and 85.63% for the two growing seasons, respectively.

3.2.2.2. Effect of plant phenology

A- Plant ages (X_5):

The plant ages (**X_5**) (obtained by three-degree polynomial equation); **$Y= a+ b_1X_5+ b_2X_5^2+ b_3X_5^3$** showed high relation to the variation in the percentages of infestation incidences. The explained variance values were 42.37 and 28.91% for the two successive growing seasons, respectively (Table, 5). These added values seem to be significant and fully explained the variance in the infestation incidence percentages of *A. craccivora*.

Based on this model, the percentages of infestation incidences by *A. craccivora* on faba bean plants can be predicted by looking for the plant age. As the plant age realized the main effect on the infestation incidence percentages by *A. craccivora*, regression analysis was performed using the plant age per day (X_5) and the corresponding log of the percentages of infestation incidence by *A. craccivora* (Y_2). The regression equation was presented in Fig. (3):

First growing season (2019/20):

$$Y_2 = -9^{-5}\ X_5^3 + 0.0132\ X_5^2 - 0.2083\ X_5 + 54.243 \qquad R^2 = 0.4237$$

Second growing season (2020/21):

$$Y_2 = -0.0001\ X_5^3 + 0.0209\ X_5^2 - 0.8522\ X_5 + 60.866 \qquad R^2 = 0.2891$$

Also, the combined effect of these tested factors on percentages of infestation incidence by *A. craccivora* was a insignificant where the "F" values were 3.19 and 1.76 during the two growing seasons, respectively (Table, 5).

3.2.2.3. Effect on independent variables (X_1, X_2, X_3, X_4, X_5, X_5^2 and X_5^3) on percentages of

infestation incidence by A. craccivora (Y_2) (dependent variable)

The Results presented that the combined effect of the [abiotic factors (four climatic factors) and plant age (in days)] on the variation in the percentages of infestation incidences by *A. craccivora*. The degree of variability attributed to the combined influence of all these examined parameters on percentages of infestation incidences by *A. craccivora* was highly significant, with the "F" values of 13.75 and 8.04 during the two growing seasons, respectively (Table, 5). The results of the multiple regression analysis revealed that all of the variables tested were responsible for variations in percentages of infestation incidence. In the two growing seasons, the percentages of explained variation (E.V.%) were 91.45 and 86.22**%**, respectively (Table, 5).

It obvious that the effects of climatic variables and plant age on population density and infestation incidence percentages by *A. craccivora* were extremely important during the two seasons tested, and these parameters changed from season to season. Also, during the analyzed two seasons, the dew point and mean daily minimum temperature were the most accurate variables for explanation differences in the insect population and, on the percentages of infestation incidences, as compared the three other variable (mean daily of maximum temperature, relative humidity and plant age).

Climatic factors exert a great influence on the growth, development, distribution, and population dynamics of insect pests (Chang *et al.* 2008). Both the physical and biological factors are much vital causing the variations in the densities of aphid population (Naeem, 1996). Plant phenology can have a significant impact on the status of aphid species infestation. For example, phenology determines at which growth stage the crop is likely to be invaded by aphids and which crops are likely to be affected most severely (Williams and Dixon, 2007).

The present results are close to that mentioned by Selman and Mohamed, 2000) in Assiut, Egypt, concluded that the infestation by *A. craccivora* was negatively correlation with maximum temperature in faba bean, also, minimum temperature. Reza and Ahmad (2000) in India, showed that the multiple regression model showed that aphid incidence differed significantly (P<0.001) with the environmental factors. Mahmoud *et al.* (2015) in El-Menofeyia Governorate, Egypt, studied that both the climatic factors and plant age vary in their effect on *A. craccivora* population, where the correlation between weather factors, plant age and the insect population density was insignificant. Also, they recorded that the combined effect of the ecological factors on aphid population in season (2011-2012) was 98.98 and 50.42% in season (2012-2013), which was somewhat different from the present results. Saleh *et al.* (2021) at Qaha, Qalyubiya Governorate, Egypt, studied that the simple correlation between *A. craccivora* and daily mean temperature showed negative insignificant relation during the 1st season while was significant in the 2nd season. Also, the simple correlation with *A. fabe* was insignificant negative in both seasons. As well as *A. craccivora* and *A. fabe* showed the insignificant positive value in both seasons with relative humidity. The authors reported that the determination of effects of different weather factors on the population of aphids in faba bean plantations was essential for effective pest management.

