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ABSTRACT

of the dissertation for the degree Doctor of Philosophy

EFFECT OF TEMPERATURE AND PHOTOPERIOD ON THE BIOLOGY OF THE BEETROOT APHID (*Aphis fabae* Scop.)

Specialty: 2413.01 – Entomology

Field of Science: Biology

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BAKU – 2025

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INTRODUCTION

Relevance and development of the topic: Following the significant technical crops such as cotton and tobacco in our country, the development of the beet plant has been in the focus in recent years. Sugar beet is an indispensable raw material for extracting sugar, which is considered to be one of the most valuable food products. Moreover, when sugar beet products are processed, additional products of great importance for animal husbandry are obtained. In some regions, it is also cultivated as a fodder plant.

The fact that the leave blade of the plant is tender and colorful, and the root fruit is extremely nutritious, makes them be infected by pests and spread very willingly which leads to a decrease in productivity. One of the insects that seriously affects productivity is *Aphis fabae* Scop. (beetroot aphid), which refers to the Aphididae family of the Aphidinea suborder of the uniform-winged (Homoptera) order.

This genus is widespread in Azerbaijan and damages agricultural crops every year, mainly Cruciferae, Cucurbitaceae, Fabaceae, Asparagaceae, and *Liliaceae* plants.

The aphid is polyphagous, piercing the leaf tissues of the plant it feeds and sucks its juice, resulting in the sprouts not developing or completely drying up. At the same time, when aphids feed, they secrete a liquid containing sugar, which causes the massive growth and spread of mold fungi in those areas, and the disruption of the photosynthesis process in the plant.

Beetroot is also considered to be a carrier of various viral diseases. Because of the above-mentioned reasons, effective ways of combating pests reducing the productivity of sugar beet have to be explored.

A detailed study of the beet aphid in the beet agrosenosis, the exploration of environmental factors affecting it, the factors causing its polymorphism, migration and remigration characteristics, determining the role of entomophages in regulating the number of pests are the relevant issues of the day.

Object and subject of the study: The object of the study is the beetroot aphid, which is a sucking pest of agricultural plants, including sugar beet. The subject of the study is to determine the role of temperature, photoperiod and population density, which are the main ecological factors in the development and reproduction of the pest, as well as the formation of various morphs during the ontogenesis of the pest, and to clarify the existence of vertical migration on the plant.

Goals and tasks of the study: The goal of the present work is to study the effect of temperature and photoperiod on the biological development of the Azerbaijani population of the beetroot (=bean) aphid, to determine the factor that plays an important role in the manifestation of polymorphism, and to study the aphids involved in the regulation of the number dynamics of this dangerous pest in the agrocenosis and to reveal the possibilities of using them in control measures.

The main objective of the study includes the followings:

1. To determine the role of some environmental factors in the development and reproduction of beetroot aphid;
2. To study the main factors affectig the polymorphism of beetroot aphid;
3. To set practical proposals by determining the development dynamics of the pest in agrocenosis and the entomophages that regulate its number.

To achieve the goal, the following tasks are planned:

- To determine the effect of the temperature factor on the biological indicators of the beetroot aphid;
- To determine the effect of temperature on the reproduction of beetroot aphid and the formation of winged morphs;
- To study the manifestation of the effect of temperature on the next generations;
- To study the effect of photoperiod on biological indicators (development and reproduction) of aphid;
- To determine the role of photoperiod in the polymorphism of beetroot aphid;
- To detect the effect of population density on the polymorphism of aphid;
- To monitor the daily and seasonal development of beetroot aphid in agrocenosis, to determine the appearance periods of morphs in nature, periods of migration and remigration, and trophic relationships;
- To monitor the development phases of the pest in nature;
- To study the entomophages involved in regulating the number of aphid in agrocenosis.

Research methods: The research was performed during 2014-2023 at the Applied Zoology Center of the Institute of Zoology of AR MSE (until 2017, the Center was called the "Laboratory of Ecology and Physiology of Insects") in automatically controlled special thermostats (made in Japan and Turkey) and in stationary areas (agrocenoses) under natural conditions. Field observations and experiments are mainly conducted in the beet planting areas of the Imishli district. During field observations and experiments, the lifestyle and biological characteristics of the pest and its entomophages in natural conditions are investigated using the method of K. Fasulatin. When studying the effect of temperature and photoperiod on the biological indicators of the beet leaf aphid and its entomophages, the methods of N.Gorishin[1] and I.Kozhanchikov[2] are used. The mathematical processing of the obtained results is carried out according to the method presented by Y. Merkuryeva[3].

The main provisions presented for the defense:

1. The role of temperature in the reproduction and development of beetroot aphid is vital.
2. The role of temperature in the polymorphism of beetroot aphid is seasonal.
3. The daily and seasonal effect of temperature on the migration of beetroot aphid is huge.
4. Using a variable temperature regime during mass reproduction of the pest is more expedient.
5. The role of photoperiod in the reproduction and development of beetroot aphid is secondary.
6. Photoperiod has a significant effect on the polymorphism of beet aphid.
7. Population density plays an important role in the process of wing development, together with the physiological state of food plants.

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[1] Горышин, Н.И. Техническое оснащение экологических исследований в энтомологии.- Ленинград: Изд. ЛГУ, -1966, - 235 с.

[2] Кожанчиков, И.В. Методы исследования экологии насекомых. -Москва: Изд. Высшая школа,- 1961,- 283с.

[3] Меркурьева, Е.К. Биометрия в селекции и генетики с/х животных. -Москва: Колос, -1970.- 424с.

8. The phenology of beetroot aphid is complex.

9. Entomophages play a major role in regulating the number of beetroot aphid.

Scientific novelty of the research: for the first time in Azerbaijan, the effect of temperature and photoperiod on the reproduction and development of the beetroot aphid (*Aphis fabae* Scop.), which is one of the serious pests of sugar beet, was studied in detail.

The role of temperature and photoperiod in the polymorphism of beetroot aphid was studied for the first time, and degree of their effect, lower and upper temperature limits, and photoperiodic reactions were determined in the formation of morphs by seasons.

The effect of the number of individuals (density) on the formation of winged morphs in the beetroot aphid population was studied for the first time.

The effect of constant and variable (equivalent) temperature regime on the reproduction and development of the aphid was determined and its vertical migration on the plant during the day were studied for the first time.

The entomophages involved in regulating the phenology of the beetroot aphid and its number were studied for the first time.

Theoretical and practical significance of the research: the effect of temperature, photoperiod and population density on the reproduction and development of the beetroot aphid, as well as its polymorphism, was studied in detail for the first time in Azerbaijan, the role of temperature, photoperiod and density in the formation of migrants and morphs was evaluated, and the effective entomophagous that can reduce its number in agrocenosis, i.e., the phenology of the *Coccinella septempunctata,* was determined. At the same time, for the first time, as a result of experiments in laboratory conditions, it was clarified that it is more appropriate to use a variable temperature regime during the mass reproduction of insects. The result we obtained regarding the vertical migration of the beet leaf aphid on the plant during the day was of great importance from a practical point of view, it is invaluable information for speci- fying the time of struggle measures.

The results and practical suggestions obtained during the research can be fully used when developing complex struggle measures against the beetroot aphid.

