

Effect of Certain Climatic Factors and Plant Phenology on Population Density of *Schizaphis graminum* on Wheat Plants in Luxor Governorate, Egypt

Moustafa M.S. Bakry ^{1*}, Roya Arbabtafti ² and Lamiaa H.Y. Mohamed ¹

¹ Plant Protection Research Institute, A.R.C, Dokki, Giza, Egypt.

² Iranian Research Institute of Plant Protection, Agricultural Research, Education and Extension Organization (AREEO), Tehran, Iran.

*Corresponding author email id: md.md_sabry@yahoo.com

Abstract – The aim of this research is to determine the impacts of some climatic factors and plant phenology on the population density of *Schizaphis graminum*. Field experiments were conducted at wheat program of El-Mattana Agricultural Research Station, Luxor Governorate, Egypt, during two successive growing seasons (2017/18 and 2018/19) to study the seasonal activity of *S. graminum* (Rondani) (Hemiptera: Aphididae) on wheat plants (Giza 171 cultivar). Results indicated that *S. graminum* infested wheat plants from 17th December 2017 to 8th April 2018 during the first growing season and from 27th January 2019 to 13th April 2019 in the second growing season. The cumulative counts of *S. graminum* were 597.00 and 310.33 individuals per season for the two growing seasons, respectively. The total mean of *S. graminum* population through the whole season was 35.12 ± 3.31 and 25.86 ± 1.96 individuals per 10 tillers over the first and second growing seasons, respectively. Generally, it was found that the climatic conditions of weekly inspection dates were more favorite for *S. graminum* to grow its population during December, January and February of the first season and during February and March 2019 in the second season. Furthermore, it was found that the number of *S. graminum* disappeared during the wheat maturation period in two consecutive growing seasons. Results revealed that the combined effects of the climatic factors and the plant phenology can explain the variation in the population density of *S. graminum*. The percentages of explained variance (E.V. %) were 95.93 and 98.02% for the two successive growing seasons, respectively. Mean daily maximum temperature of *S. graminum* population changes was 25.75 and 18.57% for 2018 and 2019, respectively and it was the most effective variable. These pieces of information can be useful for planning an IPM program of aphid on wheat plants.

Keywords – *Schizaphis graminum*, Seasonal Abundance, Wheat Plants, Environmental Conditions, Plant Age, Growth Stage.

I. INTRODUCTION

Wheat, *Triticum aestivum* L. (Family: Gramineae) is one of the most important cereal crops in Egypt. It is used for human food, as well as in animal and poultry feeding. During different growth stages, wheat plants are attacked by many insect pest species which aphids are the most destructive the crop loss assessment was 7.5 – 18.7% (Tantawi, 1985).

The green cereal aphid, *Schizaphis graminum* (Rondani) (Hemiptera: Aphididae) is one of the 14 aphid species that considered as a worldwide key pest (Blackman and Eastop, 2007). Severe damage was happened by sucking the plant sap followed by deformation and excreting large amount of honeydew that encourages the growth of sooty mould. Then photosynthesis and vegetative growth of the infested plants decreased. Furthermore, it is so important because of transmission of viral diseases ability (El-Fatih, 2000 and 2006). In recent years, *S. graminum* has become the most frequent species on wheat crop, and is abundant throughout all developmental stages of wheat plants (Youssef, 2006, Parizoto *et al.*, 2013, Ahmad *et al.*, 2016 and Awadalla *et al.*, 2018).

To develop an effective control against *S. graminum*, it is essential to know its bio-ecology including population dynamics under different climatic factors influencing the different phenological stages. The temperature has a direct effect on insect activity and the rate of development (**Lamb, 1992**). In addition, such changes in climatic conditions could profoundly affect the population dynamics and the status of insect pests of crops (**Woiod, 1997**). The abundance of *S. graminum* varied on barley plants with the growth stage of the plant, the season and probably other factors related to plant physiology (**El-Fatih, 2006**).

Plant phenology can have a significant impact on 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 most severely affected (**Williams and Dixon, 2007**).

The present investigation was carried out to estimate the impact of certain climatic weather factors and plant phenology on the population density of *S. graminum* on wheat plants over the two growing seasons to plan an effective program for its control.

II. MATERIALS AND METHODS

1. Seasonal Activity of *S. graminum* Infesting Wheat Plants:

Field experiments were carried out at wheat program of El-Mattana Agricultural Research Station, Luxor Governorate during two successive growing seasons (2017/18 and 2018/19). Four replicates (of 3 m × 3 m log = 9 m² each). Replicates were distributed in complete randomized blocks design and it sown using the commercial wheat cultivar (Giza 171) in optimum sowing date (November, 25th every season). All agricultural practices were followed except pest control. For estimating the population density of *S. graminum*, 10 tillers were sampled randomly in the morning every week, using 10x lenses in the field. Sampling 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 tillers 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.

Aphid-Days and the Cumulative Aphid-Days:

Aphid days are cumulative number was used as a term to express the total impact of an ever-changing population over time. Aphid-days, 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**).

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

Where:

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

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

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

2. Plant Phenological Characters i.e. Plant Age (in Days) and Growth Stage (as Decimal Code):

Growth Stage (ZGS):

Growth stage refers to a decimal code for the cereal growth stage according to **Zadoks et al. (1974)** in Table (1). The decimal growth stage can help in understanding crop adaptation and development (**Barber et al., 2015**).

Accumulated Numbers of Aphids' Population:

Mean numbers of *S. graminum* per 10 wheat tillers 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 tillers 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**).

