Diurnal and seasonal rhythm of the melon ladybird - Epilachna chreysomelina (*Coleoptera, Coccinellidae*) activity in the conditions of the Kashkadarya region of Uzbekistan

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Abstract. The paper describes that the first signs of beetle movement after night rest in the month of May occur at 8 am at an air temperature of about 20^0C. Increasing the temperature to 22-29^0C tends to increase their mobility. By 11 a.m., when the air temperature reached 34^0C, almost all the beetles went into the shade, into the lower part of the plants, where they remained immobile until almost 4 p.m. After 17 h. the air temperature dropped to 33^0C, by 20:00 to 20^0C. By this time, only a small part of the beetles remained active. In summer, the motor activity of beetles intensifies at 8-10 am, when the air temperature rises to 34^0C. From 11 a.m. to 6 p.m. at a temperature of 34-42^0C, humidity 34-40%, the beetles were placed in the shade and were inactive. In autumn, after night cooling, the air temperature increased later and the movement of beetles began at 11 am At noon hours (between 12-4 pm) at an air temperature of 20-25^0C. and humidity 55-60%, beetle activity was maximum. In summer, beetles actively feed in the morning (from 8-9 a.m.) and evening (from 19 to 22 p.m.) hours, when the air temperature was 26-33^0C. In the middle of the day (13-16 hours) and at night (3-5 hours), their feeding activity is somewhat reduced. The intensity of beetle feeding in the autumn months increases from 9 a.m. and reaches a maximum by 11-13 a.m., and after 5 p.m. it begins to decrease and almost stops at 9 p.m. in the evening.

1 Introduction

In the biology of the melon ladybird, like other representatives of the class of insects in general, two types of fundamentally different states are clearly distinguished: active vital activity and rest. Active life is characterized by movement, nutrition, reproduction and development. During active life, there is an increase in the number of individuals in populations and their dispersal. And during the rest period, it is quite typical to be in a state

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of suppression or absence of locomotor activity, nutrition, in some cases, inhibition of gas exchange, digestion, and development. The issue of diurnal and seasonal rhythms of behavior and physiological processes in different species of insects has been studied by a number of authors [1-8].

Though this kind of research on the melon ladybird, which is a malicious pest of melons in the south of Uzbekistan, has not been carried out yet. The purpose of this work was to determine the diurnal and seasonal activity in the behavior of the melon beetle depending on the environmental conditions, because data of this kind, in addition to theoretical, is of practical importance with the correct organization of measures to exterminate this pest.

2 Materials and Methods

The study in the behavior of melon ladybirds was carried out during the summer season of 2015-2016 at the areas around Kuchkak and Gubdin of the Karshi district of the Kashkadarya region and at the Department of Physiology of Karshi State University. The daily and seasonal (locomotor, nutritional, etc.) activity of the melon ladybird was determined in different seasons of the year in different generations, depending on environmental conditions. To determine the locomotor activity of the melon ladybird, the number of moving individuals in natural conditions was counted on testing areas. The moving melon beetles were counted on each $1m^2$ of melon plantations, on melon leaves. Melon bugs in the shade under leaves or under lumps of soil in a motionless state were considered as inactive. The daily activity of the beetles was monitored from 6 am to 8 pm, during the time from May to November, while the air temperature was always under control checking hourly using a soil thermometer. The daily feeding rhythm was determined in overwintered individuals, beetles of the I and II generations on the 10^{th} day of feeding, as well as during the pre-winter preparation period. Observations were carried out on females and males (10 each) during the day (from 9 a.m. to 9 a.m. of the next day). The beetles were taken peer 2 copies, placed in glass jars (0.5 litre) with fresh melon leaves. The leaves were replaced with fresh ones every 2 hours. The area of the leaf eaten by the beetles was determined by imposing the damaged leaf on graph paper. There was a 10 times-repetition in each variant of the experiment. The air temperature was recorded during the experiment.

3 Results and Discussions

3.1 Diurnal and seasonal rhythm of the locomotor activity

The research on the diurnal and seasonal rhythm of the locomotor activity of the adult melon ladybird has shown that the main factors determining the cyclicity of the locomotor activity of this insect in nature are temperature, humidity and lighting. Due to our observations, the first signs of beetle movement after night rest in May were noted at 8 am at an air temperature of about 20°C (Fig. 1).

