EurAsian Journal of BioSciences
Eurasia J Biosci 14, 3349-3358 (2020)

Climate impact on the population dynamics of Cruciferae Bugs (Heteroptera, Pentatomidae, *Eurydema*)

Lola Gandjaeva [1*], Ikram Abdullaev [1], Kahramon Razzakov [2], Komila Allabergenova [2]

[1] Khorezm Mamun Academy, 220900, Khiva, Markaz Str.,1. UZBEKISTAN
[2] Urgench State University, Khamid Alimjan str.14, Urgench, UZBEKISTAN
*Corresponding author: tulipa_83@mail.ru

Abstract

The current research was conducted to investigate the seasonal population dynamics of Cruciferae bugs in the territory of the Lower Amu Darya River. We carried out a study of population dynamics and field observations of Cruciferae bugs from the hatching period until their disappearance in the autumn during the years 2017-2019. The aim of this research was to study the effects of diverse temperature and humidity conditions on the population dynamics of the Central Asian species *Eurydema maracandica* (Oshanin, 1871) and *Eurydema wilkinsi* (Distant, 1879), which are prevalent species in the territory of the Lower Amu Darya River. It is known that climate change has an impact on the number of bugs and on their development. Therefore, the rates of temperature and humidity change are very important factors determining the seasonal population dynamics of both species.

Keywords: population dynamic, Cruciferae bugs, *E. maracandica* Osh., *E. Wilkinsi* Dist., the Lower Amu Darya River, Uzbekistan

Gandjaeva L, Abdullaev I, Razzakov K, Allabergenova K (2020) Climate impact on the population dynamics of Cruciferae Bugs (Heteroptera, Pentatomidae, *Eurydema*). Eurasia J Biosci 14: 3349-3358.

INTRODUCTION

Environmental factors, e.g., abiotic (temperature, humidity, and light) and biotic (host, vegetative biodiversity, and group) stresses, significantly impact the development and population dynamics of insects (McLaren & Pottinger, 1969; Patra et al., 2013; Khaliq et al., 2014; Pilkay et al., 2015; Puja & Sabiha, 2016; Saeed et al., 2017). Regarding the influences of weather factors on the population dynamics of insects, it was found that if temperature decreased as a result of a cooler climate and relative humidity (R.H., %) increased, the population dynamics of insects decreased (Embaby & Lofty, 2015; Adepoju, & Osunsanmi, 2018).

According to the literature, climate change has a considerable impact on the abundance and population dynamics (Khan & Talukder, 2017; Samra et al., 2015; Sangle et al., 2015), adaptation (Numata & Nakamura, 2002), embryonic development, incubation period, rate of development, and other life cycle characteristics (Abdullayev et al., 2020; Staaf et al., 2011) of insects.

Observations of populations, as well as the identification of prevailing insects, will allow us to take earlier measures and use better methods and application rates relative to the economic threshold of all insects found on crop plants. Therefore, it is important to study the seasonal population dynamics of insects during the crop growing season and to create a benchmark that could be used by crop producers, ecologists, agricultural economists, scientists, and consultants for efficient and productive pest control (Djaman et al., 2019; Johnson et al., 2018; Lord, 2004).

The initial information about the Central Asian cabbage bug *Eurydema maracandica* Osh. appeared in the works of the Russian entomologist Vasily Fedorovich Oshanin in 1871, whereas research on *Eurydema wilkinsi* Dist. was first conducted by the English entomologist William Lucas Distant in 1879 and by the Russian entomologist Vasily Evgrafovich Jakovlev in 1881 (Plotnikov, 1926; Yakhontov, 1953).

The first research on *E. maracandica* Osh. and *E. wilkinsi* Dist. of the subgenus *Eurydema* Lap. in Central Asia was published by Plotnikov (1926) and Yakhontov (1953). However, the literature provides only scarce data on the presence of these species, most of which have been recorded in only some areas of Uzbekistan. Despite this, the biology and ecology of the true bugs in Uzbekistan have remained completely unexplored. Moreover, no information on the diapause entry and overwintering locations of bugs identified in Central Asia has been provided in the literature.

