EGYPTIAN ACADEMIC JOURNAL OF

BIOLOGICAL SCIENCES

ENTOMOLOGY

A

ISSN
1687-8809

WWW.EAJBS.EG.NET

Vol. 15 No. 4 (2022)

Citation: *Egypt. Acad. J. Biolog. Sci. (A. Entomology) Vol. 15(4) pp.209-219 (2022)*
DOI: 10.21608/EAJBSA.2022.275289

Egypt. Acad. J. Biolog. Sci., 15(4):209-219(2022)

Egyptian Academic Journal of Biological Sciences
A. Entomology

ISSN 1687- 8809
http://eajbsa.journals.ekb.eg/

Change of the Density-Independent and Dependent Environmental Factors on The Population Dynamics of *Bemisia tabaci* and *Empoasca fabae* Under the Potato Agroecosystem

Omnia Ahmed [1], Wedad, A.Atwa [1], Manal Elshaier [1], Mohamed, G. H. [2], and Enayat M. Elqady[1]

1- Zoology and Entomology department, Faculty of Science, Al-Azhar University-Naser city- Cairo, Egypt.

2- Plant protection research institute, Agriculture research center, Cairo, Egypt.

***E-mail: drenayat2017@gmail.com**

ARTICLE INFO

Article History
Received:13/11/2022
Accepted:21/12/2022
Available:24/12/2022

Keywords:
Potato plant, *Bemisia tabaci, Empoasca fabae,* population dynamic, independent factors, *C. undecimpunctata, C.carnea, S.corolla, E. eremicus* and *O. laevigatus*.

ABSTRACT

Effect of density-independent factors (minimum–maximum temperatures and relative humidity) and density dependant factors (plant age and natural enemies*; Coccinella undecimpunctata*, *Chrysoperla carnea, Syrphus corolla*, *Eretmocerus eremicus* and *Orius laevigatus*) of the environment on the population dynamics of Silverleaf whitefly, *Bemisia tabaci* (Genn.) and potato leaf hopper, *Empoasca fabae* (Harris) attacking potato plant *Solanum tuberosum* at El-Gharbia governorate, Egypt were investigated on autumn and spring plantation of 2019/2020 &2020/2021 seasons. The results revealed that the population fluctuation of *B. tabaci* & *E. fabae* recorded the highest infestation in December during both autumn seasons, while in both spring seasons the highest peak for the two pests was reached in May. The combination of abiotic and biotic environmental factors on population densities of *B. tabaci* and *E. fabae* was effective as the explained variance (E.V.) values were (88% - 92%) and (85% - 86%) for *B. tabaci*, while E.V. was (94% - 91%) and (92% - 77%) for *E. fabae* during autumn and spring of the plantation 2019/2020 &2020/2021 seasons, respectively. The present research can be helpful to the ecological characteristics of main potato pests to obtain more effective pest management.

INTRODUCTION

Potato, *Solanum tuberosum*, is the world's fifth most important food crop in the least developed countries (FAO, 2018) and third most important food crop in terms of human consumption, after wheat and rice (FAOSTAT, 2013)**,** with the most production in the temperate zones, followed by numerous subtropical and tropical countries (Devaux *et al.*, 2014)**.** In Egypt, potatoes are considered the first exporting vegetable crop (Abd-Elgawad, 2020) based on the imputation methodology of the Food and Agriculture Organization (FAO), potato production in 2017 was about 4.33 million tons from a harvested area of 163,939 ha (FAO, 2020)**.**

Potatoes provide humans with an abundant and relatively inexpensive source of high-quality nutrients. Historically, their incorporation into everyday diets commonly coincided with periods of rapid population growth in a variety of nations (Zuckerman, 1999). Presently, potatoes continue to play a very important role in feeding the human population(Devaux *et al*., 2021). The last 30 years were characterised by an explosive growth in their popularity in Asia and Africa, which were previously reliant on other staple crops. Therefore, ensuring the sustainability of potato production is currently an important challenge facing agricultural professionals worldwide(Vincent *et al.*, 2013)**.** *B. tabaci* is a common pest in tropical and subtropical regions but is less prominent in temperate habitats. Currently, it has become a cosmopolitan pest, with records in every zoogeographic region of the world (CABI, 2017)**,** It causes direct damage by feeding on leaf sap and indirect damage to potato plants, which results in a yield reduction of 40% or more (Agriculture *et al*., 2005; CABI, 2017; Guzmán-Barney *et al.*, 2013)**,** and transmits more than 200 plant viruses (Polston *et al*., 2014) such as Geminiviruses were transmitted to potato cultivars infested by *B, tabaci* (Alyokhin *et al*., 2022) also the cotton whitefly, *B. tabaci* transmits the Tomato leaf curl New Delhi virus to potato plant leading to the appearance of the Apical leaf curl disease causing huge yield losses (Shah *et al*., 2019). Feeding by white fly adults and larvae causes chlorotic catching, premature leaf dropping and growth deformation.(Alemandri *et al*., 1998).