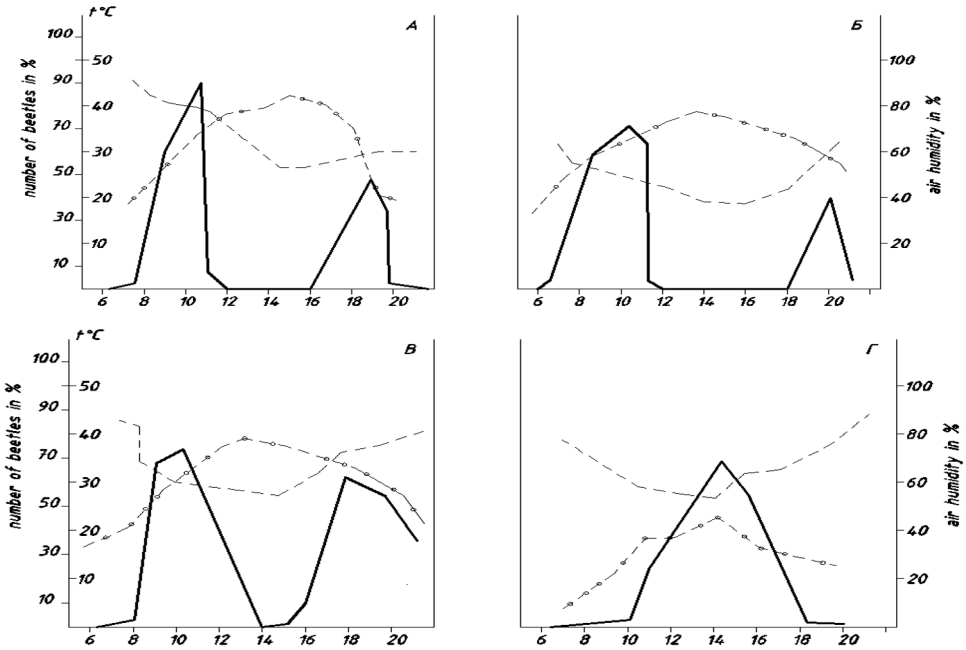

Fig. 1. Distribution of diurnal activity of a melon ladybird.
conditional designation: _____ - number of beetles, in %; –x–x – - air temperature, in ºC; – – – - air humidity, in%. A - May /II d./; B-July /II d./; C-September /II d./; D - October.

Increasing in temperature up to 22-27°C led to an increase in their mobility, they began to crawl along the stems and leaves of the melon. By the further heating of the air (at about 9 a.m., up to 29°C), a large number of beetles were noticed being actively in the movement along the lower part of the plants. At this time, they were observed in copulating and laying eggs on the lower surface of the leaves. From 9 to 10 a.m., when the air temperature rose to 20-32°C, the beetles were actively feeding, moving along the melon stalks, copulating and flying up to several meters. A small part of them were at rest in the shade on the back of the leaves. By 11 a.m., when the air temperature reached 34°C, almost all the beetles went into the shade, to the lower part of the plants, where they were stationary until almost 4 p.m. The air temperature in the midday hours reached 34-40°C, and the air humidity reached 50-60%. After 5 p.m. the air temperature dropped to 33ºC, by 10 p.m. to 20ºC. By this time, only a small amount of the beetles remained active. The results of observations in the daily locomotor activity of the melon ladybird, obtained by us during the months of June and August were very close, and therefore it is possible to consider the generalized data only for the month of July. In summer, by 7 a.m. the air temperature rose up to 20°C. The morning activity of beetles began for an hour earlier than in May. It reached its maximum value at 8 a.m. up to10 a.m., when the air temperature rose to 34°C, and the air humidity was in the range of 40-50%. During the period of time from 11 a.m. to 6 p.m. at a temperature of 34-42°C, humidity of 34-35%, the beetles moved in the shade and were inactive. The evening drop in temperature (to 33°C and below) in summer was noted somewhat later, and the activity of beetles recommenced later. In September, the air temperature decreased slightly compared to the summer period. The morning activity of the beetles began at 8 o'clock, when the air temperature rose to 21°C and the humidity rose to 68%. It reached its maximum value at 9a.m. up to12p.m. at a temperature of 34°C and air humidity of 50-70%. From 1p.m. to 3 p.m. the beetles were inactive. The air temperature at that time was 35-40°C while humidity reached 60%. After 4 p.m. the temperature dropped to 34°C, by 6