Received: July 2019
Accepted: March 2020
Printed: September 2020

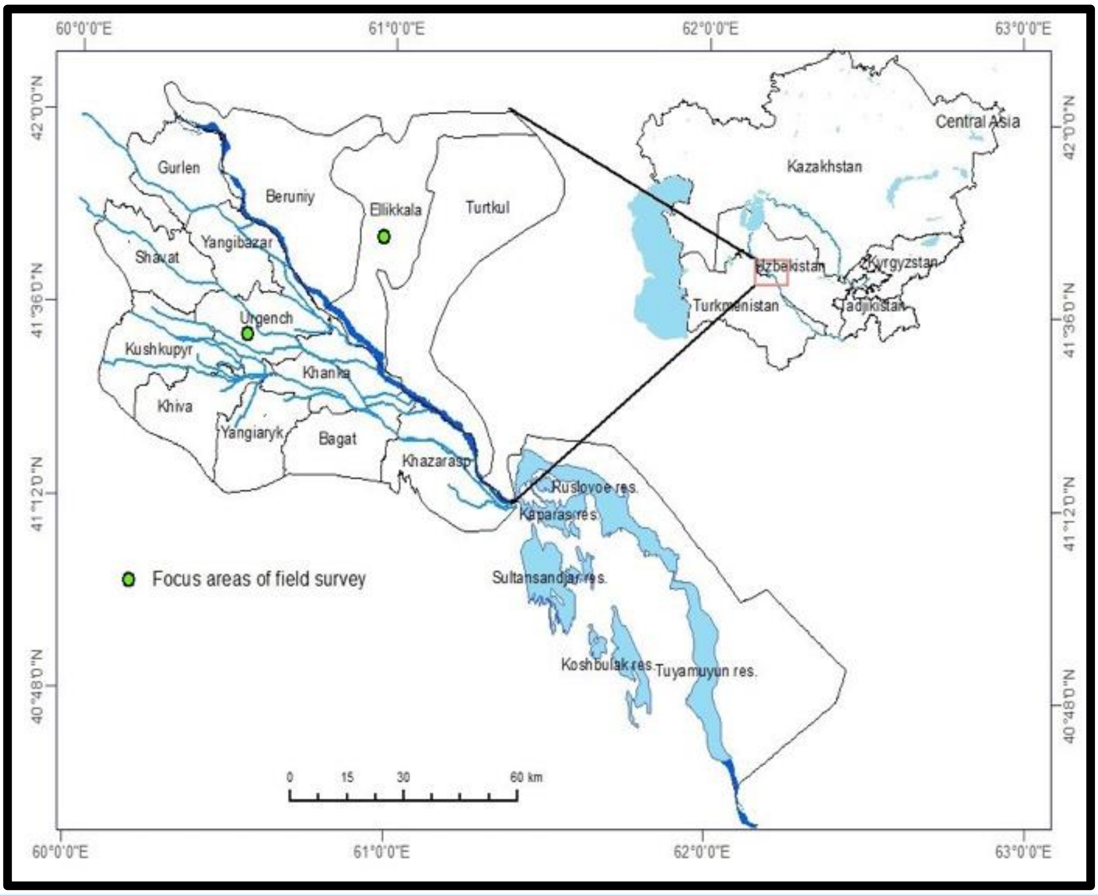

Fig. 1. Map of the study area (green dots show the regions: the Urgench district, Khorezm region, and the Ellikkala district, Republic of Karakalpakstan)

The aim of this research was to study the influence of diverse temperature and humidity conditions on the population dynamics of the Central Asian species *Eurydema maracandica* Oshanin, 1871 and *Eurydema wilkinsi* Distant, 1879 in the four seasons of the yearly cycle in the territory of the Lower Amu Darya River.

MATERIALS AND METHODS

Description of the study area

The territory of the Lower Amu Darya River consists of two provinces: the Khorezm region and the Republic of Karakalpakstan. The Khorezm region is located on the old Amu Darya River delta at approximately 100 metres above sea level. The Republic of Karakalpakstan is located in the northwest of the Khorezm region and is halved by the Amu Darya River. Karakalpakstan is bordered to the southwest by Turkmenistan and to the north by Kazakhstan and the southern part of the Aral Sea.

The Khorezm region's total area is approximately 630 000 ha, of which 275 000 ha is irrigated land. The Republic of Karakalpakstan has a territory of 167 500 km^2, most of which (86%) is the Kyzyl Kum Desert and the Ustyurt Plateau, while only 14% of the total overland area is located in the river dale.

The river dale generally inclines towards the Aral Sea and is sheeted mainly by ridges and sand dunes. The maximum dale elevations reach 100 m above sea level in the south and 54 m above sea level in the north. In the Amu Darya delta, there are many channels and small lakes with Tugai (riparian) forests, reed thickets and boggy areas (Khamraev, 2003).

Regional studies

We carried out a study of population dynamic monitoring and field observations of Cruciferae bugs during the years 2017-2019. The sites where specimens were collected were located in the Khorezm region and the Republic of Karakalpakstan, situated in the territory of the Lower Amu Darya River.

We studied the population dynamics of the species of cabbage bugs through direct observations, which were conducted in cabbage plantations at the “Odilbek” farm, Urgench district, Khorezm region, and at the "Zaripboy" farm, Ellikkala district, Republic of Karakalpakstan (**Fig. 1**).

Analysing the population dynamics on crop plants

A study on the number dynamics of cruciferous bugs surviving on cultivated cruciferous plants was carried out by means of periodic weekly observations of 100


Fig. 2. Gauze insulators on cabbage plants

cruciferous plants and inspection of cultivated plants, which were conducted along the diagonal of the fields. Information on the numbers of imagoes, larvae, pupae and eggs was recorded.

The species of bugs were observed from the end of March to November, more specifically, from the day of hatching until migration for the winter.

In this study, some materials were collected with a gauze insulator (60x60x70 cm and 75x75x115 cm, **Fig. 2**), and some insects were collected by hand, which involved carefully combing agricultural plants and the soil surface in the fields.

Under laboratory conditions, the influence of temperature on the rate of development of the cruciferous bugs was determined (according to Kozhanchikov, 1961). More specifically, the bug eggs and larvae were placed in thermostats with different temperatures.

Based on the data obtained, it was possible to derive a hyperbola of the development of the cruciferous bugs.

The developmental threshold was calculated by the formula of I.V. Kozhanchikov (1961):

$$C = \frac{t_1 T_1 - t_2 T_2}{t_1 - t_2};$$

where C - developmental threshold;

t - the number of developments; and

T - the temperature at which the development of the insect took place.

The thermal constant and the sum of the effective temperatures were calculated by the following formula:

$$t_1(T_1 - C) = X$$

where X - thermal constant;

t - the number of development days; and

T - the temperature at which development was completed.