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

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

3. Simultaneous Effects of the Abiotic Factors (three Climatic Factors) and Biotic factors i.e., plant Phenology as [plant age (in days) and Growth Stage (as Decimal Code)] on *S. graminum* Population Density Infesting Wheat Plants:

The weekly counts of three climatic weather factors viz., mean daily maximum temperature (X_1), minimum temperature (X_2), mean of % relative humidity (X_3) of Luxor governorate during two successive growing seasons (2017/2018 and 2018/2019) 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, 25.67°N and 32.71°E, respectively.

Concerning, the biotic factors i.e. (plant phenology), the first biotic factor was considered as plant age (X_4) were determined during two successive experimental seasons (2017/18 and 2018/19). This relation was presented by the polynomial equation of third-degree ($Y = a + b_1X_4 + b_2X_4^2 + b_3X_4^3$).

The second biotic factor, the growth stage (X_5) as expressed, the decimal code for the growth stages of cereals and refers to plant development and crop adaptation according to **Barber et al. (2015)**. This relation was presented by polynomial equation of third degree ($Y = a + b_1X_5 + b_2X_5^2 + b_3X_5^3$).

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 phenology (plant age and growth stage) as independent variables on *S. graminum* 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.

III. RESULT AND DISCUSSION

The weekly counts of *S. graminum* that infested wheat plants at Esna district, Luxor Governorate were recorded through the two successive growing seasons (2017/18 and 2018/19). As well as, weekly mean records of climatic weather factors and plant phenological characteristics for wheat tillers throughout the two growing seasons of investigation are tabulated in Tables (2 and 3) and Figs. (1 and 2). The effects of the climatic factors and plant phenological properties of wheat tillers on the seasonal abundance of *S. graminum* were estimated based on the average number of alive insects (nymphs and apterae individuals) counts per ten tillers in the successive sampling dates.

1. Population Studies:

1.1. Seasonal Activity of *S. graminum* Population on Wheat Plants:

A. The First Growing Season (2017/2018):

The population density of *S. graminum* appeared in few numbers on wheat plants on December 17th and then it highly increased continuously to reach the first peak of abundance on January 7th during the tillering stage, with mean counts of 24.33 ± 0.88 individuals per 10 tillers under field conditions (21.14 °C, Max. temp.; 5.86°C Min. temp. and 50.71% R.H.) (Table, 2 and Fig. 1). Furthermore, the phenological characters of wheat plants viz. (plant age, 42 days and the decimal code for the growth stages, 27). The population decreased on January 14th and then increased gradually to reach the second peak on January 21st (59.00 ± 4.51 individuals per 10 tillers) at (24.57 °C, Max. temp.; 8.57°C Min. temp. and 49.14% R.H.) and the phenological characters (plant age, 56 days and the decimal code, 31), as suitable with growth up to the first node of stem becomes visible. Then, the population decreased on January 28th and then increased gradually to reach the third peak on February 4th (69.00 ± 3.79 individuals per 10 tillers) under field conditions at (22.43 °C, Max. temp.; 5.86°C Min. temp. and 50.29% R.H.) when the phenological characters were (plant age, 70 days and the decimal code, 35), as compatible with the stem extension period. Afterward, the population decreased successively until it reached to February 18th. Another increase in population took place on February 25th indicating the fourth peak (66.33 ± 3.28 individuals per 10 tillers) at 23.43 °C, Max. temp.; 7.00°C Min. temp. and 47.57% R.H.). As well, the phenological characters (plant age, 91 days and the decimal code, 50) as coincided with the date of first heading. After that, the population of aphids decreased gradually until April 8th till the disappearance of any aphid infestation during the period between the end of heading and maturation (Table 2 and Fig., 1).

B. The Second Growing Season (2018/2019):

The results presented in (Table, 3) and illustrated in Fig. (1), indicated that *S. graminum* appeared in few numbers on wheat plants on January 27th (6.00 ± 0.58 individuals per 10 tillers), then its population increased gradually, until reaching its maximum (30.67 ± 1.20 individuals per 10 tillers) on March, 2nd at 24.00 °C, Max. temp.; 8.43°C Min. temp. and 33.14% R.H.). As well, the phenological characters of wheat plants were (plant age, 91 days and the decimal code for the growth stages, 45), being coincided with the period after emergence of the flag leaf sheath. Then, aphids' population decreased on March, 16th and it rein creased gradually to reach the

highest peak of abundance on March, 30th (44.67 ± 1.45 individuals per 10 tillers) at (26.71°C, Max. temp.; 14.14°C Min. temp. and 24.57% R.H.) and the phenological characters (plant age, 119 days and the decimal code, 65), is compatible with the anthesis period. After that, the population decreased continuously until April, 13th and this aphid species disappeared during the maturation period.

The present results agree with those of **Abou-Elhagag and Abdelhafez (1998)**, **Abdel-Aziz et al. (2002)**, **El-Rawy (2013)**, and **Youssif et al. (2017)** who recorded that the maximum population density of cereal aphids occurred during February and March on wheat plants. **El-Heneidy et al. (2004)** found that the population densities of cereal aphids on wheat plants in Sakha and Sides regions occurred in high numbers during February and March. **Abd El-Megid et al. (2007)** in Egypt, stated that the infestation by aphids on wheat started during the 2nd week of February. The population reached a peak during the 1st week of March and disappeared towards the end of April.

It was obvious that infestation by *S. graminum*, completely, disappeared on wheat plants from December to the 3rd week of January during the second growing season. This may be due to the low temperature during these periods. **El-Rawy (2013)** recorded that the lowest number of cereal aphid species on wheat plants (61.6 aphids/10 plants) occurred in January.

