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Population Fluctuation and Thermal Requirement for Development of *Empoasca decipiens* (Homoptera, Cicadellidae) on Different Bean Species in Natural Conditions

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ABSTRACT

The leafhopper *Empoasca decipiens* Paoli is a widespread polyphagous insect pest of several major crops especially bean in Iran and many other parts of the world. Population fluctuation and thermal requirement for development of *E. decipiens* was studied on four bean species including *Phaseolus vulgaris* L. (var. Talash), *P. lunatus* L. (var. Sadaf), *P. calcaratus* Roxb. (var. Goli) and *Vigna sinensis* L. (var. Parastoo) in Tehran region, Iran during 2004-2005. In both years, the highest population density of the leafhopper was observed on *V. sinensis* and on all host plants species, this density increased with increasing temperature and decreasing relative humidity. During two years, the highest and lowest population density of the pest was in early September and late October, respectively. Significantly, the highest and lowest rate of thermal constant related to overall nymph period (max: 288.95; min: 197.43 Degree-days) and overall immature period (max: 473.75; min: 384.05 Degree-days) was recorded on *P. calcaratus* and *V. sinensis*, respectively, in which the shortest development time was recorded on *V. sinensis* (11.59 days for overall nymph and 22.58 days for overall immature). It could be concluded that the host-plant species influence population fluctuation, development time and thermal requirement for development of immature stages of *E. decipiens*. Thermal requirements can be used to predict the occurrence, development and population dynamics of *E. decipiens* on different bean species.

Key words: *Empoasca decipiens*, thermal requirement, development, population fluctuation, bean species.

INTRODUCTION

Leafhoppers feed by piercing plant tissue, usually mesophyll, and sucking up plant sap. Abundant, extensive injury, known as hopperburn, may then result to the plants (Lavigne & Campion, 2001). *Empoasca decipiens* Paoli is a widespread polyphagous insect pest of several major crops especially bean in Iran (Rassoulian *et al.,* 2005; Naseri *et al.,* 2007) and many other parts of the world (Umesh & Rajak, 2004; Genceoylu & Yalcin, 2004). Both the adults and nymphs feed by puncturing phloem vessels of the leaves. This induces an obstruction of the vessels, a reddening and necrosis of leaves, thus reduced photosynthesis, resulting in delayed maturity or a reduced sugar content of the harvest (Raupach *et al.,*2002; Backus *et al.,*2005).

Temperature is a critical abiotic factor influencing development rate and survival in immature stages of arthropods, especially insects (Gilbert & Raworth, 1996; Jervis & Copland, 1996). Finding relationship between temperature and development rate can be useful in prediction of phenological events such as the timing of development, dormancy or migration (Haghani *et al.,* 2006). Thermal characteristics may vary between species, populations, development stages and with other ecological factors such as food source (Roy *et al.,* 2003). The effects of temperature on insect metabolism and growth have been studied for a variety of species and over a period of some 50 years several useful hypotheses and principles have evolved. There are a few statements in the literature pertaining to the effects of temperature on the development of leafhoppers and no research has focused on thermal requirement for development of *E. decipiens* on different bean plants in natural conditions.

Fenton & Hartzell (1923) Reported that the maximum rate of development time of *Empoasca fabae* (Harris) occurred at 85°F, while in below and above this temperature, this rate was decreased. The effect of temperature on development rate of the potato leafhopper, *E. fabae* at field and laboratory conditions was studied by Kouskolekas & Decker (1996). The base temperature for this insect was reported approximately 52.5°F (or 11.39°C). In the laboratory and field experiments, a thermal constant was obtained 453 and 480-500 degree days (°C x day), respectively. Hartzell (in Delong, 1928) mentioned that at 78°F the period from egg to adult of *E. fabae* was 19 days.

Influence of temperature-driven phenology on population dynamics of the leafhopper, *Erythroneura comes* Say was investigated in New York, USA. The results revealed that the developmental zero was 10°C and accumulations of >710 degree-days before August 1 are required to produce the second generation of *E. comes* under climatic conditions (Martinson & Dennehy, 1995).