The identification of wintering sites for cruciferous bugs was carried out as follows: in late autumn and early spring, wintering sites were searched.

Plant debris on the soil surface, soil cracks and the soil surface layer (to a depth of 5 cm) were examined, both near and in the fields that were occupied by cruciferous crops and along the edges of irrigation ditches, roads, and gardens.

Surveys were conducted on test sites measuring 0.16 m^2; the sites located in fields and gardens were surveyed in a checkerboard pattern around the fields, and the edges of roads and irrigation canals were surveyed in a linear manner. A total of at least 100 sites were inspected each year.

In this research, some materials were collected by a gauze insulator (Figure 2), and some insects were collected by hand, which involved carefully combing crop plants and the soil surface in the fields.

We used the method recommended by K.K.Fasulati (1971) to study the population dynamics of Cruciferae bugs on cultivated vegetables and on wild cruciferous plants.

We calculated the population dynamics by using the following formula:

P = 100n/N

where P — the population dynamics (%); N — the total number of examined specimens; and n — the specimens on which the species were found.

RESULTS

A study of the seasonal population dynamics of Cruciferae bugs on cultivated vegetables and on wild cruciferous plants has practical significance in nature since it allows us to implement the most rational and timely control measures against these pests. We carried out a study of population dynamic monitoring and field observations of Cruciferae bugs during the years 2017-2019, more specifically, from the day of hatching until migration for the winter (**Table 1**).

The developmental dynamics of the Cruciferae bugs on *Lepidium draba L.* during 2017-2019, which clearly demonstrates three waves with an increasing number of bugs from the end of March to October and *E. wilkinsi* Dist. was the prevailing species and constituted 53 to 65% of the insects in the garden (**Fig. 3**).

Accounting for the population dynamics of Cruciferae bugs in the garden of the “experimental field” showed that the maximal development of *E. maracandica* Osh. occurred in the third week of May at a temperature of 20.5°C and at a relative humidity of 35%. In the first week of June, the maximum number of *E. wilkinsi* Dist. specimens (845 specimens) was collected on 100 crops at a temperature of 22.4°C and at a humidity of 35% (**Fig. 3**).

Then, the numbers of these two bug species decreased and exhibited a second increase at the end of July and at the beginning of August. The change in the average weekly temperature in the third week of July

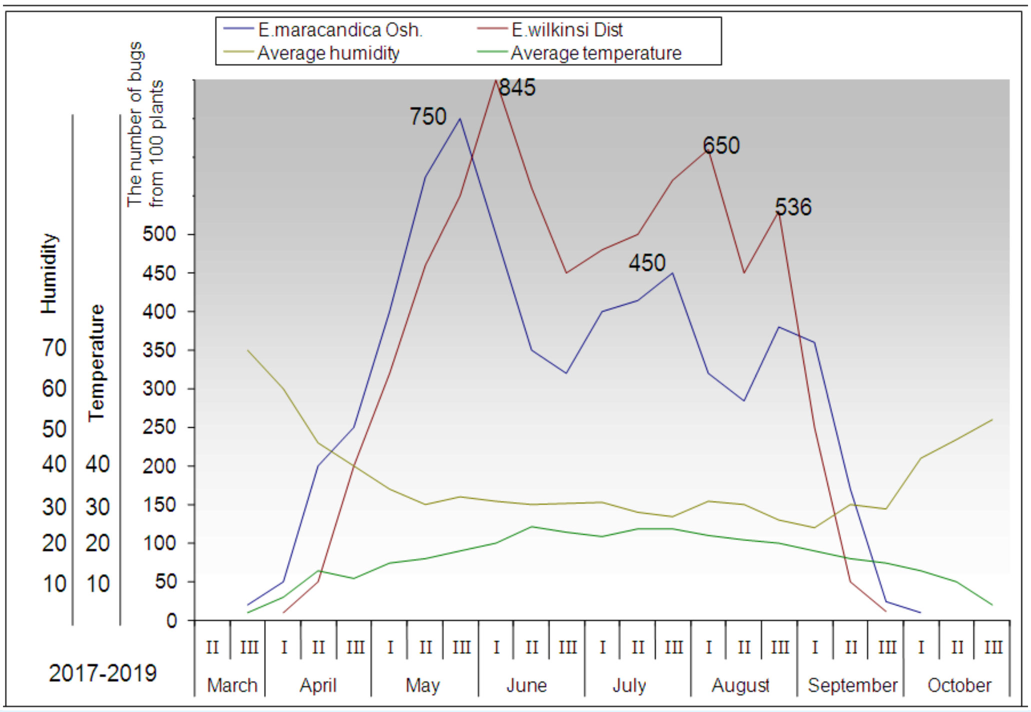

Fig. 3. The developmental dynamics of Cruciferae bugs on *Lepidium draba* L. during 2017-2019

Table 1. The hatching and winter migration dates of bugs in the Urgench district of the Khorezm region in 2017-2019

Year	Hatching date dynamics		Daily average air temperature per decade, in °C				Maximum air temperature per decade, in °C				Daily average air temperature, in °C	
	First appearance	Mass appearance	March I	April I	April II	April III	March I	April I	April II	April III	On the first day of flight	On the day of mass flight
						E. maracandica Osh.						
2017	21.III	03.IV	7.9	16.1	18.2	18.2	16.0	23.0	31.0	32.0	16.0	16.1
2018	20.III	31.III	17.5	16.1	14.3	20.9	30.0	27.0	25.0	37.0	16.9	17.1
2019	25.III	06.III	11.8	11.5	10.7	12.5	25.0	27.0	23.0	25.0	10.9	11.4
						E. wilkinsi Dist.						
2017	02.IV	09.IV	7.9	16.1	18.0	18.2	16.0	23.0	31.0	32.0	17.1	17.9
2018	01.IV	09.IV	11.6	16.1	14.3	20.9	30.0	27.0	37.0	37.0	12.9	14.5
2019	06.IV	12.IV	11.8	11.8	10.7	12.5	25.0	23.0	25.0	25.0	11.4	20.0

was 25.3°C, and in the first decade of August, it was 24.1°C; at this time, the relative humidity was 35 – 48%.

