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ABSTRACT

of dissertation submitted to be awarded the degree of
Doctor of Philosophy

**DEVELOPMENT OF RESISTANT SILKWORM BREEDS
FOR REPEATED FEEDING THROUGH THE USE OF
GENETIC RESOURCES, BREEDING-GENERIC
PARAMETERS AND CROSSING METHODS**

Specialty: 3110.01 - farm animals breeding, selection, genetics
and reproduction

Research interests: agricultural sciences

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A handwritten signature in blue ink, likely belonging to the Scientific Secretary of the Dissertation Council, Gulrukh Haji Dilbazi.

INTRODUCTION

Relevance of the topic and the degree of development. Bringing sericulture to world-class standards will enable Azerbaijan to access global markets while meeting domestic demand. Moreover, the Republic of Azerbaijan has significant potential for the development of this industry, including favorable climatic conditions, valuable species resources, and an available labor force. It is also worth noting that the specialization of the country's natural and economic regions in sericulture production, based on soil and climatic factors, will ultimately create favorable conditions for the implementation of effective state regulation measures in this sector.

The development of sericulture depends on the production of high-quality cocoons, which in turn requires the breeding of hardy and productive silkworms. Silkworms are poikilothermic organisms, and both temperature and humidity serve as critical limiting factors in their life cycle. These environmental parameters have a significant impact on the adaptive processes of individual organisms and populations.

The main factor hindering the solution of this problem is that, while the agroclimatic conditions of the spring season are quite favorable for the normal growth and development of the silkworm (*Bombyx mori* L.), the agroclimatic conditions during the summer–autumn period are highly unfavorable.

Therefore, the development of silkworm breeds resistant to the adverse conditions of the summer and autumn seasons is a crucial factor for the industrialization and sustainable advancement of sericulture in our country, and it represents an important challenge for the national economy.

These considerations indicate that the creation of new silkworm breeds and hybrids with high environmental tolerance through adaptive selection provides significant opportunities to achieve higher productivity under unfavorable production conditions and, ultimately, to enhance the economic sustainability of sericulture¹.

¹ Жученко А.А. (47). Адаптивное растениеводства (эколого-генетические основы). Теория и практика /2008 814с. Жученко А.А. (47). Адаптивное растениеводства (эколого-генетические основы). Теория и практика /2008 814с.

Adaptive selection is known to produce animal breeds, hybrids, and plant varieties with high environmental tolerance. However, until recently, the absence of adaptive breeding methods for silkworms, the lack of adequate evaluation and selection techniques, and the overall scarcity of research on genotype-environment interactions in silkworms have hindered the development of breeds and hybrids with enhanced environmental tolerance².

Therefore, just as a new priority area - adaptive selection - has emerged in livestock and crop production, leading to the creation of flexible animal breeds and plant varieties that can better adapt to wide fluctuations in environmental conditions and tolerate adverse environmental factors, it is equally important to conduct similar work in the field of sericulture^{3 4}.

The research matter and subject of the study. Development of new eco-genetic silkworm breeds that meet modern requirements through the selection of local and introduced breeds from Azerbaijan's gene pool.

The subject of the research is the assessment of environmental tolerance, productivity, and economic efficiency of new silkworm breeds using adaptive selection, conventional selection, alternating selection, and evaluation of selection-genetic parameters.

Purpose and objectives of the study.

The main objective of this research is to develop two environmentally tolerant silkworm breeds and hybrids capable of producing relatively high yields (10–15% lower than spring yields)

² Gasanova, G.M., Rustamov, H.H., Hummatov, N.G., Talay Ch.M. The role of genotype and environmental factors in the formation of grain quality indicators in soft wheat varieties // Scientific works of the Institute of Genetic Resources of the National Academy of Sciences of Azerbaijan - 2017. Vol. VI No. 1-2, pp. 13-18.

³ Molchan, I.M. Genetic characteristics of a plastic variety and principles of adaptive selection - Selection and seed production, - 1993. No. 3, pp. 10-15.

⁴ Strande Ismo⁰¹, Kantane Juha⁰¹, Russo Isa-Rita M.², Wenge Pablo Orozcoter¹², Brufor Michael W.⁴²³ nad Clingen Consortium. (139). Genomic selection strategies for breeding adaptation and production in dairy cattle under climate change //Genetics society, 2019. Sep: 123(3) p.307–317.

under the unfavorable summer–autumn conditions for selective feeding.

To achieve this goal, the following tasks have been planned for completion:

1. Selection of the most suitable source material from silkworm breeds preserved in genetic reserves and conducting research under laboratory conditions, following agronomically defined experimental protocols;

2. Development of early forecasting techniques;

3. Creation of synthetic populations through the crossing of selected material using adaptive selection, followed by testing and the development of a new breed;

4. Evaluation of experimental data using mathematical and statistical methods and parameters:

- The ecological stability (ES) method can be employed to more accurately identify genotypes with high environmental tolerance.