p.m. - to 25°C. Beetle activity recommenced again. In autumn, after nighttime cold snaps, the air temperature in the morning increased even later and the movement of the beetles began at 11a.m. In the midday hours (between 12 p.m. and 4 p.m.), at an air temperature of 20-25°C and a humidity of 55-65%, the activity of beetles reached its maximum. From 4 p.m., with a decrease in air temperature (below 20°C), the activity of beetles decreased and from 6 p.m. up to 10 a.m. of the next day they remained inactive. The data obtained by us show a distinct rhythm of the daily and seasonal motor activity of the melon ladybird, manifested in a regular change in the periods of activity and rest, due to the corresponding changes in the air temperature. The optimum temperature for the movement of the melon ladybug is in the range of 25-30°C. In different seasons of the year, the diurnal rhythm of the locomotor activity of beetles changes significantly. In May, the high activity of ladybirds reaches two maxima: morning – from 9 to 10 a.m., and evening – from 5 to 7 p.m. In the hottest summer period, the peak of maximum activity takes place at around 8 to10 a.m. in the mornings and 6 to 7 p.m. in the evenings. The period of daytime rest lasts from 11 a.m. to 16 p.m. The September maxima of the daily rhythm of motor activity: the morning one – from 10a.m. to 12p.m. and the evening one – from 5.p.m. to 7 p.m. with a period of relative rest from 1 p.m. to 3 p.m. The Autumn maximum reaches between 12p.m. and 4 p.m. Consequently, in then periods of May, July and September, the locomotor activity of the melon ladybird has a bicyclic character, while in October, with the decrease in air temperature, it is monocyclic.

3.2 Diurnal and seasonal rhythm of nutrition

The intensity of feeding of the melon ladybird during the day and the season is unequal (Fig. 2).

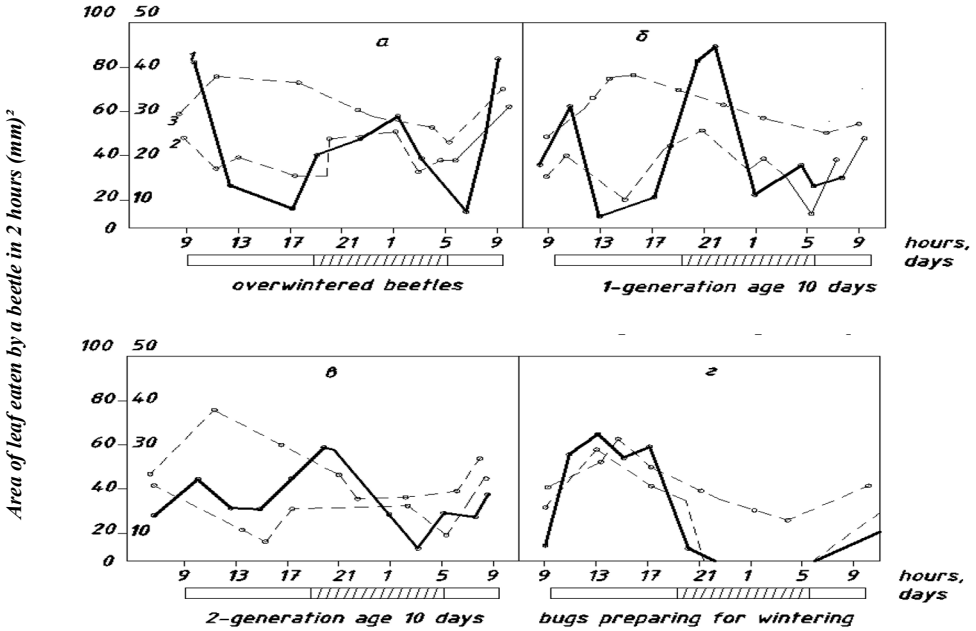

Fig.2. Diurnal rhythm of nutrition of imago *Echrysomelina.*
1. - females. 2. - males. 3. - t. °C air.