Increases in the population sizes of Cruciferae bugs were observed in a short period of time; then, at the end of August, the average weekly temperature was 21.1°C, with an average weekly relative humidity of 40%. In the years of this study, when observing some cruciferous bugs on early-sown crops, it became obvious that the populations of bugs on wild cruciferous crops quickly decreased and the populations on cultural crops rapidly increased (**Figs. 4** and **5**).

After vegetables or sown cabbages sprouted from the ground, imagoes of *E. maracandica* Osh. appeared on wild cruciferous plants for one or two weeks, and then they flew to the next cultural crops.

The result shows that *E. maracandica* Osh. had one developmental peak on cruciferous crops in the experimental field, which occurred at the end of May. *E. wilkinsi* Dist. showed two developmental peaks: the first large increase occurred at the end of May at a temperature of 20.5°C and a relative humidity of 35%, and the second large increase occurred in the second week of August at a temperature of 23.8°C and a relative humidity of 46% (**Fig. 4**).

The population dynamics of Cruciferae bugs on cabbage in the experimental field during the years 2017-2019 are shown in **Fig. 5**. From the results in **Fig. 5**, it can be seen that *E. wilkinsi* Dist. was not a prevailing species on cabbage, whereas *E. maracandica* Osh. was a prevailing species on cabbage, accounting for 66% of the total bugs. The ratio of different species of bugs indicated that *E. maracandica* Osh. caused a reduction in the yield of cabbage.

The development of Cruciferae bugs on cabbage in the field experiment performed in the Urgench district was characterized by the maximum population sizes of *E. maracandica* Osh. at the end of June and at the beginning of July. The intensive population growth of *E.*

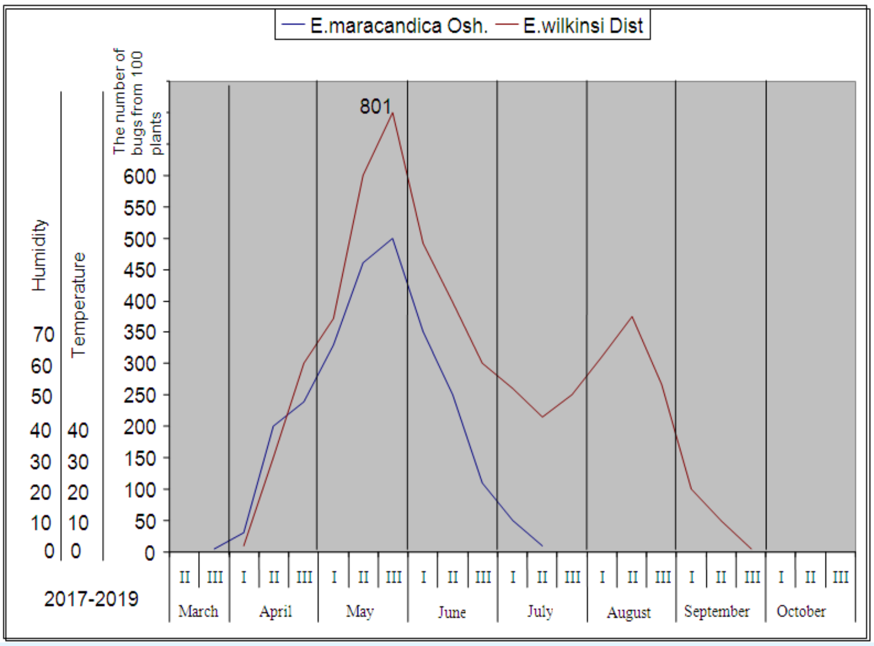

Fig. 4. The developmental dynamics of the Cruciferae bugs on wild cruciferous plants during 2017-2019