The obtained results cleared that the total population density of *S. graminum* during the first growing season (2017/18) was higher than the subsequent growing season (2018/19). The mean total *S. graminum* population through the whole season was 35.12 ± 3.31 and 25.86 ± 1.96 individuals per 10 tillers over the first and second growing seasons, respectively. This may be due to the influence of environmental factors in this region and the plant phenology of wheat as recorded in Tables (2 and 3) and illustrated in Fig. (1).

It was noticed that *S. graminum* disappeared during the maturation period of wheat plants during the two successive growing seasons. The same findings were noticed by **Vidya (1982)** who reported that the aphid population started to decline when ear head emergence started. **Dent (1991)** clarified that the rate of insect's population abundance at any location is influenced by the environmental factors at that location.

1.2. Weekly Incidence of *S. graminum* Population, its Accumulation and their Percentages in Relation to the Seasonal Total:

To facilitate comparisons within each season compared to another, the seasonal population density of the above criteria, was expressed in terms of percent of counted numbers, in each inspected week relative to the overall season grand total of the insect population. As well, the percentages of accumulated counts of each week were related to that of the overall seasonal number, to reflect the general trend of the population density as presented in Tables (2 and 3) and illustrated in Fig. (1).

Results in Tables (2 and 3) and in Fig. (1), indicating that the highest percentages of *S. graminum* numbers occurred during the first growing season (9.88, 11.56 and 11.11 % from the grand total), occurred in Jan., 21st, Feb., 4th and Feb., 25th, respectively, may be attributed to the suitable climatic conditions during these periods. While, during the second growing season, those were (9.88, 13.53 and 14.39%) found during March month, 2nd, 23rd and 30th, respectively. On the contrary, the lowest percentages of numbers were 1.33% took place on December 17th, 2017 during the first season and 1.93% recorded on January 27th, 2018 during the second season.

Data recorded in Tables (2 and 3) showed that the cumulative numbers of *S. graminum* were 597.00 and 310.33

individuals per season for the two growing seasons, respectively. As well, the percentages of accumulated numbers of *S. graminum* in each inspected week increased with increasing the periods the inspection during the growing season.

1.3. Cumulative Aphid-Days:

Data in Tables (2 and 3) and illustrated in Fig. (1), presented the aphid-days and the cumulative aphid-days for *S. graminum* on wheat plants to express the total impact of an ever-changing population over time. These present results indicated that the impact of *S. graminum* population on wheat plants was higher at the first growing season (1782.00 cumulative aphid-days) as compared to the second one (898.00 cumulative aphid-days). Thus resulting in higher impact on plant phenology in the first season than the second one. 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 *S. graminum* Population (R.W.V.P.):

The monthly variation rates in the population of *S. graminum* on wheat plants were calculated (Tables, 2 and 3). The rate of monthly variation in the population is considered an indicator of the favorable month 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.

The obtained results cleared that the favorable weeks of annual increase for *S. graminum* population were December, 24th, Dec., 31st, Jan., 7th, Jan., 21st, Feb., 4th, and Feb., 25th during the first growing season (2017/18), when the rates of weekly variation were [2.75, 3.27, 2.03, 3.16, 1.68 and 1.26, respectively (Table, 2)]. As for the second growing season (2018/19), the favorable times of annual increase for total *S. graminum* population appeared to be in February, 2nd, 9th, 16th and 23rd and during March, 2nd, 16th, 23rd and 30th, when the rates of monthly variation were (1.72, 1.68, 1.23, 1.27, 1.14, 1.25, 1.50 and 1.06, respectively; Table 3).

Generally, it was clear that climatic conditions during weekly inspection dates in December, January and February months during the first season and weekly inspection dates in February and March in the second one when all conditions 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.

2. Effect of the Abiotic and Biotic Factors on Population Density of *S. graminum* Infesting Wheat Plants:

2.1. Effect on Independent Variables [three Climatic Factors (X_1 , X_2 and X_3), Plant Age (X_4) and Growth Stage (X_5)] on total Population of *S. graminum* (Y) (Dependent Variable):

A. Effect of Daily Mean Maximum Temperature (X_1):

Results presented in Table (4) showed that the simple correlation (r) between the daily mean maximum temperature and the total insect population of *S. graminum* was insignificantly positive (0.14 and 0.51) 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 increase the population by 1.15 and 1.95 individuals per 10 tillers for the two growing seasons, respectively (Table 4).

The partial regression coefficient values for the effect of daily mean maximum temperature on the total *S. graminum* population are shown in Table (4). Data revealed that this factor had a highly significant positive relation with the insect's population (P. reg. value; 9.07) during the first growing season and highly significant negative effect (P. reg. value; -3.37) for the second growing season. Also, the values of partial correlation were (0.87 and -0.86, respectively), and the t-test values were (5.73 and -4.13, respectively), Table (4). The obtained results revealed that daily mean maximum temperature entirely under the optimum range of total *S. graminum* population activity during the first growing season and entirely above the optimum range of total population activity during the second growing season. This climatic factor was the most effective variable on total *S. graminum* population changes by 25.75 and 18.57% during the first and second growing seasons, respectively (Table 4).

B. Effect of Daily Mean Minimum Temperature (X_2):

The results of statistical analysis of simple correlation (Table, 4) showed an insignificantly negative correlation between the daily mean minimum temperature and the total population of *S. graminum* (r value; -0.23) during the first growing season and highly significant positive relation (r value; 0.80) for the second growing season. As well, 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 1.63 and would increase the 3.03 individuals per 10 tillers during the two seasons of study, respectively.