- The economic efficiency of the newly developed breeds has been evaluated.

5. Evaluation of the new breeds in production trials in comparison with silkworm hybrids currently cultivated in the Republic;

6. Analysis, synthesis, presentation, and evaluation of the obtained results using computer software.

Research methods. The following were used in the study:

- Comprehensive evaluation;

- Adaptive selection techniques;

- Selection-genetic parameters.

Basic provisions of protection:

1. The studies were conducted under agro-zootechnical experimental conditions, and a more precise assessment of genotype indicators was achieved through the development of a composite evaluation coefficient;

2. Based on the early forecasting method, it was established that there is no correlation between the cold resistance (tolerance to

negative temperatures) of silkworm breeds and their overall environmental tolerance;

3. The application of adaptive selection methods makes it possible to develop more resistant and productive silkworm breeds and hybrids;

4. To more accurately assess the suitability of the newly developed breeds, selection-genetic parameters and mathematical-statistical methods were applied;

- The ecological stability (ES) method can be applied to identify genotypes with enhanced environmental tolerance.

- The economic efficiency of a newly developed breed for a specific product is determined by the additional net income it generates compared to the reference breed.

5. The main requirements for production testing of new breeds include their conformity with the overall standards of the silk industry and high performance in key indicators such as grade, color, size, graininess, weight, silkiness, silk yield, unwinding capacity, total and continuous silk filament length from the cocoon, cocoon metric number, and other related parameters.

Scientific novelty of the research.

- For the first time in sericulture, a comprehensive evaluation of multiple breed indicators was conducted using a composite advantage coefficient;

- Explore how to accelerate research projects through the application of early forecasting techniques;

- Using the adaptive selection method, new silkworm hybrids—Hesa 2/1 × Khayal and Mizuri 5 × Mayak 6—as well as the Atlaz 1 and Atlaz 2 breeds were developed. These hybrids exhibit resistance to environmental stress factors and the unfavorable summer–autumn conditions, possess high biological and technological performance indicators, feature a unique morphological structure, and fully meet modern requirements.

Theoretical and practical significance of the research.

- In practice, this will facilitate the identification of genotypic and phenotypic selection methods within a shorter timeframe.

- At the same time, the results obtained are of significant importance for enriching the fields of biology, sericulture, and agriculture with modern scientific and methodological knowledge, and they can be utilized in the development of seminars, lectures, curricula, and textbooks for universities specializing in agricultural and biological disciplines.

- This will create opportunities to increase cocoon and silk production and exports in the country, while generating additional economic income.

- It will enhance cocoon production under unfavorable conditions and improve the profitability of silkworm farms.

Approbation and application of the case. The main results and findings of the dissertation were presented annually and discussed at the Academic Council of the former Azerbaijan Scientific Research Institute of Sericulture (2012–2014), as well as at seminars related to the program for the development of sericulture.

- As a result of the research, the silkworm hybrid “Hesa 2/1 x Khayal”. selected for its complex of high biological, reproductive and productive properties, was tested by the State Commission for Testing and Protection of Breeding Achievements of the Republic of Azerbaijan.

- Materials of the international scientific conference “The role of young scientists in agriculture: problems and opportunities” dedicated to the 91st anniversary of the National Leader of the Azerbaijani people Heydar Aliyev and the Day of National Salvation (Baku-2014);

- Materials of the International Scientific and Practical Conference “Application of Innovations in the Development of Veterinary Medicine” (Baku-2019);

- This was reported based on the materials of the V International Conference “Science in an era of imbalance” (M. Kiev-2019);

- Hereditary variability of biological features of mulberry silkworm under different conditions. Siberian Journal of Life Sciences and Agriculture. 2020;

- Economic efficiency of new silkworm breeds' resistance to adverse environmental conditions. Proceedings of the 11th

International Scientific and Practical Conference. "Current Problems of Mathematics and Natural Sciences" (Petropavlovsk-Baku-Surgut. 2023).

Name of the organization in which the dissertation work is carried out. This dissertation was carried out at the Sericulture Research Institute under the Ministry of Agriculture between 2012 and 2015. The field experiments were conducted at the Gakh Breeding Station.

Publications. Based on the dissertation materials, 13 scientific works were published, including 11 articles, 1 book and 1 thesis in domestic and foreign publications.

