Creation and laboratory testing of new complex and simple industrial hybrids with improved technological properties of cocoons

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Abstract. This article highlights the results of testing new complex and simple industrial hybrids of silkworms, focusing on their improved productive and technological properties in comparison with foreign analogues. Various reproductive, biological, productive, and technological indicators were used to evaluate the performance of these hybrids. The research demonstrated that local complex and simple hybrids outperformed the control variants in terms of these indicators, indicating their high performance and potential for silk production. These findings suggest that the local silkworm hybrids have significant advantages over foreign analogues, particularly in terms of cocoon quality and quantity. Based on the positive results obtained from the testing, the article proposes increasing the volume of preparation of local silkworm hybrids for the production of industrial cocoons. This recommendation is supported by the superior performance of these hybrids in comparison with foreign analogues, indicating their suitability for large-scale silk production. This study provides valuable insights into the potential of local silkworm hybrids for improving silk production in Uzbekistan. By utilizing these hybrids, the silk industry in the country could enhance its productivity and competitiveness in the global market, while also promoting the development of local sericulture.

1. Introduction

Sericulture, the production of mulberry cocoons, stands out as one of the economically lucrative branches of the agricultural sector when organized correctly and timely. However, a significant challenge in sericulture worldwide is ensuring the purity of hybrids, free from contamination with purebred material, to fully capitalize on the benefits of heterosis [1].

The creation of pure hybrids for use in industrial sericulture requires precise separation of the component species by sex in grenage factories [2]. Grenage factories play a crucial role in the sericulture process, as they are responsible for rearing silkworms from the larval stage to cocoon formation. During this stage, it is essential to ensure that male and female silkworms are segregated accurately to prevent unintended breeding and maintain the genetic purity of the hybrids [3].

Achieving this precision in sex separation is critical for several reasons. Firstly, pure hybrids exhibit superior characteristics such as increased cocoon production, improved silk quality, and enhanced resistance to diseases and environmental stressors [4]. These traits are essential for maximizing silk production and ensuring the sustainability of the sericulture industry [5].

Furthermore, maintaining the genetic purity of hybrids is crucial for preserving the integrity of the silkworm strains and preventing genetic dilution. Contamination with purebred material can lead to a loss of heterosis, reducing the productivity and quality of the silk produced [6].

The successful production of pure hybrids in sericulture requires meticulous attention to detail and adherence to strict protocols in grenage factories. By ensuring the accurate separation of male and female silkworms, sericulturists can optimize silk production, enhance the quality of the silk produced, and sustain the profitability of the industry [7].

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In industrial sericulture, the use of interbreed hybrids is common practice due to the significant advantages offered by heterosis. Hybrids exhibit increased productivity and enhanced resistance to adverse environmental conditions compared to purebred silkworms [8]. The success of hybridization largely depends on the compatibility of the breeds involved and their combinative ability.

In the breeding laboratory, various high-yielding silkworm breeds were available, each with its own unique characteristics. Some breeds excelled in productivity, while others were known for producing high-quality raw silk with long threads. Recognizing the potential for creating superior hybrids, an unscheduled initiative was undertaken last year to create new hybrid combinations [9].

The process of creating these hybrids involved careful selection of parent breeds based on their genetic characteristics and performance traits. The goal was to combine the desirable traits of each breed to create offspring with improved productivity and silk quality. The initial testing of these new hybrid combinations was conducted in the spring of 2023 to evaluate their performance under controlled conditions [10].

During the testing phase, various parameters were monitored, including the growth rate of the larvae, cocoon quality, silk yield, and overall silk quality. Preliminary results indicated promising outcomes, with some hybrid combinations showing significantly improved performance compared to the parent breeds.

2. Materials and Methods

In this paper, 14 breeds and lines were studied for their acceptability in the breeding process of developing new breeds with improved technological properties. For each original breed or line, 50 grenade clutches were studied for reproductive characteristics. The eggs in the clutches were counted, weighed and the number of normal eggs, the percentage of physiological defects, the weight of eggs and the average weight of one egg were determined. Using the method of biological statistics, the arithmetic mean ($\overline{X}$), the error of the arithmetic mean ($\mathbf{S}\bar{x}$) were calculated based on the main signs of reproduction.

Then, within each breed, the clutches of grens were combined into mixtures. Samples were taken from the grena mixture - 4 replicates of 200 eggs each, incubated and the percentage of egg viability was calculated based on the number of non-revitalized eggs.

Green mixtures of experimental breeds and lines were incubated in the spring season. The caterpillars emerging from the eggs on the first or second day of revival are removed into rearing boxes. In the second instar, caterpillars within the studied breeds were formed in 8 replicates of 200 pieces and fed until the cocoons curled. After harvesting, the cocoons in each replication were sorted into normal (with a healthy pupa), doubles, wood grouse, and carapace. The viability of caterpillars and diseased cocoons was calculated.