The precise effects of mean minimum temperature on the total insect population of *S. graminum* are presented in Table (4), those showed significant negative relation for the first season (P. reg. value; -4.94) and significant positive effect (P. reg. value; 2.08) during the second season. Furthermore, the values of partial correlation were (-0.68 and 0.72) and the values of the t-test were (-3.10 and 2.56) during the two growing seasons, respectively. The obtained results revealed that, mean daily minimum temperature above the optimum range of total *S. graminum* population activity during the first growing season and under the optimum range of total population activity during the second growing season. This climatic factor was responsible for certain changes in the total *S. graminum* population by 7.54 and 7.12% for the two successive growing seasons, respectively (Table, 4).

C. Effect of the Mean Relative Humidity (X_3):

Data in Table (4), showed that the correlation between relative humidity and the total population of *S. graminum* was insignificantly positive (r-value; 0.27) for the first growing season and highly significant negative relation (r value; -0.82) during the second growing season. In the same time, the simple regression coefficient indicated that an increase by 1% in the mean relative humidity would increase the population by 0.92 individuals per 10 tillers during the first season and would decrease the population by 1.42 individuals per 10 tillers for the second season (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 *S. graminum* was highly significant positive (P. reg. value; 3.04) for the first growing season and significant negative (P. reg. value; -1.33) during the second growing season. Also, the partial correlation values were (P. cor. values; 0.75 and -0.78) and t-test values were (3.77 and -3.08) for both seasons, respectively. Results revealed that, mean relative humidity was entirely under the optimum range of total population activity during the first season and above the optimum range of total population activity of *S. graminum*

during the second season. This climatic factor was responsible for certain changes in the total population of *S. graminum* by 11.12 and 10.32% for the two successive growing seasons, respectively (Table 4).

The obtained results indicated that the effect of mean daily maximum temperature and relative humidity affected the total population of *S. graminum* more than the mean daily of minimum temperature.

D. Effect of the Plant Age (X_4):

Data in Table (4) show the effect of the plant age on total population of *S. graminum*. The correlation coefficient (r) was insignificantly positive (r-value; 0.20) for the first growing season and highly significant positive relation (r-value; 0.76) during the second growing season. The calculated regression coefficient (b) for the effect of this factor indicated that for everyday increase in the plant age of wheat, the total population of *S. graminum* would increase by 0.13 and 0.36 individuals per 10 tillers during the two seasons of study, respectively.

The exact relation between the wheat plant age and total population of *S. graminum* was determined by the partial regression values (Table 4), which were highly significant positive (P. reg. value; 1.49) for the first growing season and insignificantly negative relation (P. reg. value; -0.25) during the second growing season. Also, the partial correlation values were (0.83 and -0.22) and the t-test values (4.89 and -0.56) for the two growing seasons, respectively. Also, the plant age of wheat was the most effective variable on *S. graminum* population of 18.76% during the first growing season and was the least effective variable on the total *S. graminum* population changes by 0.34% during the second growing season.

F. Effect of the Growth Stage [as Decimal Code (X_5):

Data presented in Table (4), showed that the decimal code of wheat growth stage had an insignificantly positive effect on the total *S. graminum* population in the first growing season, since the correlation coefficient was (0.04) and a highly significant positive relation (r-value; 0.73) during the second season. The unit effect (regression coefficient) indicated that one-degree increase in decimal code of wheat growth stage would increase the population by 0.05 and 0.56 individuals per 10 tillers, for the two seasons, respectively.

The real effect of the decimal code of growth stage of the wheat plant was clear from the partial regression values (Table 4), which showed a highly significant negative effect (P. reg.; -2.27) in the first growing season and insignificant positive effect (0.74) during the second season. The partial correlation values were (-0.72 and 0.40) and the "t-test" values were (-3.40 and 1.06) during the two growing seasons, respectively. The obtained results indicated that the decimal code of the growth stage of wheat plant was responsible for certain changes in the total population of *S. graminum* by 9.04 and 1.22% during the two seasons, respectively.

G. The Combined Effect of [three Climatic Factors (X_1 , X_2 and X_3), Plant Age (X_4) and Growth Stage (X_5)] on the Total Population of *S. graminum*:

As shown in Table (4), the combined effect of these tested factors on the *S. graminum* total population during the two growing seasons was highly significant where the "F" values were 23.31 and 17.19, respectively. The amounts of variability were 91.38 and 93.47% for the two growing seasons, respectively.

2.2. Effect of Plant phenology:

A. Plant Age (X_4):

The plant phenology as plant age (X_4) (obtained by three-degree polynomial equation); $Y = a + b_1X_4 + b_2X_4^2 + b_3X_4^3$ revealed high relation to the variation in the population. E.V. values were 87.39 and 78.01% for the two successive growing seasons, respectively (Table 4). These added values seem to be significant and fully explained the variance in the population density of *S. graminum*. Based on this model, the population density of *S. graminum* on wheat plants can be predicted by looking for the plant age. As the plant age realized the main effect on the population density of *S. graminum*, regression analysis was performed using the plant age per day (X_4) and the corresponding log of the mean number of *S. graminum* (Y). The regression equation was presented in Fig. (2):

$$\text{First growing season (2017/18): } Y = -0.0001X_4^3 + 0.0053X_4^2 + 1.5019X_4 - 38.192 \quad R^2 = 0.8739$$

$$\text{Second growing season (2018/19): } Y = -0.0002 X_4^3 + 0.0565 X_4^2 - 3.9169X_4 + 90.781 \quad R^2 = 0.7801$$

Also, the combined effect of these tested factors on *S. graminum* total population was a highly significant where the “F” values were 30.03 and 9.46 during the two growing seasons, respectively (Table, 4).