Empoasca fabae is highly polyphagous, and able to reproduce on more than 200 plant species in 25 families (Lamp *et al.*, 1994)**.** The potato leafhopper *E. fabae* is a sucking insect that extracts sap directly from the vascular system of the leaflets, petioles and sometimes the stems. The attack on potato crops is sporadic and is favored by humid conditions. Insects live in the abaxial (lower) part of the leaflets (Galetto *et al*., 2011). Many species of leafhoppers are common and damaging to potatoes causing damage to the potato by feeding directly or acting as vectors for potato disease. They transmitted Potato phytoplasmas which are particularly important because diseases caused by them are on the rise worldwide (Alyokhin *et al.,* 2022). They inject toxic saliva while feeding, causing leaf necrosis and interfering with plant growth. Under severe attack, the attacked plants die prematurely. Leafhoppers can transmit some viruses, although their occurrence is rare (CIP, 1996; Cook A., *et al*., 2004)**.**

MATERIALS AND METHODS

Field Trials (Random or "stratified random" methods):

Experiments were carried out on potato plants at Mahalet Menof village, Tanat, El-Gharbia governorate, Egypt during two successive years of plantations (2019,2020 and 2021) to study the population dynamics of *Bemisia tabaci*& *Empoasca fabae* which helped their management. Kara variety (genotype) was cultivated in autumn and spring plantations. The autumn plantation started from September till January during both seasons, whereas, the spring plantation started from the last week of January until the end of May in 2020 and 2021. A complete randomized block design with six replicates (60 leaflets/replicate) was used in both seasons Sample content 10 leaves (60 leaflets/replicate) Six replicates were used and each replicate 10 leaves from the upper, mid and lower parts of the plants. Samples were taken early in the morning between 8 and 10 a.m. and transferred to the laboratory in plastic bags, the upper and lower surface of the leaflets were extremely examined with the aid of a stereomicroscope on the same day for examination and identify the collected pests and natural enemies.

Data Analysis:

The data were statistically analyzed using SAS statistical software (SAS Institute, 2010) to study the effect of abiotic factors (Maximum temperature, Minimum temp. and mean relative humidity) and biotic factors (natural enemies) on the population dynamics of these pests, the simple correlation (r) and the partial regression (b) were calculated between each of the above-mentioned factors (Xs) and the weekly mean numbers of these pests. Analysis of variance (ANOVA) was performed on infesting pests by using the SPSS program (Version 20.0). Using Duncan's multiple range test, significantly distinct means were separated at a p ≤0.005 level of probability**.**

RESULTS AND DISCUSSION

Population Fluctuation of *B. tabaci* and *E. fabae* Pests Infesting Potato Plants:

It revealed that the seasonal mean abundance of the *B. tabaci* and *E. fabae* pests was higher during 2020/2021 (82.21 individual /pests) than 2019/2020 (67.11 individual/pests). Both seasonal mean abundance of two pests was higher in autumn than in spring plantation and also higher in the first autumn season 2019/2020 than the second season 2020/2021 as (45.55 & 42.20) & (5.49 & 4.28) for *B. tabaci* and *E. fabae*, respectively whereas mean seasonal abundance was higher in second season spring than the first one as (33.35 & 14.59) & (2.38 & 1.49) for whitefly and leafhopper, respectively Fig (1).