Population fluctuation of *E. decipiens* on some summer crops such as *Phaseolus vulgaris* L., cowpea and mung bean using the sweep net technique was studied in Egypt and revealed that the peak of population was in 8th May 2001 on early summer crops and 5th June and 31th July 2001 on late summer crops (Ebadah, 2002). Fluctuation of population density of *E. decipiens* on potato was determined in field tests at Egypt. On the early crop, population of *E. decipiens* was very small at the end of March and reached peak numbers in the second week of June. On the late crop, population of this leafhopper reached peak numbers in late October and gradually declined thereafter

(El- Saadany *et al.,* 1976). Population fluctuation of *E. decipiens* was studied by Ammar *et al.* (1977) in Egypt and the results suggested that the leafhopper population was high in the warmer months regardless of relative humidity and in the monthly sweep-net samples, was caught on 19 field crops, especially broad bean. Population dynamic of the leafhopper, *Amarasca biguttata* on brinjal and effects of abiotic factors on its dynamics were investigated (Mahmood *et al.,* 2002). Theire results revealed that the maximum population activity of pest was from 21th May to 6th August and significantly, the minimum and maximum temperatures were positively influenced population fluctuation of *A. biguttata*. But, relative humidity had non-significant effect on its population fluctuation.

The present study was undertaken to obtain information on the effect of naturally fluctuating temperatures on development rate of *E. decipiens* for estimating thermal requirement (degree-days) and population fluctuation of the pest on four bean species. This data deemed essential to an understanding of population dynamics in the field and a prerequisite to any attempt to forecasting and predict field population trends or migration patterns.

MATERIAL AND METHODS

Experimental design

The experiments were carried out in experimental field of Tarbiat Modares University in Tehran suburbs, Iran, during 2004–2005. Four bean species including *Phaseolus vulgaris* L. (var. Talash), *P. lunatus* L. (var. Sadaf), *P. calcaratus* Roxb. (var. Goli) and *Vigna sinensis* L. (var. Parastoo) were planted in randomized complete block design in field (35×18 m) with four blocks and four plots per block. The plots mensuration was 4×8 m.

Thermal requirement for development

The effect of naturally fluctuating temperatures on development of *E. decipiens* was studied on four bean species using leaf cages (6 cm diameter and 2 cm high) in the field conditions. One female and one male leafhopper were introduced into each leaf cage for oviposition. Twenty-four hours later the adult leafhoppers were removed and incubation period was determined on each bean species. After appearance of the first instar nymphs, development of nymphs was recorded separately on four bean species. Information related to the field temperature and relative humidity was obtained from Aerology Station of Tarbiat Modares University.

Several mathematical equations can be used for calculating degree-day based on minimum and maximum temperature. The easiest method was presented by Ring *et al.* (1983). In this method, they calculate degree-day on a daily basis and add up the daily value, during the developmental period to determine the total degree-days for each case. The daily degree-day is calculated as:

$$DD = \sum_{i=1}^{n} \frac{Min_i + Max_i}{2} - T_0$$

Whenever, the Min_i and Max_i are the daily minimum and maximum temperatures respectively, the T_0 is developmental zero and the *DD* is degree-day. Developmental zero related to this research (T_0=11.39 °C) was obtained from the results of Kouskolekas & Decker (1996) study.

Sampling program

The leafhopper, *E. decipiens* usually colonizes on the under-surface of leaves and female individuals lay their eggs within the veins and leaves tissues, thus, one leaf of bean crops was selected as a sample unit. Sampling of leaves was carried out randomly and population density of the nymphs and adult leafhoppers was recorded by means of direct observation technique.

The sampling was conducted in 3-4 days periods in 2004 and weekly in 2005. All counts were performed at the same time and usually made mid-morning. The beginning of sampling was 7th August in 2004 and 11th June in 2005 and prolonged until late October.

The reliable sample size was determined using the following equation:

$$N = [ts / dm]^2$$

where *N*= sample size, *t*= t-student, s= standard deviation of primary data, *d*= desired fixed proportion of the mean and *m*= the mean of primary data.

Population fluctuation

Population density of *E. decipiens* was determined on different bean species from 7th August to 19th October in 2004 and 11th June to 15th October in 2005. Linear regression method was used to describe the relationship between population fluctuation of *E. decipiens* and temperature and relative humidity in natural conditions on four bean species.

