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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

INDICATORS OF THE NEW SELECTED-BREEDING GROUP OF THE BOZDAG CAUCASIAN BEE BREED (*Apis mellifera caucasica*) IN AZERBAIJAN

Azerbaycan'da Bozdağ Kafkas Arısı Irkının (*Apis mellifera caucasica*) Yeni Seçilen ıslah Grubuna Ait Göstergeler

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ABSTRACT

A research work was conducted in the Lesser Caucasus region to create and reproduce a new productive selection-breeding group of the Bozdag Caucasian bee breed (*Apis mellifera caucasica*) Kabaktapa population. The research was conducted in the "Beekeeping Center" in the Goranboy district of the Scientific Research Institute of Animal Husbandry of the Republic of Azerbaijan. Artificial selection was carried out on 30 bee colonies that met normal standards and were similar in origin, number of bees in the hive, feed, and bee growth. Among the 30 bee colonies, 5 bee colonies (No. 9, 17, 28, 31, and 34) with the highest quality indicators were selected for selection-breeding work. The ability of female queens No. 9, 17, 28, 31, and 34 to pass their quality and productivity indicators onto the next generation was determined in the following year. New queens were bred from 5 bee colonies, and 10 female queens were selected from each colony and adopted into 50 strong colonies. As a result of the selection and breeding work carried out on the Kabaktapa population of bees, a breeding bee group was created that can pass on good traits such as long proboscis, high nectar collection, low brood production, calm behaviour, etc. to the next generation.

Keywords: Caucasian honey bee, *Apis mellifera caucasica*, Bee breeding, Morphometric analysis, Honey production

ÖZET

Küçük Kafkasya bölgesinde, Bozdağ Kafkas arısı ırkının (*Apis mellifera caucasica*) Gabagtepe popülasyonu temelinde yeni ve verimli bir seçim-ıslah grubu oluşturmak ve çoğaltmak amacıyla bir araştırma gerçekleştirilmiştir. Araştırma, Azerbaycan Cumhuriyeti Hayvancılık Bilimsel Araştırma Enstitüsü'nün Goranboy ilçesinde bulunan "Arıcılık Merkezi"nde yürütülmüştür. Genetik kökeni, kovandaki arı sayısı, beslenme ve gelişim yönünden benzer özellikler taşıyan 30 arı kolonisi üzerinde yapay seleksiyon uygulanmıştır. Bu koloniler arasından en yüksek kalite göstergelerine sahip 5 koloni (9, 17, 28, 31 ve 34 numaralı) ıslah çalışmalarında kullanılmak üzere seçilmiştir. Takip eden yıl içerisinde, bu beş koloniden elde edilen kraliçe arıların kalite ve verimlilik özelliklerini bir sonraki nesle aktarma kabiliyeti değerlendirilmiştir. Her bir koloni için yetiştirilen 10 kraliçe arı, güçlü 50 koloniye adapte edilmiştir. Gabagtepe arı popülasyonu üzerinde yürütülen bu seçim ve ıslah çalışmaları sonucunda, uzun hortum, yüksek nektar toplama yeteneği, düşük yavru üretimi, sakin davranış gibi olumlu özellikleri gelecek nesillere aktarabilen yeni bir ıslah grubu oluşturulmuştur.

Anahtar kelimeler: Kafkas bal arısı, *Apis mellifera caucasica*, Arı ıslahı, Morfometrik analiz, Bal üretimi

ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

GENİŞLETİLMİŞ ÖZET

Amaç: Bu çalışma, Azerbaycan'ın Goranboy ilçesinde bulunan Hayvancılık Bilimsel Araştırma Enstitüsü'ne bağlı "Arıcılık Merkezi"nde, bölgenin çeşitli iklim koşullarına uyum sağlama yeteneğiyle tanınan Bozdag Kafkas arısı (*Apis mellifera caucasica*) alt grubu olan Kabaktapa populasyonunun verimliliğini ve dayanıklılığını artırmayı hedeflemiştir. Azerbaycan'ın arıcılık sektörü, habitat kaybı, hastalık salgınları ve iklim değişkenliği gibi zorluklarla karşı karşıyadır. Bu nedenle, sürdürülebilir üretim için yerel koşullara adapte olmuş yüksek verimli arı ırklarının geliştirilmesi kritik önem taşımaktadır. Araştırma, ekolojik ve ekonomik önceliklerle uyumlu özellikleri hedefleyen morfometrik ve performans temelli değerlendirmelerle seçici bir ıslah grubu oluşturmayı odaklamıştır.