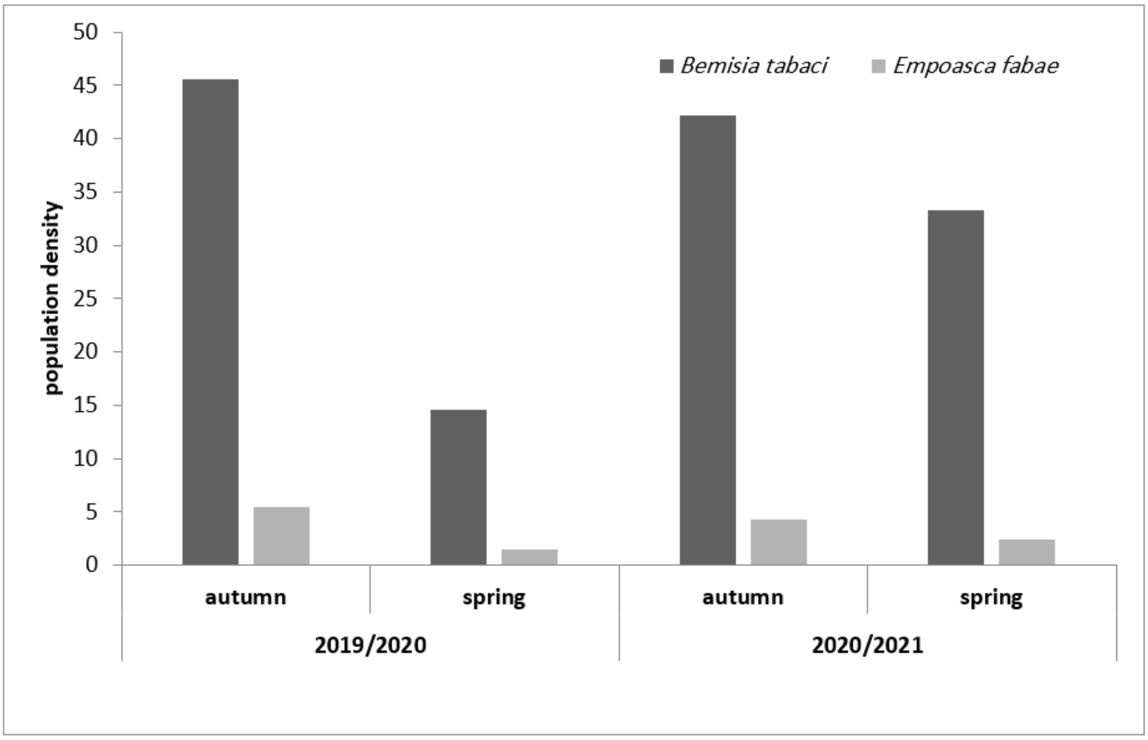

Fig. 1: General weekly mean numbers of sap-sucking pests infesting Potato plants during autumn and spring plantations 2019/2020 & 2020/2021 seasons.

Infestation by Silverleaf Whitefly, *Bemisia tabaci* & Potato **Leafhopper, *Empoasca decipiens* on Potato Plant:**

Whitefly, *B. tabaci* and leafhopper *E. decipiens* are important pests of potato plants that appeared in both the years (2019/2020 and 2020/2021). Its abundance and degree of infestation not only varied with seasons but also over the years. In autumn 2019/2020 & 2020/2021 occurrence of *B. tabaci* and *E. decipiens* was observed from 3rd week and the last week of October, respectively. After that fluctuated to increase gradually and eggs of *B. tabaci* density recorded two peaks in 1st season on 1st and 3rd week of December but one peak in 2nd one with mean numbers (of 39.90 & 44.80 eggs/leaf) in 1st season & (27.76 eggs/leaf) on 2nd season, respectively. Where the highest population of whitefly immature stages (81.7& 78.73 individuals/leaf) were recorded in 3rd week of December during 1st season and in 2nd week of December during the second autumn respectively.

On the other hand, *E. fabae* recorded 2 peaks on the 21st of November and 5th of December for the first season and the 3rd week of November and December for the second with a mean number (7.90 & 11.20) & (5.73 and 13.2) individuals /leaf, respectively (Fig. 2).