The total volume of the thesis with a sign indicating the volume by structural units of the thesis separately. The dissertation is composed of an introduction, six chapters, a conclusion, findings, recommendations, and a bibliography. The total volume of the work is 150 pages. It contains 27 figures and 26 tables. and references 159 sources, 125 of which are foreign publications. The total volume of the dissertation, including punctuation marks, amounts to 218,483 characters, of which: the literature review comprises 67,102 characters, the materials and methods section-19,846 characters, the research results-72,862 characters, the conclusion-8,079 characters, the summary-2,061 characters, and the recommendations-1,622 characters.

CHAPTER 1. ORIGIN, DISTRIBUTION AND BIOLOGICAL CHARACTERISTICS OF THE SILKWORM (*Bombyx mori* h.).

This chapter of the dissertation analyzes information on the genera and hybrids of the silkworm (*Bombyx mori* L.), their origin, distribution, biological characteristics, technological properties, and agroecological conditions. It also examines the productivity of silkworm species existing both worldwide and within the republic, explores the application of adaptive selection methods, and highlights the importance of genetic selection techniques. Furthermore, the chapter presents and compares the results of scientific research on the role of mulberry leaves in the development of the silkworm.

CHAPTER 2. EXPERIMENTAL PART, MATERIALS AND METHODS OF THE STUDY

The research was carried out at the Azerbaijan Scientific Research Institute of Sericulture, utilizing a live collection of silkworm genetic resources as the initial material. During the experimental phase, 12 superior breeds were selected as the starting material—six indigenous and six introduced—each characterized by a comprehensive set of biological, technological, and productive traits.

This chapter of the dissertation analyzes information on the genera and hybrids of the silkworm (*Bombyx mori* L.), their origin, distribution, biological characteristics, technological properties, and agroecological conditions. It also examines the productivity of silkworm species existing both worldwide and within the republic, explores the application of adaptive selection methods, and highlights the importance of genetic selection techniques. Furthermore, the chapter presents and compares the results of scientific research on the role of mulberry leaves in the development of the silkworm.

Local breeds: Caucasus, Success, Dream, Mayak-3, Mayak-4, Mayak-6.

Presented breeds: Mziuri 2, Mziuri 3, Mziuri 4, Mziuri 5, Vratsa 2003, Hesa2 / 1.

The experiment was conducted over a period of three years by artificially creating unfavorable conditions - temperatures and humidity levels above the normal range - during the spring feeding period. Beginning from the first day of the fourth year and continuing until the end of the feeding period, the temperature in the incubator was maintained at 27-28 °C (normal: 23-24 °C), while the relative humidity was kept below 50-55% (normal: 70-75%).

Worms from six local and six foreign breeds selected for the study were maintained under standard agro-zootechnical conditions without replication until the end of the third year. On the first day of the fourth year, three replicates of 250–300 worms from each breed were established and reared under unfavorable (pessimal) conditions until the completion of feeding. During the fourth year, the worms

were fed six times per day, and during the fifth year, four times. After the feeding period, the breeds were comprehensively evaluated based on a set of four biological traits—viability, average weight of the wet cocoon, average weight of the cocoon shell, and silkiness of the wet cocoon—as well as the yield of wet cocoons. The top three local and three foreign breeds were determined according to the value of the complex superiority coefficient. The selected local breeds were used as maternal lines, and the foreign breeds as paternal lines. Crossbreeding between them was performed according to a defined scheme, resulting in nine hybrid combinations, in addition to pure grains obtained from the six selected breeds. Among the nine hybrid combinations produced, two hybrids with the highest complex superiority coefficients were selected for further experimentation.

Starting with the third generation, both selected populations were obtained in the spring, summer and fall of each year using family breeding and adaptive selection methods and selected until they fully met the established limits⁵.

For selection and mathematical analysis of the results of experimental studies:

- The ranges of biological characteristics and productivity indicators of the initially selected and developed breeds were determined;

- The most suitable breeds were selected from the available genetic resources to serve as source material;

- Synthetic (hybrid) populations enriched with genetic material through crossbreeding were created and tested, and, based on a comprehensive assessment, two of the most promising populations from the first selection were identified;

- Silkworm has two types of performance indicators: wet cocoon product (DBM) and raw silk product (RMC);

- A comprehensive assessment was conducted employing genetic and mathematical analysis;

⁵ Salimjanov, S. The quality of mulberry leaves is one of the ways to improve the efficiency of sericulture. Salimjanov S., Juraboev D., Marupov D.//Actual problems of agricultural science development. Dushanbe. - 2011. - pp. 252.

- Two new breeds were developed and improved based on biological characteristics, productivity indicators, and the application of the adaptive selection method to the selected breeding populations.

The genetic and mathematical analyses conducted on the material of the two newly developed breeds revealed the patterns of selection development, genetic parameters, and the principles of adaptive selection methods.