Research approbation and application: Research results were discussed at scientific seminars, laboratory meetings of the Institute of Zoology, that is: at the 11th International scientific-practical conference ”Science and practice implementation modern society” (Great Britain, Manchester, 18-19.10.2021); at the 12th International scientific-practical conference ”Experimental and theoretical research in modern science ” (Kishinev, Moldova, 16- 18.05.2022); at the 2nd International scientific-practical conference “Recent advances in scientific world “ (Mexico, Monterrey, 06-08.08.2022); at the international conference “Heydar Aliyev and the Nature of Azerbaijan” (Baku, June 19-20, 2023), the Eurasian International Scientific Research and Innovation Congress (Guba, July 21-22, 2023), the 2nd International Çukurova Scientific Research Conference (Adana, Turkey, August 22-24, 2023) and the International Scientific and Practical Conference on “Disruptions in the functioning of ecosystems due to global climate change and ways to eliminate them” (Baku, June 11-12, 2024), and at the same time, in accordance with the requirements of the SAC, 6 scientific articles and 7 theses were published in various (4 articles abroad, 3 of them in AGRIS; 2 articles locally) publishing houses.

The obtained results and practical suggestions can be used by the relevant organizations during the complex fight against the pest.

The name of the organization where the dissertation work was carried out: The dissertation work was carried out in the Center for Applied Zoology of the Institute of Zoology of MSERA.

Structure and volume of the dissertation work: The total volume of the dissertation consists of 127 pages (171756 characters), it consists of Introduction (11095 characters), 6 chapters (156560 characters), Conclusion (3233 characters), Practical proposals (868 characters), 176 titles of literature in Azerbaijani, Russian and other languages. 11 tables, 1 figure, 7 graphs, 1 scheme are given in the thesis work.

CHAPTER I. LITERATURE REVIEW

This chapter of the dissertation analyzes the main types of the seasonal development of aphid, its phases, the role of environmental factors in the regulation of polymorphism, etc. based on the works of both foreign and local researchers related to these issues.

As a result of the analysis, it was found that although there is a large number of literatures on the study of the beet leaf aphid at the international level, the seasonal adaptation characteristics, migration, remigration, etc. of the pest have not yet been studied in Azerbaijan.

CHAPTER II. MATERIAL AND METHODS

Laboratory experiments were carried out in 2014-2023 at the Applied Zoology Center of the Ministry of Science and Education of the Republic of Azerbaijan, Institute of Zoology (until 2017, the Center was called the "Laboratory of Ecology and Physiology of Insects") in special automatically controlled thermostats (made in Japan and Turkey) and in stationary areas (agrocenoses) under natural conditions. Field observations and experiments are mainly conducted in the beet planting areas of the Imishli region. During field observations and experiments, the lifestyle and biological characteristics of the pest and its entomophages in natural conditions are investigated using the method of K. Fasulatin. When studying the effect of temperature and photoperiod on the biological indicators of the beet leaf aphid and its entomophages, the methods of N.Gorishin and I.Kozhanchikov are used. The mathematical processing of the obtained results is carried out according to the method presented by Y.Merkuryeva. Mainly individuals collected from nature were involved in the experiments. The aphid brought to the laboratory were fed and propagated at a temperature of 19-20°C and 24-hour light conditions. The humidity in the cameras was between 65-75%. Only larvae obtained under the same conditions were used in the experiments.

CHAPTER III. INDIVIDUAL RESEARCH AND THEIR ANALYSIS. RESPONSES OF BEET APHIS TO VARIABLE PHOTOTHERMAL CONDITIONS

3.1. Phenological development of the *Aphis fabae* Scopoli

In the sugar beet growing fields of Azerbaijan, the beetroot aphid can produce more than 15 generations. Overwintering of this pest occurs mainly in the egg stage on bushes (table 3.1.1).

The emergence of eggs from overwintering and the appearance of the first larvae (fundatrix) on the plants they overwintered is observed in early spring (mainly in the second ten days of March), when the air temperature is above 6 - 8ºC. During this period, the development is very slow. In the 1st ten days of April, when the air temperature is above 12 - 13ºC, the development of larvae accelerates. Larvae feed on primary plants and produce 2-3 generations up to the early May. Individuals of the last generation consist almost entirely of winged individuals. In late April and early May, these individuals mi- grate to the fields of beet cultivation along with other plants (goose- foots, saltbush, thistle, spinach, salsola, arctium, carrot, parsley, etc.). In 2015-2017, during the observations of sugar beet agrosenosis planted in Imishli region, it was determined that winged parthenogenetic (born alive) individuals migrate to beet plants in the first ten days of May (May 3-5).

In agrocenosis, winged individuals of this pest can be found en masse in the second and third ten days of May (10-25 May).

In the middle of May, the winged individuals observed en masse in the agrocenosis spread to different places of the field and start reproducing rapidly. In this period, the plants infection is sometimes above 55-60%. The development of the pest on the beet plant lasts mainly until the third tendays of July, and during this period it gives 10-12 generations. Due to the roughening of the plant leaves, the winged individuals formed in the last generation move to the nearby weeds (goose- foots, solanum, saltbush, thistle, etc.).

Migrants give 2-3 wingless offspring on weeds from late July to the second half of September. In late September, winged reproductive individuals form. These individuals migrate to the bushes growing on the field edges, such as spindle tree, alhagi, salsola, etc. and mate there. Fertilized females end up their lives by laying 8-12 eggs between the shoots of the plant or in the axils of the leaves (scheme 3.1.1).

Table 3.1.1

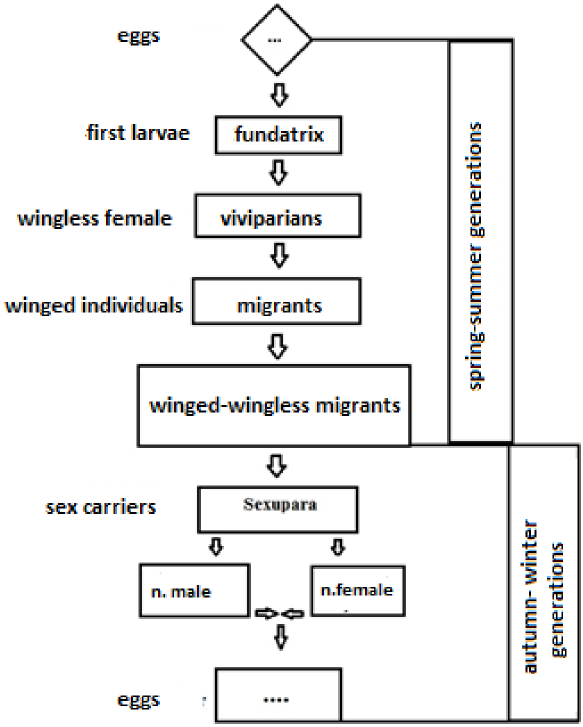
Phenological calendar of the *Aphis fabae* Scop., 1763 (Imishli 2015-2017)

Months	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
Temperature (C^0)	3,1	6,8	10,6	15,1	20,7	25,2	27,3	29,4	21,8	14,7	12,5	10,3
Photoperiod (in hours)	9,2	10,4	11,5	12,6	13,8	15,0	15,1	14,5	13,0	12,3	12,0	11,3
Humidity (in relative%)	85	83	75	73	70	65	63	60	71	75	76	81
Generations												
Overwintering	●● ●	●●●	● ● ●	●								
Generation I			– – ■	– ■ ■ ■								
II-III			–	– – – ■ ■ ■	– – – ■ ■ ■	– ■						
IV-XII					■■■	■■■	■■ ■	■■■	■			
XIII amphigones								G	GG			
XIV sexual vectors									♂♂♂ ♀♀♀	♂ ♀		
Overwintering									●	●●	●●	●●

Note: ■ - Period of mass spread in agrocenosis

As a result of many years of research on the biology and phenology of beetroot aphid, it was found that beetroot aphid produces up to 15 generations in Imishli, one of the main sugar beet growing regions of the Republic. 10-12 of them grow and reproduce in the beet agrosenosis, causing serious damage to farms.