Table 1. Weekly mean numbers, aphid days, % cumulative no. and cumulative aphid-days of *A. craccivora* (Koch) and the percentages of infestation incidence on faba bean plants, with climatic factors, at Esna district, Luxor Governorate during the first growing season (2019/20).

Sampling date		Plant age	Aphids count per 10 plants ± S.E.	% No. aphids from overall seasonal total	Cumulative numbers per 10 plants	% Cumulative	Aphid -Days	Cumulative aphid-days	Infestation incidence (%)	Max. temp.	Min temp.	% R.H.	Dew point
Nov., 2019	21	14	11.56 ± 1.40	3.59	11.56	3.59	17.33	17.33	52.22 ± 4.34	29.60	17.94	52.56	12.84
	28	21	33.78 ± 6.50	10.51	45.33	14.10	68.00	85.33	62.22 ± 5.72	30.00	14.05	42.81	7.74
Dec.,	5	28	6.26 ± 0.94	1.95	51.59	16.05	60.06	145.39	52.22 ± 9.54	25.87	12.70	55.91	9.73
	12	35	9.89 ± 1.39	3.08	61.48	19.12	24.22	169.61	48.89 ± 4.84	25.24	11.35	57.24	8.96
	19	42	14.33 ± 1.59	4.46	75.81	23.58	36.33	205.94	68.89 ± 5.88	23.81	9.68	53.84	6.61
	26	49	11.89 ± 2.92	3.70	87.70	27.28	39.33	245.28	63.33 ± 3.33	23.65	8.10	50.40	5.35
Jan., 2020	2	56	26.00 ± 4.23	8.09	113.70	35.37	56.83	302.11	73.33 ± 6.01	21.11	7.30	54.64	4.65
	9	63	18.78 ± 1.14	5.84	132.48	41.21	67.17	369.28	81.11 ± 4.23	18.17	6.59	57.54	3.75
	16	70	12.00 ± 1.00	3.73	144.48	44.94	46.17	415.44	60.00 ± 3.73	21.35	7.54	60.86	6.29
	23	77	21.89 ± 2.60	6.81	166.37	51.75	50.83	466.28	81.11 ± 6.11	19.76	10.08	58.10	6.44
	30	84	31.89 ± 4.60	9.92	198.26	61.67	80.67	546.94	74.44 ± 2.94	22.38	6.19	55.07	4.40
Feb.	6	91	17.33 ± 1.91	5.39	215.59	67.06	73.83	620.78	66.67 ± 6.87	23.41	8.02	52.93	5.31
	13	98	29.56 ± 2.36	9.19	245.15	76.26	70.33	691.11	90.00 ± 1.67	21.43	8.65	50.56	4.40
	20	105	14.89 ± 2.10	4.63	260.04	80.89	66.67	757.78	55.56 ± 8.18	25.56	11.03	49.86	7.19
	27	112	28.11 ± 1.56	8.74	288.15	89.63	64.50	822.28	81.11 ± 2.00	22.06	9.68	53.64	6.13
Mar.	5	119	23.00 ± 2.19	7.15	311.15	96.79	76.67	898.94	72.22 ±7.41	24.75	9.84	37.37	4.55
	12	126	10.33 ±1.24	3.21	321.48	100.00	50.00	948.94	51.11 ± 3.09	27.71	11.43	31.71	6.14
Total			321.48	100.00			948.94						
General average			18.91 ± 0.92						66.73 ± 1.60	23.87	10.01	51.47	6.50

Table 2. Weekly mean numbers, aphid days, % cumulative no. and cumulative aphid-days of *A. craccivora* (Koch) and the percentages of infestation incidence on faba bean plants, with climatic factors, at Esna district, Luxor Governorate during the second growing season (2020/21).