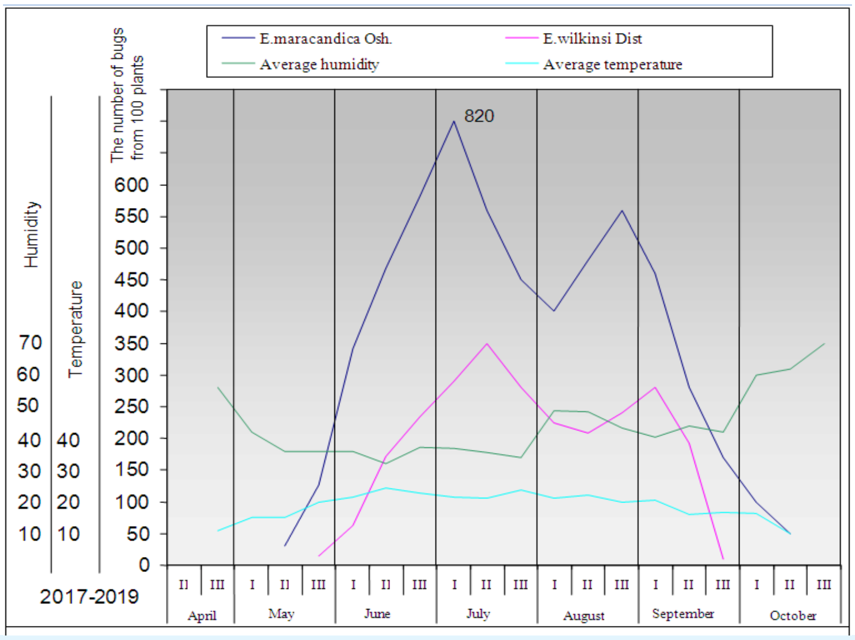

Fig. 5. The developmental dynamics of the Cruciferae bugs on cabbage during 2017-2019

wilkinsi Dist. began in July and reached a peak in the second week of July at an average weekly temperature of 24°C and a humidity of 39%.

The reduction in the number of bugs on cabbage that occurred after the maximum point was more gradual than that on cruciferous crops. After a slight reduction in the number of bugs, there was a sharp increase in their population size (**Fig. 5**).

This number reached a peak at the end of August; however, the last peak of the curve did not reach the level that was observed in July.

The development of Cruciferae bugs in 2017 on cabbage at the "Zaripboy" farm in the Urgench district was characterized by one maximum point in summer and one in autumn.

From the beginning of July, the number of Cruciferae bugs gradually increased. The maximum number of *E. maracandica* Osh. was observed at the end of the first week of July, and that of *E. wilkinsi* Dist. was observed in the middle of July (**Fig. 6**). In the second week of July, a reduction in the size of the bug population occurred. The small fluctuation in population size at the beginning of August was related to the harvest of early-sown cabbages. Subsequent development of Cruciferae bugs proceeded on the late-sown cabbages. The number of bugs on separate plants in the garden at the "Zaripboy"

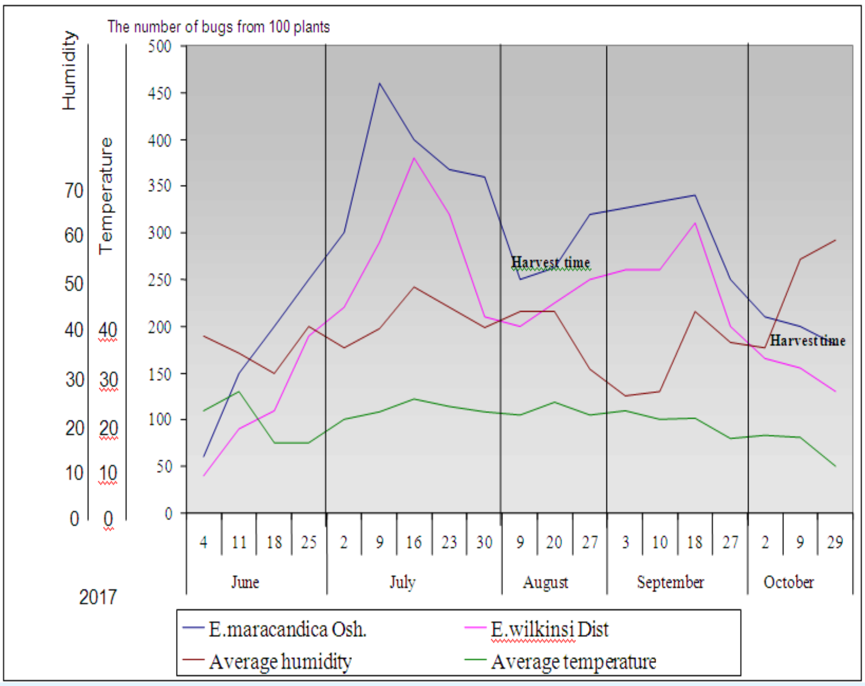

Fig. 6. The developmental dynamics of the Cruciferae bugs on cabbage at the "Zaripboy" farm during 2017

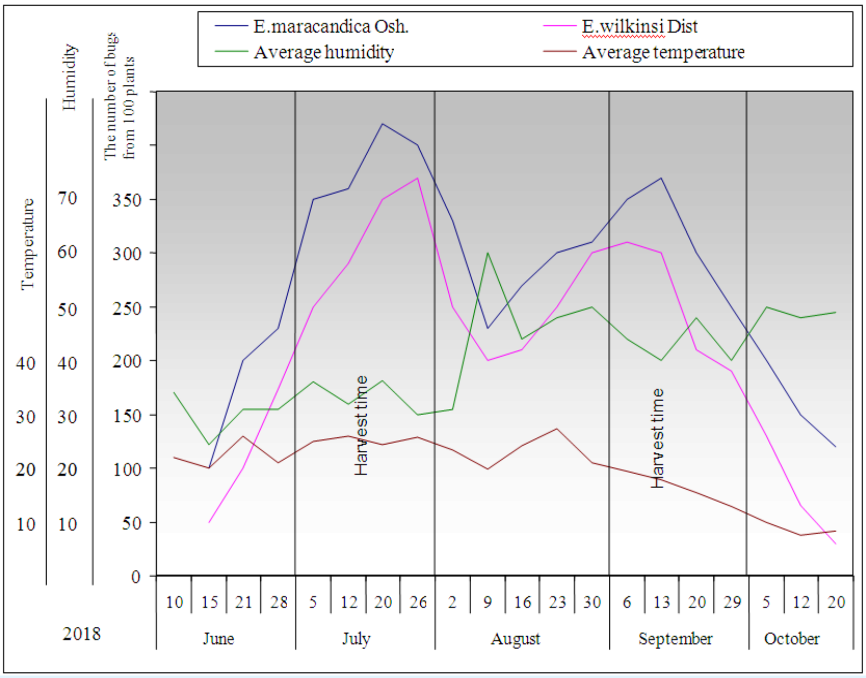

Fig. 7. The developmental dynamics of the Cruciferae bugs on cabbage at the "Zaripboy" farm during 2018

farm changed from 55 to 125 (on average, 90 specimens on one crop).

