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Climate and Plant Phenology (Plant Age and Growth Stage) Influence of *Rhopalosiphum Padi* L. Abundance on Wheat Plants in Luxor Governorate, Egypt

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Abstract

Field experiments were conducted at El-Mattana Agricultural Research Station, Luxor Governorate, during two successive wheat growing seasons (2017/18 and 2018/19). This was to study the seasonal abundance of *Rhopalosiphum padi* (Hemiptera: Aphididae) on wheat plants (Giza 171 cultivar). We also investigated the effects of climate and plant phenology on the *R. padi* population density. Results indicated that *R. padi* infested wheat plants from December 17, 2017, until April 8, 2018, within the first growing season (2017/18), and from Jan. 27th, 2019, up to April 13th, 2019, within the second growing season (2018/19). The cumulative counts of *R. padi* in growing season one was 9486.17, and in growing season two, 3444.00 individuals. The mean population of *R. padi* per 10 tillers over the whole first season was 80.12 ± 7.90, and for the second season, 42.36 ± 2.96. The first season, December, January, and February, had the most favorable climate for *R. padi* population growth (measured during weekly inspections). In contrast, February and March were more favorable in the second season. *R. padi* was not detected on the wheat during the wheat maturation period within both growing seasons. The combined effects of climate and plant phenology strongly correlate with *R. padi* population density, with explained variance (EV) of 93.86% in the first season and 99.11% in the second season. Daily mean maximum temperature was the most influential variable explaining changes in total *R. padi* population, with EV 28.37%in the first season and 28.62% in the second season. The data provided here can assist in the design of Integrated Pest Management (IPM) programs for aphid control on wheat plants.

Keywords

Rhopalosiphum padi, seasonal abundance, wheat plants, environmental conditions, plant age, growth stage

INTRODUCTION

Wheat, *Triticum aestivum* L. (Family: Gramineae), is one of Egypt's most important cereal crops. It is used to feed humans, livestock, and poultry. Wheat is highly susceptible to loss of quality and production mass through invertebrate pests across the whole period from planting to harvest. In Egypt, aphids are among the most destructive pests that attack wheat plants. Tantawi (1985) recorded crop production losses due to aphids averaging 7.5 – 18.7%.

The bird cherry-oat aphid, *Rhopalosiphum padi* (Linnaeus) (Hemiptera: Aphididae), is one of the 14 aphid species considered of highest agricultural importance worldwide (Blackman & Eastop, 2007). This pest causes severe damage to infested plants by sucking the plant sap with the mouth parts, causing plant deformation due to the aphid's toxic saliva and excretion of large amounts of honeydew that encourages the growth of sooty mold. This inhibits photosynthesis and decreases vegetative growth of the infested plants and aphids, transmitting viral diseases to plants (El-Fatih, 2000 and 2006). *R. padi* is Egyptian wheat fields' most abundant aphid species (El-Heneidy, 1994). In recent years, *R. padi* has become the most frequent aphid species on wheat crops and is abundant throughout all developmental stages of wheat plants (Parizoto *et al*., 2013; Ahmad *et al*., 2016).

To develop an effective control against *R. padi*, it is essential to know its bio-ecology, including population dynamics under different climatic factors, which influence the timing of different phenological stages. Climatic conditions also profoundly affect the population dynamics of insect pests of crops (Woiwod, 1997), and temperature affects insect activity and development rate (Lamb, 1992). El-Fatih (2006) found that *R. padi* abundance varied in barley plants with the growth stage of the plant, the season, and likely other factors related to the plant physiology.

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 & Dixon, 2007; Bakry *et al*., 2020).

The present study was carried out to estimate the effect of climate and plant phenology on the population density of *R. padi* on wheat plants over two growing seasons and to inform effective programs in pest control.

METHODS

Seasonal abundance of R. padi infesting wheat plants

Field experiments were carried out at El-Mattana Agricultural Research Station, Luxor Governorate, during two successive growing seasons (2017/18 and 2018/19). Wheat was sown in a plot using a commercial wheat cultivar (Giza, 1971) on the optimum sowing date of 25 November (for each of the two seasons). All agricultural practices were followed except pest control. Four replicates areas, each of 3 m × 3 m, were sampled using a randomized block design. Ten wheat tillers were sampled randomly from each 9m^2 sample area once a week in the morning. *R. padi* population density was estimated by examining the tillers using a 10x magnification lens. Sampling started from the week seedlings appeared above ground and continued until crop harvesting. Aphids were counted on the same morning for all samples, as described by Dewar *et al*. (1982). Numbers of live insects (nymphs and apterous adults) on tillers were counted and recorded to represent every inspection date. Taxonomists at the Department of Piercing-Sucking Insects, Plant Protection Research Institute, Agriculture Research Center at Giza, Egypt, identified aphids.

Aphid-days

Aphid days estimate the total number of aphids counted if sampling had occurred every day and these counts had been added together. It assumes a linear trend between the one sample and the subsequent sample. Aphid days as a measure are standard in such studies and allow better comparisons between treatments, locations, and other variations observed during the experiment. Bakry and Fathipour (2023**)** utilized this method.

$$D = t \times \frac{(a_1 + a_2)}{2}$$

Where:
a_1 = Mean number of aphids per tiller (counted over the 10 tiller sample) on the previous inspection date.
a_2= Mean number of aphids per tiller (counted over the 10 tiller sample) on the subsequent inspection date.
t = the number of days between the two sample dates.