- A simple and effective method has been developed for determining the parameters of environmental sustainability;

- Quantitative signs were characterized;

- Development of phenotypic correlations based on generally accepted methods;

- Inheritance of the genetic traits of the silkworm;

- The economic efficiency of tolerance of breeds and hybrids in unfavorable environmental conditions has been studied;

CHAPTER 3. RESULTS OF EXPERIMENTAL STUDIES

Temperature, relative humidity, ventilation, and the quality and quantity of leaves are of great importance for the development of silkworms.

As a result of three years of experimental research, it was concluded that the deterioration of traits does not occur uniformly across all breeds and crossbreeds. Certain breeds and crossbreeds exhibited greater deterioration, while others were less affected. This indicates that the resilience of breeds and crossbreeds to adverse environmental conditions is largely determined by heredity, specifically the rate of genotype response. Additionally, the study demonstrated that the environmental resilience of breeds and crossbreeds can be enhanced through selective breeding.

In the summer of 2012, the air temperature during the feeding period ranged from 28 to 29 °C, with humidity levels of 60–65%. During the fall feeding period, the air temperature decreased, and rainy weather caused humidity to rise to 65–70%. In the early years of the study, the air temperature was maintained at 28–29 °C, while in the later years, it was 23–24 °C.

During the summer feeding period of 2013, unfavorable conditions caused the temperature and relative humidity to fall below the standards established for silkworm fattening. Cocoon temperatures ranged from 27.5 to 28.5 °C during the first three years, increased to 29 °C in the third and fourth years, and reached 30 °C and above during the fourth year until the end of fattening. Relative humidity reached 55–60% during the fifth year and beyond. Although temperatures exceeded normal levels at the beginning of the autumn fattening period, they ranged from 27 °C in the third year to 29 °C in the fourth year and then decreased from the fifth year until the end of fattening, aligning with the accepted upper limit of the normal range.

During the 2014 summer fattening period, hatchery conditions ranged from 28.0 to 29.0 °C with 60–65% relative humidity during the first three years, and reached 30 °C with 55–60% relative humidity from the third year until the end of fattening. During the autumn fattening period, despite above-normal temperatures at the start, the observed temperatures were as follows: first year – 30.0 °C; second year – 30 °C; third year – 30 °C; fourth year – 29.5 °C; and fourth year until the end of the fifth year – 29.5 °C.

It should be noted that the new breeds and hybrids developed during this research exhibited the highest resilience to environmental stress factors.

3.1 Development of a method for early prediction of environmental tolerance of species

Experimental determination of silkworm stress tolerance is a matter of time, money and labor. With this in mind, we decided to explore the possibility of early prediction of the ecological tolerance of breeds.

The experiment was carried out as follows: at the beginning of the 3rd year, before the 1st feeding and in the last 7-8 days of the 5th year (during the yellowing of the cocoon), worms were placed in specially designed containers in the freezer. The temperature in the chamber was -3°C. The samples were removed from the chamber after 30, 45, 60, 90 and 120 minutes, removed and observed at 24-250 °C. The time elapsed from the moment the sample was removed

The complex adaptability coefficient of the experimental breeds was determined based on these four production traits. A comprehensive assessment was then performed using a set of biological and production indicators, which allowed us to identify the three best local and three best introduced breeds according to the magnitude of the complex superiority coefficient.

The breeding experiment was conducted according to the scheme presented in Table 3.3.1. In the second season, a base comprising six varieties and nine newly developed hybrids was established. The experiment was continued using adaptive selection, and the results of the breeding and hybrid combinations were analyzed to identify and select the best-performing lines.

3.3 Creation of synthetic populations by crossing, selection of the first two most promising breeding populations based on a comprehensive assessment.

The breeding experiment was conducted according to the scheme presented in Table 3.3.1. In the second season, a base comprising six varieties and nine newly developed hybrids was established. The experiment was continued using adaptive selection, and the results of the breeding and hybrid combinations were analyzed to identify and select the best-performing lines.

Table 3.3.1. Crossing scheme of selected local and foreign breeds.

Name of selected local breeds (♀)	Name of selected foreign breeds (♂)		
	Mziuri 2	Mziuri 5	Hesa 2/1
Mayak 3	Mayak 3 x Mziuri 2	Mayak 3 x Mziuri 5	Mayak 3 x Hesa2/1
Mayak 6	Mayak 6 x Mziuri 2	Mayak 6 x Mziuri5	Mayak 6 x Hesa2/1
Khayal	Khayal x Mziuri 2	Khayal x Mziuri 5	Khaval x Hesa2/1

Two highly environmentally stable hybrids were used in the breeding experiment: *Mizuri-5* × *Mayak-6* and *Hesa 2/1* × *Khayal*. These lines were provisionally designated as follows: the *Hesa 2/1* × *Khayal* hybrid was named the Atlaz-1 line, and the *Mizuri-5* × *Mayak-6* hybrid was named the Atlaz-2 line.