Statistical analysis

Thermal constant of incubation period, 1st to 5th nymphal instars, total nymphal period and development time were analyzed with one-way ANOVA (MINITAB, 2000) on different bean species. If significant differences were detected, multiple comparisons were made using the LSD test. Data were checked for normality prior to analysis. Population fluctuation of *E. decipiens* versus temperature and relative humidity was analyzed using linear and non-linear regression methods on different bean species.

RESULTS

Thermal requirement for development

The mean development rate of immature stages of *E. decipiens* on four bean species was determined (Table 1). Thermal constant (degree-day) of each development stages of the leafhopper such as incubation period, 1st to 5th nymphal instars, total nymphal period and development time are shown in Table 2. The rate of thermal constant required for egg development was not significantly different on four bean species. But, the number of degree-days required for total nymphal period and development time of *E. decipiens* had significant difference on different bean species. Significantly, the highest and lowest rate of thermal constant related to nymphal development and development time were recorded on *P. calcaratus* and *V. sinensis*, respectively (Table 2).

Table 1. Mean (±SE) development time of *E. decipiens* on four bean species in natural conditions

Immature stage	Bean species			
	P. vulgaris	*P. calcaratus*	*P. lunatus*	*V. sinensis*
Egg	10.75±0.43^{a}	10.92±0.50^{a}	10.75±0.55^{a}	11.00±0.46^{a}
1st instar nymph	3.25±0.66^{a}	3.08±0.23^{a}	2.92±0.23^{a}	2.42±0.31^{a}
2nd instar nymph	3.17±0.24^{a}	3.58±0.29^{a}	3.08±0.29^{a}	2.33±0.26^{b}
3rd instar nymph	2.67±0.26^{ab}	3.08±0.19^{a}	2.83±0.21^{a}	2.17±0.24^{b}
4th instar nymph	2.83±0.21^{a}	2.92±0.23^{a}	2.50±0.19^{a}	2.25±0.25^{a}
5th instar nymph	3.50±0.29^{a}	3.58±0.31^{a}	3.08±0.19^{ab}	2.42±0.26^{b}
Overall nymph	15.42±0.12^{a}	16.24±0.12^{a}	14.41±0.10^{a}	11.59±0.11^{b}
Overall immature	26.17±0.87^{a}	27.17±0.67^{a}	25.17±0.66^{ab}	22.58±0.50^{b}

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Table 2. Mean thermal constant (SE) for development of immature stages of *E. decipiens* on four bean species in natural conditions.

Immature stage	Bean species			
	P. vulgaris	***P. calcaratus***	***P. lunatus***	***V. sinensis***
Egg	182.11±7.61^{a}	184.79±9.08^{a}	182.28±10.20^{a}	186.61±8.21^{a}
1st instar nymph	46.24±4.38^{a}	43.55±3.54^{ab}	40.97±3.54^{ab}	33.51±4.73^{b}
2nd instar nymph	44.84±3.73^{a}	51.51±4.55^{a}	43.66±4.52^{ab}	32.13±3.88^{b}
3rd instar nymph	37.19±3.91^{ab}	43.54±2.99^{a}	39.68±3.20^{a}	29.64±3.61^{b}
4th instar nymph	39.68±3.20^{ab}	40.97±3.54^{a}	34.53±3.01^{ab}	30.85±3.79^{b}
5th instar nymph	50.22±4.59^{a}	51.62±4.98^{a}	43.54±2.99^{ab}	33.42±3.93^{b}
Overall nymph	272.95±15.72^{ab}	288.95±11.05^{a}	252.52±11.36^{b}	197.43±10.47^{c}
Overall immature	455.12±16.80^{ab}	473.75±13.17^{a}	429.76±11.10^{b}	384.05±9.24^{c}

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Sampling program and population fluctuation

