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Hasanova Sabina Shahruddin
Institute of Zoology of Azerbaijan National Academy of Sciences, Passage 1128, Block 504, Baku 1073, Azerbaijan

Ahmadov BA
Institute of Zoology of Azerbaijan National Academy of Sciences, Passage 1128, Block 504, Baku 1073, Azerbaijan

Correspondence
Hasanova Sabina Shahruddin
Institute of Zoology of Azerbaijan National Academy of Sciences, Passage 1128, Block 504, Baku 1073, Azerbaijan

Factors influencing the reproduction of the seven-spot Ladybird (*Coccinella Septempunctata*, Coleoptera: Coccinellidae)

Hasanova Sabina Shahruddin and Ahmadov BA

Abstract
The paper presents the detailed information about behavoir of *Coccinella septempunctata* (C-7), existance of reproductive diapause, fertilisation, effect of number of aphids (*Aphis gossypii Glov*.) on reproductivity of C-7, response of larvae and adults of C-7 to number of pests, and causes of cannibalism. It was experimentally established that the absence of aphids in the diet of C-7 is the only factor inducing diapause (26-27 ^{0}C). At a temperature of 26-27 ^{o}C oviposition occurs continuously for 30-45 days, and then it is gradually weakened until the complete cessation. If beetles deny access to the aphids, they first eat the eggs laid by them, and then completely stop breeding.
The productivity of coccinellids was directly proportional to the number of aphids. The next year productivity of the C-7 actually depends on the weight of hibernating beetles and there was right proportional dependence between them.

Keywords: *Coccinella septempunctata*, *Aphis gossypii*, behavioral abilities, reproductivity, cannibalism

1. Introduction
Biological control is the main and successful part of the integrated pest control. The role of the predators in the biological pest control is great. The family Coccinellidae includes many important predators of insect pests. About 6000 species of Coccinellidae have been described around the world [1]. The coccinellids are the first agents used for biological pest control [2]. Therefore, the biological control should be grateful to these beetles for its success.
It should be noted that for biological control programs against pests the agents used to be acclimatize from the other countries. But now a lot of attention is paid to studying of bioecological peculiarities and effectivenes of native species for further using them in biological control [2].
Integrated pest manegement requires cheep and simple ways of artificial rearing of entomophags. Therefore one of the main challenges facing the experimental entomology is the development of optimal mode for artificial rearing of entomophags. For this purpose studying of behavioral abilities of species selected for biological control and factors influenced the reproductive abilite of females of these species is of great important.

2. Material and Methods
Beetles used in experiments were collected from the wild in the 2015-2016. Overwintered beetles were reared in the laboratory at a temperature of 25 ^{0}C and 65-75% humidity and used in experiments. They were fed on cotton aphid (*Aphis gossypii* Glov.) which was reared on watermelon (*Citrulus vulgaris*).
To study the behavioural reactions of seven-spot ladybird to number of pest in laboratory conditions 30; 50; 100; 200 and 500 aphids were located on host plant (watermelon) growed in 5 flowerports. One pair of copulated coccinellids (1♂+1♀) were located on each host plant. The experiments were carried out in July-August, under natural light, at 27-28 ^{0}C. The relative humidity was 50-65%. The experiments were repeted three times. Daily observation was carried out. The present study was carried out experiments to determine the relation between body weight and productivity of the C-7.
For this purpose we collected 50 overwintered beetles in Hovsan settlement in March 28-29, 2016. Beetles were weighed on electronic scales and divided into 3 groups. Each group contained 5♂+5♀.

Beetles were transferred on the plants growing in the flowpot and carrying necessary amount of aphids (more than 50-60 specimen) on them. Experiments were carried out at 25-26 ^{0}C. Feeding and egg number control was carried out every day. Experiments were carried out from early April till the end of May.

Experiments carried out at the laboratory of Ecology and Physiology of Insects of the Institute of Zoology of the National Academy of Sciences of Azerbaijan.