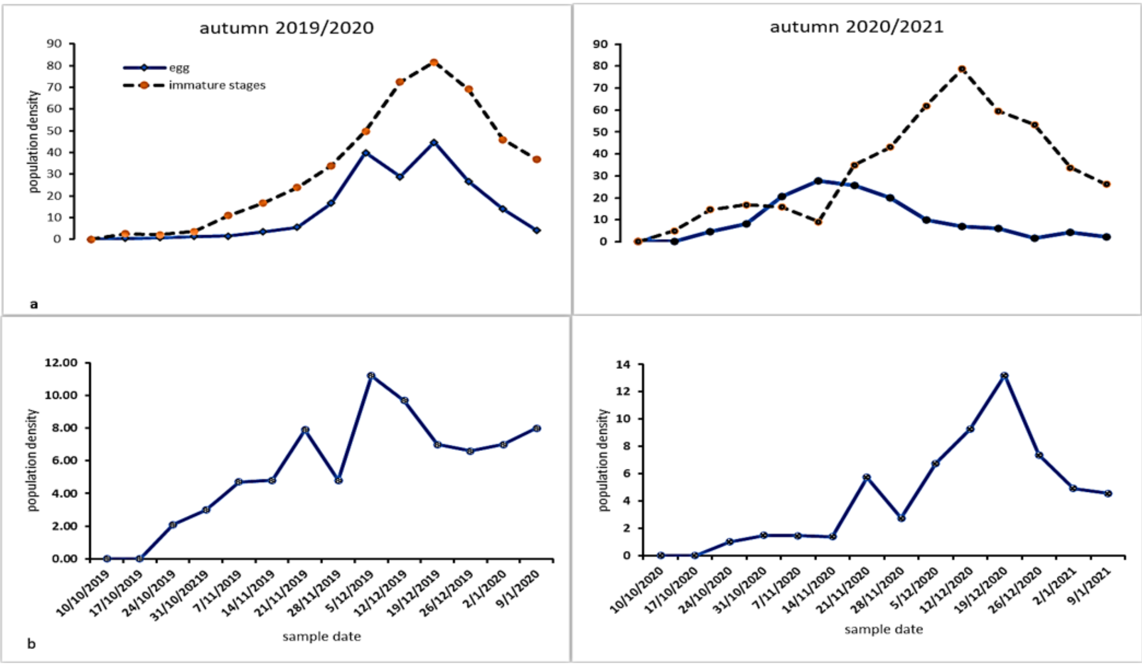

Fig.2: Seasonal incidence of (a) *B. tabaci* (egg & immature stages) - (b) *E. fabae* populations during the autumn plantation of 2019/2020..

In spring, *B. tabaci* and started to appear from 1st week of March on the first spring and on 2nd week of March on the second one but *E. fabae* started to appear from 2nd week 3rd week of March in spring 2020 & 2021, respectively, then increased gradually whereas the population of eggs recorded three peaks on 1st, 3rd week of April and third week of May (6.66, 5.07 & 3.26 eggs/leaf), and two peaks during 2nd season with an average (8.73 &29.57 eggs/leaf) on 1st and last week of April respectively. On the other hand, in 1st spring immature stages recorded only two peaks with an average number of 11.13 & 29.99 individual/leaves in 2nd week of April and 1st week of May. whereas the highest infestation in 2nd season was at the end of the season on the last week of May with a mean number of 87 numbers/leaf. whereas *E. fabae* recorded two peaks in 2nd week of April and 1st week of May during 1st spring with mean numbers of 3.46 & 4.75 individual/leaf, respectively. Whereas recorded 3 peaks in 2nd spring on the 26th of March, 23rd of April and 21st of May with mean numbers 1.60, 4.60& 8.87 individual/leaf, respectively (Fig. 3).

The present results are very close to the results of (El-Khawas & Shoeb, 2004; Mogahed, 2000; Mogahed & Abdelmaksoud, 2016) who discovered that whiteflies, *B. tabaci* (Genn.) and potato leaf hopper, *E. discipiens* (Paoli) were among the sucking insect pests that attacked potato plants from the time seedlings initially emerged until harvest time. Also, it agrees with the result of (Darwish, 2018; Mogahed & Abdelmaksoud, 2016) who found that the mean number of whiteflies and the intensity of the potato leafhopper population were higher than the thrips or aphid populations. According to (DeLong, 1938; Poos & Smith, 1931) reports, this leafhopper prefers the potato as an oviposition host plant.