Cumulative aphid-days

With more than two sampling periods, cumulative aphid days can be calculated. This is the cumulative addition of all the aphid days, allowing a cumulative trend to be produced i.e. $t/2(a_1+a_2) + t/2(a_2+a_3) + t/2(a_3+a_4)$...

Plant phenological characteristics

The plant phenological characteristics were characterized by plant age (in days) and Zadocs Growth Scale (ZGS), a decimal code indicating cereal growth stage developed by Zadoks *et al*. (1974) (see Table 1). ZGS helps in understanding crop adaptation and development (Barber *et al*., 2015).

Accumulated numbers of aphids population

To facilitate comparisons between the growing seasons of different years and the different seasons within a single year, the seasonal population density of *R. padi* was calculated. This was done by adding the *R. padi* aphid counts from the 10 tillers sampled each week, over the whole season, to produce the 'total accumulated aphid population'. This was done for both growing seasons. The percentage of the accumulated aphid population was also calculated on each sample date, and the sum of aphids counted up to that date was divided by the total accumulated aphid population. These percentages were used to reflect the general trend of the population density, following Bakry (2018) and Bakry and Abdel-Baky (2023).

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

$$\text{(R.W.V.P)} = \frac{\text{Mean aphid counts across samples that week}}{\text{Mean aphid counts across samples from the previous week}}$$

Effects of abiotic and biotic factors

Mean daily maximum temperature (X_1), minimum temperature (X_2), and mean % relative humidity (X_3) for the Luxor governorate were obtained from daily records at the Central Laboratory for Agricultural Climate, Agricultural Research Center, Ministry of Agriculture, Giza. Correlations were assessed between aphid counts on the sample date and the mean of the abiotic factor over the seven days before the aphid count. Luxor is at 99 m altitude, with latitude 25.67ºN and longitude 32.71ºE. The two biotic factors examined were associated with plant phenology, i.e., the plant age in days (X_4) and growth stage (the ZGS decimal code) (X_5) at the time of aphid counts. Correlations of these factors with aphid population density were modeled using a third-degree polynomial function, i.e., $Y= a+ b_1X_4+ b_2X_4^2+ b_3X_4^3$ for each of the biotic factors (where Y is aphid population density, and a, b_1, b_2 and b_3 are constants), Bakry *et al.* (2023) employed this technique.

Correlation and regression analysis was used to relate each of the independent variables (abiotic or biotic factors) to the dependent variable (*R. padi* population density) according to the method of Fisher (1950).

The percentage explained variance (E.V.%) in *R. padi* population density explained by each independent variable was calculated using MSTATC Program software(1980) and SPSS (1999), and data presented graphically using Microsoft Excel 2010.

RESULTS AND DISCUSSION

Weekly counts of *R. padi* infesting wheat plants at Esna district, Luxor Governorate, recorded through the two successive growing seasons (2017/18 and 2018/19), are shown in Tables 2 and 3 and Figures 1 and 2. Weekly mean records of the wheat tillers' climatic factors and plant phenological factors are also shown. The effect of climatic factors and plant phenological factors on the seasonal abundance of *R. padi* were estimated based on mean live insect (Nymphs and apterae individuals) counts per ten tillers on each sampling date.

Population studies

Seasonal abundance of R. padi population on wheat plants

First growing season (2017/2018)

Data presented in Table (2) and illustrated in Fig. (1) showed that the population density of *R. padi* on wheat plants was low on 17 December 2017 and then rapidly increased to reach the first peak of abundance on 7 January 2018 during the tillering stage. This reached mean *R. padi* counts of 56.33 ± 2.03 individuals per 10 tillers under field conditions of Max temp21.14 °C; Min. temp. 5.86°C; Relative Humidity (R.H.) 50.71%. The phenological characteristics of the wheat on 7 January were: Plant age, 42 days; ZGS, 27).

Following this, the population decreased up to 14 January 2018, then gradually rose again to reach a second peak on 21 January 2018 of 139.00 ± 9.71 individuals per 10 tillers. On this date, climatic factors were Max. temp. 24.57 °C; Min, temp. 8.57°C, and R.H. 49.14%. Phenological characteristics were: plant age, 56 days; ZGS, 31; i.e., growth up to the first node of the wheat stem was visible.

The population decreased and then rose from 28 January for a third peak on 4 February: population density 160.00 ± 6.43 individuals per 10 tillers. Max. Temp. 22.43 °C; Min. temp. 5.86°C; R.H. 50.29%. Plant age, 70 days; ZGS, 35, i.e., wheat plants at the stem extension period.

Between this date and 18 February, the population density decreased until 18 February, then increased to a fourth peak on 25 February. 153.00 ± 7.94 individuals per 10 tillers. Max. Temp. 23.43 °C, Min. temp. 7.00°C, R.H. 47.57%. Plant age, 91 days; ZGS, 50, i.e., date of first wheat plant heading.

After that, the population of aphids decreased gradually to zero by 8 April, with no further aphids detected from this period (end of heading) and maturation (Table 2 and Fig. 1).