In general, when the plant age of wheat was 70 days for the first growing season and in plant age was 119 days during the second growing season, at these times, *S. graminum* recorded the maximum population density (69.00 ± 3.79 and 44.67 ± 1.45 individuals per 10 tillers) during the two successive seasons, respectively.

B. Growth Stage (Decimal Code; X_5):

The decimal code for the growth stages of the wheat plant is presented by the polynomial equation of third-degree, $Y = a + b_1X_5 + b_2X_5^2 + b_3X_5^3$. It seems that the equation provided the best fit of the data by indicating the high value of the percentage of explained variance (E.V. = 89.63 and 82.08%) as compared with the other biotic factor (plant age), Table (4). These added values seem to be significant and fully explained the variation in *S. graminum* population density.

Based on this model, the population density of *S. graminum* on wheat plants can be predicted by looking for the growth stage (as the decimal code). As the growth stages of wheat realized the main effect on the population density of *S. graminum*, regression analysis was performed using the growth stage (as the decimal code) (X_5) and the corresponding log means the number of *S. graminum* (Y). The regression equation was presented in (Fig., 2).

$$\text{First growing season (2017/18): } Y = 0.0011X_5^3 - 0.2551X_5^2 + 16.688X_5 - 261.94 \quad R^2 = 0.8963$$

$$\text{Second growing season (2018/19): } Y = -0.001X_5^3 + 0.1283 X_5^2 - 4.0906X_5 + 45.008 \quad R^2 = 0.8208$$

Also, the combined effect of these tested factors on the *S. graminum* total population was highly significant where the “F” values were 37.45 and 12.21 during the two growing seasons, respectively (Table, 4).

In general, when the wheat plants were in the stem extension stage during February, at this time *S. graminum* recorded the highest population density during the two growing seasons. **El-Fatih (2006)** recoded that the stem extension growth stage of barley harbored the highest population density of *Rhopalosiphum maidis* (Hemiptera: Aphididae) in comparison with the tillering or heading stages.

2.3. Effect on Independent Variables ($X_1, X_2, X_3, X_4, X_4^2, X_4^3, X_5, X_5^2$ and X_5^3) on Total Population of *S. graminum* (Y) (Dependent Variable):

The Results revealed that the combined effect of the abiotic factors (three climatic factors) and biotic factors *i.e.*, plant phenology as [plant age (in days) and growth stage (as decimal code)] on the variation in the population

density of *S. graminum*.

The amount of variability, attributed to the combined effect of all these tested factors on the total population density of *S. graminum* have a highly significant where the ‘F’ value was 18.32 during the first growing season and insignificant where the ‘F’ value was 10.98 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 *S. graminum*. The percentages of explained variance (E.V. %) were 95.93 and 98.02% 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, plant phenological characteristics as (plant age and growth stage) influenced mathematically the effect of weather factors.

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**).

The aphid population density was partially and negatively affected by temperature, wind velocity, photoperiod and rainfall in summer and nili plantations of 1995 and 1996. In addition, plant age was positively related to aphid population density in nili one (**Abd El-Fattah et al., 2000**).

Aphid population on tomato showed a significant negative correlation with minimum and maximum temperatures (**Shakeel et al., 2015**). They recorded also, significant positive correlation with relative humidity and non-significant negative correlation with rainfall. The same authors reported that the determination of effects of different weather factors on the population of aphids in tomato plantations was essential for effective pest management.

Aphid population on wheat varied due to temperature (**Aheer et al., 2008**). They indicated that the aphid population showed, significant negative correlation with maximum and minimum temperatures and precipitation, whereas relative humidity was positively correlated. The significant negative correlation of the aphid population with maximum temperature was reported by **Chandrakumar et al. (2008)**. The highest aphid population occurred during March (**Aheer et al., 2007; Wains et al., 2010 and Iqbal et al., 2008**).

The population of aphid increased with the decrease in temperature, lowest population was found on tomato at 32.5°C, while, the highest population was recorded at 27.5°C (**Shakeel et al., 2015**).

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**).

Table 1. Growth stages of wheat according to Zadoks *et al.* (1974).

Stages	Zadoks Code	Cereal growth stages	Stages	Zadoks Code	Cereal growth stages
Sowing	0	Sowing	Booting	37	Flag leaf visible
	03	Germination, seed swollen		39	Flag leaf collar just visible
	05	Radicle emerged from seed		41	Early-boot stage
	07	Coleoptile emerged from seed		43	Mid-boot stage
	10	Emergence		45	Late-boot stage
Leaves on main shoot	11	1 st leaf more than half visible	Heading	47	Flag leaf sheath opening
	12	2 nd leaf more than half visible		49	First awns visible
	13	3 rd leaf more than half visible		50	First spikelet of spike just visible
	14	4 th leaf more than half visible		52	20% of spike visible, early heading
	15	5 th leaf more than half visible		55	50% of spike visible, mid heading
	16	6 th leaf more than half visible		58	80% of spike visible, late heading
	17	7 th leaf more than half visible		60	Full heading but not flowering
Tillering	18	8 or more leaves visible and stem not elongating.	Flowering	62	20% of spikes are flowering
	21	Main shoot and 1 tiller		65	50% of spikes are flowering
	22	Main shoot and 2 tillers		68	80% of spikes are flowering
	23	Main shoot and 3 tillers	Kernel extending	70	kernels extended 20-50% kernels watery ripe, clear liquid
	24	Main shoot and 4 tillers		71	
	25	Main shoot and 5 tillers		73	Early milk, liquid off-white
	26	Main shoot and 6 tillers	Milk development	75	Mid milk, increase in solids
	27	Main shoot and 7 tillers		77	Late milk, increase in solids
	28	Main shoot and 8 tillers		79	Very late milk, half solid/half liquid
29	Main shoot and 9 or more tillers	81		Very early dough	
Stem elongation	30	Stem starts to elongate	Dough development	83	Early dough
	31	1 st node detectable		85	Soft dough
	32	2 nd node detectable		87	Hard dough
	33	3 rd node detectable		90	kernels hard - difficult to divide by thumb nail
	34	4 th node detectable	Ripening	92	harvest ripe - can no longer be dented by thumb nail
		93		kernels loosening in daytime	
		94		over-ripe - straw dead and collapsing	