By primary sampling, the reliable sample size with maximum variation fro precision of 20% was obtained about 40. The relative variation (RV) of the primary sampling estimated about 10% that was very appropriate for this research goal. Estimated parameters of population density of *E. decipiens* versus temperature and relative humidity using linear regression method on different bean species are presented in Tables 3 and 4. In 2004, significantly positive relationship was observed between population density of the leafhopper and fluctuating temperature on three bean species except *P. vulgaris* ($P<0.05$). At this year, population of the leafhopper revealed a significantly positive relationship with relative humidity on *P. calcaratus* and negative relationship on *V. sinensis* ($P<0.01$). In 2005, the population density of *E. decipens* showed significantly positive relationship with temperature on *P. calcaratus* and *V. sinensis* ($P<0.05$) and significantly positive relationship with relative humidity on *P. lunatus* ($P<0.05$) and *V. sinensis* ($P<0.01$). In overall years, non-significant relationship was observed between population density of the pest and relative humidity. But, except on *P. vulgaris*, population density of the leafhopper showed significantly positive relationship with temperature on the other three bean species. The results from non-linear regression method were showed non-significant relationship among population density with the field temperature and relative humidity.

Table 3. Estimated parameters of linear regression between population density of *E. decipiens* and temperature on different bean species in 2004, 2005 and overall years.

Estimated parameters							
Years	Bean species	a±SE	Slope±SE	$P_{regression}$	r^2	P_a	P_{slope}
2004	*P. vulgaris*	0.249±0.836	0.031±0.031	0.327	0.001	0.769	0.327
	P. lunatus	-1.650±0.752	0.134±0.028	0.000	0.523	0.041	0.000
	P .calcaratus	-2.990±1.677	0.188±0.061	0.005	0.306	0.091	0.005
	V. sinensis	-22.60±10.810	1.60±0.403	0.001	0.424	0.050	0.001
2005	*P. vulgaris*	0.040±0.429	0.012±0.015	0.447	0.000	0.927	0.447
	P. lunatus	-0.320±1.114	0.041±0.038	0.299	0.008	0.779	0.299
	P. calcaratus	-1.930±1.354	0.110±0.047	0.032	0.199	0.171	0.032
	V. sinensis	-26.80±14.440	1.390±0.500	0.013	0.272	0.081	0.013
Overall years	*P. vulgaris*	0.622±0.616	0.004±0.022	0.845	0.000	0.319	0.845
	P. lunatus	-0.434±0.866	0.067±0.031	0.038	0.085	0.619	0.038
	P. calcaratus	-1.830±1.262	0.129±0.045	0.007	0.143	0.155	0.007
	V. sinensis	-18.400±9.246	1.260±0.332	0.001	0.243	0.054	0.001

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Table 4. Estimated parameters of linear regression between population density of *E. decipiens* and relative humidity on different bean species in 2004, 2005 and overall years

Estimated parameters							
Years	Bean species	a±SE	Slope±SE	$P_{regression}$	r^2	P_a	P_{slope}
2004	*P. vulgaris*	1.460±0.454	-0.011±0.013	0.379	0.000	0.005	0.379
	P. lunatus	2.850±0.557	-0.028±0.015	0.084	0.104	0.000	0.084
	P .calcaratus	4.910±0.902	0.081±0.025	0.002	0.318	0.000	0.002
	V. sinensis	39.000±6.343	-0.572±0.176	0.004	0.322	0.000	0.004
2005	*P. vulgaris*	0.148±0.137	0.005±0.002	0.092	0.109	0.295	0.092
	P. lunatus	0.125±0.340	0.016±0.007	0.029	0.206	0.718	0.029
	P. calcaratus	0.324±0.477	0.019±0.009	0.060	0.146	0.506	0.060
	V. sinensis	-0.450±4.757	0.286±0.093	0.007	0.319	0.925	0.007
Overall years	*P.vulgaris*	1.010±0.245	-0.007±0.005	0.234	0.012	0.000	0.234
	P. lunatus	1.680±0.368	-0.007±0.008	0.409	0.000	0.000	0.409
	P. calcaratus	2.390±0.550	-0.017±0.012	0.185	0.021	0.000	0.185
	V. sinensis	17.000±4.393	-0.020±0.100	0.846	0.000	0.000	0.846

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The maximum range of population fluctuation of *E. decipiens* was occurred on *P. vulgaris* and *P. lunatus* and the minimum range of fluctuation was observed on *V. sinensis* and *P. calcaratus*. Population density of the leafhopper was increased with increasing temperature and decreasing relative humidity on four bean species during 2004. In both years, the highest and lowest population density of the pest was in early September and late October, respectively (Fig.1). The field temperature and relative humidity fluctuations during 2004 and 2005 are shown (Fig.2).