Second growing season (2018/2019)

Results presented in Table 3 and illustrated in Fig. 1 indicated that there were few *R. padi* on the wheat tillers on 27 January (10.00 ± 1.15 individuals per 10 tillers). The population then increased gradually, reaching a maximum of 44.67 ± 1.76 individuals per 10 tillers on 2 March. This was at Max. temp 24.00°C; Min. temp. 8.43°C and 33.14% R.H.). Phenological characteristics of the wheat were plant age, 91 days; ZGS 45, i.e., after the emergence of the flag leaf sheath.

The aphid population decreased on 16 March and rose again to reach another peak on 30 March (76.67 ± 2.40 individuals per 10 tillers) at Max. temp 26.71°C; Min. temp. 14.14°C. and 24.57% R.H. Phenological characteristics: plant age, 119 days; ZGS 65, i.e., the anthesis period. After that, the population decreased continuously until 13 April to zero during the wheat maturation period.

In our study, no *R. padi* infestation was evident on wheat plants during December and up to the third week of January in the second experimental growing season. This may have been due to the low temperature during these periods. El-Rawy's 2013 study also recorded that the lowest number of cereal aphid species on wheat plants (61.6 aphids/10 tillers) occurred in January.

The total population density of *R. padi* in our first growing season (2017/18) was higher than in the second growing season (2018/19). The mean total *R. padi* population throughout the season was 80.12 ± 7.90 and 42.36 ± 2.96 individuals per 10 tillers over the first and second growing seasons, respectively. This may be due to the influence of climatic factors and the phenology of the wheat, as recorded in Tables (2 and 3) and illustrated in Figure 1. This is supported by Dent (1991), who stated that the environmental factors at that location influence the rate of insect population abundance at any location.

Weekly incidence of R. padi population, its accumulation, and their percentages about the seasonal total

To facilitate comparisons across the year and growth period, the population density was expressed in terms of the percentage of counted numbers in each inspected week relative to the total growth season. The percentage accumulated count of aphids for each consecutive week was also related to the progression of the season and thus wheat development (Tables 2 and 3, Fig. 1). These indicate that the highest percentages of *R. padi* numbers occurred during the first growing season (10.21, 11.75 and 11.23 % of the total), recorded January 21, February 4. and February 25 respectively. This may be due to the suitable climate during these periods. During the second growing season, 8.79, 13.25 and 15.08% *of R. padi* (as a percentage of the total cumulative numbers) were found on 2, 23, and 30 March, respectively. The lowest percentages of *R. padi* were 0.22% on 17 December 2017 during the first season and 1.97% on 27 January 2018 for the second season.

Data recorded in Tables 2 and 3 showed that the cumulative numbers of *R. padi* were 1362.00 and 508.33 individuals per season for the two growing seasons, respectively.

Cumulative Aphid-Days

Data in Tables 2 and 3 and illustrated in Fig. 1, present the aphid-days and the cumulative aphid-days for *R. padi* on wheat plants to express the cumulative impact of the changing environment on the aphid population, as well as the cumulative impact of aphid burden on the phenology and development of the wheat plants (El-Fatih, 2006). The cumulative aphid days for *R. padi* was higher in the first growing season (9486.17) as compared to the second one (3444.00 individuals per season). The higher number of aphid days also impacted plant phenology in the first season than in the second one.

Rate of weekly variation in R. padi population (R.W.V.P.)

The monthly variation rates in the population of *R. padi* 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 in this insect population through the season. When R.W.V.P. was**>**1, that meant more activity, < 1 meant lower activity, and = 1 meant no change in the insect activity (Bakry *et al*., 2024).

The favorable weeks of annual increase for *R. padi* population were 24 and 31 December, seven and21Jan., 4 and 25 Feb. during the first growing season (2017/18), with rates of weekly variation were (3.33, 2.73, 2.06, 7.19, 1.70 and 1.24, respectively; Table, 2). As for the second growing season (2018/19), the favorable times of annual increase for the total *R. padi* population were 2, 9, 16, 23 February16thand 2, 16, 23, and 30 March, with the rates of monthly variation were 2.50, 1.23, 1.25, 1.13, 1.03, 1.25, 1.37 and 1.14, respectively; Table, 3).

It was evident that climatic conditions in December, January, and February were better for insect reproduction during the first season than in February and March for the second season.

Effect of independent variables (climate and phenology) on the population density of R. padi

A- Effect of daily mean maximum temperature (X_1)

The statistical analysis results of simple correlation (Table, 4) showed positive but non-significant correlations between the daily mean maximum temperature and total population of *R. padi* during the first and second growing seasons (r values: 0.17 and 0.39 respectively. The regression coefficient (b) for the effect of Max. Temp. They indicated that for every 1˚C increase in the daily mean maximum temperature, the population would increase by 3.32 and 2.25 individuals per 10 tillers during the two seasons, respectively.

The effects of daily mean maximum temperature on the total population of *R. padi* are presented in Table 4. There was a highly significant positive relation between the first season (P. reg. value was 22.70) and a highly significant negative effect (P. reg. value was -6.29) during the second season. Also, partial correlation values were (0.84 and -0.91), and the t-values were 5.23 and -5.51 during the two growing seasons, respectively. Thus, daily mean maximum temperature is always below the optimum for *R. padi* population activity during the first growing season and above the optimum for total population activity during the second growing season. The daily mean maximum temperature was the climatic factor that explained the most variance in the total *R. padi* population, with EV of 28.37 and 28.62% for the two growing seasons, respectively (Table 4).