Cocoon samples of 15 ♀, 15 ♂ were taken in 4 replicates and indicators of productivity traits were determined - the average weight of the cocoon, shell and silk production. Then the cocoons are combined within breeds and lines and samples of 400 cocoons are taken, which are frozen and unwound at the Uzbekistan Research Institute of Natural Fibers. The indicators of the leading technological features were determined - the yield of raw silk, all silk products, unwinding, total length and continuously unwinding length of the cocoon thread, metric number of the thread. Based on the indicators of reproduction traits, viability, productivity and especially technological properties of cocoons, a judgment was made about the acceptability of the studied breeds and lines in the breeding process.

3. Results and Discussion

It is known that the indicators of reproductive traits of hybrids depend on the degree of fertility of butterflies of the mother breeds. Naturally, the larger the cocoons, the higher the fertility of the butterflies emerging from them, so we tried to attract large-cocoon breeds with high fertility as maternal forms, which provided a good, full-fledged hybrid breed. First of all, the reproductive characteristics of new hybrid combinations were studied (Table 1).

Table 1. Number and weight of eggs in clutches of new hybrid combinations

Name of industrial hybrids	Number of normal eggs in a clutch	Mass of eggs in a clutch, mg	Weight of 1 egg, mg
(Marhamat x Line 28) x (Asaka x Line 27)	861	550	0.637
Asaka x Marhamat	845	520	0.615
Chinese hybrid (control 1)	705	388	0.550

Analyzing the indicators shown in Table 1, we come to the conclusion that the new hybrid combinations are endowed with good reproductive properties. The number of eggs in a clutch ranges from 705 to 861 eggs, the mass of the clutch

is from 388 mg to 550 mg. In the Chinese hybrid (control), the weight of one egg is 15.81 percent less than that of the complex hybrid (Markhamat x Line 28) x (Asaka x Line 27), respectively, this indicator directly affects the yield of cocoons from one box of caterpillars. And the number of normal eggs in a clutch is 22 percent greater in a complex hybrid compared to the control. This is also an important factor in the productivity of silkworm breeds and hybrids. Thus, the given figures in the table once again confirm the superiority of complex hybrids in many economically valuable traits.

In the practice of selection, one has to solve the issues of choosing traits based on their compatibility. At the same time, it is extremely important to maintain a certain ratio between the live weight of animals and wool diameter indicators.

The following correlation coefficients were established: live weight and wool diameter under conditions of abundant feeding - 0.37, average feeding - 0.48. A fairly high positive correlation coefficient was calculated between fiber fineness and pure wool shearing (r=0.53) for Australian Merino sheep. You can find the following message: certain breeds of sheep (Lincoln, Leicester and Romney-Marsh) are distinguished by the production of long wool. This quality should be considered as an expression of the high functional ability of the follicles to synthesize keratin fibers from nutrients circulating in the blood. This functional ability is inherent to the follicle and is genetically determined. It is well expressed already during the period of intrauterine development of the lamb. Based on the foregoing, it can be assumed that a large share of genetically determined variability in runa occurs under the influence of gene systems.

Experiments that were interesting from the point of view of fiber manufacturability ended with very positive results. The authors, through systematic crossbreeding, achieved the production of crossbred semi-fine wool sires with a wool length of at least 18 cm and a fineness of no higher than 48 quality.

Knowledge of the patterns of formation of technological traits will allow for scientifically based selection. The above fully applies to the silkworm, which produces silk fiber. It is important to know the processes of fiber formation and the factors influencing this process [4, 7]

We tried to find works in the literature that address these issues. In the 30s it was argued that the more silk fiber the cocoon contains, the better the silk shell unwinds. The length of the silk correlates positively with the size of the cocoon. There is a negative correlation between the length and thickness of the mulberry [1, 9].

Among the technological characteristics of silkworm products, which are of particular importance for the silk industry, is the unevenness of the intracocoon thread. The variability of the intracocoon thread unevenness varies within a fairly large range of 6.0-45.7%. Such great variability indicates the presence of great potential for selection for this trait. Along with variability, a scientific study of intra-cocoon unevenness of the thread using the example of breeding families of the SANIISH 17 breed [5, 7].

Sufficiently high numbers and weight of eggs in hybrid combinations will ensure high egg yields from each box. Large eggs hatch into healthy, full-fledged, more active larvae.