The development of bugs in 2018 also had two maximum indicators: the first was in the second week of July (at a temperature of 25°C and a relative humidity of 29%), and the second was a small increase in the first half of September (in the first week at a temperature of 19.6°C and a humidity of 45%) (**Fig. 7**).

A significant increase in population size was observed in summer, i.e., at the end of June (**Fig. 6**). The growing population of *E. maracandica* Osh. migrated until the second week of July, and that of *E. wilkinsi* Dist. migrated until the 26th of July.

A sharp reduction in the population size of the bugs in this field occurred from the end of July until the second half of August. Then, in the first half of September, there

Table 2. The lifespan of Cruciferae bugs at different stages of development

Species of bug	Generation stages of the species	Year	Lifespan of both sexes, days	
			Males	Females
E. maracandica Osh.	Overwintering	2017	70 (55-85)	85 (60-105)
	1 – Generation		60 (40-81)	75 (55-95)
	2 – Generation		45 (35-68)	60 (40-85)
	Overwintering	2018	68 (50-80)	84 (62-100)
	1 – Generation		55 (36-74)	73 (50-90)
	2 – Generation		42 (32-64)	58 (38-75)
	Overwintering	2019	78 (54-95)	86 (66-105)
	1 – Generation		54 (33-77)	74 (56-92)
	2 – Generation		44 (32-66)	58 (38-76)
E. wilkinsi Dist.	Overwintering	2017	60 (38-84)	82 (60-100)
	1 – Generation		52 (36-70)	60 (45-75)
	2 – Generation		38 (28-55)	45 (28-70)
	Overwintering	2018	62 (49-85)	80 (58-95)
	1 – Generation		50 (38-72)	57 (44-70)
	2 – Generation		40 (30-61)	46 (30-68)
	Overwintering	2019	64 (50-85)	82(58-98)
	1 – Generation		50 (38-72)	55 (44-72)
	2 – Generation		42 (30-63)	47 (30-69)

was an increase due to the appearance of the autumn generation of the bugs.

In 2019, the effect of the growing population of Cruciferae bugs on cabbage at the “Zaripboy” farm began at the end of June, where the highest peak occurred in the first week.

After some reduction, a gradual increase in the population of *E. wilkinsi* Dist. was observed from the beginning of August until the end of August, and the population size of *E. maracandica* Osh. reached its maximum point at the beginning of September. The reduction in the population size of bugs after the second maximum point occurred at a daily average temperature between 3.7 and 16.6°C with a daily average relative humidity between 53 and 68%.

The winter migration of bugs and the overwintering places of cruciferous bugs, which are found in Central Asia according to the literature, are not known.

The duration of the preparatory period for overwintering in autumn changes depending on seasonal weather conditions and on the nature of host plant species.

On the cabbage plantations, when the harvesting process was finished and lower leaves and stems of cabbage were left behind, favourable conditions were established for bug feeding. The most significant location for these bugs was cabbage plantations. The Cruciferae bugs themselves exhibited mass migration from the fields where the plants had stopped growing owing to drought or severe damage, regardless of harvest.

Mass migration of stage IV and V larvae and flying of bugs from severely damaged and drought-affected fields were observed in 2017 in the Ellikkala district of Karakalpakstan.

The larvae travelled along roads, crawled in ditches that separated the seed plots from the cabbage and migrated in large numbers to the seed cabbage. The duration of the preparatory period for overwintering occurred faster in the bugs that fed on the generative organs of cruciferous plants than in those that fed on other vegetative parts of the crops.

A lack of sunlight and cool and rainy weather delayed the preparatory period for overwintering of the pupae. The early-instar larvae may be particularly cold-sensitive, and during early frosts, larvae that did not develop into imagoes died.

According to data from the literature, the vast majority of bug species (almost 70%) overwinter in the imago phase. Only a few species (19.0%) overwinter in the egg phase, and only 4.3% overwinter in the larval phase (Saulich & Musolin, 2007).

After the mass hatching of bugs in the third generation, the bugs strongly overfeed, accumulating fat reserves for overwintering. Cruciferous bugs overwinter in the imago phase. The departure of bugs for the winter is extended: the first diapausing imago of *E. maracandica* Osh. appeared in late October, and diapausing imagoes of *E. wilkinsi* Dist. were observed from mid-September to the second week of October, depending on the temperature conditions in autumn.

The first bugs of *E. maracandica* Osh. that migrated for overwintering were found at the end of September in 2017 and 2018 and at the beginning of October in 2019. Those of *E. wilkinsi* Dist. were observed in the second week of September.

Both types of bugs develop in 3 generations. The large majority of *E. maracandica* Osh. and *E. wilkinsi* Dist. individuals overwinter as adults (in the third generation). The diapause of bugs at this stage has been studied in both males and females (**Table 2**).