Effect of daily mean minimum temperature (X_2)

Results presented in Table (4) showed that the simple correlation (r) between the daily mean minimum temperature and the total insect population of *R. padi* was negative (-0.19) but non-significant for the first growing season, but had a highly significantly positive correlation (0.73) in the second growing season. The regression coefficient indicated that an increase of 1˚C in the daily mean minimum temperature would decrease the population by 3.25 individuals per 10 tillers for the first season and increase the population by 4.16 individuals per 10 tillers through the second season (Table 4).

The partial regression coefficient values for the effect of daily mean minimum temperature on the total *R. padi* population are shown in Table 4. Daily mean minimum temperature had a significant negative relation with the insect population (P. reg. value; -9.82) during the first growing season and a significant positive correlation (P. reg. value; 3.03) for the second growing season. The partial correlation values were -0.56 and 0.74, respectively, with the t-values of -2.24 and 2.66, respectively (Table 4). The results reveal that the daily mean minimum temperature is above the optimum for *R. padi* population activity during the first growing season and below the optimum range for total population activity during the second growing season. This climatic factor was the least effective variable in explaining total *R. padi* population changes: EV being 5.24% during the first growing season and 6.67% in the second growing season (Table 4).

Effect of the mean relative humidity (X_3)

As shown in Table 4, the correlation between relative humidity and the total population of *R. padi* was positive but not significant (r-value: 0.24) for the first growing season and highly significant and negative (r-value: -0.79) during the second growing season. The simple regression coefficient indicates that an increase of 1% in the mean relative humidity would increase the population by 2.02 individuals per 10 tillers during the first season and decrease the population by 2.04 individuals per 10 tillers for the second season (Table 4).

Partial regression shows that the effect of relative humidity on the total population activity of *R. padi* was highly significant and positive (P. reg. value; 7.93) for the first growing season and highly significant and negative (P. reg. value; -2.48) during the second growing season. Partial correlation values were 0.73 and -0.86, and t-values were 3.59 and -4.09 for each growing season, respectively. Mean relative humidity was always under the optimum range for total population activity during the first season and above the optimum range of total population activity of *R. padi* during the second growing season. Mean relative humidity explained 13.35 and 15.81% of the total population variance in *R. padi* for the two growing seasons (Table 4). Daily mean maximum temperature and relative humidity were thus shown to have a more significant effect on the total population of *R. padi* than daily mean minimum temperature.

Effect of the plant age (X_4)

Table 4 shows the effect of plant age on the total population of *R. padi*. The correlation coefficient (r) was non-significant and positive (r-value: 0.21) for the first growing season and significant and positive (r-value: 0.68) during the second growing season. The calculated regression coefficient (b) for the effect of this factor indicated that for every additional day of wheat age, the total population of *R. padi* increases by 0.33 and 0.48 individuals per 10 tillers for each season, respectively.

The relationship between the wheat plant age and the total population of *R. padi* was determined by partial regression (Table 4), which was highly significant and positive (P. reg. value; 3.38) for the first growing season and non-significant and negative (P. reg. value; -0.37) during the second growing season. The partial correlation values were 0.77 and -0.24), and the t-values were 4.04 and -0.60 for each of the two growing seasons, respectively. Plant age was the most effective biotic variable for explaining the variance in the total population of *R. padi*: 16.92% during the first growing season, but was the least effective biotic variable in the second season, only explaining 0.33% of the variance.

Effect of the growth stage (as decimal code; X_5)

Table 4 shows that the decimal code of the Zadocs Growth Scale (ZGS), indicating the growth stage of the wheat plant, had a non-significant positive correlation with the total *R. padi* population activity in the first growing season (r-value: 0.06) and a significant positive correlation (r-value: 0.64) during the second season. The regression coefficient indicated that one increase in the decimal code of the growth stage of the wheat plant would increase the population by 0.18 and 0.73 individuals per 10 tillers for each of the two seasons, respectively.

Partial regression (P. reg.) values in Table (4) show that the growth stage had a significant but negative effect (P. reg. value: -5.27) in the first growing season and a non-significant positive effect (P. reg. value: 1.04) during the second growing season. The partial correlation values were -0.65 and 0.40and the t-values were -2.87 and 1.07 for each of the two growing seasons, respectively. The ZGS of wheat plants explained 8.54 and 1.08% of the variance in the total population of *R. padi* for each of the respective seasons.

The combined effect of the abiotic and biotic factors on the total population of R. padi:

As shown in Table 4, the combined effect of these tested factors on the *R. padi* total population was highly significant, with the F-values being 17.07 and 19.98 for the first and second growing seasons. The amounts of variance were 88.58 and 94.33% for the two growing seasons.