Development, reproduction, fertility (offspring) of animals, and other biological indicators are closely related to temperature, humidity, nutrition quality and, of course, the length of the day.



Scheme 3.1.1. Development scheme of beetroot aphid in nature

The average development period of larvae during the vegetation period varies from 6 to 10 days. It ends between 5-6 and 13-15 days depending on the temperature in different months. In some cases, the development of the larval stage is observed to be completed in 4-18 days. Depending on the conditions, one mother individual can give from 4 to 115 cubs during breeding. The birthing process of mother individuals may last 4-17 days. The productivity of one female varies from 3 to 12 larvae per day.

The temperature in agrocenosis is above 25°C (27-30°C) and has a negative effect on the reproduction and development of microorganisms. Thus, the temperature above 27°C causes a sharp shortening of the life span of the aphid, the full development period of the larvae, and a decrease in spawning potential.

3.2. The effect of temperature on the bioecological characteristics of beetroot aphid

Being an environmental factor, temperature seriously affects the development of biochemical processes in the organisms, the activity of enzymes and other biological substances.

The development process of each insect shows that the temperature limit required for their normal development varies depending on the area and nutrition environment of that species.

When determining the adaptation process of insects to the natural environment and the impact of some environmental factors, it is important to study the following issues:

- The effect of temperature on the transition of insects to the active state and their reproduction, development rate, movement and death process;
- The role of temperature in the regulation of development stages by seasons, in the alternation of periods of activity and calmness;
- The role of temperature changes by days and seasons in the insects' development;
- The effect of the amount of temperature required for the reproduction of insects, etc.

Taking all this into account, we carried out a series of experiments to determine the effect of temperature on some biological indicators of beetroot aphid.

The results of the conducted studies showed that the temperature factor is of particular significance for the development of beetroot aphid.

As can be seen from Table 3.2.1., the development period of each age stage of larvae is shortened with increasing temperature.

At temperatures of 18-23°C, the development is almost constant in all age stages, except the 4th age stage, and there are no significant differences between the periods. On the other hand, when the temperature rises above 25°C, the development periods of the age stages become uneven and abnormal. This situation is more distinct at 30°C.

Since the temperature regime of 18-23°C is optimal for the development of larvae, there is no doubt that the stable shift of development stages is also related to this factor.

The fact that the 4th age stage is longer than other age stages can probably be explained by the physiological changes occurring in this stage, mainly by the preparation for the reproductive period.

Just as the rise in temperature affects the individual age stages of the larvae, it also undoubtedly affects its overall development period.

Acceleration of larval development is justified up to a certain temperature limit, i.e., up to 25°C. The subsequent increase in temperature, on the other hand, has an adverse effect on the development of larvae, causing a relative prolongation of the period of this stage and an increase in their mortality rate.

As can be seen from the table, larval development at 30°C takes 6.44 days. At 25°C, this period accounts for 5.97 days. However, at 30°C, although the development period of the larvae is prolonged, their reproductive ability is weakened, and the mortality rate rises to 71.8% (Table 3.2.1).

Table 3.2.1

Effect of temperature on the development of beetroot aphid larvae

T (°C)	Photo-period (hour)	Average development time of age stages (in days)				Full larval develop-ment period
		I	II	III	IV	
18	14	1,93±0,13	1,68±0,08	1,92±0,05	2,38±0,08	7,91±0,11
20	14	1,86±0,02	1,62±0,09	1,64±0,09	2,32±0,09	7,44±0,09
23	14	1,64±0,08	1,58±0,062	1,60±0,12	2,12±0,06	6,94±0,16
25	14	1,58±0,08	1,14±0,06	1,24±0,08	2,01±0,07	5,97±0,13
30	14	1,50±0,09	1,02±0,03	1,14±0,07	2,78±0,14	6,44±0,07
Control	24	1,66±0,07	1,60±0,08	1,44±0,08	1,92±0,06	6,62±0,08

A slight increase in temperature, i.e., raising it to 35°C, causes the larvae to live for only 3-4 days, and the mortality rate to reach 100%.

Taking into account that the damage rate of aphid depends on its reproductive period and fertility potential, the effect of temperature on these processes was widely studied in different regimes in laboratory conditions.

The obtained results showed that the effect of temperature on this stage as well as on the larval stage of aphid is great. An increase in temperature above 15°C leads to a shortening of the reproductive, including full development period. At 18°C, the reproductive stage lasts 14.8 days, whereas at 25°C, this figure is 12 days, at 28°C, 5.3 days, and at 30°C, 3.4 days. At 35°C, the aphid is destroyed without giving birth at all.

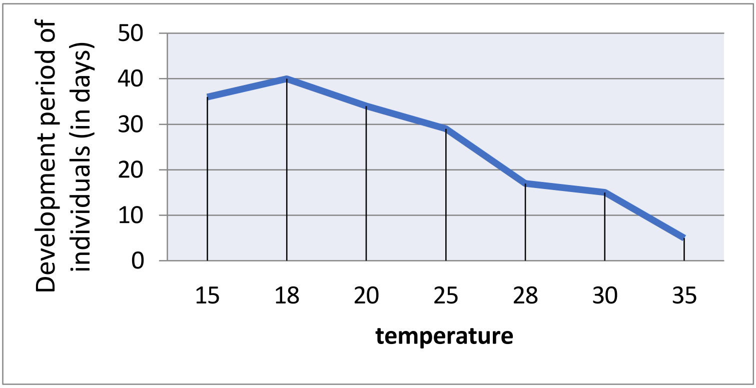
Table 3.2.2

The role of temperature in the development and reproduction of beetroot aphid

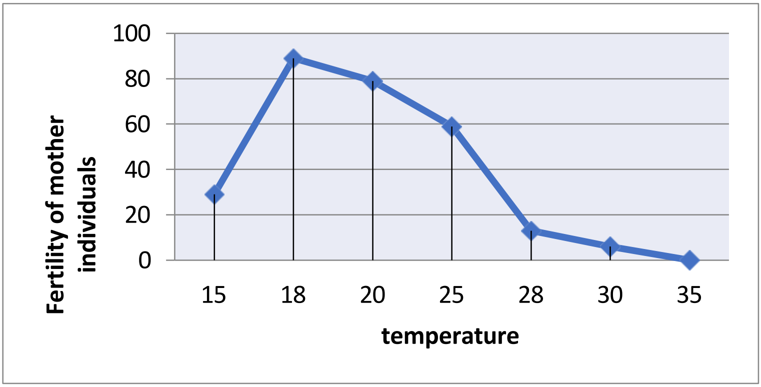
tt°C	Development period of different stages (in days)				Fertility of 1 mother individual, (average)	Mortality %
	Larval stage	Reproductive stage	Post-reproductive stage	Full development period		
15	12,5±0,52	17,1±0,72	6,2±0,89	35,80±0,77	28,7±1,14	-
18	8,40±0,56	14,8±0,93	16,1±1,18	39,30±0,76	88,7±0,86	-
20	7,42±1,12	13,5±1,12	12,2±0,96	33,12±1,13	78,6±0,12	-
25	6,02±0,96	12,0±0,86	10,1±1,12	28,12±0,86	58,0±0,01	-
28	7,12±0,81	5,3±0,76	4,2±0,86	16,62±0,09	12,1±1,6	42,2
30	8,66±0,77	3,4±0,81	2,1±0,07	14,16±0,11	5,6±0,19	71,8
35	4,11±0,36	0	0	4,11±0,36	0	100