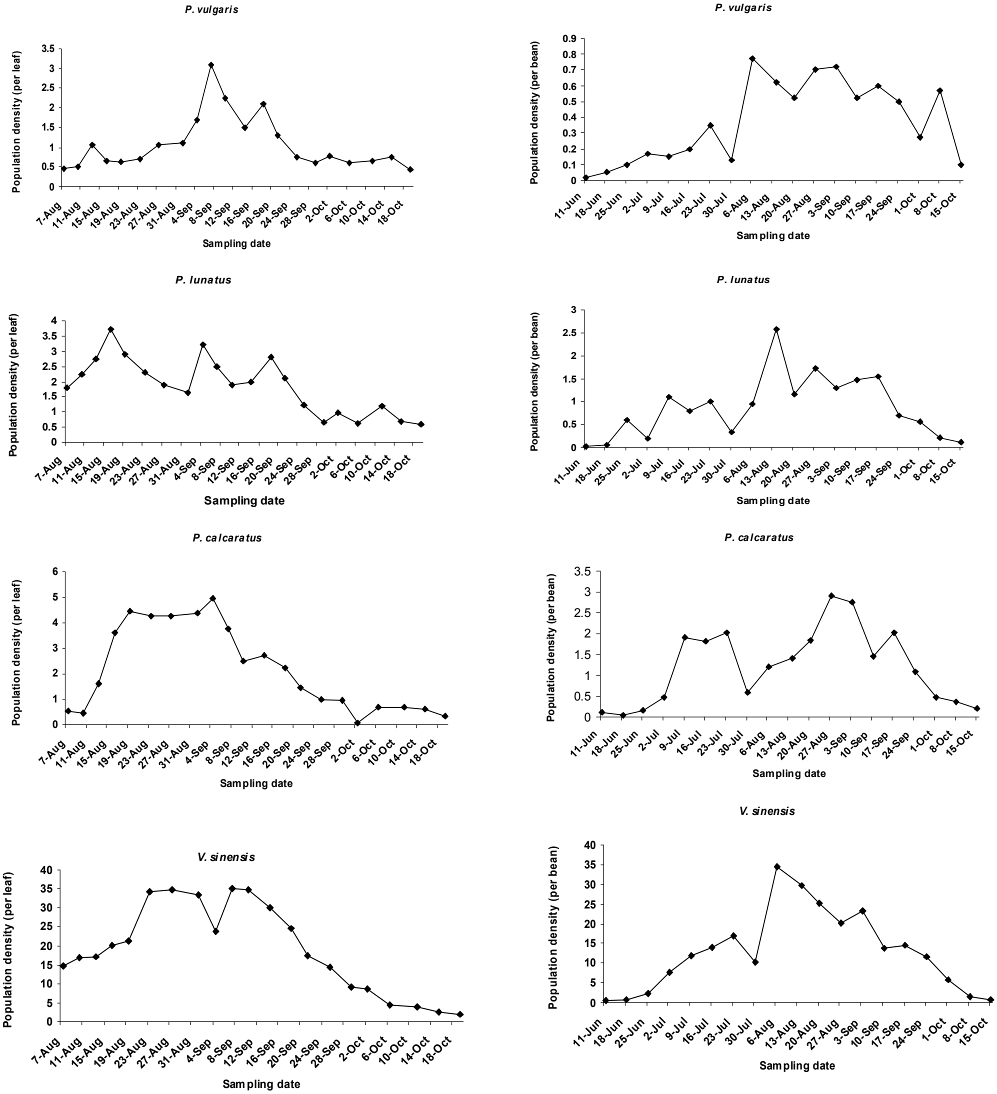

Fig. 1. Population fluctuation of *E. decipiens* on different bean species in 2004 (left column) and 2005. (right column)