The daily food activity of overwintered individuals and the beetles of the 1and 2 generations for 10 days was almost the same. The beetles were actively feeding in the

morning hours (8 to 9 a.m.), when the air temperature was 26-33°C. With an increase in air temperature up to 35°C and higher by noon, the intensity of feeding decreased markedly. The second peak of the increase in the intensity of feeding was observed at 9 p.m. to 10 p.m. when the air temperature was 25-35°C. After midnight, food consumption for beetles markedly decreased, becoming more active at dawn and reaching its maximum by 8 to 9 a.m. The amplitude of daily feeding activity of overwintered beetles reaches its highest point in the morning hours: in beetles of the 1 and 2 generations, for 10 days of feeding, in evenings (Fig. 2 a, b). Consequently, in summer, beetles feed especially actively in the mornings (from 8 to 9 a.m.) and in the evenings (from 7 to 10 p.m.) In the middle of the day (from 1 to 3 p.m.) and at night (3 a.m. to 5a.m.), their feeding activity decreases slightly. In October, the beetles prepare for wintering and, with a cold snap, they hide under cover. Their daily food activity during this period has a slightly different character than in summer. The feeding intensity of beetles in the autumn increases from 9 a.m. and reaches its maximum by 11a.m. to 1p.m. The high feeding activity persists until 5 p.m., after which it begins to decrease and in the evening at 9 p.m. it almost stops. This type of feeding activity is associated with a decrease in air temperature at the end of the growing season, especially at night (up to 10-15°C). Females consume more food than males. For example, overwintered female melon ladybirds consume on average 195 mm^2 of melon leaves from 8 to 10 a.m., and 138 mm^2 from 7 to 9 p.m., while males, and respectively consume about 134 and 107 mm^2 leaves. At noon, females are at rest more often than males. For example, in the middle of the day (from 1 to 3 p.m.), the area of the eaten leaf in females is 37 mm^2, while in males it is of 85 mm^2. The most intensive feeding of beetles is observed in warm sunny weather. In the warm summer months, beetles feed even at night. Thus, the data on the daily and seasonal feeding activity of the melon ladybird show that in the conditions of the south of Uzbekistan in summer, beetles feed most actively in the morning and evening hours. In the middle of the day and after midnight, their food consumption drops sharply. During preparation for wintering, the food activity of beetles is highest in the middle of the day. Daily fluctuations in the intensity of food consumption by beetles depend mainly on the temperature of the external environment, which determines the level of metabolism among insects. In the summer period of the overwintered beetles of the first and second generations, two maxima of feeding are observed during the day in the morning and afternoon hours, i.e. nutritional activity is bicyclic. In October, under the influence of nighttime cold snaps, monocyclic food activity forms in them. Our observations of the oviposition rhythm of the melon ladybird show that the oviposition rhythm is also determined by the temperature and humidity of the environment. The melon ladybirds active in daily hours lay eggs mainly during the day. Oviposition of the beetle in natural conditions occurs after the air is heated up to 24-30°C. In the hot summer period, the female lays eggs from 8 to 11 a.m. and in the evening, from 4 p.m. to 6 p.m. On cool spring days, the oviposition starts at about 12 p.m. and lasts till 3 p.m. Larvae hatching from eggs, the emergence of young beetles from cocoon occur in the morning spring hours at an air temperature of 24-30°C. Overwintered beetles ascend from hibernation in the middle of the day, i.e. during the hours when the heating of air and soil reaches its maximum.