3. Results and Discussion

The most favourable and effective food for *C.septempunctata* was *Aphis craccivora* K., *A.gossypii* G., *A.fabae* S. and other aphids. Daily food and reproductive rate of C-7 depends on the temperature. The favourable temperatur regimen for it was 15-35 ^{0}C. The temperatures of below or upper effect negatively on development of pupae and larvae. The adults of *C.septempunctata* were usually gathered for hibernation in the edges of sown areas, under the litter and bark. They can even hibernate in the cane trunk. The coccinellids began to prepare for hibernation from September by accumulatinge the required amount of fat and glycogen [3].

If the air temperature was high during hibernation it has a negative effect on larvae and adults. The larvae are activated and consume all accumulated nutrients. Therefore the level of egg-laying in females decreases and males become very weak and die shortly after hibernation.The level of cannibalism in coccinellids was very high. Even female can eat its eggs at food shortage. Maybe it is a biological requirement to provide next olviposition in favourable condition and in favourable time.

The present study observed the coccinellid larvae to be more voracious. During experiments the just hatched larvae feeding on the eggs or little instar (sometimes older instar) larvae of other coccinellids were recorded (Fig. 1a,b).

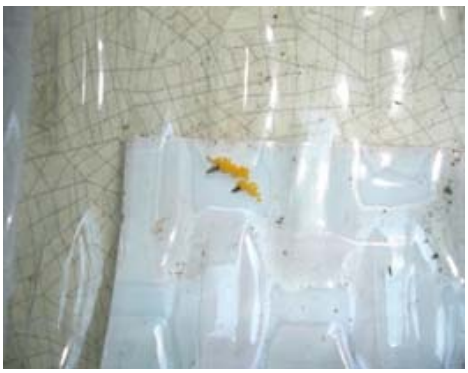


Fig 1a: Just hatched larvae are eating eggs.

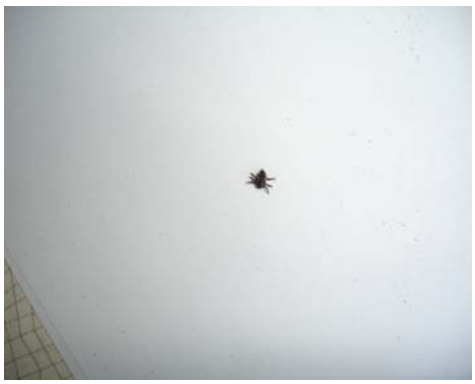
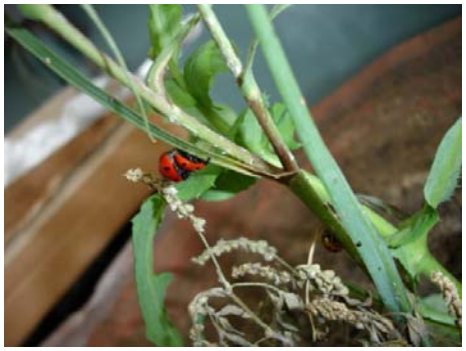


Fig 1b: Larva with detached abdominal segments.

The mating behaviour of the C-7 was very interesting. Mounting the female the male immediately began to copulate it. The male was very active during mating behaviour periodically (with 3-5 second intervals) dramatically swaying from left to right. Mating process lasts several hours (Fig. 2 a,b).

A



B

Fig 2a,b: Mating behavior of seven-spot ladybird.

During mating process the male copulates the female not depending on its state. The copulation can occur even when the female was hanging on a leaf. In the process of mating the female does not move. The female even can feed in this situation. Only a few irritable male movement can cause the female to change the location. Female can eat on during mating behaviour, but male do not did that until the end of process.

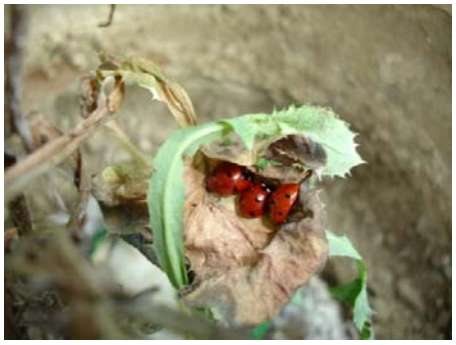
According to some authors the meaning of this long process of mating is to prevent the approach of other males to female [4]. Thus the male creates conditions for the spread of its genes within the population.