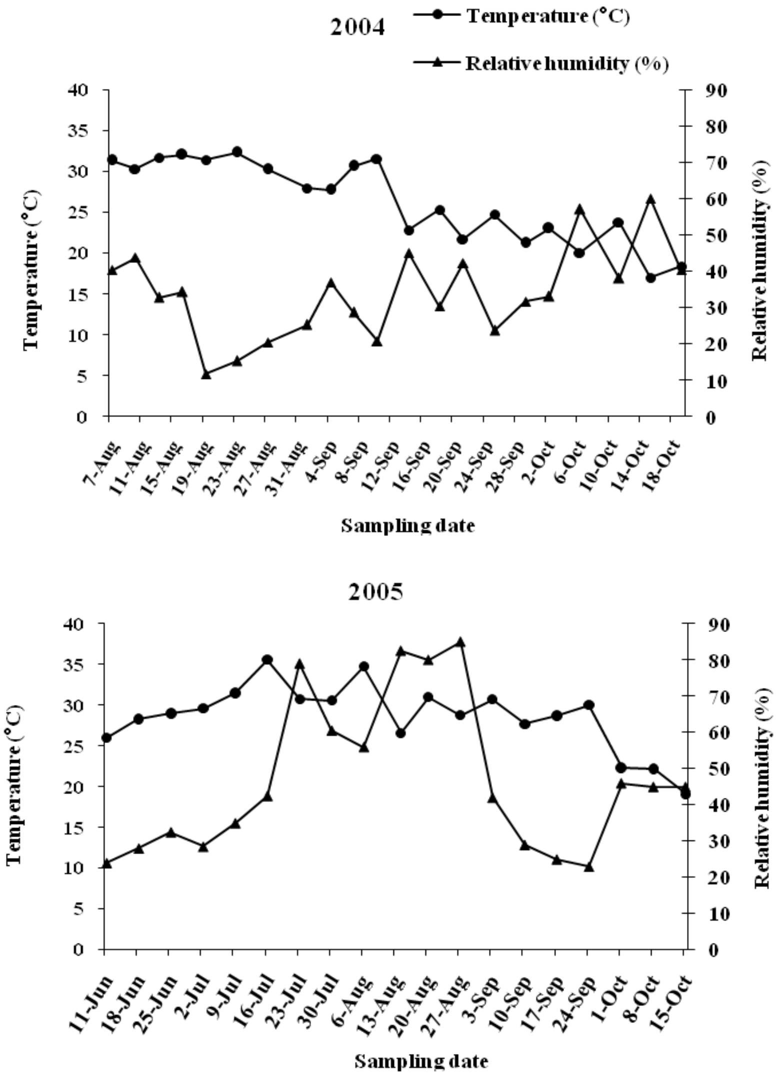

Fig. 2. Field temperature and relative humidity fluctuations during 2004 and 2005

CONCLUSIONS AND DISCUSSION

On the basis of the results obtained from the field data, it can be said that the different four bean species had significant effect on development time and thermal requirement for development of some immature stages of *E. decipiens*, suggesting that thermal constant of an insect also affected by host plant type via affecting the development time. Thermal constant for incubation period of *E. decipiens* was not significantly different on four bean species, because there was no significant difference between incubation periods of the leafhopper on these bean species. The highest and lowest nymphal period and development time of the pest was recorded on *P. calcaratus* and *V. sinensis*, respectively. Thereby, thermal constant for nymphal period and development time of *E. decipiens* was the maximum on *P. calcaratus* and minimum on *V. sinensis*. Thermal constant for nymphal period and development time of the leafhopper on four bean species was recorded about 197-288 and 384-473 degree-days, respectively.

No other study has examined thermal requirement for development of *E. decipiens* and the results of this study present new information on development and thermal characteristics of this pest. Kouskolekas and Deeker (1960) reported that thermal constant of *E. fabae* on Buffalo alfalfa was 248.89-260 degree-days (over a base of 11.39°C). These contrasts may be due to difference in our studied pest species, host-plant type and field climatic conditions. Since incubation period of *E. decipiens* on four bean species was not significantly different, the rate of thermal constant required for egg development was not significantly different. Thermal requirement for development of the leafhopper on *V. sinensis* was significantly lower than the other bean species, because nymphal period of the pest was the shortest on this crop in comparison with other three bean species. This revealed that nymphal period of the leafhopper affected by host-plant type.