There is no doubt that the change in the development period of individual stages with the increase in temperature has its effect on the development period and at the same time on the productivity of individuals.

As can be seen from Table 3.2.2, an increase in temperature leads to a shortening of the full development period of aphid from 39.3 days (at 18°C) to 14.16 days (at 30°C). It leads to a decrease in the productivity of one female individual from an average of 88.7 larvae (at 18°C) to 5.6 larvae (at 30°C) (Line graphs 3.2.1 and 3.2.2).



Line graph 3.2.1. Effect of temperature on the life span of mother individuals



Line graph 3.2.2. Effect of temperature on the fertility of viviparians

The analysis of the results shows that the optimal temperature for the development and reproduction of beetroot aphid varies between 18-23°C. Temperatures above 25°C have a negative effect on the development and reproduction of this species.

In order to clarify the response of the temperature effect on the development and productivity of the aphid in the next offspring, similar experiments are followed consecutively over 3 offspring (table 3.2.3). The results of the experiments show that the indicators observed in the second and third offspring at 18-20°C do not significantly differ from the results obtained in the first offspring. However, at 25°C, a sharp difference between the offspring is observed. Thus, in the third off- spring, the reproductive period of the aphid, the full development period significantly shortens in relation to the first generation, and the productivity decreases. At this temperature, the reduction of the reproductive period and productivity begins to manifest itself already from the second offspring.

The results show that constant feeding of individuals at high temperature (25°C) has a negative effect on the biological indicators of the next offspring.

Table 3.2.3

Effect of temperature on the next offspring of beetroot aphid

t°C	Offspring	Development Stages (in days)			Full development period	Average fertility for a mother
		Larval stage	Reproductive period	Postreproductive period		
18	I	8,42±0,52	13,9±0,91	15,9±1,09	38,22±0,84	86,5±3,2
	II	8,09±0,61	13,1±1,09	12,8±0,78	33,99±0,83	82,2±1,3
	III	7,94±1,03	14,0±0,93	9,1±0,81	31,04±0,92	84,5±2,5
20	I	7,01±0,49	12,4±0,62	11,8±0,64	31,21±0,58	78,8±2,81
	II	6,19±0,53	11,1±1,11	8,4±0,32	25,69±0,83	67,7±1,97
	III	6,02±0,71	9,8±0,89	7,8±0,14	23,42±0,75	72,2±1,04
25	I	4,2±0,26	8,1±0,53	6,8±0,39	23,3±0,39	38,2±0,80
	II	4,6±0,72	7,4±0,92	5,6±0,02	17,6±0,82	32,4±1,04
	III	3,8±0,24	4,2±0,86	2,1±0,03	10,1±0,37	18,8±0,86

3.3. The effect of variable and constant temperature regime on some biological indicators of aphid

During the research, a number of experiments were carried out to determine the effect of a constant and equivalent variable temperature regime on the biological indicators of aphid, mainly during laboratory experiments.

The experiments were carried out in 3 replicates at a constant 20°C during the day and at temperatures equivalent to 24°C (8 hours) and 18°C (16 hours), that is, in both cases, the average daily temperature was 20°C. In terms of photoperiod, 8 hours of light and 16 hours of darkness regimes were applied in both cameras. The table below presents the results of the conducted experiments (table 3.3.1).

Table 3.3.1

Effect of constant and variable temperature regime on some biological indicators of beetroot aphid

Regime	Life span	Reproductive period	Number of larvae (average per mother)	Mortality %
Constant 20°C	30,2±0,98	12,2±0,88	62,1±2,01	0,03
Variable 24°C + 18°C	34,1±1,08	14,8±1,22	84,6±0,30	0,00

As can be seen from the table, there are several advantages of the experiments conducted in the variable regime compared to the constant one, so that in the variable temperature regime, the life span and reproductive period of individuals are long, and the life span and reproductive rate are also high. Consequently, it can be concluded that during laboratory experiments, the advantage of a variable temperature regime in the mass reproduction of any species should be taken into account. Because such a regime is closer to the day and night modes existing in nature, it has a more positive effect on the biology of insects.

3.4. Vertical migration of *A. fabae* on plants

Plants can strongly affect the temperature of the environment. Thus, they can raise the temperature of the air during the day by absorbing the sun's rays, and at the same time, due to the characteristics of transpiration in the conditions of low humidity and high temperature in the environment, they can lower the temperature in the nearby area up to 15°C[4].

Insects are always looking for areas with a favorable temperature environment for them. A clear example of this is the vertical migration of the cotton aphid (*Acyrthosiphan gossypii* Mordv.) on the cotton plant during the day[5]

[4] Чернышев, В.Б. Экология насекомых. М.: Изд. Моск.Ун-та, -1996,- 267 с.

[5] Чернышев В.Б., Афонина В.М. Нарушения биологического ритма и продолжителъностъ жизни некоторых насекомых. Общ. Биол., 1975, т.36, №6, 859-862.

In order to monitor the vertical migration of the beetroot aphid on the plant during the day, observations were made under natural conditions by placing 50 aphid on the beet grown in a pot. Observations were made visually every 2 hours both at night and during the day. Experiments were conducted in 3 repetitions on June 25-28. As a result of the conducted observations, it was found that there is indeed a vertical migration of the beetroot aphid on the plant. Thus, after 9:00 pm, aphid move up along the stem of the plant, gather around the tall sprout of the plant and settle there from 6:30 am to 7:00 am. After 7:00 am, they gather from there on the upper leaves, and then on the lower surface of the lower leaves. They feed in the parts where they gather, and when the temperature drops in the evening, they begin to migrate again towards the upper sprout of the plant.

The results of the experiment show that indeed there is a vertical migration of the beet leaf aphid on the plant it feeds on, and as a result of this migration, they can choose a favorable environment for their living. Therefore, in contrast to laboratory conditions, in agrocenosis, they can live using these characteristics even in high environmental temperature conditions, sometimes above 40°C.

3.5. The role of temperature in the formation of winged individuals

Obviously, the temperature effect is the primary factor in the spread and development of pests.

The specific thermal mode limiting the spread of insects varies for different species and is specific for them. For some species, the change in temperature and the demand for it is a vital factor in summer, and for others in winter, differing from each other.