Table 2. Weekly mean counts, aphid days, % cumulative, cumulative aphid-days and R.W.V.P. of *S. graminum* on wheat plants, with climatic factors, at Esna district, Luxor Governorate during the first growing season (2017/18).

Sampling date	Plant age (days)	Growth stage (ZGS)*	Aphids count per 10 tillers ± S.E.	% No. aphids from overall seasonal total	Cumulative numbers per 10 tillers	% Cumulative	Aphid - Days	Cumulative aphid-days	R.W.V.P	Climatic factors			
										Max. temp.	Min temp.	% R.H.	
Dec., 2017	17	21	23	1.33 ± 0.33	0.22	1.33	0.22	2.00	2.00	—	22.00	7.71	46.43
	24	28	24	3.67 ± 0.67	0.61	5.00	0.84	7.50	9.50	2.75	23.00	7.29	41.29
	31	35	25	12.00 ± 1.15	2.01	17.00	2.85	23.50	33.00	3.27	19.29	7.14	49.71
Jan., 2018	7	42	27	24.33 ± 0.88	4.08	41.33	6.92	54.50	87.50	2.03	21.14	5.86	50.71
	14	49	29	18.67 ± 0.33	3.13	60.00	10.05	64.50	152.00	0.77	20.43	4.86	47.71
	21	56	31	59.00 ± 4.51	9.88	119.00	19.93	116.50	268.50	3.16	24.57	8.57	49.14
	28	63	32	41.00 ± 2.08	6.87	160.00	26.80	150.00	418.50	0.69	25.43	10.14	42.14
Feb.	4	70	35	69.00 ± 3.79	11.56	229.00	38.36	165.00	583.50	1.68	22.43	5.86	50.29
	11	77	39	62.33 ± 1.20	10.44	291.33	48.80	197.00	780.50	0.90	24.71	8.43	39.57
	18	84	41	52.67 ± 2.40	8.82	344.00	57.62	172.50	953.00	0.84	21.14	8.00	49.86
	25	91	50	66.33 ± 3.28	11.11	410.33	68.73	178.50	1131.50	1.26	23.43	7.00	47.57
Mar.	4	98	55	58.67 ± 1.86	9.83	469.00	78.56	187.50	1319.00	0.88	28.71	11.43	37.57
	11	105	60	50.67 ± 1.76	8.49	519.67	87.05	164.00	1483.00	0.86	28.00	10.43	36.71
	18	112	65	36.67 ± 1.86	6.14	556.33	93.19	131.00	1614.00	0.72	26.46	11.71	38.71
	25	119	69	24.00 ± 1.15	4.02	580.33	97.21	91.00	1705.00	0.65	25.79	13.86	37.71
April	1	126	71	10.67 ± 0.67	1.79	591.00	98.99	52.00	1757.00	0.44	27.85	14.00	30.00
	8	133	73	6.00 ± 0.58	1.01	597.00	100.00	25.00	1782.00	0.56	28.11	17.14	29.86
Total			597.00					1782.00					
General average			35.12 ± 3.31								24.26	9.38	42.65

*(ZGS) = A decimal code for growth stage of cereal (Zadoks *et al.*, 1974).

Table 3. Weekly mean counts, aphid days, % cumulative, cumulative aphid-days and R.W.V.P. of *S. graminum* on wheat plants, with climatic factors, at Esna district, Luxor Governorate during the second growing season (2018/19).

Sampling date	Plant age (days)	Growth stage (ZGS)*	Aphids count per 10 tillers ± S.E.	% No. aphids from overall seasonal total	Cumulative numbers per 10 tillers	% Cumulative	Aphid - Days	Cumulative aphid-days	R.W.V.P	Climatic factors				
										Max. temp.	Min temp.	% R.H.		
Jan., 2019	27	56	29	6.00 ± 0.58	1.93	6.00	1.93	9.00	9.00	—	25.14	7.14	39.14	
Feb.	2	63	31	10.33 ± 0.88	3.33	16.33	5.26	24.50	33.50	1.72	22.59	7.31	40.02	
	9	70	34	17.33 ± 1.20	5.59	33.67	10.85	41.50	75.00	1.68	25.43	10.86	38.14	
	16	77	39	21.33 ± 1.20	6.87	55.00	17.72	58.00	133.00	1.23	21.57	9.00	41.57	
	23	84	41	27.00 ± 1.53	8.70	82.00	26.42	72.50	205.50	1.27	23.86	12.14	34.71	
Mar.	2	91	45	30.67 ± 1.20	9.88	112.67	36.31	86.50	292.00	1.14	24.00	8.43	33.14	
	9	98	47	22.33 ± 1.45	7.20	135.00	43.50	79.50	371.50	0.73	28.57	12.43	25.43	
	16	105	55	28.00 ± 1.15	9.02	163.00	52.52	75.50	447.00	1.25	28.86	12.57	28.71	
	23	112	60	42.00 ± 2.31	13.53	205.00	66.06	105.00	552.00	1.50	28.43	14.29	22.14	
	30	119	65	44.67 ± 1.45	14.39	249.67	80.45	130.00	682.00	1.06	26.71	14.14	24.57	
April	6	126	71	38.67 ± 2.40	12.46	288.33	92.91	125.00	807.00	0.87	32.43	17.71	24.14	
	13	133	75	22.00 ± 1.15	7.09	310.33	100.00	91.00	898.00	0.57	28.00	10.43	34.57	
Total			310.33					898.00						
General average			25.86 ± 1.96							26.30	11.37	32.19		