Sampling date		Plant age	Aphids count per 10 plants ± S.E.	% No. aphids from overall seasonal total	Cumulative numbers per 10 plants	% Cumulative	Aphid -Days	Cumulative aphid-days	Infestation incidence (%)	Max. temp.	Min temp.	% R.H.	Dew point
Nov., 2020	22	14	14.99 ± 1.82	4.40	14.99	4.40	22.49	22.49	43.33 ± 8.82	28.88	16.37	42.39	11.92
	29	21	40.67 ± 8.99	11.94	55.66	16.34	83.49	105.97	73.33 ± 3.33	29.27	12.82	34.54	7.18
Dec.,	6	28	7.00 ± 1.00	2.05	62.66	18.39	71.50	177.47	43.33 ± 16.67	25.24	11.59	45.10	9.03
	13	35	9.00 ± 2.65	2.64	71.66	21.04	24.00	201.47	40.00 ± 5.77	24.62	10.36	46.17	8.32
	20	42	14.00 ± 3.46	4.11	85.66	25.14	34.50	235.97	53.33 ± 6.67	23.23	8.84	43.43	6.14
	27	49	8.33 ± 1.20	2.45	93.99	27.59	33.50	269.47	56.67 ± 3.33	23.08	7.39	40.65	4.97
Jan., 2021	3	56	14.33 ± 1.20	4.21	108.32	31.80	34.00	303.47	66.67 ± 8.82	20.60	6.66	44.08	4.32
	10	63	15.67 ± 1.20	4.60	123.99	36.40	45.00	348.47	63.33 ± 8.82	17.73	6.01	46.42	3.48
	17	70	16.00 ± 1.15	4.70	139.99	41.09	47.50	395.97	50.00 ± 5.77	20.83	6.88	49.09	5.84
	24	77	30.00 ± 2.00	8.81	169.99	49.90	69.00	464.97	76.67 ± 3.33	19.28	9.20	46.87	5.98
	31	84	37.67 ± 4.26	11.06	207.66	60.96	101.50	566.47	66.67 ± 3.33	21.84	5.65	44.42	4.09
Feb.	7	91	15.67 ± 1.45	4.60	223.32	65.56	80.00	646.47	53.33 ± 8.82	22.84	7.32	42.69	4.93
	14	98	32.67 ± 1.76	9.59	255.99	75.15	72.50	718.97	76.67 ± 3.33	20.91	7.89	40.78	4.09
	21	105	26.00 ± 2.00	7.63	281.99	82.78	88.00	806.97	56.67 ± 14.53	24.93	10.07	40.22	6.68
	28	112	24.67 ± 2.67	7.24	306.66	90.02	76.00	882.97	66.67 ± 8.82	21.53	8.84	43.27	5.70
Mar.	6	119	20.00 ± 1.15	5.87	326.66	95.89	67.00	949.97	63.33 ± 3.33	24.14	8.98	30.15	4.22
	13	126	14.00 ± 0.58	4.11	340.66	100.00	51.00	1000.97	43.33 ± 3.33	27.04	10.43	25.58	5.70
Total			340.66	100.00			1000.97						
General average			20.04 ± 1.52						58.43 ± 2.28	23.29	9.13	41.52	6.03