Temperature changes in different seasons, annual amplitude and annual dynamics of climatic factors play an important role in the spread of insects. The role of temperature in the formation of winged individuals was observed at 15, 17, 20, 25°C and under 12-hour light conditions. All experiments were performed in 3 replicates and over 3 consecutive offspring. In each variant, 10 newborn larvae and the next generations obtained from them were used.

The results obtained from the experiments show that high temperature hinders the formation of winged individuals, as does a long photoperiod. Low temperature, on the contrary, strengthens this process (Table 3.5.1).

Table 3.5.1

The role of temperature in the formation of winged individuals of beetroot aphid (light = 12 hours)

T °C	15°C		17°C		20°C		25°C	
Generations	Number of larvae	Winged individual (%)	Number of larvae	Winged individual (%)	Number of larvae	Winged individual (%)	Number of larvae	Winged individual (%)
I	31	90,3	29	88,2	31	38,7	30	6,6
II	30	93,3	31	87,1	30	33,3	29	10,3
III	31	100	29	93,1	29	27,6	31	12,9

As the table shows, the winged individuals are observed in only 6.6% of the individuals in the first generation at 25°C. At low temperatures, on the contrary, wings are formed in 90.3; 88.2 and 38.7% of individuals at 15; 17 and 20°C, respectively. The highest percentage of winged individuals in the first generation (90.3%) was recorded at 15°C. At 17°C, this figure drops slightly (88.2%).

Analogous results are observed in the second generation. Thus, in this generation, 93.3; 87.1 and 33.3 winged individuals form at 15; 17 and 20°C respectively.

The number of winged individuals de- creases with increasing temperature (33.3% at 20°C; 10.3% at 25°C). In the third generation, the maximum temperature effect is recorded at 15 and 17 °C. In these regimes, the amount of winged individuals was recorded as 100% and 93.1%, respectively. At a 25°C, this figure accounted for 12.9%.

The results of the experiments showed that the temperature is one of the main factors in the formation of winged individuals in the beetroot aphid colony. While a low temperature regime (of course within a certain limit) stimulates the formation of winged individuals, a high temperature prevents this process.

It should also be noted that the effect of temperature is more distinct in the next generations.

CHAPTER IV. THE EFFECT OF PHOTOPERIOD AND POPULATION DENSITY (COLONY) ON THE POLYMORPHISM OF BEETROOT APHID (*APHIS FABAE* SCOP.)

4.1.Photoperiod's effect of on the development of beetroot aphid

There is a number of data on the effect of photoperiod on the development of the larval stage of the aphid, the nature and intensity of reproduction under constant temperature conditions (Mendjul[6], 1969; Ahmadov[5], 1982; Kuliyeva[6], 2017, etc.).

The role of photoperiod in the development and reproduction of aphid was studied in the regimes of 3 temperatures (17, 20, 25ºC) and 7 photoperiods (8, 10, 12, 14, 16, 24 hours of light).

In the course of the experiments, the following photoperiod parameters were mainly taken into account during the aphid development:

- Development periods of the larval stage;
- Mortality rate of larvae during the development;
- Reproductive period of mature individuals and spawning (fertility) potential;
- Full development period of an offspring, etc.

The results obtained during the experiments show that the effect of photoperiod on the development of beetroot aphid is of great interest. Thus, it affects the duration of larval stages of aphid, the duration of the reproductive period and the duration of the development period as a secondary factor compared to temperature.

When larvae are fed at 17^0C in an 8-hour photoperiod, the development of the larval stage is completed in 8.9 days. When the daily light period is increased to 16 hours, the development of this stage is shortened to 7.2 days. In a 24-hour photoperiod, the complete deve-

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[6] Менджул, В.Н. Влияние температурного и светового факторов на размножение и развитие гороховой (*Acyrthosiphon pisum* Harr.) и свекловичной (*Aphis fabae* Scop.) тлей:/автореф.дисс.канд.биол.наук /- Киев, 1969.-24с.

[7] Ахмедов, Б.А. Ролъ температуры и фотопериода в развитии тли *Aphis gossepii* Glov. // - Москва: Вторая Всесоюзная конференция молодых ученых по вопросам сравнителъной морфологии и экологии животных,- 1975,- с.5..

[8] Кулиева, Х.Ф. Ролъ фотопериода в развитии азербайджанской популяции зеленой яблонной тли - *Apis pomi* Deg. (Homoptera, Aphididae) / Published by IASHE,- 2017,- pp. 23-27.

lopment period of the larval stage is 7.1 days (Table 4.1.1).

Probably, the observation of such differences occurs depending on the different effects of light periods on the metabolic process and the time of the period.

Table 4.1.1

Effect of photoperiod on the larval stage of beet root aphid

Photoperiods (in hours)	Average age duration (in days)				The complete development period of the larval stage
	I	II	III	IV	
0	1,88±0,028	1,82±0,051	1,97±0.050	2,02±0,052	7,69±0,085
8	2,19±0,021	1,98±0,038	1,96±0,014	2,84±0,062	8,97±0,063
10	1,98±0,020	1,96±0,104	1,99±0,031	2,76±0,012	8,69±0,076
12	2,01±0,027	1,82±0,084	1,68±0,060	2,29±0,053	7,80±0,085
14	2,10±0,052	1,82±0,092	1,29±0,062	2,08±0,107	7,29±0,040
16	1,74±.053	1,85±0,080	1,66±0,064	1,98±0,081	7,23±0,101
24	1,71±0,075	1,70±0,052	1,69±0,050	2,07±0,064	7,17±0,063

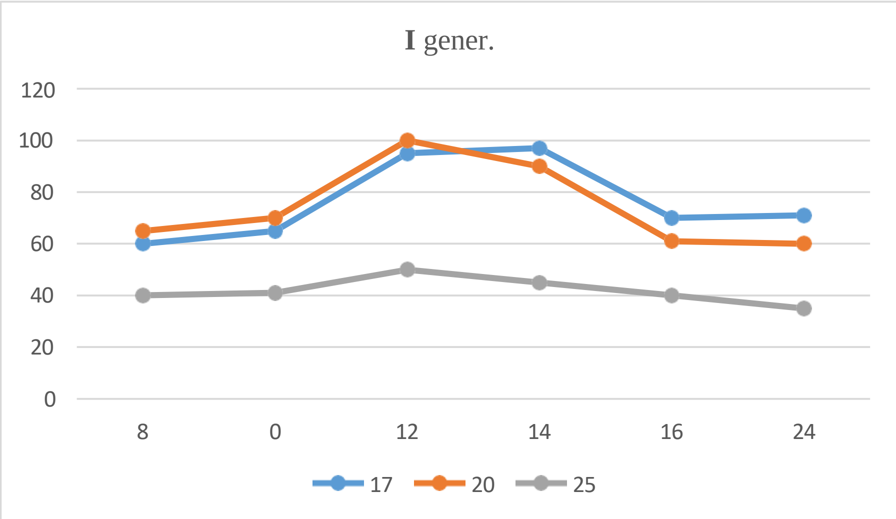
A similar effect is observed during the photoperiod lengthening, just as the reproductive period shortens during the increase in temperature. Thus, at 17ºC, the maximum reproductive period of beet leaf aphid lasts 9.1 days in a 16-hour photoperiod. Remarkably, in full darkness and full light regimes, this period is slightly longer than that of the 16-hour photoperiod (table 4.1.2).