Effect of plant phenology:

Plant age (X_4):

Plant age (X_4), when modeled using a three-degree polynomial ($Y= a+ b_1X_4+ b_2X_4^2+ b_3X_4^3$), showed a high correlation with the log of aphid population (Y). E.V. was 83.27 and 74.52% for the two growing seasons. The plant age model is the most effective in predicting the population density of *R. padi* on wheat plants. The equations of the 3rd-order polynomial regression are:

First growing season (2017/2018):

$$Y = -0.0003\ X_4^3 + 0.0257\ X_4^2 + 2.5704X_4 - 73.671$$

$R^2 = 0.8327$

Second growing season (2018/2019):

$$Y = -0.0004\ X_4^3 + 0.1014\ X_4^2 - 7.1976X_4 + 174.45$$

$R^2 = 0.7452$

The F-values were 21.58 and 7.80 in this regression for the first and second growing seasons, respectively (Table 4).

Maximum *R. padi* population density was 70 days (population density 160.00 ± 6.43 per 10 tillers) in the first growing season and 119 days (76.67 ± 2.40 per 10 tillers) in the second growing season.

Growth stage (ZGS decimal code; X_5)

The ZGS decimal code for the growth stages of the wheat plant was also regressed against *the R. padi* population using a third-order polynomial, as done above, and again, the factor was used to explain log aphid population density. Explained variance with this equation was 85.91% in the first season and 81.37% in the second season.
The third-order regression equations are:

First growing season (2017/2018):

$$Y = 0.0021\ X_5^3 - 0.5458\ X_5^2 + 36.834X_5 - 586.3$$

$R^2 = 0.8591$

Second growing season (2018/2019):
$Y = -0.0021\ X_5^3 + 0.2694\ X_5^2 - 9.6091X_5 + 122.17$
$R^2 = 0.8137$
The ZGS growth stage was significant in explaining log aphid population density, with F-values of 26.43 and 11.65 for each season (Table 4).

R. padi generally recorded the highest population density when wheat plants were in the stem extension stage (around February). El-Fatih (2006) also found that *Rhopalosiphum maidis* (Hemiptera: Aphididae) was most dense on barley at this stage (rather than tillering or heading stage).

Combined effect of all abiotic and biotic factors on the R. padi population

The combined effect of the abiotic factors (three climatic factors) and biotic factors (phenology) was used to model *R. padi* population density in a multiple regression analysis. The explained variance was 93.86 and 99.11% in the two growing seasons. The model was significant, with F-values of 11.89 for the first growing season and 24.68 for the second (Table 4).

Discussion

The present study showed that December, January, and February of the first season had the most favorable climate for *R. padi* seasonal activity (measured during weekly inspections), but in the second season, February and March were more favorable. These results agree with those of **Abou-**El-Hagag and Abdel-Hafez (1999), Abdel-Aziz *et al*. (2002), El-Rawy (2013), El-Mitwally *et al*. (2013) and Youssif *et al*. (2017), who recorded that the maximum population density of cereal aphids on wheat plants occurred during February and March.

For example, El-Heneidy *et al.* (2004) found 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) stated that the infestation by aphids on wheat in Egypt started during the second week of February, peaking the first week of March, and disappeared towards the end of April. El-Maraghy *et al*. (2015) reported that *R. padi* began infesting wheat plants early during the middle of January when wheat plants were in the stem-elongation stage, peaking at the flowering stage in the third week of February, then declining over the next three weeks. After that, the timing of the disappearance of *R. padi* during the maturation period of wheat plants in our two successive growing seasons also reflects findings on seasonal phenology by Vidya (1982), who reported that the aphid population started to decline when ear head emergence started.

Results revealed that the combined effects of the climatic factors and the plant phenology can explain the variation in the population density of *R. padi*. The percentages of explained variance (E.V.%) were 93.86 and 99.11% for the two successive growing seasons, respectively. Daily mean maximum temperature was the most influential variable for the total *R. padi* population changes by 28.37 and 28.62% for the two successive seasons, respectively.

Climate has significantly influenced insect pests' growth, development, distribution, and population dynamics (Chang *et al.,* 2008). Indeed, abiotic and biotic factors are of primary importance in causing variations in aphid population densities (Naeem, 1996). Other climatic factors beyond temperature and humidity could have also affected the aphid population growth. Abd El-Fattah *et al. (*2000) found that aphid population density increases with reduced temperature, wind velocity, photo-period, and rainfall in summer on nili plantations within their study over the years 1995 and 1996. The aphid population density was also found to increase with plant age.

Shakeel *et al*. (2015) also found that a decrease in temperature (measured by minimum or maximum temperature) increased aphid populations on tomato plants, with the lowest population at 32.5°C and the highest population at 27.5°C. Increased relative humidity also increased aphid population density. They suggested that understanding the weather patterns and climate is essential for pest management in tomato plantations. Aheer *et al*.(2008) and Chandrakumar *et al.* (2008) found the exact relationship between aphid population density and temperature as was in the Abd El-Fattah *et al.* and the Shakeel study and Aheer *et al*. also found the same relationship with relative humidity. Williams and Dixon (2007) stated that plant phenology can significantly impact 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. The highest aphid population in several studies occurred in March (Aheer *et al*., 2007; Wains *et al*., 2010; and Iqbal *et al*., 2008).