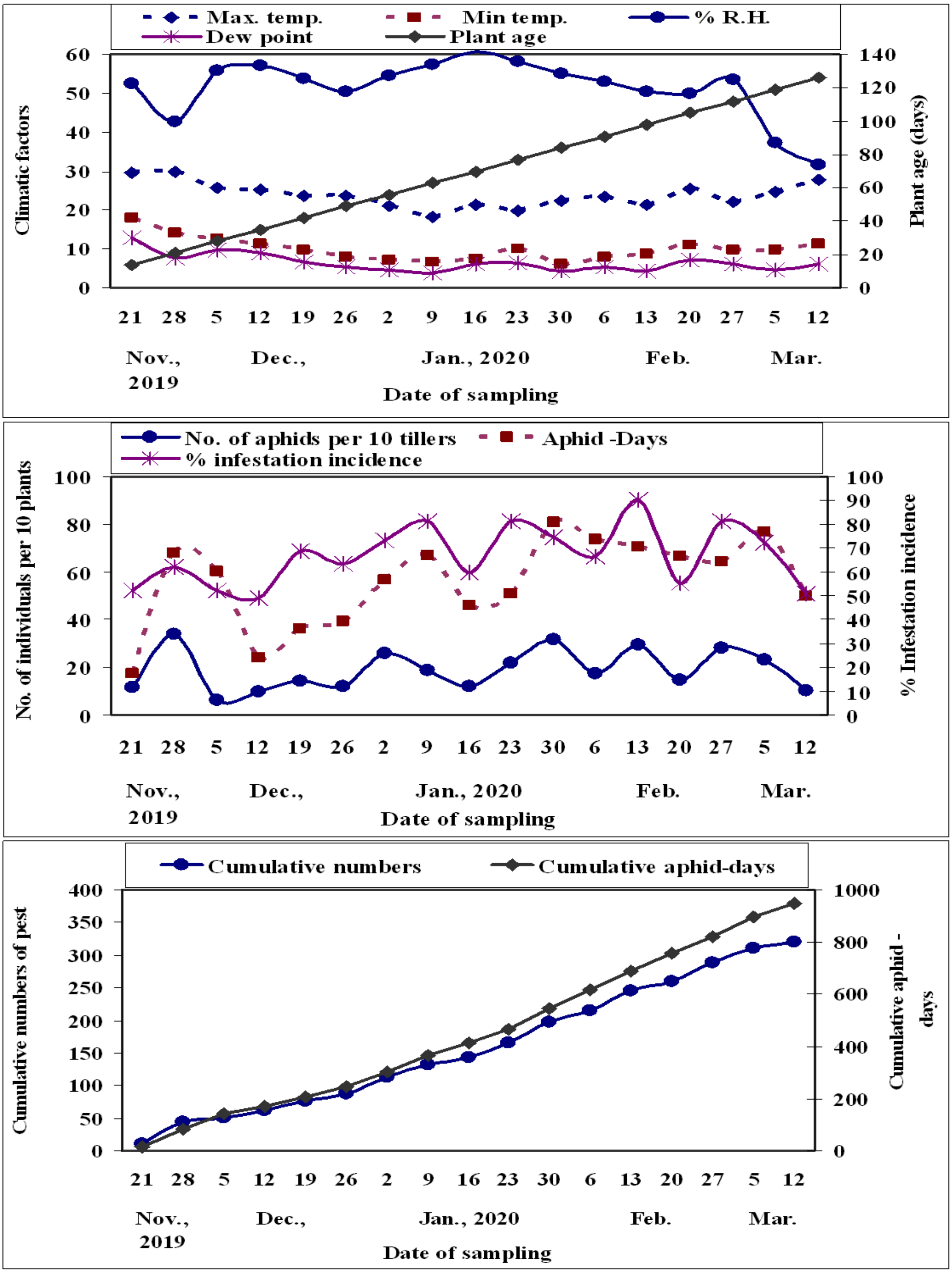

Fig. 1. Weekly mean numbers of aphid days, % cumulative, cumulative aphid-days of *A. craccivora* and the percentages of infestation incidences on faba bean, with climatic factors at Esna district, Luxor Governorate during the first growing season (2019/20).