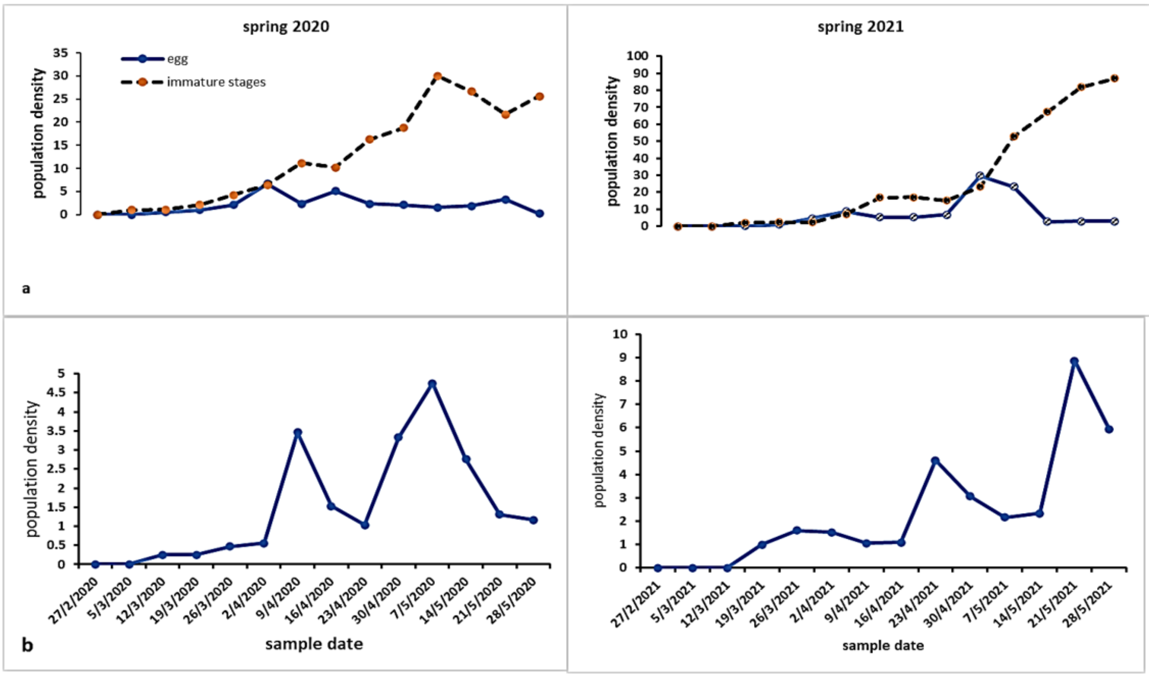

Fig. 3: Seasonal incidence of (a) *B. tabaci* (egg & immature stages) - (b) *E. fabae* populations during spring plantation of 2020&2021.

Moreover, the findings showed that the green lacewing, *Crysopella carnea*; eleven spotted lady beetle, *C. undecimpunctata* and the pirate bug, *Orius sp*. were the most important predators in the potato plants and the green lacewing numbers were found in more than that other predator. that was in agreement with (Darwish, 2018; Sherief *et al.*, 2013) but in contrast to (Hamouda *et al.*, 1993) who revealed that the presence of coccinellid predator species more Abundant than that of chrysopid predators in vegetable fields. The results coincidence with(Abdel-Gawaad *et al.*, 1990) who showed that *Coccinella undecimpunctata* was noticed fed on *Bemisia tabaci*'s immature stages, *Late in the year, Chrysopa carnea (Chrysoperla carnea)* larvae were observed feeding mostly on *B. tabaci* pupae on a variety of host plants, and solitary parasitoids *Eretmocerus mundus* were observed emerging from both larvae and pupae. Additionally, *Eretmocerus delhiensis*, a parasitoid wasp, was feeding on the nymphal instars of the greenhouse whitefly, which caused decreasing in the populations of greenhouse whiteflies (Ebrahimifar & Jamshidnia, 2022). But the other. In comparison to the winter treatment, *Eretmocerus eremicus* parasitized considerably more whitefly hosts in the summer (Zilahi-Balogh *et al*., 2006). Also, the results of natural enemies revealed that among the predators of white flies was Syrphus *corollae* Fabricius which was found in few numbers. These results were in consonance with those of (El-Awady *et al*., 2010) who revealed that *Syrphus corellae*, was among the predators of whitefly in addition to *Coccinella spp*., *Chrysoperla carnea* and *Orius spp.*