It is known that in both sexes, diapause is accompanied by active growth of fat in the third-generation stage, changes in the biochemical composition of tissues, and then decreased oxygen consumption. We observed that in these two species, the males and females overwintered in various physiological states. For example, in *E. maracandica* Osh., diapause lasted from 95 to 105 days during the overwintering period, and in *E. wilkinsi* Dist., it lasted from 85 to 100 days (**Table 2**).

The Cruciferae bugs migrated to gardens, Tugai forests, and other places for winter diapause, where they could overwinter under dry leaves. They migrate away from cold damp places, explaining why the bugs did not remain in the cabbage plantation.

Overall, this study provided information on the population dynamics of Cruciferae bugs during the growing season on plants of the family *Brassicaceae* in the territory of the Lower Amu Darya River.

DISCUSSION

Our study revealed differences in the seasonal population dynamics of Cruciferae bug species.

Despite diverse perennial entomological studies, the dynamics of the number of cruciferous bugs are not well understood.

This was the first study to provide information on and evidence regarding the population dynamics of Cruciferae bugs in the territory of the Lower Amu Darya River.

The research was conducted from the period when bugs appeared in overwintering places until they left for overwintering.

The information on Cruciferae bug population dynamics over three years could provide insight into the periods when population size increases to a peak and decreases.

According to our observations on the hatching of bugs in the Urgench district of the Khorezm region in 2017-2019, the first appearance of *E. maracandica* Osh. occurred in the period from March 20 to 25 at an average daily temperature of 10.9 - 16.9°C. The mass appearance of this species occurred from March 6 to 3 April at an average daily temperature of 11.4 - 17.1°C. Observations of the species *E. wilkinsi* Dist. showed that the bugs first appeared from April 1 to April 6 at an average daily temperature of 11.4 - 17.1°C, and mass appearance occurred from April 9 to April 12 at an average daily temperature of 14.5 - 20.0°C. Flight in cruciferous crop fields takes place at an average daily temperature of 16.5 to 18.0°C, with a maximum of 20.5 to 22.4°C.

Experimentally, it was found that the dynamics of the number of cruciferous bugs in the fields depended on favourable weather conditions. In addition to weather conditions, field-related factors also influence the number of bugs. Thus, we can assume that the fluctuations in the number of bugs are determined in a complex manner.

Based on the analysis of observed abundances on *Lepidium draba* L., it was established that the maximum development of *E. maracandica* Osh. occurs in the third week of May, at a temperature of 20.5°C and a humidity of 35%, and that of *E. wilkinsi* Dist. occurs in the first week at a temperature of 22.4°C and a humidity of 35% (**Fig. 3**).

Concerning the observations on weedy cruciferous plants, *E. maracandica* Osh. had one peak of development at the end of May, and *E. wilkinsi* Dist. had two developmental peaks: at the end of May at a temperature of 20.5°C and a humidity of 35% and in the second week of August at a temperature of 23.8°C and a humidity of 46% (**Fig. 4**).

The study of the dynamics of the number of cruciferous bugs on cabbage showed that the maximum development of *E. maracandica* Osh. occurred in late June and early July, and in the species *E. wilkinsi* Dist., it began in July and reached a maximum point in the second week of July with an average weekly temperature of 24°C and a humidity of 39%.

The most tumultuous period for the population of bugs began when the daily average temperature changed from 23°C to 29.5°C and the daily average air humidity changed from 24 to 59% (**Fig. 6**).

The highest relative humidity of air was between 51 and 76%, and the average weekly temperature changed from 3 to 11.2°C, leading to a reduction in the number of bugs until they completely disappeared at the end of October.

If we compare the population dynamics of *E. maracandica* Osh. on cabbage in the field of the “Zaripboy” farm with the population dynamics of *E. wilkinsi* Dist. in the same location, we can see that between the Cruciferae bugs, *E. maracandica* Osh. was always the prevailing species, and the dynamics of the two species of bugs were temporally similar. These results may also apply to some extent to all Cruciferae bugs of subgenus *Eurydema* Lap.

According to our studies, which were conducted in the period 2017–2019, it was found that under the conditions of the territory of the Lower Amu Darya River, the longest life expectancy of bugs occurred in the third generation (overwintering) of females of *E. maracandica* Osh. (ranging from 95 to 105 days). Females of *E. wilkinsi* Dist. showed a shorter life expectancy (ranging from 85 to 100 days) than *E. maracandica* Osh (**Table 2**).

Our study showed that the main reasons for the increase in the number of cruciferous bugs were the influences of various factors, such as temperature, humidity and food supply. These factors regulate the timings of hatching, migration and overwintering of cruciferous bugs.

Over the years of research, it was revealed that the timing of overwintering and preparation for wintering are two important periods in the development of bugs. It was determined from the results that the degree of preparedness of the new generation of bugs for overwintering mainly depends on their previous nutrition, and the life expectancy of cruciferous bugs depends on the stage of development of the generation.

In conclusion, knowledge of the impact of climate on the seasonal development of these two species may help clarify their taxonomic positions, seasonal adaptations, and seasonal life cycles in the territory of the Lower Amu Darya River.

ACKNOWLEDGEMENTS

The authors express their warm gratitude to Professor Khamrayev Aloviddin Samsiddinovich for checking the material, to Dr. Murod Sultonov for the map of study area and sampling locations and to the team from the Institute of Zoology of the Academy of Sciences of the Republic of Uzbekistan for their assistance.