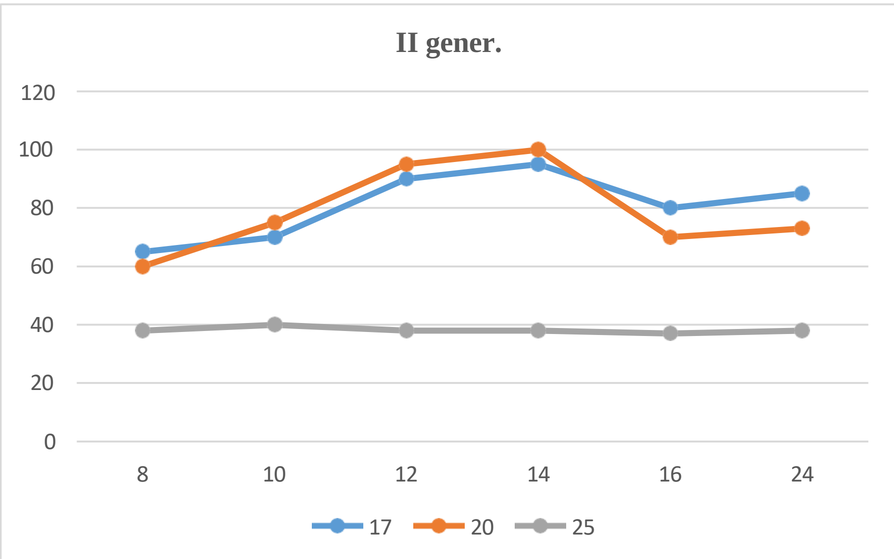
Table 4.1.2

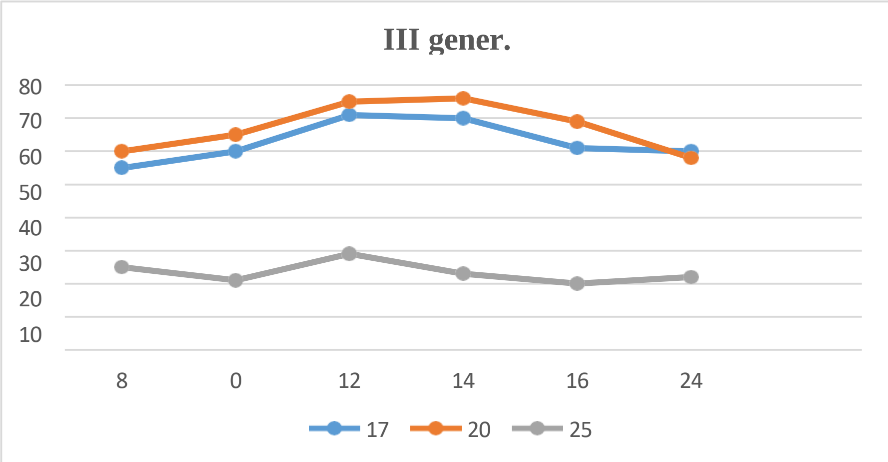
Effects of photoperiod on the reproductive cycle of beetroot aphid

Photoperiods	Prereproductive stage	Maximum reproductive stage	Post-reproductive stage	Full reproductive stage
0	1,62±0,078	11,10±0,222	3,60±0,609	16,32±0,320
8	1,55±0,067	12,13±0,348	3,99±0,419	17,67±0.624
12	1,68±0,891	11,43±0,329	3,78±0,650	16,89±0,240
16	1,72±0.094	9,25±0,150	3,94±0,492	14,91±0,318
24	1,26±0,081	9,38±0,170	4,72±0,472	15,36±0,504

Experiments at temperatures 17, 20 and 25ºC were carried out in several repetitions in order to clarify the transmission rate of the effect of photoperiod on the above indicators to the next generations (line graph 4.1.1).







Line graph 4.1.1. Temperature dependence of the photoperiod effect on beetroot aphid reproduction in the next (I, II, III) generations

Note: 17;20;25°C-temperature regimes

As the line graph shows, the effect of photoperiod may manifest itself more strongly at low temperatures. Thus, at 17 and 20⁰ temperatures, the effect of photoperiod on the reproduction of individuals occurs within a certain regularity, whereas at 25⁰C this regularity is violated and becomes chaotic. At both 17⁰C and 20⁰C, the fertility of female individuals varied graphically, and high fertility was observed at 12-hour and 14-hour photoperiods in both regimes. When analyzing by generations, it becomes clear that the effect of photoperiod on re- production is unambiguous, both in the second generation and in the third generation at the mentioned temperatures. At 25⁰C, however, it turns out that high temperature nearly avoids the effect of photoperiod in all three successive generations and largely regulates reproduction. It can be concluded that photoperiod shows its effect more actively within a certain temperature range, and excessively high temperature can change the effect of photoperiod.

4.2. The role of photoperiod in the formation of winged in dividuals in the beetroot aphid (*Aphis fabae* Scop.) colony

The study of ecological traits of insects requires uncovering the behavior patterns of individuals related to their environment.

Such information is of great importance for determining the activity indicators of insects, mainly their migrations.

Studying the process of cultural migration has a great practical importance. Thus, aphid pass from one plant to another through these morphs, feed there, multiply and maintain the existence of the population.

Therefore, studying the effect of photoperiod on the formation of winged individuals within the beet leaf aphid population is one of the important issues.

During the experiments, larvae collected from nature and fed in a stable mode in laboratory conditions (19-20°C, 24 hours of light) were used.

The role of photoperiod in the formation of winged individuals was monitored at constant temperature (17°C) and 7 photoperiods (8, 10, 12, 14, 16, 18, 24 hours of light).

As a result of our experiments, it was determined that photoperiod has a significant effect on the formation of winged individuals in beetroot aphid colonies (table 4.2.1).

Table 4.2.1

The role of photoperiod in the formation of winged individuals in a population of *Aphis fabae* Scop.

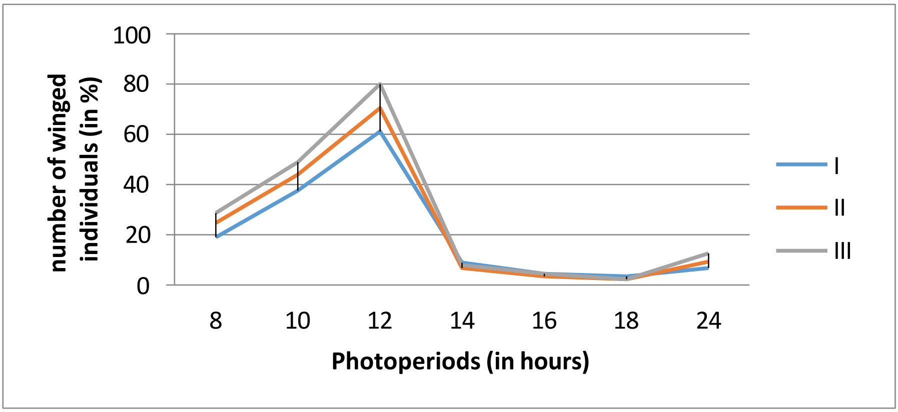
Generations	Photoperiods (in hours) t= 17°C													
	8		10		12		14		16		18		24	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b
I	90	18,9	88	37,5	90	61,1	90	8,9	90	4,4	87	3,4	90	6,7
II	89	24,7	91	43,9	88	70,4	90	6,7	88	3,4	90	2,2	86	9,3
III	91	28,6	90	48,9	90	80	90	7,8	90	4,4	88	2,3	88	12,5
Total	270	24,1	269	43,3	268	70,5	270	7,8	268	4,1	265	2,6	264	3

Note: a– the number of individuals used in the experiment (in numbers) b – number of winged individuals (in %)

Thus, in 8-hour photoperiod, 18.9% of individuals in the first generation became winged individuals, 24.7% in the second generation, and 28.6% in the third generation. It should be noted that the highest percentage of wing formation was recorded in 12-hour photo- period. In this photoperiod, 61.1% winged individuals were recorded in the first generation, 70.4% in the second generation, and 80% in the third generation.