Correlation Study of Different Abiotic and Biotic Factors with *B. tabaci* and *Empoasca fabae* Infesting Potato, S. *tuberosum* L.:

***B. tabaci*:**

During both autumn seasons, 2019-20 and 2020-21, the partial regression analysis in Table (1) cleared that high negative significant effect to a minimum, maximum temperature, (-0.73**& -0.80***) & (-0.67** & -0.74**), respectively which indicates that increase in morning and evening leads to decrease in *B. tabaci* population and vice-versa. *C. carnea* had a positive effect of high significance in 1st season (“r”= 0.68**), which implies an increase in *C. carnea* population leads to an increase in the whitefly population.

E. eremicus was positively significant in their effect whereas “r” = 0.47* & 0.62* in both autumn seasons, respectively. plant age had a positive effect on white fly “r” were 0.80*** &0.67*, respectively. The combined effect of these factors as a group (E.V) showed responsible 88% and 92% effects on the population dynamics of *B. tabaci* (“F” values were 3.18 & 5.08*) throughout both seasons, respectively.

Table 1: Simple correlation of the three main weather factors and biotic factors on *B. tabaci* & *E. fabae* and corresponding percentage of explained variance on potato **autumn** plantation at El- Gharbia governorate during 2019/ 2020 and2020/ 2021seasons.

B. tabaci								
Autumn seasons		**Abiotic factor**				**Biotic factor**		
		Max. temp	**Mini. Temp**	**RH**	**Plant age**	***C. undecimpunctata***	***C. carnea***	***E. eremicus***
2019/2020	**R**	**-0.73****	**-0.80*****	**0.11**	**0.80*****	**0.25**	**0.68****	**0.47***
	P	**0.002**	**0.0005**	**0.69**	**0.0005**	**0.37**	**0.007**	**0.08**
		E.V% = 88%					**F value= 3.18**	
2020/ 2021	**R**	**-0.67****	**-0.74****	**-0.19**	**0.57***	**0.41**	**0.42**	**0.62***
	P	**0.007**	**0.002**	**0.50**	**0.03**	**0.13**	**0.14**	**0.01**
		E.V% = 92%					**F value= 5.08***	
E. fabae								
		Max. temp	**Mini. Temp**	**RH**	**Plant age**	***C. undecimpunctata***	***C. carnea***	***O. laevigatus***
2019/ 2020	**R**	**-0.77****	**-0.86*****	**0.07**	**0.79*****	**0.15**	**0.85*****	**0.37**
	P	**0.001**	**<.0001**	**0.80**	**0.0007**	**0.59**	**0.0001**	**0.19**
		E.V% = 94%					**F value= 8.36***	
2020/2021	**R**	**-0.55***	**-0.59***	**0.17**	**0.72****	**0.74****	**0.44**	**0.77****
	P	**0.04**	**0.02**	**0.54**	**0.003**	**0.002**	**0.11**	**0.001**
		E.V% = 91%					**F value=4.55***	

During spring plantation 2020&2021 a significant positive correlation was found between *B. tabaci* number, maximum and minimum temperature “r” = (0.66** & 0.68**) & (0.79***& 0.80***), respectively. The mean percentage of relative humidity had an insignificant negative effect in 2020 but was highly sign., in 2021 whereas “r” value was -0.38 & -0.79***, respectively. C. carnea *&* ***E****. eremicus* was significant positive effects whereas “r” value was (0.52* and 0.54*) for spring 2020 and (“r”= 0.59* & 0.45*) for spring 2021, respectively. C**.** *undecimpunctat* had a highly significant effect on 1st season and an insignificant positive effect on 2nd one as “r”= 0.68**& 0.44, respectively. *Syrphus corollae* effect was significant in 1st season and insignificant in 2nd one whereas “r”= 0.65*& 0.40. the age of plant effect on the seasonal fluctuations of *B. tabaci* in both spring seasons (2020 & 2021) was highly significant, whereas r= 0.74**& 0.83***, respectively. The combined effect of these factors as a group (E.V) showed responsible 85% & 86% effects on the population dynamics of *B. tabaci* throughout seasons (2020 &2021) and (“F” values were 1.83*& 1.86*), Table (2).