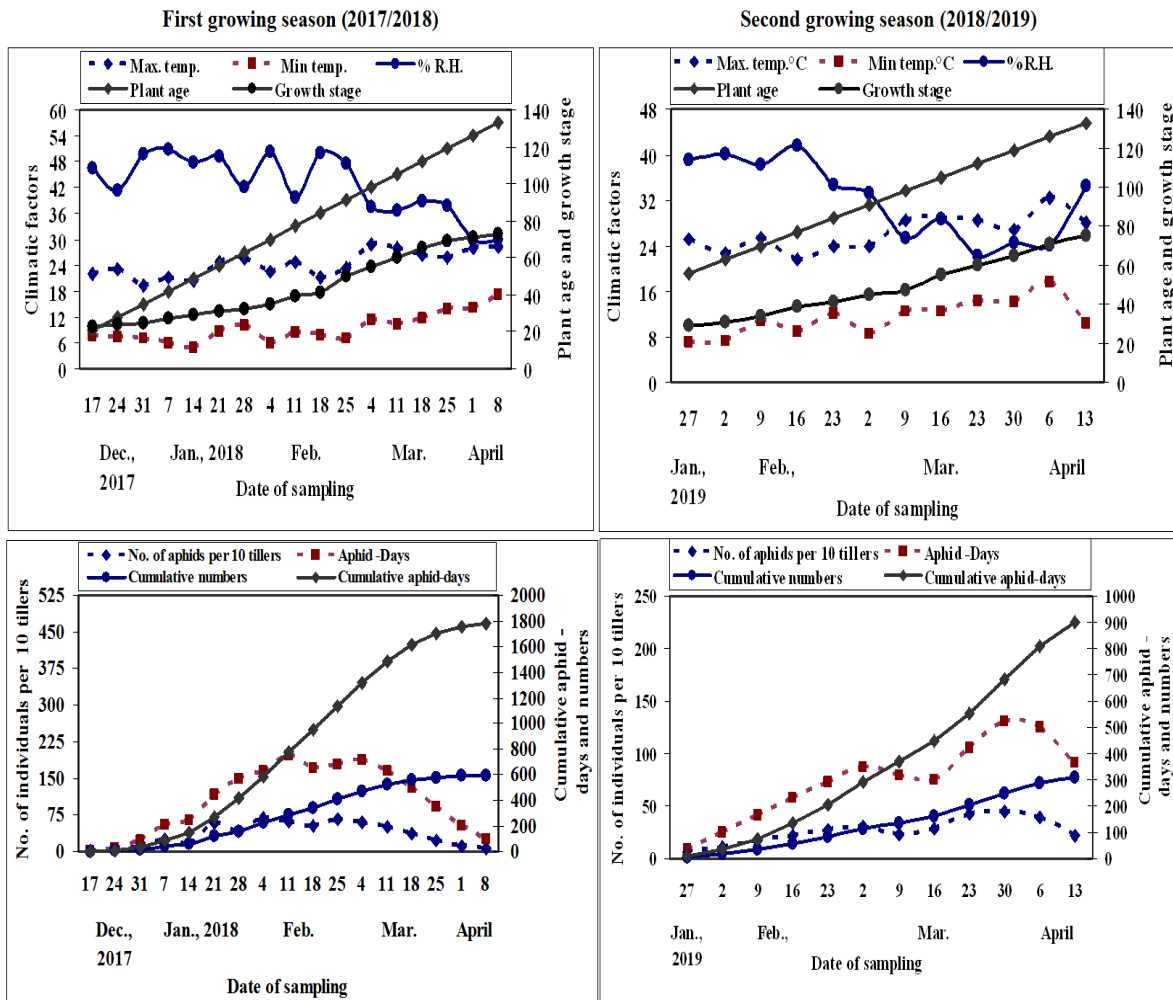


Fig. 1. Weekly mean numbers of aphid days, % cumulative, cumulative aphid-days of *S. graminum* on wheat plants, with climatic factors at Esna district, Luxor Governorate during the two successive wheat seasons (2017/18 and 2018/19).

Table 4. Different models of correlation and regression analyses for describing the relationship between some weather factors and plant age on population fluctuations of *S. graminum* on wheat plants during the two successive wheat growing seasons (2017/18 and 2018/19).