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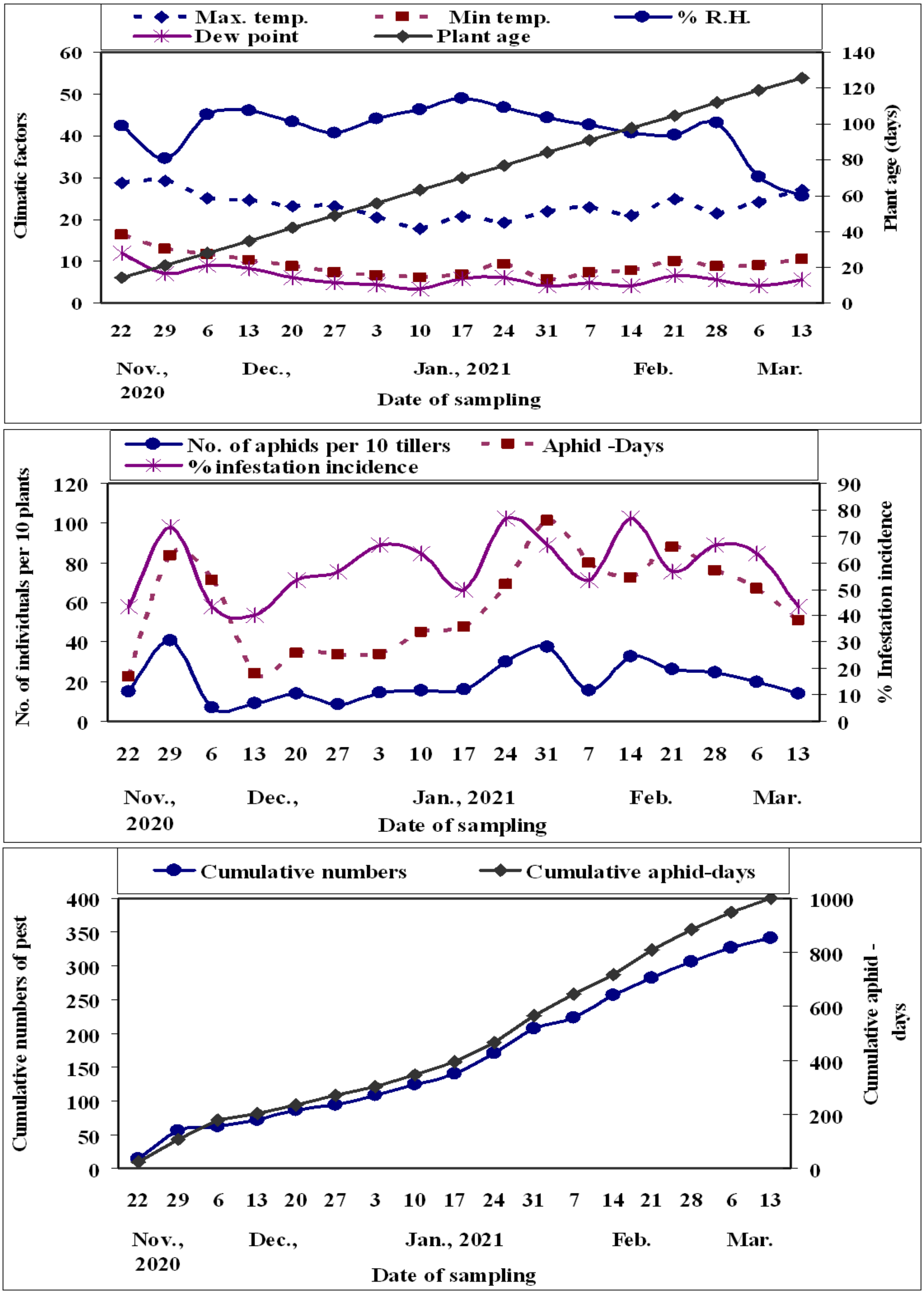

Fig. 2. Weekly mean numbers of aphid days, % cumulative, cumulative aphid-days of *A. craccivora* and the percentages of infestation incidences on faba bean, with climatic factors at Esna district, Luxor Governorate during the second growing season (2020/2021).

Table 3. Rate of weekly variation (R.W.V.P) in the mean number of *A. craccivora* and the infestation incidence percentages counted on faba bean plants at Esna district, Luxor Governorate during the two growing seasons (2019/20 and 2020/21).

First growing season (2019/20)				Second growing season (2020/21)			
Sampling date		R.W.V.P		Sampling date		R.W.V.P	
		Population density	%Infestation incidence			Population density	%Infestation incidence
Nov., 2019	21	——	——	Nov., 2020	22	——	——
	28	2.92	1.19		29	2.71	1.69
Dec.,	5	0.19	0.84	Dec.,	6	0.17	0.59
	12	1.58	0.94		13	1.29	0.92
	19	1.45	1.41		20	1.56	1.33
	26	0.83	0.92		27	0.60	1.06
Jan., 2020	2	2.19	1.16	Jan., 2021	3	1.72	1.18
	9	0.72	1.11		10	1.09	0.95
	16	0.64	0.74		17	1.02	0.79
	23	1.82	1.35		24	1.88	1.53
	30	1.46	0.92		31	1.26	0.87
Feb.	6	0.54	0.90	Feb.	7	0.42	0.80
	13	1.71	1.35		14	2.09	1.44
	20	0.50	0.62		21	0.80	0.74
	27	1.89	1.46		28	0.95	1.18
Mar.	5	0.82	0.89	Mar.	6	0.81	0.95
	12	0.45	0.71		13	0.70	0.68

Table 4. Different models of correlation and regression analyses for describing the relationship between the some weather factors and plant ages on population fluctuation of *A. craccivora* on faba bean plants during the two growing seasons (2019/20 and 2020/21).