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	1st leaf more than half visible		47	Flag leaf sheath opening
	12	2nd leaf more than half visible		49	First awns visible
	13	3rd leaf more than half visible	Heading	50	First spikelet of spike just visible
	14	4th leaf more than half visible		52	20% of spike visible, early heading
	15	5th leaf more than half visible		55	50% of spike visible, mid heading
	16	6th leaf more than half visible		58	80% of spike visible, late heading
	17	7th leaf more than half visible		60	Full heading but not flowering
	18	8 or more leaves visible and system not elongating	Flowering	62	20% of spikes are flowering
Tillering	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	Milk development	73	Early milk, liquid of-white
	26	Main shoot and 6 tillers		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	Dough development	81	Very early dough
Stem elongation	30	Stem starts to elongate		83	Early dough
	31	1st node detectable		85	Soft dough
	32	2nd node detectable		87	Hard dough
	33	3rd node detectable	Ripening	90	Kernels hard-difficult to divide by thumb nail

Stages	**Zadoks Code**	**Cereal Growth Stages**	**Stages**	**Zadoks Code**	**Cereal Growth Stages**
	34	4th node detectable		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 Numbers of Aphids, Aphid Days, % Cumulative Aphids, Cumulative Aphid-Days and R.W.V.P. of *R. Padi* on wheat Plants, with Climatic Factors, at Esna District, Luxor Governorate During the First Growing Season (2017/2018).

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	3.00 ± 0.58	0.22	3.00	0.22	10.50	10.50	–	22.00	7.71	46.43
	24	28	24	10.00 ± 1.00	0.73	13.00	0.95	45.50	56.00	3.33	23.00	7.29	41.29
	31	35	25	27.33 ± 1.76	2.01	40.33	2.96	130.67	186.67	2.73	19.29	7.14	49.71
Jan., 2018	7	42	27	56.33 ± 2.03	4.14	96.67	7.10	292.83	479.50	2.06	21.14	5.86	50.71
	14	49	29	19.33 ± 0.88	1.42	116.00	8.52	264.83	744.33	0.34	20.43	4.86	47.71
	21	56	31	139.00 ± 9.71	10.21	255.00	18.72	554.17	1298.50	7.19	24.57	8.57	49.14
	28	63	32	94.33 ± 4.98	6.93	349.33	25.65	816.67	2115.17	0.68	25.43	10.14	42.14
Feb.	4	70	35	160.00 ± 6.43	11.75	509.33	37.40	890.17	3005.33	1.70	22.43	5.86	50.29
	11	77	39	144.33 ± 2.33	10.60	653.67	47.99	1065.17	4070.50	0.90	24.71	8.43	39.57
	18	84	41	123.33 ± 5.93	9.06	777.00	57.05	936.83	5007.33	0.85	21.14	8.00	49.86
	25	91	50	153.00 ± 7.94	11.23	930.00	68.28	967.17	5974.50	1.24	23.43	7.00	47.57
Mar.	4	98	55	138.00 ± 4.16	10.13	1068.00	78.41	1018.50	6993.00	0.90	28.71	11.43	37.57
	11	105	60	117.33 ± 7.06	8.61	1185.33	87.03	893.67	7886.67	0.85	28.00	10.43	36.71
	18	112	65	85.00 ± 4.36	6.24	1270.33	93.27	708.17	8594.83	0.72	26.46	11.71	38.71
	25	119	69	54.67 ± 2.40	4.01	1325.00	97.28	488.83	9083.67	0.64	25.79	13.86	37.71
April	1	126	71	23.33 ± 0.88	1.71	1348.33	99.00	273.00	9356.67	0.43	27.85	14.00	30.00
	8	133	73	13.67 ± 0.88	1.00	1362.00	100.00	129.50	9486.17	0.59	28.11	17.14	29.86
Total				1362.00				9486.17					
General average				80.12 ± 7.90							24.26	9.38	42.65

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

Table 3. Weekly Mean Numbers of Aphids, Aphid Days, % Cumulative Aphids, Cumulative Aphid-Days and R.W.V.P. Of *R. Padi* on Wheat Plants, with Climatic Factors, at Esna District, Luxor Governorate During the Second Growing Season (2018/2019).

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	10.00 ± 1.15	1.97	10.00	1.97	35.00	35.00		25.14	7.14	39.14
Feb.	2	63	31	25.00 ± 1.73	4.92	35.00	6.89	122.50	157.50	2.50	22.59	7.31	40.02
	9	70	34	30.67 ± 2.40	6.03	65.67	12.92	194.83	352.33	1.23	25.43	10.86	38.14
	16	77	39	38.33 ± 1.67	7.54	104.00	20.46	241.50	593.83	1.25	21.57	9.00	41.57
	23	84	41	43.33 ± 2.40	8.52	147.33	28.98	285.83	879.67	1.13	23.86	12.14	34.71
Mar.	2	91	45	44.67 ± 1.76	8.79	192.00	37.77	308.00	1187.67	1.03	24.00	8.43	33.14
	9	98	47	39.33 ± 2.40	7.74	231.33	45.51	294.00	1481.67	0.88	28.57	12.43	25.43
	16	105	55	49.00 ± 2.08	9.64	280.33	55.15	309.17	1790.83	1.25	28.86	12.57	28.71
	23	112	60	67.33 ± 3.53	13.25	347.67	68.39	407.17	2198.00	1.37	28.43	14.29	22.14
	30	119	65	76.67 ± 2.40	15.08	424.33	83.48	504.00	2702.00	1.14	26.71	14.14	24.57
April	6	126	71	51.33 ± 3.71	10.10	475.67	93.57	448.00	3150.00	0.67	32.43	17.71	24.14
	13	133	75	32.67 ± 1.76	6.43	508.33	100.00	294.00	3444.00	0.64	28.00	10.43	34.57
Total				508.33				3444.00					
General average				42.36 ± 2.96							26.30	11.37	32.19