The materials obtained by us allow us to establish a quite distinct diurnal and seasonal rhythm of activity in the melon ladybird. It manifests itself in a certain regular change in the periods of an active and inactive state and reflects changes in abiotic environmental factors. Thus, considering the reaction of beetles to changes in environmental conditions in the summer, we can distinguish two periods of activity and two - inactive states. The first, morning period of activity is observed in the warm season when the air temperature rises above 20ºC. It manifests itself in the positive phototaxis of beetles, their movement towards warmer places and the activation of nutrition. The period of inactivity, due to thermal depression, begins with an increase in air temperature up to 35-40°C. Together with the

weakening of solar radiation in the afternoon and a drop in temperature below 35°C, a second period of daily activity takes its start. At this particular period of time, the beetles move towards light and warm places, slide onto the plant and feed vigorously. In October, melon ladybird is only capable on one maximum of activity from 12 to 4 p.m. Consequently, melon ladybird is characterized by a monocyclic nature of activity in October, while it has a biocyclic nature of activity during the period from May to September. A drop in air temperature below 20°C and the rapid darkness are a signal to stop movement and fall into an inactive state, which continues until the morning of the next day. This distinct rhythm of the daily and seasonal existence of beetles is a consequence of the continuous interaction of exogenous environmental factors and endogenous factors of the organism. Without remaining constant and changing consistently and naturally, it manifests itself externally in the periods of beetle life described above. It is widely known that the behavior of insects at any time expresses the desire of the organism to coordinate its state with the influence of the environment, i.e. adapting to them. Adaptation of insects, including beetles, to the changing conditions of the external environment allows them to more or less satisfy their vital needs. Therefore, the life of beetles throughout the day and the season of the year is a combination of movements in the direction of heat, light and food, close to the same individuals, alternating with periods of inactive state. In cases of immobility of beetle individuals (night or day), determined by a temperature shock, they fall into depression, a general suppression of all physiological functions of the body. At these moments, the vital activity of the body is suppressed, irritability is reduced or even completely absent. The state of rest, under optimal conditions, is characterized by a high tension of vitality, readiness at any time in the event of unfavorable influences, to switch to vigorous activity. This state is usually very short and is mostly replaced by intense activity. Long-term observations show that the variable temperature of the environment, close to the natural daily cycle temperature, is usually more favorable for insects with a daily rhythm of activity. It accelerates development, reduces mortality and increases resistance to extreme temperatures. While considering the reasons for the daily activity of beetles, as noted above, in addition to exogenous environmental factors, there are endogenous ones, determined by physiological changes occurring in the body. Compilation of the frequency of activity of insects with the rhythm of respiration showed that periods of activity in time coincide with an increase in oxygen intake. It was established that oxygen consumption depends on locomotor activity in the beetles *Opatrum sabulosum L., Anatolica erimita* Sb., *Pseudophus pubescens* Mull., Tenebrio molitor [9]. According to this author, for daytime forms the maximum breathing energy was noted at noon, for nighttime forms - between 1 and 4 a.m., and for crepuscular ones - at dawn and in the evening after sunset, i.e. during the active state of insects. Also a number of authors noted a direct relationship between the rhythm of respiration as well as the locomotor and food activity of insects in different species of insects [10-13]. Thus, our data indicate that there is a certain rhythm in the existence of the studied beetles, which manifests itself a change in active and inactive states, which depends on the correlative changes in the physical factors of the environment and the physiological state of insects.

4 Conclusions

The results of the research allow us to draw the following conclusions:

1. The data obtained reveal a distinct rhythm of the daily and seasonal motor and food activity of melon beetles, manifested in a regular change in the periods of activity and inactivity (rest) under the influence of the ambient temperature.

2. The temperature optimum for the activity of the melon ladybug is in the range of 25-33^{o}C.

3. In spring, the high locomotor activity of beetles has two maxima: the morning one during the period from 9 a.m. to 10 a.m. and the evening one from 5 p.m. to 7 p.m. In the hottest summer period, as the maximum activity of beetles, it moves in the morning (from 8 to 10a.m.) and in the evening (from 7 to 8 p.m.). The period of daytime rest takes place between 11 a.m. and 4 p.m. In autumn (October) – during the period of the vegetative season, there is only one maximum of activity per day, which is between 12p.m. and 4 p.m.

4. In the south of Uzbekistan, in summer, beetles feed most actively in the morning and evening hours; in the middle of the day and after midnight, food consumption decreases sharply. During pre-winter preparation, the feeding activity of beetles reaches its peak in the middle of the day.

5. In case of using chemicals against this pest, it is necessary to take into account the diurnal and seasonal rhythm of its activity.

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