Season	Tested Variables	Simple correlation and regression values				Partial correlation and regression values				Efficiency %	Rank	Analysis variance			
		r	b	S.E	t	P. cor.	P. reg.	S.E	t			F values	MR	R^2	E.V. %
2019/2020	Max. temp (X_1)	-0.22	-0.58	0.66	-0.87	0.63	3.61	1.35	2.68 *	17.14	4	6.17 **	0.86	0.73	73.71
	Min. temp (X_2)	-0.28	-0.79	0.72	-1.11	0.79	8.14	1.90	4.29 **	44.06	2				
	R.H.% (X_3)	-0.09	-0.11	0.29	-0.37	0.74	2.21	0.61	3.66 **	32.02	3				
	Dew point (X_4)	-0.49	-1.80	0.83	-2.16 *	-0.84	-14.69	2.90	-5.07 **	61.52	1				
	Plant age (X_5)	0.24	0.06	0.06	0.94	0.34	0.07	0.06	1.20	3.39	5				
	Plant ages (X_5, X_5^2, X_5^3)											1.22	0.47	0.22	21.90
	Combined effect (X_1 to X_5^3)											4.90 *	0.89	0.79	79.21
2020/2021	Max. temp (X_1)	-0.01	-0.05	0.83	-0.05	0.70	5.73	1.76	3.25 **	28.81	4	5.17 **	0.84	0.70	70.17
	Min. temp (X_2)	-0.04	-0.16	0.97	-0.17	0.80	11.57	2.64	4.38 **	52.04	2				
	R.H.% (X_3)	-0.13	-0.21	0.43	-0.50	0.78	3.98	0.95	4.17 **	47.31	3				
	Dew point (X_4)	-0.25	-1.18	1.19	-0.99	-0.83	-19.29	3.97	-4.86 **	64.18	1				
	Plant age (X_5)	0.24	0.07	0.07	0.95	0.59	0.19	0.08	2.44 *	16.11	5				
	Plant ages (X_5, X_5^2, X_5^3)											2.52	0.61	0.37	36.78
	Combined effect (X_1 to X_5^3)											3.17	0.84	0.71	71.15

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

Table 5. Different models of correlation and regression analyses for describing the relationship between the some weather factors and plant ages on the percentages of infestation incidences by *A. craccivora* on faba bean plants during the two growing seasons (2019/20 and 2020/21).

Season	Tested Variables	Simple correlation and regression values				Partial correlation and regression values				Efficiency %	Rank	Analysis variance			
		r	b	S.E	t	P. cor.	P. reg.	S.E	t			F values	MR	R^2	E.V. %
2019/2020	Max. temp (X_1)	-0.73	-2.79	0.68	-4.14 **	-0.22	-1.02	1.34	-0.76	0.63	4	15.94 **	0.94	0.88	87.87
	Min. temp (X_2)	-0.57	-2.42	0.89	-2.72 *	0.83	9.22	1.88	4.91 **	26.63	1				
	R.H.% (X_3)	0.19	0.31	0.41	0.76	0.62	1.55	0.60	2.58 *	7.39	3				
	Dew point (X_4)	-0.69	-3.73	1.01	-3.70 **	-0.82	-13.40	2.87	-4.67 **	24.16	2				
	Plant age (X_5)	0.36	0.13	0.08	1.50	0.22	0.05	0.06	0.75	0.61	5				
	Plant ages (X_5, X_5^2, X_5^3)											3.19	0.65	0.42	42.37
	Combined effect (X_1 to X_5^3)											13.75 **	0.96	0.91	91.45
2020/2021	Max. temp (X_1)	-0.45	-1.69	0.87	-1.95	0.40	2.06	1.43	1.44	2.73	4	13.11 **	0.93	0.86	85.63
	Min. temp (X_2)	-0.37	-1.63	1.06	-1.54	0.88	13.37	2.15	6.21 **	50.53	2				
	R.H.% (X_3)	0.02	0.03	0.50	0.06	0.77	3.09	0.78	3.97 **	20.72	3				
	Dew point (X_4)	-0.58	-3.23	1.18	-2.74 *	-0.89	-20.78	3.23	-6.43 **	54.23	1				
	Plant age (X_5)	0.26	0.09	0.08	1.04	0.23	0.05	0.06	0.80	0.82	5				
	Plant ages (X_5, X_5^2, X_5^3)											1.76	0.54	0.29	28.91
	Combined effect (X_1 to X_5^3)											8.04 **	0.93	0.86	86.22