The effect of fluctuating temperature and relative humidity on population density of *E. decipiens* on different bean species was studied using linear regression model. In addition to changes in temperature and relative humidity, the host-plant species significantly affected the population fluctuation of *E. decipiens* as well. The lowest population density of *E. decipiens* was obtained on *P. vulgaris* among different bean species. Presence of hooked dens trichomes on the leaves of *P. vulgaris* assumed as the most important reason of its unsuitability for the leafhopper activity. Robbins & Daugherty (1969) found glabrous varieties of soybean to have both the highest numbers of leafhoppers and highest ovipositional rates, while the dens pubescent varieties had the lowest number and lowest incidence of oviposition. More specifically, it appears that length and orientation of hairs rather than density alone (Broersma *et al.,* 1972) are major factors in protecting most commercial cultivars from serious damage by leafhoppers.

During two years, significantly positive relationship was observed between the population density and temperature on three bean species except *P. vulgaris*, presuming that changes in field temperature lead to linear population fluctuation of the leafhopper.

But in these two years, non-significant relationship was recorded between population density and relative humidity. A similar belief was expressed by Ammer *et al.* (1977), who reported that population density of *E. decipiens* is high in the warmer months regardless of relative humidity. Mahmood *et al.* (2002) noted that the field minimum and maximum temperature was positively influenced on population fluctuation of *A. biguttata* but, relative humidity had non-significant effect on its population fluctuation.

During 2004, population density of the leafhopper increased with increasing temperature and decreasing relative humidity on four bean species. This is similar to the results of Rassoulian *et al.* (2005) on soybean plants. Population density of *E. decipiens* on different bean plants was peaked in late August to mid September. Our estimates on population fluctuation of *E. decipiens* conflict with the results of some authors. Two possible reasons for disagreements are: physiological differences depending on the host plants and variation in experimental climatic conditions. Many behaviors and events in the life histories of insects can be predict using temperature-dependent (degree-day) models, because development of poikilotherms is directly related to temperature. Thus, development of appropriate degree-day models may facilitate the development of management strategies for *E. decipiens* on different bean plants. The results of this study can be used in association with other ecological data in order to development and implementation of pest management programs on different bean species. Furthermore, our findings may provide necessary information for comprehensive integrated pest management of *E. decipiens* on bean species.

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REFERENCES

Ammar, E. D., Nahal, E. L., El-Bolok, A. K. M., Nahal, M. M., Bolok, A. K. M., Bolok, M. M. E. L., 1977, Fluctuations of population densities of *Empoasca decipiens* paoli and *Balctutha hortensis* Lindb at Giza, Egypt (Homoptera, Cicadellidace). *Bulletin de la Societe Entomologique d'Egypte*, 61: 245-255.

Backus, E. A., Serrano, M. S., Ranger, C. M., 2005, Mechanism of hopperburn: an overview of insect taxonomy, behavior and physiology. *Annual Review of Entomology*, 50: 125-151.

Broersma, D. B., Bernard, R. L., Luckmann, W. H., 1972, Some effects of soybean pubescence on populations of the potato leafhopper. *Journal of Economic Entomology*, 65: 78-82.

Delong, D. M., 1928, Some observations upon the biology and control of the potato leafhopper (*Empoasca fabae* Harris). *Journal of Economic Entomology*, 21: 183-188.

Ebadah, I. M. A. 2002, Population fluctuations and diurnal activity of the leafhopper, *Empoasca decipiens* on some summer crops in kalubia Governorate. *Egypt Bulletin of Agriculture Cairo University*, 53: 653-670.

El-Saadany, G., Abdel-Fattan, M. L., Saadany, G. E. L., Abdel, M. L., 1976, Fluctuations of population densities of three homopterous pests, *Myzus persicae* (Sulzer), *Aphis gossypii* Glover and *Empoasca decipiens* Paoli, attacking potato plants in Egypt. *Bulletin of the Entomological Society of Egypt*, 60: 389-394.

Fenton, F. A., Hartzell, A., 1923, Bionomics and control of the potato leafhopper, *Empoasca mali* Le Baron. *Agricultural Experiment Station, Iowa State College of Agriculture and Mechanical Arts. Research Bulletin*, 78: 377-440.