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. %				
2017/2018	Max temp (X ₁)	0.14	1.15	2.07	0.56	0.87	9.07	1.58	5.73 **	25.75	1	23.31 **	0.96	0.91	91.38				
	Min temp (X ₂)	-0.23	-1.63	1.80	-0.91	-0.68	-4.94	1.59	-3.10 *	7.54	5								
	R.H.% (X ₃)	0.27	0.92	0.86	1.07	0.75	3.04	0.81	3.77 **	11.12	3								
	Plant age (X ₄)	0.20	0.13	0.17	0.78	0.83	1.49	0.30	4.89 **	18.76	2								
	Growth stage (X ₅)	0.04	0.05	0.34	0.16	-0.72	-2.27	0.67	-3.40 **	9.04	4								
	Plant ages (X ₄ , X ₄ ² , X ₄ ³)															30.03 **	0.93	0.87	87.39
	Growth stages (X ₅ , X ₅ ² , X ₅ ³)															37.45 **	0.95	0.90	89.63
Combined effect (X ₁ to X ₅ ³)											18.32 **	0.98	0.96	95.93					
2018/2019	Max temp (X ₁)	0.51	1.95	1.04	1.86	-0.86	-3.37	0.82	-4.13 **	18.57	1	17.19 **	0.97	0.93	93.47				
	Min temp (X ₂)	0.80	3.03	0.71	4.25 **	0.72	2.08	0.81	2.56 *	7.12	3								
	R.H.% (X ₃)	-0.82	-1.42	0.31	-4.57 **	-0.78	-1.33	0.43	-3.08 *	10.32	2								
	Plant age (X ₄)	0.76	0.36	0.10	3.72 **	-0.22	-0.25	0.45	-0.56	0.34	5								
	Growth stage (X ₅)	0.73	0.56	0.16	3.38 **	0.40	0.74	0.69	1.06	1.22	4								
	Plant ages (X ₄ , X ₄ ² , X ₄ ³)															9.46 **	0.88	0.78	78.01
	Growth stages (X ₅ , X ₅ ² , X ₅ ³)															12.21 **	0.91	0.82	82.08
Combined effect (X ₁ to X ₅ ³)											10.98	0.99	0.98	98.02					

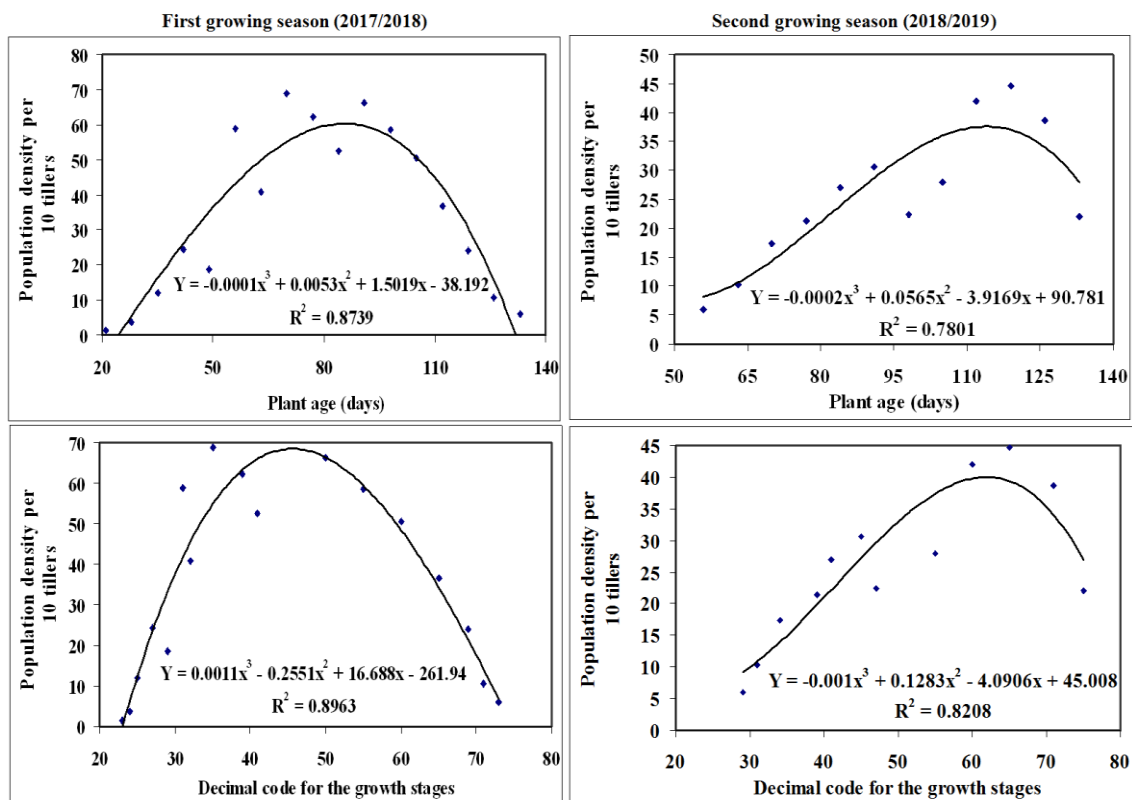


Fig. 2. The polynomial relationship between plant age (X₄) and total population of *S. graminum* (Y), as well growth stage (X₅) during the two successive growing seasons (2017/2018 and 2018/2019).

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AUTHOR'S PROFILE

First Author

Moustafa M.S. Bakry, Plant Protection Research Institute, A.R.C, Dokii, Giza, Egypt.

Second Author

Roya Arbabtafti, Iranian Research Institute of Plant Protection, Agricultural Research, Education and Extension Organization (AREEO), Tehran, Iran.

Third Author

Lamiaa H.Y. Mohamed, Moustafa M.S. Bakry, Plant Protection Research Institute, A.R.C, Dokii, Giza, Egypt.