Remarkably, at times longer than 12 hours of photoperiod (14, 16, 18, 24 hours of light) few winged individuals appear. But all these individuals are winged migrants and reproduce by parthenogenesis. Most of the individuals obtained from larvae developing under short day conditions consist of sexupara (gynoparae). The highest percent- age is still recorded in the 12-hour photoperiod (55-60%).

When studying the reaction of individuals fed in the same re- gime to the photoperiod in the next generations, it is determined that the short photoperiod manifests itself more in the next generations. It seems that the information collected in previous generations is directly transmitted to the next generations (line graph 4.2.1).



Line graph 4.2.1. Effect of photoperiodic information on the next generations
Note: I-II-III generations

The results show that the reproduction of this species through continuous parthenogenesis is possible only in a long (14, 16, 18, 24-hour) day regime. Winged individuals are dominant in short photoperiods. The fact that there are more winged individuals in the 24-hour photoperiod than others (14-18 hours) is probably related to the physiological changes occurring in them.

The results obtained during the experiments almost coincide with the results obtained during the monitoring of the phenology of beetroot aphid. Thus, in spring and summer in Azerbaijan, long days (14-15 hours of daylight) are observed in May-August, and the shortest days in February-March and late September and October (10-12 hours of daylight). During the phenological observations, the observation of winged migrants in March, a small number of migrants in July-August, and sexupara in September-October proves once again how important the photoperiod is in seasonal adaptation of this pest.

Therefore, its polymorphism characteristics should be taken into account when developing complex control measures against this pest.

4.3. Effects of population density on winged individuals in different photoperiods

Obviously, in nature, in different years and in different environmental conditions, the density of pests, generally insects, varies in places. Along with the effect of a number of environmental factors, density also has a special role in the emergence of various morphs and behaviors among individuals in the population.

The emergence of various qualities among individuals, which are the main factors of population dynamics, must be taken into account when forecasting the number of pests.

Taking into account all this, during the research years, several variants of experiments were performed to determine the role of density in the formation of winged individuals in colonies of beet leaf aphid. Experiments were carried out under constant temperature (17^{o}C) and different photoperiods in automatically controlled thermostats. During the experiments, the effect of 3 densities (10, 30, 50 individuals) was observed in each regime.

As a food plant, it was planted in separate pots and taken after the formation of a pair of first leaves.

The results of the experiments show that as the density of colonies on the plant increases, the number of winged individuals increases proportionally. Thus, when 10 larvae were fed on one leaf, the individuals with wing protrusions were observed in all regimes except for 16 and 24-hour photoperiods on the fifth day of development. The highest percentage is recorded in photoperiods of 10 and 12 hours, which are 12.5 and 15.2% proportionally (table 4.3.1).

Table 4.3.1

Effect of density on the formation of winged individuals in a beetroot aphid colony

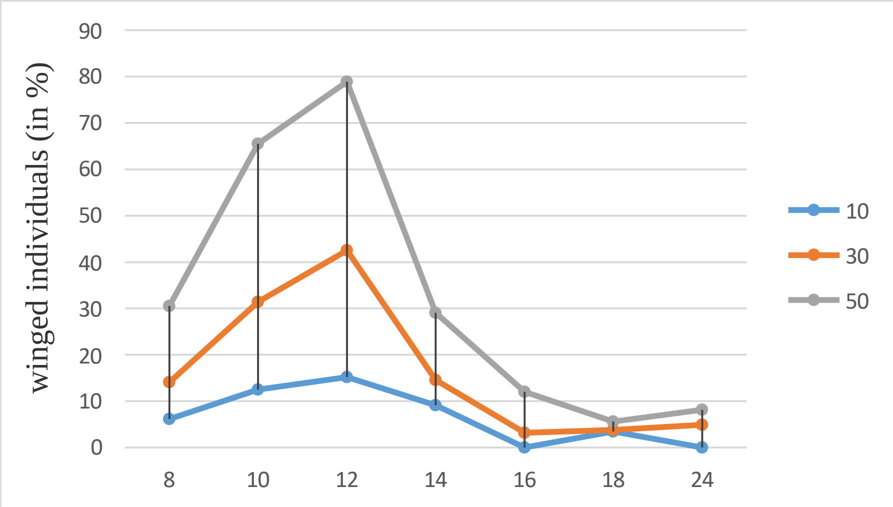
Number of individuals	Photoperiods (in hours)						
	8	10	12	14	16	18	24
	Amount of winged individuals (in %)						
10	6,2	12,5	15,2	9,1	-	35	-
30	14,1	31,4	42,5	14,6	3,2	3,8	4,9
50	30,5	65,5	78,9	29,1	12	5,6	8,2

When the number of larvae in the colony reaches 30 individuals, the individuals with wing protrusions are found in almost all photoperiods. However, winged individuals prevail in short-day photoperiods.

When the number of individuals on a leaf reaches 50, the winged individuals are observed in all photoperiods.

For example, 30% of individuals are winged morphs in an 8-hour photoperiod, whereas this figure is only 12% in a 16-hour light regime. In this mode, the highest result is obtained in photoperiods of 10 and 12 hours. Thus, 65.5% winged morphs are observed in 10-hour photoperiod, and 78.9% in 12-hour light conditions (line graph 4.3.1).

The obtained results suggest that the population density should not be viewed as the main factor in the formation of winged individuals, but as a factor strengthening the process by influencing the phenomenon quantitatively. It would be more correct to view such a strengthening factor as a method of lessening the fear of malnutrition due to density.



Line graph 4.3.1 Effect of density on wing formation process
Note: on the ordinate axis - photoperiods; 10;30;50 - number of individuals

CHAPTER V. BIOLOGICAL BASIS OF THE USE OF APHIDOPHAGS IN REGULATING THE NUMBER OF BEETROOT APHID

Some entomophages (*Aphelinus mali; A. ervi,; Diaeretiella rapae M.*, *Chrysopa carnea* Steph., *Adalia bipunctata*, *Coccinella septempunctata* and etc.) regulating the number of beetroot aphids are found in the research carried out in the agrocenosis. Among the entomophages the *Coccinella septempunctata* prevails both in terms of quantity (55-60%) and activity, so its phenology was studied in detail. Coccinella can be found in beet fields almost until harvest.

During the phenological observations, it was determined that the *Coccinella septempunctata* produce 3 generations in the area. Thus, the development of the first generation continues from late April to early May until the second half of June. The development of the second generation continues from the early June, and the development of the third generation continues from late June to early July until the middle of September. Imagos (insects) of the third generation is going to overwinter starting from the second half of September (table 5.1).