Gencsoylu, I., Yalcin, I., 2004, The effect of different tillage systems on cotton pests and predators in cotton fields. *Asian Journal of Plant Sciences*, 3: 39-44.

Gilbert, N., Raworth, D. A., 1996, Insect and temperature, a general theory. *Canadian Entomologist*, 128: 1-3.

Haghani, M., Fathipour, Y., Talebi, A. A., Baniameri, V., 2006, Comparative demography of *Liriomyza sativae* (Diptera, Agromyzidae) on cucumber at seven constant temperatures. *Insect Science*, 13: 477-483.

Haghani, M., Fathipour, Y., Talebi, A. A., Baniameri, V., 2007, Temperature- dependent development of *Diglyphus isaea* (Hymenoptera, Eulophidae) on *Liriomyza sativae* (Diptera, Agromyzidae) on cucumber. *Journal of Pest Sciences*, 80: 71-77.

Jervis, M. A., Copland, M. J. W., 1996, *The Life Cycle.*In: Jervis, M., Kidd, N., (Eds.). Insect Natural Enemies. Practical Approaches to Theire Study and Evaluation. Chapman and Hall, London, 63-161.

Kouskolekas, C., Decker, G. C., 1966, The effect of temperature on the rate of development of the potato leafhopper, *Empoasca fabae* (Homoptera, Cicadellidae). *Annals of the Entomological Society of America,* 59: 292-295.

Lavigne, R. J., Campion, M. K., 2001, The effect of ecosystem stress on the abundance and biomass of leafhoppers (Homoptera, Cicadellidae) on the short-grass prairie. *Journal of the Entomological Research Society*, 3: 5-16.

Mahmood, T., Hussain, S. I., Khokhar, K. M., Jeelani, G., Ahmad, M., 2002, Population dynamic of the leafhopper, *Amarasca biguttata* on brinjal and effects of abiotic factors on its dynamics. *Asian Journal of Plant Sciences*, 1: 403-404.

Martinson, T. E., Dennehy, T. J., 1995, Influence of temperature-driven phenology and photoperiodic induction of reproductive diapause on population dymamics of *Erythroneura comes* (Homoptera, Cicadellidae). *Environmental Entomology*, 24: 1504-1514.

Minitab, 2000, Minitab users Guide, version 13.1. Minitab Ltd, UK.

Naseri, B., Fathipour, Y., Talebi, A. A., 2007, Seasonal parasitism of *Empoasca decipiens* (Homoptera, Cicadellidae) by *Anagrus atomus* (Hymenoptera, Mymaridae) in Tehran area). *Applied Entomology and Phytopathology*, 75 (1), (in Persian) (in press).

Rassoulain, G. R., Sardarbandeh, H., Kharazi-Pakdel, A., 2005, Study of soybean leafhoppers fauna and an investigation on biology of dominant species *Empoasca decipiens* Paoli in Karaj area. *Communication Agricultural Applied Biological Science*, 70: 671-675.

Raupach, K., Borgemeister, C., Hommes, M., Poehling, H. M., Setamou, M., 2002, Effect of temperature and host plants on the bionomics of *Empoasca decipiens* (Homoptera: Cicadellidae). *Crop Protection,* 21: 113-119.

Ring, D. R., Harris, M. K., Jackman, J. A., Henson J. L., 1983, *A Fortran Computer Program for Determining Start Date and Base Temperature for Degree-Day Models*, The Texas Agricultural Experiment Station Bull Mp-1537, Texas.

Robbins, J. C., Daugherty, D. M., 1969, Incidence and ovipostition of potato leafhopper on soybean of different pubescent types. *Proc. N. Cent. Br. Entomological Society of America*, 24: 35-36.

Roy, M., Brodeur, J., Cloutier, C., 2003, Effect of temperature on intrinsic rate of natural increase (r_m) of a coccinellid and its spider mite prey. *Biological Control*, 48: 57-72.

Umesh, C., Rajak, D. C., 2004, Studies on insect pests on urd bean (*Vigna mungo*). *Annals of Plant Protection Sciences*, 12: 213-214.

Worner, S. P., 1992, Performance of phenological models under variable temperature regimes: consequence of the kaufman or rate summation effect. *Environmental Entomology*, 21: 689-699.

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