Viability plays a direct role in the evaluation of hybrids, since the level of larvae emerging from eggs and the survival of caterpillars before the start of the cocooning process are signs that affect the yield of cocoons from each box of greens. The higher the viability of the eggs and the greater the number of caterpillars that have curled cocoons, the higher the yield of cocoons. Table 2 provides indicators for the viability of eggs and caterpillars of new hybrids.

Table 2. Viability of hybrids at the embryonic and postembryonic stages of silkworm development

Name of industrial hybrids	**Egg viability** $\overline{X}$ **±S** $\overline{x}$ **, %**	**Viability of caterpillars** $\overline{X}$ **±S** $\overline{x}$ **, %**
(Marhamat x Line 28) x (Asaka x Line 27)	94.4±0.43	92.7±2.47
Asaka x Marhamat	98.8±0.25	91.8±2.10
Chinese hybrid (control 1)	94.8±0.32	88.6±0.26

The data in Table 2 indicate that the newly created hybrid combinations are characterized by fairly good egg viability (94.4-98.8%) and exceed the standard widely zoned hybrid Tetrahybrid 3 by 5.9-11.3%.

The egg viability indicators of the complex hybrid (Marhamat x Line 28) x (Asaka x Line 27), although the same with the control Chinese hybrids, are the same, but for the Asaka x Markhamat hybrid it is 4% higher than for the control hybrid. And the viability of caterpillars in a complex hybrid is 4.1% higher compared to the control, and in a simple hybrid it is 3.2% higher, respectively. This all means that the yield and quality composition of cocoons in complex hybrids will be higher and better than in the control. However, not all new hybrids have an advantage over control hybrids in terms of caterpillar viability. The remaining tested hybrids are almost at the control level in terms of caterpillar viability.

Among the economically valuable traits of silkworm hybrids, much attention is paid to the traits of silk productivity (Table 3).

Table 3. Indicators of productivity traits of the tested hybrids

Name of industrial hybrids	Cocoon mass		Silk shell weight		Silkiness	
	$\overline{X} \pm S_{\overline{x}}$, g	in % to control 1	$\overline{X} \pm S_{\overline{x}}$, mg	in % to control 1	$\overline{X} \pm S_{\overline{x}}$,%	in % to control 1
(Marhamat x Line 28) x (Asaka x Line 27)	2.40±0.012	123.1	554±6.1	133.5	23.1±0.20	109.0
Asaka x Marhamat	2.59±0.019	132.8	610±8.5	147.0	23.6±0.34	111.3
Chinese hybrid (control 1)	1.95±0.190	100.0	415±4.7	100.0	21.3±0.41	100.4

From Table 3 the conclusion follows that the new hybrid combinations significantly exceed the foreign Chinese cocoon in weight (by 23.1-32.8%), and some of them have an advantage even over the standard large-cocoon Tetrahybrid 3.
It is appropriate to note the fact that the group of tested hybrids included 3 purely male hybrid combinations. Let us recall that male cocoons are 18% lighter than cocoons of the opposite sex. Despite this biological feature, due to the high heterosis, the caterpillars of these hybrids curled cocoons that significantly exceeded the mass of the Chinese foreign hybrid - 2.40 g, 2.50 g versus 1.95 g in the control.
All tested hybrids have fairly high silk shell mass (554-610 mg) versus 415 mg in the control Chinese hybrid. New hybrids differ from the control ones in terms of silk production of cocoons by 2.3% and amount to 23.6%, which is clearly seen from Table 3 - this is the highest silk production, and for complex hybrids this figure was 23.1%. High performance of hybrids in terms of silk production in combination with sufficiently large cocoons consisting of 100% males will determine their great economic value.
In the process of creating new breeds of silkworms, he selected breeding cocoons based on silk content and grain size. The silkiness of cocoons is a stable hereditary property; it is less susceptible to changes under the influence of environmental conditions than the mass of the cocoon.
As for grain size, here the author admits inaccuracies, namely that different breeds have different grain sizes of cocoons. Larger horses also have coarser grains. The achievements of breeders to a certain extent refute this position. The fact is that at present, lines have already been obtained that combine increased cocoon mass with a fine-grained shell. In the literature, there are almost no works devoted to the study of variability and heritability of cocoon granularity. Some studies report that granularity is used in the cocoon selection system as an indirect feature [2, 4].
Research and knowledge of the biological patterns of formation and development of animal fur makes it possible to develop scientific methods for managing the quantity and quality of wool productivity and the technological properties of wool.
Research has shown that the development of skin and fur is determined by genetic and environmental factors [3]. Important indicators of the skin are skin thickness, density and depth of hair follicles. The thickness of the skin is closely related to many characteristics of the body, with general development, productivity and coat quality.
Skin folding is one of the important features of fine-wool sheep. This property is in close relationship with the constitution, some morphological and physiological characteristics. Since the folding of the skin correlates with the area of the fur field, the desire of breeders to increase the folding of the skin is completely justified. Folding is formed by relatively different growth rates of sheep skin during embryonic and postembryonic development. Skin folding is a polygenic trait. At the same time, environmental conditions have a significant impact on the formation of skin folding in sheep.
The more favorable the conditions of embryonic development, the more intense the growth of the embryo occurs and intensifies within the hereditarily determined type of development of folding.
The correlation coefficient between the skin reserve at birth and wool clipping at 2 years of age reached a significant size of r = 0.80.
How the total thickness of the skin (astrakhan) is closely related to the timing of fruiting and the smok types of parental pairs. Abundant feeding of the queens during the period of fetal development ensures the production of full-fledged broadtail.
The process of determining the color shade of cocoons makes it possible to select cocoons with high identical technological indicators and to produce high-quality raw silk. For example, the raw silk produced from the purple shell of cocoons met the requirements of international class “A”, while the raw silk produced from traditionally sorted cocoons without taking into account the shade of the color of the shell corresponded to class “B”.
In order to clarify the influence of silk shades on the coloristic properties of smoothly dyed material, experimental and control samples were subjected to the process of dyeing with an active dye. Silk produced from raw materials using new sorting, having the same color base, received a color with high uniformity. Due to the different shades of the original raw material, the control samples of the material were painted unevenly with a defect.
Based on the conducted studies of the influence of functional and stepwise changes in the linear density of raw silk on the unevenness of raw silk, it can be assumed that when selecting raw materials for sampling a given assortment, it is