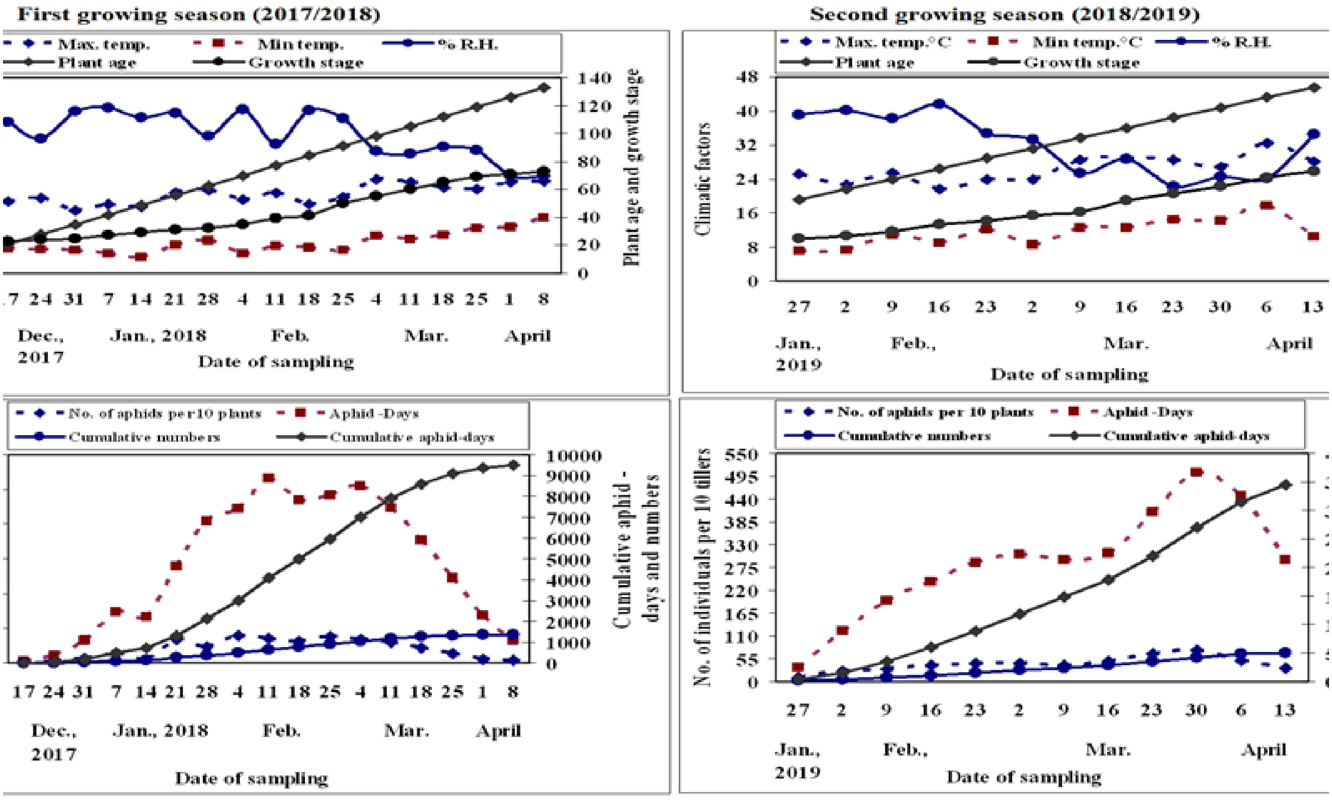

Figure 1. Weekly Mean Numbers of Aphid Days, % Cumulative Aphids, Cumulative Aphid-Days of *R. Padi* on Wheat Plants, with Climatic Factors at Esna District, Luxor Governorate During the Two Successive Seasons (2017/18 And 2018/19).

Table 4. Different Models of Correlation and Regression Analyses for Describing the Relationship Between the Some Weather Factors and Plant age on Population Fluctuation of *R. Padi*on Wheat Plantsduring 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)	0.17	3.32	4.92	0.67	0.84	22.70	4.34	5.23 **	28.37	1				
	Min. temp (X_2)	-0.19	-3.25	4.33	-0.75	-0.56	-9.82	4.38	-2.24 *	5.24	5				
	R.H.% (X_3)	0.24	2.02	2.07	0.98	0.73	7.93	2.21	3.59 **	13.35	3	17.07**	0.94	0.89	88.58
	Plant age (X_4)	0.21	0.33	0.41	0.82	0.77	3.38	0.84	4.04 **	16.92	2				
	Growth stage (X_5)	0.06	0.18	0.82	0.21	-0.65	-5.27	1.84	-2.87 *	8.54	4				
	Plant ages (X_4, $X_4{}^2$, $X_4{}^3$)											21.58**	0.91	0.83	83.27
	Growth stages (X_5, $X_5{}^2$, $X_5{}^3$)											26.43**	0.93	0.86	85.91
	Combined effect (X_1 to $X_5{}^3$)											11.89**	0.97	0.94	93.86