E. fabae*:*

In both autumn seasons, 2019-20&2020-21 data in Table (1) indicated that for max. & min. temp. had negative significant in both seasons “r” = (-0.77*** & -0.86***) and (-0.55* & -0.59*),respectively. *C. carnea* had a positive effect on both seasons highly significant in the first autumn but insignificant in the second one as “r”= 0.85***&0.44, respectively. *Orius laevigatus & C. undecimpunctata* had the same effect in both seasons as it had an insignificant positive effect in 2019-20 but had a highly significant positive effect in 2020/2021” r”=(0.37 &0.77**)&(0.15&0.74**), respectively and plant age was positively high significant in their effect during both season on the seasonal fluctuations of *E. fabae* whereas, “r” value was (0.79***&0.72** respectively). The combined effect (E.V.) of these factors on *E. fabae* during both seasons showed that these factors were responsible as a group for 94% &91% of effects on the population dynamics of *E. fabae* (“F” value was 8.36* & 4.55* sign.) on 2019/2020& 2020/2021, respectively.

Table 2: Simple correlation of the three main weather factors and biotic factors on *B. tabaci* & *E. fabae* and corresponding percentage of explained variance on potato spring plantation at El Gharbia governorate during 2020 and 2021 seasons.

					B. tabaci				
Spring seasons		**Abiotic factor**				**Biotic factor**			
		Max. temp	**Mini. temp**	**RH**	**Plant age**	***C. undecimpunctata***	***C. carnea***	***E. eremicus***	***S. corollae***
2020	**R**	0.66**	0.68**	-0.38	0.74**	0.68**	0.52*	0.54*	0.65*
	P	0.009	0.007	0.17	0.002	0.007	0.05	0.04	0.01
		E.V% =		85%				F value= 1.83	
2021	**R**	0.79***	0.80***	-0.79***	0.83***	0.44	0.59*	0.45*	0.40
	P	0.0007	0.0006	0.0007	0.0002	0.11	0.02	0.09	0.15
		E.V% = 86%					F value= 1.86		
					E. fabae				
		Max. temp	**Mini. temp**	**RH**	**Plant age**	***C. undecimpunctata***	***C. carnea***	***O. laevigatus***	
2020	**R**	0.30	0.38	-0.08	0.59*	0.71**	0.73**	0.76**	
	P	0.28	0.17	0.78	0.02	0.004	0.002	0.001	
		E.V% =		92%				F value= 4.91*	
2021	**R**	0.67**	0.71**	-0.63*	0.79***	0.43	0.36	0.24	
	P	0.007	0.003	0.01	0.0006	0.11	0.19	0.39	
		E.V% = 79 %					F value= 1.71		

In Table (2) during the spring seasons of 2020 & 2021 the results showed that max. & min. temp. were positively affected by the seasonal fluctuations of *E. fabae* but it was insignificant in spring 2020 and highly significant in spring 2021 as “r”= (0.30 & 0.38) and (0.67** & 0.71**). R.H. had a negative insignificant effect in 1st spring and a negative significance in 2nd one whereas, “r” values were (-0.08 & -0.63*), respectively. although, all biotic factors (*C. carnea*, *C. undecimpunctata* and *O. laevigatus* had a highly significant positive effect on the population of *E. fabae* as (“r”= 0.73**, 0.71**, 0.76**, respectively whereas it was positive but insignificant in spring 2021 as “r”= 0.36, 0.43& 0.24, respectively. On the other hand, a significant positive correlation was obtained between the mean of *E. fabae* and the age of plant life stage in **1st** spring and positive highly significant in **2nd** one Where, the calculated r =0.59* and 0.79***. Thus, the weather factors, biotic factors and plant age affected *E. fabae* with E.V. percentage, 92% & 79% F value= of 4.91*& 1.71 in 2020 and 2021, respectively.