Table 3.3.2. Reproductive indicators of the lines (on average from 3 years)

No	Names of lines	Number of grenades of a butterfly, pcs	Weight of 1 box, mg	In grams, pieces	Weight of one grenade, mg	Incubation period, day	Resurrection percentage, %
1	Atlaz 1	743±3	410±0,42	1809	0,552	10	93,8±1
2	Atlaz 2	683±4	437±0,55	1650	0,640	11	92,2±4

From the lines, Atlas 1 starts up for a rich harvest of grenada, and Atlas 2 for a quality product.

As a result of our 3-year experience of work in adverse conditions and 3 seasons (spring, summer, autumn), high viability of the Atlas 1 line ($92,9 \pm 0,97$), relatively low viability of the Atlas 2 line ($89,0 \pm 0,95$) had. As we know, the Atlas 1 line has a higher viability than the Atlas 2 line, but in terms of biological productivity, the Atlas 2 line has higher characteristics than the Atlas 1 line. By the weight of the living cocoon, the Atlas 1 line was $1,92 \pm 2, 1$ g, line Atlas 2 – $2,00 \pm 5,2$ g. The weight of the cocoon was higher than that of line Atlas 1.

In terms of cocoon yields, the Atlas-1 line was -33,39 kg, and the Atlas 2 line was -33,12 kg. As for the productivity of silk, the Atlas-1 line was 7,70 kg, the Atlas-2 line – 7,27 kg. Both had high productivity rates. Even in terms of silk performance, it had an optimal limit. As a result, this is a high figure.

Table 3.3.3. Productivity indicators of Atlas 1 and Atlas 2 breeds (on average from 3 years)

Indicators	Measurement unit	Atlas 1	Atlas 2
Ability to survive	%	92,9±0,97	89,0±0,95
Wet cocoon mass	g	1,92±10,1	2,00±0,2
Cocoon shell mass	mg	443±3	467±3
Silkiness of wet cocoon	%	23,17±1	23,24±2
Cocoon yield from 1 standard (20,000) box of grenade	kg	33,39	33,12
Silk yield from 1 standard (20,000) box of grenade	kg	7,70	7,27
K_{tot} -comprehensive adaptive ratio	Σ average	0,803	1,006

Due to unfavorable environmental conditions, Atlas had a 2-1,006% linear advantage and Atlas 1 a -0,803% linear advantage.

CHAPTER 4. MORPHOLOGICAL STRUCTURE OF NEW DEVELOPED BREEDS

Structures of the silkworm after metamorphosis (caterpillar, cocoon, butterfly, cocoon, silk)

As observed, crossing breeds of different origins produced advantageous combinations of diverse genotypes.

The Atlas-2 worms inherited their genetic traits from both parents, with paternal breeds exhibiting dominance in morphological characteristics. Atlas-2 worms are crescent-spotted, display a khoncha pattern, and produce elongated, banded cocoons. In contrast, Atlas-1 worms are white and crescent-spotted, with elongated, oval cocoons, reflecting the dominance of traits from both parental breeds (Table 4.1).

Table 4.1. Morphological structure of species and hybrids

Local breeds			Foreign breeds		
Name of breeds	Worms	Cocoon	Name of breeds	Worms	Cocoon
Mayak-6	crescent-spotted	oblong, oval-shaped	Hesa 2\1	crescent-spotted	elongated, less belted
Khayal	crescent-spotted	oval, slightly arched	Mziuri-5	crescent-spotted khonchali	elongated, belted
Newly created lines					
Hybrids		Worms		Cocoon	
Atlas 1		crescent-spotted		elongated, oval	
Atlas 2		crescent-spotted khonchali		elongated, belted	



Figure: 4.1. Atlas 2.