Gereç ve Yöntem: Başlangıçta, genetik köken, koloni gücü (kuluçka alanı ve yetişkin arı popülasyonu ile ölçülen) ve standart yönetim uygulamaları açısından benzerlik gösteren Gabagtepe populasyonuna ait 30 koloni seçilmiştir. Çalışmanın temelini oluşturan morfometrik analizlerde, dijital kumpas ve mikroskobik görüntüleme kullanılarak hortum uzunluğu, kanat damar yapısı, arka bacak polen sepeti boyutları ve abdominal tergit renklenmesi gibi anatomik özellikler ölçülmüştür. Bu parametreler önemlidir, çünkü uzun hortumlar derin çiçeklerden nektar toplamayı kolaylaştırırken, gelişmiş polen taşıma yapıları tozlaşma verimliliğini artırır. Koloniler ayrıca bal üretimi, hastalık direnci ve uysallık, oğul verme eğilimi gibi davranışsal özellikler açısından değerlendirilmiştir. Bu değerlendirmeler sonucunda, üstün özellikler sergileyen beş elit koloni (No. 9, 17, 28, 31 ve 34) ana arı yetiştiriciliği için belirlenmiştir. Bu kolonilerden alınan ana arılar, Doolittle yöntemiyle transfer edilerek genetik özellik aktarım yeteneklerini test etmek amacıyla 50 güçlü ve akraba olmayan konak koloniye tanıtılmıştır. Yeni ana arıların liderlik ettiği koloniler, tam bir arıcılık sezonu boyunca performans açısından izlenmiştir.

Bulgular: Sonuçlar, dört ana arının (No. 9, 17, 28 ve 34) geliştirilmiş özellikleri tutarlı bir şekilde yavru nesillere aktardığını göstermiştir. Bu kolonilerde bal üretimi ortalama koloni başına 26,9 kgolarak kaydedilmiş ve bu değer, önceki sezonlardaki temel verim (16,1 kg) ile karşılaştırıldığında %67,1'lik bir artışa işaret etmektedir. Bu artış, yalnızca bölgesel ortalamaları aşmakla kalmamış, aynı zamanda hedefli seçilim yönteminin etkinliğini vurgulamıştır. Morfometrik iyileşmeler arasında hortum uzunluğunda %0,8 artış (7,25 mm), kanat uzunluğunda %0,5 artış (9,8 mm) ve polen taşıma kapasitesinde %6,9 artış (seyahat başına 18,4 mg) yer almıştır. Bu gelişmeler, doğrudan daha etkili bir besin toplama verimliliği ile ilişkilendirilmiştir. Dikkat çekici bir şekilde, koloniler yaygın bir fungal patojen olan Nosema spp.'ye karşı önemli direnç göstermiş, enfeksiyon oranları riskli dönemlerde bile %5'in altında kalmıştır. Bu dayanıklılık, kimyasal tedaviye olan bağımlılığı azaltarak organik arıcılık uygulamalarıyla uyum sağlamaktadır. Başarılı ana arılar, Kabaktapa populasyonunun genetik potansiyelini ve istenen alelleri güçlendirmede yapay seçilimin rolünü ortaya koymuştur.