REFERENCES

Abdullayev I, Matyakubov Z, Doschanova M, Abdullayev I (2020) The study of population and colony interrelation of Anacanthotermes Turkestanicus (Isoptera: Hodotermitidae) In Khorezm oasis. Journal of Critical Reviews. 7(2): 387-390. http://dx.doi.org/10.31838/jcr.07.02.74

Adepoju, A. O., & Osunsanmi, O. (2018). Gender Differentials in Labour Market Participation of Rural Households in Non-Farm Activities in Oyo State, Nigeria. International Journal of Sustainable Agricultural Research, 5(4), 85-95.

Djaman K, Higgins Ch, O'Neill M, Begay Sh, Koudahe K et al. (2019) Population dynamics of six major insect pests during multiple crop growing seasons in Northwestern New Mexico. Insects. 10(11): 1-16. http://dx.doi.org/10.3390/insects10110369

Embaby ESM, Lotfy DES (2015) Ecological studies on Cabbage pests. International Journal of Agricultural Technology. 11(5): 1145-1160.

Fasulati KK (1971) Field study of terrestrial invertebrates. Moscow: High school (in Russian).

Johnson KP, Dietricha ChH, Friedrich F, Beutel RG, Wipfler B et al. (2018) Phylogenomics and the evolution of hemipteroid insects. Proc. Natl. Acad. Sci. 115(50): 12775–12780.

Khaliq A, Javed M, Sohail M, Sagheer M (2014) Environmental effects on insects and their population dynamics. J. Entomol. Zool. Stud. 2(2): 1-7.

Khamraev ASh (2003) Soil organisms and entomocomplexes in Khorezm and Karakalpakstan (Uzbekistan). Tashkent. ZEF Work Papers for Sustainable Development in Central Asia. №6.

Khan MMH, Talukder S (2017) Influence of weather factors on the abundance and population dynamics of Spodoptera liture F. and Pieris brassicae on cabbage. SAARC J. Agri. 15(1): 13—21

Lord CC (2004) Seasonal population dynamics and behaviour of insects in models of vector-borne pathogens. Physiol. Entomol. 29(3): 214–222. http://dx.doi.org/10.1111/j.0307-6962.2004.00411.x.

McLaren GF, Pottinger RP (1969) A technique for studying the population dynamics of the cabbage aphid Brevicoryne brassicae (L.). N.Z.J. Agric. Res. 12(4): 757–770. http://dx.doi.org/10.1080/00288233.1969.10421225

Numata H, Nakamura K (2002) Photoperiodism and seasonal adaptations in some seed-sucking bugs (Heteroptera) in central Japan. EJE. 99(2): 155–161. http://dx.doi.org/10.14411/eje.2002.023

Patra S, Dhote VW, Alam SKF, Das BC, Chatterjee ML et al. (2013) Population dynamics of major insect pests and their natural enemies on cabbage under new alluvial zone of West Bengal. J. Plant Prot. Sci. 5(1): 42-49.

Pilkay GL, Reay-Jones FPF, Toews MD, Greene JK, Bridges WC (2015) Spatial and temporal dynamics of stink bugs in southeastern farmscapes. J. Insect Sci. 15(1): 23–23. http://dx.doi.org/10.1093/jisesa/iev006

Plotnikov VI (1926) Harmful Insects on agricultural plants of Central Asia. Tashkent (in Russian).

Puja D, Sabiha KA (2016) Field study of population dynamics of major insect pests and their natural enemies on cauliflower of Ajmer district. Int. J. Agric. Sci. 8(53): 2642–2645.

Razzakov KB, Abdullaev II, Saparboev KO, Allaberganova MM (2019) Natural entomophages of brevicoryne brassicae (L.) (Hemiptera: Aphididae) in Uzbekistan. Int. J. Biol. 11(4): 42–50. http://dx.doi.org/10.5539/ijb.v11n4p42

Saeed M, Shoukat RF, Zafar J (2017) Population dynamics of natural enemies and insect pest in different Brassica oleracea (cabbage) growing seasons with different production systems. J. Entomol. Zool. Stud. 5(6): 1669–1674.

Samra S, Ghanim M, Protasov A, Mendel Z (2015) Development, reproduction, host range and geographical distribution of the variegated caper bug Stenozygum coloratum (Hemiptera: Heteroptera: Pentatomidae). EJE. 112(2): 362–372.

Sangle PM, Satpute SB, Khan FS, Rode SN (2015) Impact of climate change on insects. Trends in Bioscience. 8(14): 3579–3582.

Saulich AH, Musolin DL (2007) Four seasons: Diversity of seasonal adaptations and ecological mechanisms controlling seasonal development in true bugs (Heteroptera) in the temperate climate. In: Stekolnikov AA (ed.) Adaptive strategies of terrestrial arthropods to unfavourable environmental conditions: A collection of papers in memory of Professor Viktor Petrovich Tyshchenko (Proceedings of the Biological Institute of St. Petersburg State University. 53: pp. 25–106. (in Russian, with expanded 4-page English summary).

Staaf D, Zeidberg L, Gilly W (2011) Effects of temperature on embryonic development of the Humboldt squid Dosidicus gigas. Mar. Ecol. Prog. Ser. 441: 165–175.

Yakhontov VV (1953) Pests and control of agricultural plants and products of Central Asia. Tashkent (in Russian).