The sperm of one male is enough for laying 550–600 fertilized eggs. Female can keep fertilized eggs for a long time (about 1 month) and in case of multiple mating it can lay more than 1000 eggs. It was experimentally established that the absence of aphids in the diet of C-7 is the only factor inducing diapause (26-27 ^{0}C). The diapause can last for months, but at any time can be quickly terminated if the power to renew aphids beetles.

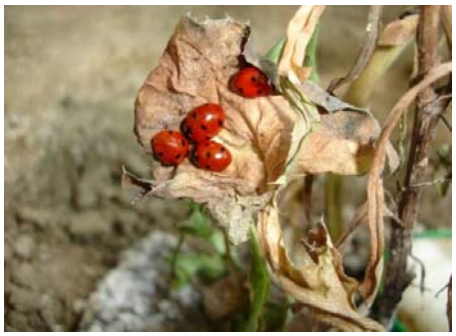
This diapause can last for months, but at any time can be quickly terminated if the feeding of beetles on aphids is renewed. However the rate of reactivation noted according to resumption of oviposition depends on the number of aphids provided. It is very likely that food plays a signaling role and perceived through chemoreception.

If larvae were constantly fed on aphids, beetles after leaving the pupa become mature and begin to actively lay eggs. At a temperature of 26-27 ^{0}C oviposition occurs continuously for

30-45 days, and then it is gradually weakened until the complete cessation. If beetles deny access to the aphids, they first eat the eggs laid by them, and then completely stop breeding, form a cluster in the folds of paper and other secluded places, showing the behavior characteristic for diapausing coccinellids (Fig. 3a,b)



A



B

Fig 3a,b: Adults in the diapause.

Thus, the characteristic behavior showed that lack of aphids in the food cause reproductive diapause in C-7. Probably the absence of aphids disturb the developmental process of oosysts in females.

In some countries the artificial rearing of coccinellids is well established. Such countries as USA, Russia, France, Marocco, Mauritania, Ispain, Greece, etc have special insectaria for rearing of coccinellids. In Adzharia region of Georgia such species as *Radoliya kriptolemus*, *Lindorus lophantae* and *Chilocorus bijugus* are reared. *Radoliya kriptolemus* is used as an agent of biololgical control in France and *Chilocorus bipustulatus* in the North Africa [5].

In USA the second and third instar larvae of C-7 werfe used for controlling apids on potatos. According to W.A.Shands *et al*. (1977) the eggs were not effective for this purpose [6].

The seasonal using of imago or larvae of coccinellids as an agents of biological pest control is very perspective method. *Adalia bipunctata, Coccinella septempunctata, Coleomegilla maculata* and *Cycloneda sanguinea* were seasonally used in greenhouses and conservatories. *C.sanguinea* turned to be very effective [7].

The effectiveness of *Coccinella transversogutta* was very high when the predary-prey ratio was 1:34 [8].

The larvae of the far east population of *Harmonia axyridis* in was used against *Aphis pomi* on apple and *Hyalopterus prumi* on apricot in the South-East of Kazakhstan. The aphids were completely destroyed during 10 days by 100 little instar larvae of predatory when the damage of plants was very high.

To conrol the population of aphids in the orchards the method of one-time release of coccinellids was deleoped [9]. 700 specimens of *Adalia bipunctata* and 1000 specimens of *C.septempunctata* were released per 1 hectare of orchards during outbrfeak of aphids.

The adult specimens of *A.bipunctata* is used against aphid *Dysaphis plantaginea* on apple tree and *A.decempunctata* against different aphids in the South France [5;8]. Sometimes the coccinellids have to eat uspecific food. In such cases imago and larvae can live up to a certain time, but females are not suitable for laying eggs.

3.1 Response of seven-spot ladybird to number of pest (*Aphis gossypii* Glov.)

The behavioural reactions of predators to the number of pests were studied by many authors and there are different opinions about it [10].