Figure: 4.2. Atlas 1

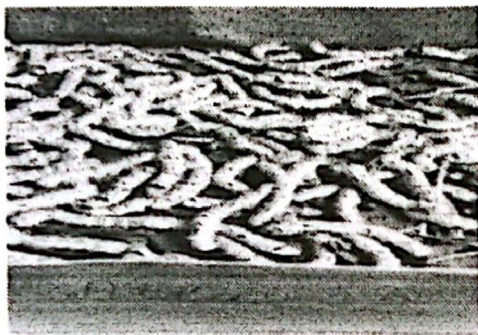


Figure: 4.3. Atlas 2. silkworm

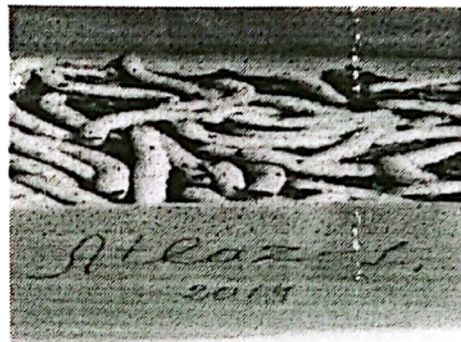


Figure: 4.4. Atlas 1. silkworm

CHAPTER 5. STUDY OF BIOLOGICAL TRAITS USING SELECTION-GENETIC PARAMETERS

5.1 Inter-seasonal assessment of silkworms using the ecological sustainability method

Selection work was carried out annually over three seasons- spring, summer, and fall-with the final selection completed in the fall of the eighth generation. Family feeding and individual phenotype selection were applied in all generations (1-8) of both breeding lines⁶.

The limits indicated at the end of feeding and the maximum mass of a living cocoon, the values of the mass of the cocoon

⁶ Petkov N.I., Petrov A.I., Yankov A.A.(128). Basic principles and organization of selection-breeding practices with mulberry silkworm //International Journal of Agriculture, Environment and BioResearch, -2021. v.6, No.1, p.23-28.

membrane (Hop and Xpsh) and the average values of the three environments (conditions) for both traits of each line, based on these values, are mainly hereditary resistance to adverse effects of environmental factors genotype environment the degree was determined by the ecological sustainability coefficient (ES) and breeding indices (SI).

Table 5.1.1. shows that the average values of the environmental sustainability coefficients (ES_i) of the average mass of a living cocoon and cocoon curtain from the total material of the Atlas 1 line in the spring-summer and spring-autumn seasons (0,920-0,931) and (0,953-0,938), respectively. Average values of breeding indices (SI) for the Atlas 2 line in the spring-summer and spring-autumn seasons (0,920 – 0,934) and (0,927-0,942) and for the Atlas 1 line (1,78 g-1,81 g) and (430 -421 respectively). mg), as well as in the Atlas 2 line (1,88 g -1,91 g) and (440-451 mg).

Table 5.1.1. Average values and ecological-genetic parameters of the leading selective traits of lines grown in spring-summer and spring-autumn conditions (on average from 3 years)

Names of the breeds	Spring-summer					Spring-autumn				
	\bar{X}_{spring}	\bar{X}_{summer}	\bar{X}_{aver}	ES	SI	\bar{X}_{spring}	\bar{X}_{autumn}	\bar{X}_{ave}	ES	SI
Wet cocoon weight, mg										
Atlas-1	2.01	1,86	1,93	0,920	1,78	2.01	1,87	1,94	0,931	1,81
Atlas-2	2.12	1,95	2,03	0,920	1,88	2.12	1,98	2,05	0,934	1,91
Weight of cocoon shell, mg										
Atlas-1	462	440	451	0,953	430	462	433	448	0,938	421
Atlas-2	492	456	474	0,927	440	492	463	478	0,942	451
Silk of the wet cocoon, %										
Atlas-1	22,39	23,70	23,05	1,058	24,39	22,39	23,17	22,78	1,034	23,55
Atlas-2	22,72	23,43	23,08	1,032	23,82	22,72	23,41	23,07	1,031	23,78

Thus, the Atlas 1 line gave 1,058%, the Atlas 2 line – 1,032%. In the spring-autumn season, the Atlas 1 line gave 1,034%, the Atlas 2 line – 1,031 %. The average values of breeding indices (SI) were Atlas 1- (24,39-23,55 %) and Atlas 2- (23,82-23,78 %), respectively. This leads us to say that not all breeds and hybrids respond in the

same way to environmental fluctuations, there is a big difference. With adaptive selection, every breed and hybrid can be improved.

5.5 Study of the inheritance of biological traits in silkworms

The pronounced effectiveness of adaptive selection is clearly demonstrated by comparing the biological indicators of the Atlas-1 and Atlas-2 breeds in the first and seventh generations (Table 5.5.3).

Table 5.5.3. The selection effect (genetic enhancement) of biological traits achieved in the 7th generation compared to the 1st generation of the Atlas-1 and Atlas-2 breeds

Generation number and selection effect	Atlas-1			Atlas-2		
	Wet cocoon weight	Weight of cocoon shell	Cocoon silkiness	Wet cocoon weight	Weight of cocoon shell	Cocoon silkiness
F ₁	1,80	426	23,66	2,02	448	22,22
F ₇	2,02	470	23,30	2,06	490	23,78
Selection effect %-l _a	112,2	110,3	98,5	101,9	109,4	107,0

Thus, the results obtained from the selection work conducted over seven generations confirmed the theoretical proposition put forward and clearly demonstrated that adaptive selection, implemented by rearing all generations under pessimal conditions, is both advantageous and effective.