There are mainly 2 generations of the *Coccinella septempunc-*

tata are active in beet fields. The third generation feeds on clover and weeds and prepares for overwintering from September.

In the beet agrosenosis, the number dynamics of the *Coccinella septempunctata* changes synchronously with the number dynamics of the beet leaf aphid in the fields and plays an indispensable role in regulating the number of the pest and reducing the number of other harm- ful insects at the same time.

Table 5.1

Phenological calendar of the *Coccinella septempunctata* (Imishli, 2014-2015)

Months	April			May			June			July			August			Septem-ber			October		
Ten days	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
I genera-tion		i	i	i	i	i	i														
			y	y	y	y	y														
				s	s	s	s	s													
					p	p	p	p													
						i	i	i	i	i											
II genera-tion							y	y	y	y	y										
							s	s	s	s	s										
								p	p	p	p	p	p								
									i	i	i	i	i	i							
III gener-ation									y	y	y	y	y	y	y						
										s	s	s	s	s	s	s					
										p	p	p	p	p	p	p	p				
											i	i	i	i	i	i	i	(i)	(i)	(i)	(i)

Note: i – imago, y – egg, s – larva, p – pup, (i) – imagos going to diapause

Therefore, the protection of the overwintering places of the *Coccinella septempunctata*, which shows high activity as a biological agent against pests in agrocenosis, should be in the focus as the main factor leading to an increase in their number in the following years and the reduction of chemical control to a minimum.

CHAPTER VI. DISCUSSION OF THE OBTAINED RESULTS

In this chapter, the results obtained during the research were compared and analyzed with the results of scientific research conducted in this field.

RESULTS

For the first time in the republic, the effect of temperature and photoperiod on the reproduction and development of beetroot aphid was explored as a result of experimental studies, the role of various environmental factors in the ontogenesis, polymorphism and migration of the pest was determined, and at the same time, the phenology of beetroot aphid in agrosenosis and effective entomophages regulating its number were studied, the following results of scientific and practical importance were obtained:

1. The temperature factor is the main factor in the reproduction and development of beetroot aphid. The optimal temperature regime for the development of the aphid is 18-23^{o}C. The lower and upper temperature thresholds for development are 9-10 and 33-35^{o}C. Temperatures above 33^{o}C are lethal to larvae [2;3].

2. When studying the effect of temperature on the process of wing formation, it was found that the highest percentage is observed at 17-20^{o}C. High temperature has a negative effect on the formation of winged individuals [13].

3. Acceleration of larvae development is justified to be up to a certain temperature limit, i.e., up to 25^{o}C. The subsequent increase in temperature, on the other hand, has an adverse effect on the development of larvae, causing a relatively long period of this stage and an increase (50-100%) in their death rate [2].

4. The life span and reproduction of female (mother) individuals directly depends on temperature. The longest lifespan (39.3 and 33.1 days) and fecundity (88.7 and 78.6 new born) of individuals were recorded at temperatures of 18 and 20^{o}C [2.3].

5. The results of the experiments showed that constant feeding of individuals at high temperatures (25^{o}C and higher) has a negative

effect on the biological indicators of the next generations. Shortens the full development period of the ovaries and reduces their ability to produce offspring [10].

6. The results obtained during the experiments showed that the effect of photoperiod on the development of beetroot aphid is very interesting. Although temperature affects the duration of the larval stages of the leaf aphids, the duration of the reproductive period and the length of the development period as a secondary factor, it plays a major role in the formation of sexually reproducing individuals [8].

7. Research conducted in nature and in the laboratory showed that low temperature (17-20^{o}C) and short photoperiod (10-12 hours) are the main factors in the formation of winged individuals in spring and autumn, and the population density of the pest and the physiological state of the plant in summer [4;5;6;9;13].

8. The phenology of the beetroot aphid was studied in detail; it was determined that the mass migration of winged individuals to the beet agrocenosis occurs in the second and third ten days of May [9].

9. When exploring the effect of constant and variable (equivalent) temperature regime on life span and reproduction, it was found that it is more appropriate to use a variable temperature regime during the mass reproduction of any species in laboratory conditions. Because such a regime is closer to the day and night regimes existing in nature, it has a more positive effect on the biology of insects [10].

10. As a result of the experiments, it was determined that there is a vertical migration (displacement) of the beetroot aphid on the plant it feeds on, and as a result of this migration, they can choose a favorable environment for their living. That is, unlike laboratory conditions, in nature they can sometimes live using these properties even in the temperature conditions above 40^{o}C [12].

11. In the beet agrocenosis, the number dynamics of the *Coccinella septempunctata* acts as the most efficient predator in regulating the number of the pest synchronously with the number dynamics of the pest [1;4;7;9;11].

PRACTICAL SUGGESTIONS

1. According to the phenological data, taking into account that the migration of the beetroot aphid to the agrocenosis occurs mainly in the second half of May, it would be more appropriate to carry out chemical control measures (if necessary) in that period.
2. Based on our results regarding the vertical migration of the beetroot aphid on the plant, the aphid settles mainly around the tall sprout of the plant until 7:00 a.m., so this factor should be taken into account during the chemical control.
3. It is necessary to destroy weeds in the agrocenosis so that when the number of pests decreases, entomophages migrate beyond the area, because nectar-bearing and flowering weeds attract entomophages and cause their destruction during agrotechnical measures.
4. Since the *Coccinella septempunctata* is more effective in biological control of beetroot aphid, it is more expedient to mass-produce it in laboratory conditions and transfer it to agrocenoses.

List of published works on the content of the dissertation

1. İsgəndərova, G.Z., Həsənova, S.Ş. *Coccinella septempunctata*-nın (Coleoptera,Coccinellidae) inkişaf xüsusiyyətləri //-Bakı: Zoologiya İnstitutunun əsərləri, - 2015, cild 33, № 1,- s. 32-36.
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3. Искендерова, Г.З. Влияние температуры и фотопериодов на некоторые биологические показатели листовой свекловичной тли (*Aphis fabae* Scop.) //- Manchester: Scientific Collection "İnterconf". October, 2021,№80,- pp.203-205.
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5. Искендерова, Г.З. Роль плотности колонии в образование крылатых форм у свекловичной тли (*A. fabae* Scop.) // - Mexiko: Scientific Collection "İnterconf", - № 119, 2022. Monterrey,- pp.151-152.
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the winged individuals in the population of black bean aphid (*Aphis fabae* Scopoli, 1763) //- Nizhnevartovsk: Bulletin of Science and Practice.- 2022, Volume 8, İssue 4,- pp.66-71.

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The defense will be held on 23 May 2025 at 14^{00} at the meeting of the Dissertation council FD 1.09 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at the Institute of Zoology of MSERA.

Address: AZ 1004, Baku, Sabail district, A.Abaszade str., 115.

Dissertation is accessible at the Library of the İnstitute of Zoology of MSERA.

Electronic versions of the abstract are available on the official website of the Institute of Zoology, Ministry of Science and Education of the Republic of Azerbaijan.

Abstract was sent to the required addresses on 22 April 2025

Signed: 21.01.2025

Paper format: 60x84 1/16

Volume: 37573

Edition: 20 copies