The results of researches on response of seven-spot lady bird to number of pest (*Aphis gossypii*) are presented in the Table 1. Oviposition was not recorded in the first day of experiment. It began the next day.

Table 1: Effect of number of aphids on reproductivity of coccinellids.

No of aphids (variants)	Eggs (per 1day averagely)	Larvae	Pupae	Adults
30	18± 4,2	—	—	—
50	24± 3,1	14±2,1 (58,3%)	—	—
100	38 ±4,4	36± 2,1 (94,7%)	18±4,1 (50%)	47,4%
200	44± 4,2	42 ±3,8 (95,5%)	32±4,8 (76,2%)	72,7%
500	48± 4,6	46±4,2 (95,8 %)	42±2,9 (91,3%)	87,5%

As it shown from the table 1 the productivity of coccinellids was directly proportional to the number of aphids. If 30 aphids were added to the food of one pair of coccinellids the productivity of female will be on average 18± 4,2 eggs. But all the eggs were eaten by female.

Adding of 50 aphids in diet of coccinellids increases the productivity of females (on average 24± 3,1 eggs). Unlike the first variant in this variant the larvae hatched from 58,3% of eggs. However because of lack of food the larvae eat each other and no one reach the adult stage. The development of pair of coccinellids on plants with 100, 200 and 500 aphids on them were similar. On plants with 100 aphids the cannibalism among larvae was 50%. Coccinellids on plants with 200 or 500 aphids developed normally and 76,6-91,3% of larvae reached the pupa stage.

Unlike other coccinellids the C-7 olviposits not among the aphid colony, but at its edge, sometimes on the other substrates (on plant stem, on leaves, on poliethilen with which the pot was covered). Therefore the percent of cannibalism was high in C-7.

It should be noted that the reaction of C-7 to the number of aphids was not the main factor proving the efficiency of predator in the depression of the level of pest population. Knowing the level of voracity beetle and larvae it can be estimated the role of predator in the bioregulation of numbers of aphids. By increasing the number of aphids to a certain

level (50-60 aphids per day for each specimen) you can achieve 80-85% level of predation by beetles and larvae. But if number of aphids was more than 50-60 the effectivenes of predators will be decreased down to 25-30%.

These characteristics of coccinellids should be taken into accound during artitificial breeding. Therefore it is necessary to take into consideration the ratio between number of predator and prey before using predators in biological control.

3.2 Dependence of the C-7 productivity on weight of beetle

It is known that sometimes when preparing the forecast of the number of pest its physiological condition is ignored. The physiological condition of the specimen is estimated by its size and live weight. B.C.Smith stated that according to size and weight of coccinellids we can forecast the viability of beetles [11]. According to G.V.O. sipov's researches (1968) the endurance of pea aphids at low temperatures changes between 5 and 40 days depending on their weight [12].

V.E. Ryvchin stated that the weight of *Sitona griseus* can serve as an index of viability and productivity of beetle at a low temperature [13]. This idea is supported by differfent authors [14, 15, 16, 12].

The wide laboratory researches on dependence of the seven-spot lady bird productivity on weight of beetle carried out and the results are presented in the table 2.

Table 2: Dependence of reproductivity of C-7 on weight of females.

Weight groups	The numberf of experimental females	Average weight of females in mq	Average reproductivity of 1female
I	5	28,83±0,12	475,2±17,8
II	5	29,93 ±0,18	530,4±15,7
III	5	31,16±0,08	588,2±21.3

As it shown from the Table 2 the beetles weighting 31,16±0,08 mq from the third qroup showed the highest productivity (588,2 eggs). The productivity of the females weighting 28,83±0,12 mq was 475,2 eggs. It is for 113 eggs lesser than those in III group. The results indicated that the next year productivity of the C-7 actually depends on the weight of hibernating beetles and there was right proportional dependence between them.

Thus during artificial breeding of the seven-spot ladybird it should be taken into account the weight of female, cannibalism in adults and larvae when feeding.

It is better to use the second and third instar larvae of the seven-spot ladybird for control aphids.

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