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. %
2018/2019	Max. temp (X_1)	0.39	2.25	1.68	1.34	-0.91	-6.29	I. 14	-5.51 **	28.62	1				
	Min. temp (X_2)	0.73	4.16	1.22	3.40**	0.74	3.03	I. 14	2.66*	6.67	3				
	R.H.% (X_3)	-0. 79	-2.04	0.51	-4.02**	-0.86	-2.48	0.61	-4.09 **	15.81	2	19.98**	0.97	0.94	94.33
	Plant age (X_4)	0.68	0.48	0.17	2.92 *	-0.24	-0.37	0.63	-0.60	0.33	5				
	Growth stage (X_5)	0.64	0.73	0.28	2.62 *	0.40	1.04	0.97	1.07	1.08	4				
	Plant ages (X_4, $X_4{}^2$, $X_4{}^3$)											7.80**	0.86	0.75	74.52
	Growth stages (X_5, $X_5{}^2$, $X_5{}^3$)											11.65**	0.90	0.81	81.37
	Combined effect (X_1 to $X_5{}^3$)											24.68 *	0.99	0.99	99.11

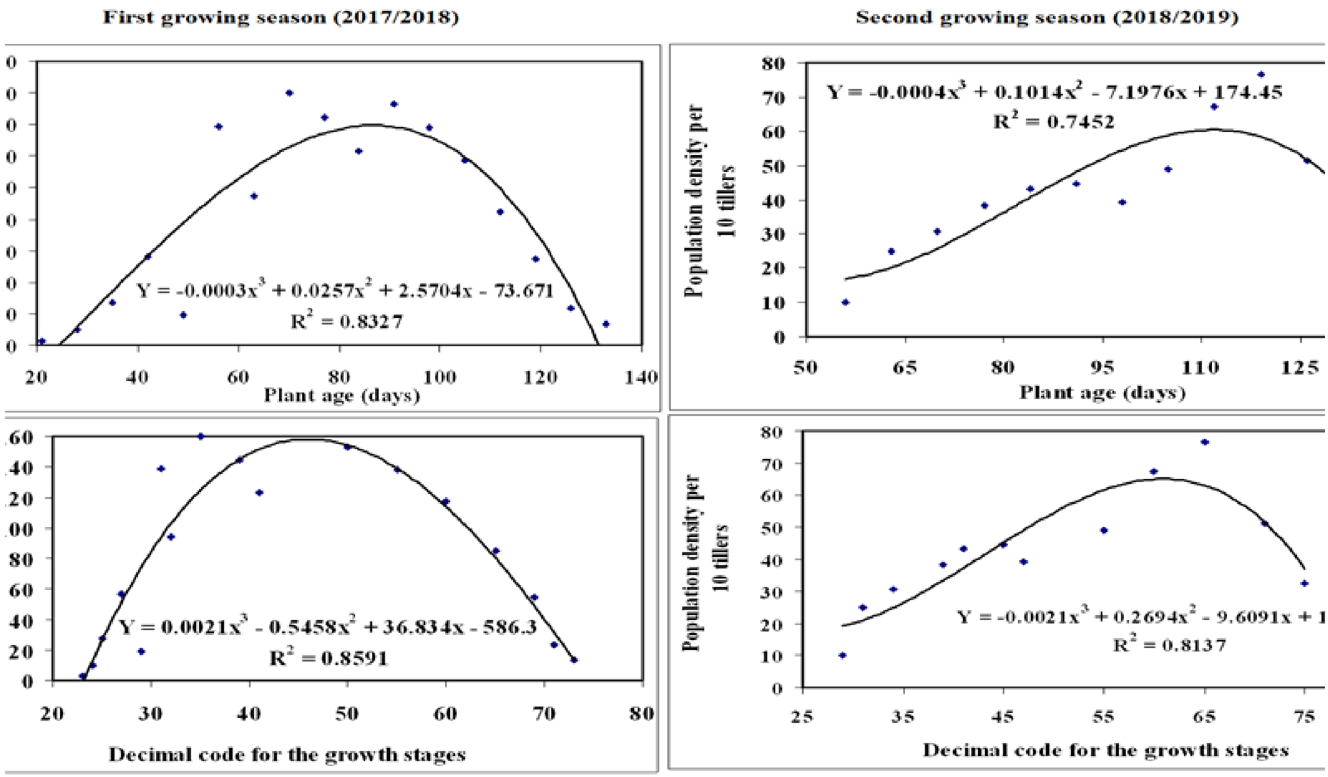

Figure 2. the Polynomial Relationship Between Plant age (X_4) and Total Population of *R. Padi* (Y), as Well Growth Stage (X_5) During the Two Successive Wheat Growing Seasons (2017/18 And 2018/19).

CONCLUSIONS

Rhopalosiphum padi was not detected on the wheat during the wheat maturation period within both growing seasons. The combined effects of climate and plant phenology strongly correlate with R. padi population density, with an explained variance (EV) of 93.86% in the first season and 99.11% in the second season. Daily mean maximum temperature was the most effective variable explaining changes in total R. padi population with EV 28.37%in the first season and 28.62% in the second season. The data provided here can assist in the design of Integrated Pest Management (IPM) programs for aphid control on wheat plants.

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