These findings are consistent with those made by (Shivanna *et al*., 2011), who found that the whitefly population peaked from April to May while the leafhopper population peaked in May. As in Gwalior, the whitefly population persisted in the potato crop throughout the growing season (Shah *et al*., 2019). The population grew gradually until it peaked in the middle of the season and then started to fall. According to (Thangjam *et al*., 2020), the third week of April saw the highest population of *B. tabaci*, and there was a significant positive correlation between the maximum temperature and average R.H. In 2014–15, the fourth week of March saw the highest incidence of *Empoasca sp*., whereas, in 2015–16, the highest incidence occurred in the third week of April. Whereas the correlation between the leafhopper population and Max. Temp. showed non-significant positive whereas significant and negative correlation was with average R.H. but it was non-significant with minimum temp. Also (El-Fakharany *et al*., 2016), revealed that the highest population densities of *B. tabaci* occurred in November, December and January. (Shah *et al*., 2021) found that whiteflies appear on potato crops immediately after crop emergence

(3rd week of October) and remain on the crops till the 3rd or 4th week of January (80–90 days after crop emergence recorded a peak in the first week of November. Also in spring plantation, the results are in harmony with that were recorded by (El-Khawas & Shoeb, 2004) in Egypt as they found that the population density of whitefly reached their peak in the 2nd and 3rd week of April in 2003 and 2004, respectively. Low numbers of *Empoasca decipiens* in spring plantation. (Abdallah & Faraj, 2015) in Egypt revealed that *B. tabaci* recorded 2-3 peaks of abundance whereas leaf hopper had 1-2 peaks in summer plantations for seasons 2012&2013. (Abdallah & Faraj, 2015) indicated that densities of *B. tabaci* remained at a low level during the winter but increased steadily from February to March until migration into field crops in April. Population fluctuation of white fly and leafhopper was somewhat similar (Rawat Scholar *et al*., 2020) as there was a non-significant positive correlation between maximum temperature and relative humidity of morning but minimum temperature showed a non-significant negative correlation and for Hopper population was a non-significant positive correlation with maximum temperature & relative humidity of morning and non-significant negative correlation with minimum temperature. the results obtained by (Shivanna *et al*., 2011) was revealed maximum temperature was significantly and positively correlated with the leafhopper and whitefly population but minimum temperature and relative humidity were showed an insignificant effect on leafhopper but there was significant effect with minimum temperature and relative humidity on whitefly.

Conclusion:

Our study aims to determine the population fluctuation and population dynamic of *Bemisia tabaci* and *Empoasca fabae* as they are considered to be among the main sucking pests infesting the potato crop. Population fluctuation of both insects differs from one season to another and also differs in the spring plantation from the autumn one. The incidence of white flies was more than that of leafhoppers also the population density in autumn was more than in spring plantation of both seasons 2019/2020& 2020/2021 for both insects. Both *B. tabaci & E. fabae* numbers recorded the highest peaks in December during both autumns 2020/2021 & 2019/2020, whereas in spring plantation the highest peaks of both pests were recorded in May. The fluctuation in the population density of both insects may be due to the presence of some abiotic (max, mini temperature, RH & plant age) and biotic factors such as the presence of natural enemies. Among the natural enemies there were *C. undecimpunctata*, *C. carnea* (aphid lion), *Eretmocerus eremicus* & *Orius laevigatus* during autumn seasons and also the appearance of *Syrphus corollae* during the spring seasons. All biotic factors and plant age have a positive effect on the population density of *Empoasca fabae* and *Bemisia tabaci*. On the other hand, max & mini temperatures have a negative effect on the population density of both white flies and leafhoppers on autumn plantations and a positive effect on spring plantations during both seasons 2019/2020&2020/2021. Relative humidity (R.H.) had a positive effect during both autumn seasons on *Empoasca fabae* whereas affected positively on *B. tabaci* during 1st autumn season of 2019/2020 but negative effect during the autumn of 2020/2021. On the other hand, R.H. affected negatively both *E. fabae* and *B. tabaci* during both spring seasons of 2020 & 2021. This study aims to study the population fluctuation and the role of natural enemies and ecological factors on the population fluctuation of some main insects infesting potatoes that help to control them avoiding damage and loss of the crop

Acknowledgment

My great thanks to the affiliates of the Professors of Entomology in the Zoology& Entomology Department, Faculty of Science (girls), Al-Azhar University & Plant protection research institute, and Agriculture research center for providing all facilities, in the fulfillment of this research.

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