necessary to take into account the qualitative characteristics of the raw materials - the linear density of the cocoon thread and its thinning, the caliber of cocoons, affecting the unevenness of the complex thread. From the point of view of reducing unevenness of threads due to a functional change in linear density and the appearance of areas with a missing segment, an optimal combination of combinations of cocoon threads must be ensured, achieved by grouping raw materials according to linear dimensions and quality of the shell. An important indicator in evaluating new hybrids is the yield of cocoons and raw silk per unit of fed caterpillars (Table 4).

Table 4. Estimated yield of cocoons and silk from one box of hybrid caterpillars

Name of industrial hybrids	Productivity from 1 box of caterpillars			
	Cocoons		Silkworm	
	Abs. kg	in % to control 1	Abs. kg	in % to control 1
(Marhamat x Line 28) x (Asaka x Line 27)	100.1	128.8	23.1	140.0
Asaka x Marhamat	95.8	123.3	22.7	113.9
Chinese hybrid (control 1)	77.7	100.0	16.5	100.0

The data given in Table 4 indicate that complex hybrids (95.8-100.1 kg) exceed the domestic hybrid Tetrahybrid 3 in terms of cocoon yield, and the remaining hybrids are almost at the level of this control hybrid. The excess of all tested hybrids over the Chinese control hybrid is even more pronounced (95.8-100.1 kg versus 77.7 kg in the control).
The increased mass of the silk shell in the new hybrids ensured a significant increase in silk from 1 box of fed caterpillars. The highest yield of silk from 1 bark of caterpillars was distinguished by two hybrids - 23.1 kg and 22.7 kg and exceeded Tetrahybrid 3 by 4.4-5 kg, and Chinese foreign by 6.2-6.6 kg. In production conditions, new hybrids, due to their great potential, will ensure sufficiently high yields of cocoons and silk and, accordingly, the income of silkworm breeders - the main producers of mulberry cocoons.
New hybrids will certainly be effective in terms of the technological characteristics of cocoons. The importance of new complex silkworm hybrids in production conditions, along with the yield and grade of cocoons, also increases in technological properties, the yield of raw silk from dry cocoons, and the length and fineness of the cocoon thread.

4. Conclusions

Based on the test results, two hybrids with reduced performance in terms of productivity and technological properties were excluded from further work. The study of other hybrids should be continued in future scientific works. Some hybrids do not have high properties in terms of thread fineness, but have high yields of raw silk and cocoon yield. Perhaps they will find application in the manufacture of outerwear and carpets.
In our observations, it was not in vain that we cited as control option No. 1 the Chinese hybrid of imports for the production of industrial cocoons in the republic, almost 70% of the total need. As can be seen from the data given in 4 tables, in all respects our local, simple and complex hybrids in the climatic conditions of our republic are superior to foreign hybrids. Therefore, paying special attention to further increasing the preparation of hybrids of local origin would give a powerful impetus to increasing the production of mulberry cocoons, improving quality and technological indicators, and, accordingly, the income of silkworm breeders and industrial enterprises.

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