5.6. Economic efficiency of new breeds

Based on the developed methodology, the economic efficiency of the newly developed varieties Atlas-1 and Atlas-2 - characterized by high environmental stability and productivity - was determined in comparison with the control varieties Mayak-6 and Hesa 2/1. The comparison was made in terms of gross and individual production per standard box (20,000 eggs) of silkworms.

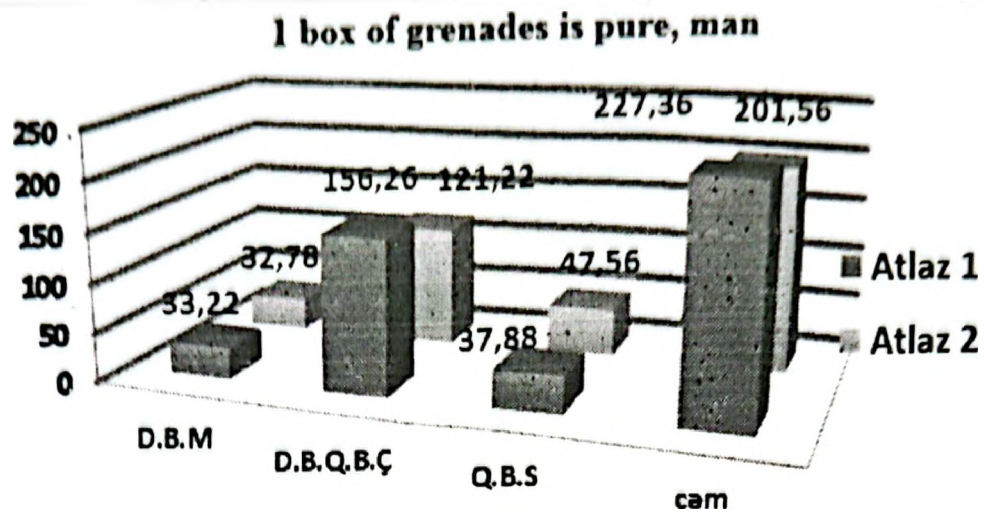


Figure 5.6.1. WCY – wet cocoon yield; DCOWC – dry cocoon output from wet cocoon, DCC – dry cocoon consumption

Under pessimal conditions, the tolerant Atlas-1 breed, compared to the control group Hesa 2/1, produced wet cocoons valued at 32.22 manat per standard box, dry cocoons valued at 156.26 manat per unit of wet cocoons, and incurred a wet cocoon consumption cost of 37.88 manat for raw material production.

Under pessimal conditions, the Atla2-2 breed, compared to the control breed Mayak-6, yielded a net income of 32.78 manat from wet cocoon production per standard box, 121.22 manat from the production of dry cocoons obtained from wet cocoons, and 47.56 manat from the consumption of dry cocoons for raw silk production.

As shown in Table 5.6.1, under unfavorable conditions, the tolerant Atlas-1 breed generated a total of 227.36 manats of additional net income compared to the control breed Hesa 2/1. This increase resulted from reduced dry cocoon consumption per standard cocoon box, higher dry cocoon yield from wet cocoons, and improved raw silk production. Similarly, the tolerant Atlas-2 breed produced a total of 201.56 manats of additional net income compared to the control breed Mayak-6, owing to lower dry cocoon consumption per standard cocoon box, higher dry cocoon yield from wet cocoons, and greater raw silk output.

Thus, the development of new tolerant silkworm breeds and their wider application in production create broad opportunities for

cocoon and raw silk producers to achieve higher incomes and enhance the economic profitability of sericulture under unfavorable production conditions.

CHAPTER 6. RESULTS OF THE PRODUCTION TESTING OF BREEDS

During the production of industrial cocoon seeds (grain) from breeding stock at cocoon-seed factories, the productivity of cocoon batches is generally evaluated based on their performance indicators. The results of the production testing for the breeds are presented in Table 6.1.

During the production trial, cocoons were classified and sorted into excellent, types I, II, III, and defective categories. The yield of excellent cocoons from the Atlas-2 breed was 12.4 kg, while the yield of type I cocoons from the same breed was higher at 21.4 kg. In contrast, the Atlas-1 breed produced fewer cocoons due to 1.0 kg of defective cocoons. The Chinese hybrid breed had 4.4 kg of defective cocoons, resulting in lower overall productivity quality. Overall, the new breeds exceeded the control group in total cocoon yield by 46.8%.