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

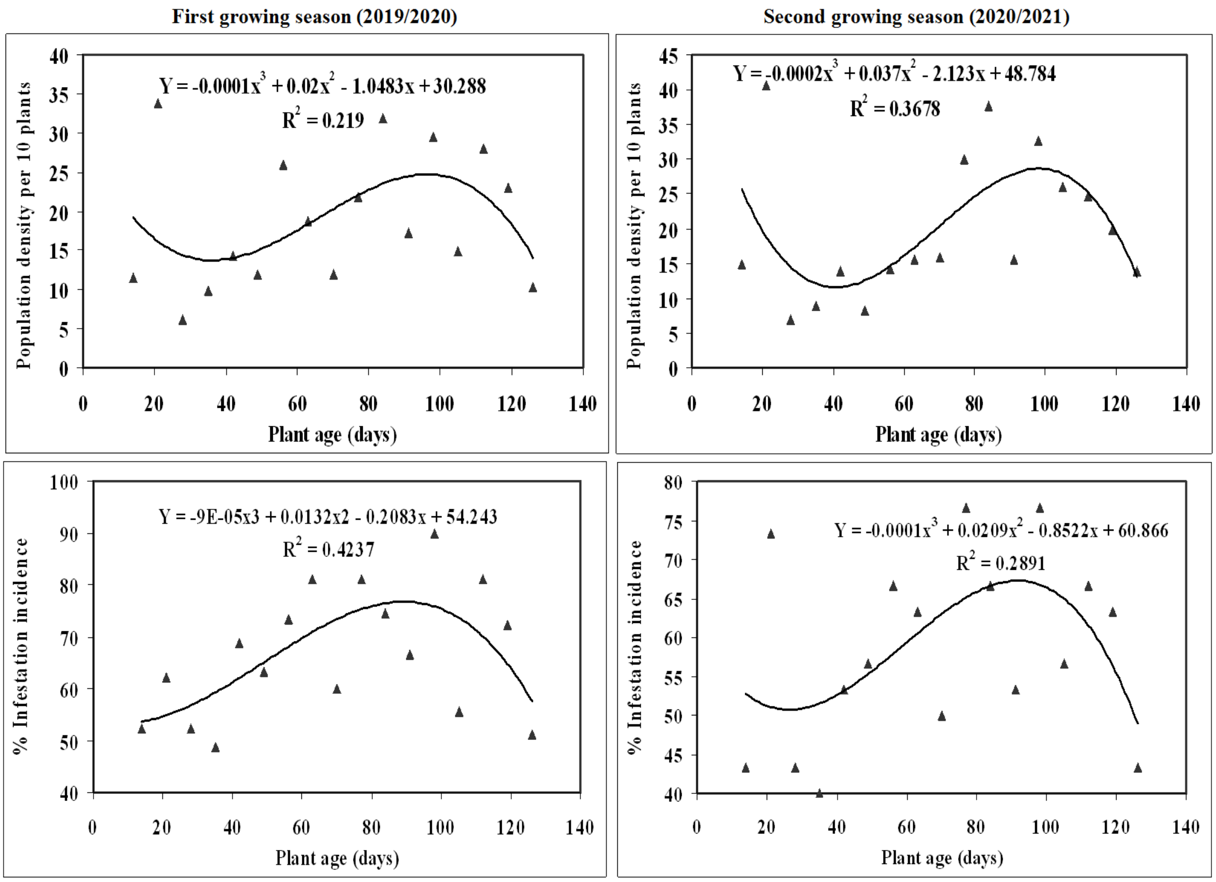

Fig. 3. The polynomial relationship between plant age (X_5) and total population of *A. craccivora* (Y_1) & percentages of infestation incidences (Y_2) during the two successive growing seasons (2019/20 and 2020/21).

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