Table 6.1. Effect of production trial on the cocoon breeds

Name of breeds and hybrids	Feeding period, days	Weight of 1 wet cocoon, g	Cocoon yield from 0.5 box grain, including					Overall productivity of cocoon breeds	
			Superior type, kg	I type, kg	II type, kg	III type, kg	defect	Up to control	
								kg	in %
Atlas-1	26.0	1.93	11.5	20.0	9.0	3.9	1.0	45.0	140.6
Atlas-2	26.5	2.0	12.4	21.4	7.3	4.7	1.2	47.0	146.8
China hybrid control	29.0	1.65	5.2	8.0	6.8	7.6	4.4	32.3	100.0

The continued use and dissemination of the newly developed resistant breeds on cocoon farms will ensure high cocoon yields and increased net income under various conditions, thereby stimulating greater interest in the development of this sector.

RESULTS

1. By employing adaptive selection methods along with appropriate evaluation and selection techniques, we successfully developed two new mulberry silkworm breeds exhibiting ecological tolerance. Both breeds have demonstrated their effectiveness in accordance with established scientific principles. Based on the percentage of cocoon revival, the Atlas-1 breed achieved 93.8%, while the Atlas-2 breed reached 92.2%. Worm survival rates were 92.7% for Atlas-1 and 89.8% for Atlas-2. The average weight of wet cocoon was 1.92 g for Atlas-1 and 2.00 g for Atlas-2, while the average cocoon shell weight was 445 mg for Atlas-1 and 470 mg for Atlas-2. Silkiness of wet cocoons was 23.09% for Atlas-1 and 23.19% for Atlas-2. The yield of wet cocoons per standard box (20,000 pieces) was 33.39 kg for Atlas-1 and 33.13 kg for Atlas-2, whereas the yield of raw silk per standard box was 7.70 kg for Atlas-1 and 7.34 kg for Atlas-2.

2. There is no connection between the cold hardiness of breeds and their environmental tolerance.

3. The inheritance of genetic traits is dominant in both sexes, whereas males exhibit dominance in morphological, biological, and technological characteristics.

4. Variations in the nutritional conditions of parents and offspring, including differences in feed quality, influence the reduction in the heritability of biological traits.

5. Genetic correlations between biological traits were reduced to a greater extent in the Atlas 2 breed than in the Atlas 1 breed.

6. Based on the conducted selection work, it was determined that selection is most effective when carried out on the same genetic material under pessimal nutritional conditions across all generations (spring, summer, and fall). Such selection not only improves biological characteristics but also significantly enhances environmental tolerance.

7. It has been established that the high hereditary tolerance of silkworm breeds and hybrids to adverse environmental conditions contributes to increased economic efficiency. For instance, one

standard box (20,000 grains) of Atlas-1 and Hesa 2/1 silkworms produces an additional income of 227.56 manat, while Atlas-2 generates an additional income of 201.56 manat due to the zoned Mayak-6 breed.

The results of our research have been validated, allowing us to identify the most effective and appropriate methods of interbreed selection, considering both practical and theoretical criteria.

RECOMMENDATIONS

1. To restore cocoon farming in the republic to its traditional levels and increase cocoon and raw silk production, seasonal feeding during spring, summer, and fall is essential. However, certain agronomic practices must be followed when implementing seasonal feeding. For instance, at cocoon temperatures of 29–30 °C and humidity levels of 80–90%, worms may develop jaundice. Therefore, when feeding at relatively high temperatures of 27–28 °C, worms should be fed frequently in small amounts, ensuring that humidity remains within 55–65%. In general, the life of a silkworm is dependent on humidity at 10%, temperature at 20%, and mulberry leaves, its only food, at 70%.

2. Regardless of the season, the lack of nutrients and water in the leaves leads to a decrease in yield and thinning of the silk thread. Therefore, if top dressing occurs in summer and autumn, it is important to frequently water and provide mulberry plantations with nitrogen, phosphorus, potash fertilizers and other organic substances.

3. When developing silkworm breeds and hybrids, it is advisable to consider their environmental tolerance alongside biological, technological, and production traits.

4. The implementation of seasonal feeding provides additional income for farmers. Our newly developed breeds enhance the competitiveness of silk products and generate increased economic returns. The use of Atlas-1 and Atlas-2 breeds in silk farms improves cocoon and raw silk yields, thereby producing additional income.

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The defense of the dissertation will be held on "28" November 2025 at 14⁰⁰ in the meeting of the Dissertation Council BFD 3.21 operating at the Institute of Genetic Resources of the Ministry of Science and Education (MSE) of the Republic of Azerbaijan

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