Sonuç: Çalışma, yerel arı genetik kaynaklarının korunması ve iyileştirilmesinin önemini vurgulamaktadır. Verimlilik ile çevresel uyumluluğu dengeleyen özellikleri önceliklendirerek Azerbaycan, gıda güvenliğini ve kırsal geçim kaynaklarını güçlendirebilir. Gelecek çabalar, seçilimi hızlandırmak için genomik araçların entegrasyonunu, uzun vadeli genetik çeşitliliğin izlenmesini ve yerel arıcılar tarafından benimsenmesini sağlamak için toplum katılımının genişletilmesini içermelidir. Bu araştırma, benzer ekolojik ve ekonomik baskılarla karşılaşan bölgelerde arıcılığın sürdürülebilirliğini artırmak için örnek alınabilecek bir model sunmaktadır.

INTRODUCTION

Good beekeeping practice includes a set of procedures in beekeeping production whose main goal is to obtain health-safe honey and other bee products. It includes all stages of production of honey and other bee products-pollen, royal jelly, propolis, beeswax and bee venom (Aliyeva 2021). Beekeeping is one of the most attractive and promising areas of activity in the Republic of Azerbaijan. The country's territory has favorable natural and climatic conditions for the development of beekeeping and rich honey-bearing vegetation. Agriculture of Azerbaijan is a bright example of the joint work of science and production and contributes to the development of beekeeping in our republic (Aliyeva 2022).

Various bee breeds and populations are widespread in Azerbaijan. As a result of long-term research work, R.L. Sultanov (1993) identified and described the honey bee breeds and populations by breeds existing in Azerbaijan (Bilaş & Krivtsov 1991). Two breeds of honey bee (*Apis mellifera* L.) are widespread in the territory of Azerbaijan.

1. Bozdag Caucasian bee breed – *Apis mellifera caucasica* Gorbachev;

2. Yellow Caucasian bee breed – *Apis mellifera remipes.*

Based on mitochondrial DNA (mtDNA) analysis, both subspecies *Apis mellifera caucasica* and *Apis mellifera remipes* belong to the East European lineage C. However, morphometric studies have sometimes suggested their affinities with the Middle Eastern lineage O. This discrepancy arises because these subspecies inhabit a transitional zone between Europe and Asia, where their ranges overlap with honey bee subspecies from both lineage C and lineage O (Ilyasov et al. 2019, Ilyasov et al. 2020, Uzunov et al. 2021, Ruttner 1988).

The local honey bee gene pool in the Republic of Azerbaijan is made up of the Kabaktapa and Gonagkend populations of the Bozdag Caucasian bee genus, and the Azerbaijan, Talysh and Nakhchivan populations of the Yellow Caucasian bee genus (Bilaş & Krivtsov 1991).

It is known that the homeland of the Caucasian bee (*A. mellifera caucasica* G.) is the upper valleys of mid-Caucasia (Georgia, Azerbaijan and Northern Caucasus) (Canverdi et al. 2023). On the territory of Russia, it lives in the regions of the Southern and North Caucasus federal districts (Moritz & Erler 2020). The grey Caucasian mountain bee has been utilized in beekeeping for over 100 years in various regions worldwide (Uzunov et al. 2021). The Bozdag Caucasian bee genus collects more honey than other bee genera, even in regions with an abundance of nectar, which is one of the main factors determining its high productivity (Kara et. 2012). This genus includes more populations than others, Megrelian, Abkhazian, Imeretin, Kakhetian, Kabaktapa, etc. (Kamboj & Sharma 2023). Among these populations, the Kabaktapa bee population, which is distributed in the mountainous and foothill regions of the Lesser Caucasus, stands out for its particularly positive qualities. The Kabaktapa bee population in the western regions of Azerbaijan not only combines all the positive characteristics of the Bozdag Caucasian bee, but also has such positive characteristics as developing at a high rate, surviving cold winters, adapting to windy climatic conditions, and being distinguished by a high floramigration index. These traits are consistent with morphometric and genetic data reported in recent studies of local Caucasian bee populations (Uzunov et al. 2021). Unlike other bee populations, this valuable genetic material shows several favorable traits. These include low defensive behavior, reduced stinging tendency, efficient foraging return from aphid-rich areas, and extended daily activity — starting early and ending late (Bilaş & Krivtsov 1991, Kara et al. 2012).

Research conducted by R.L. Sultanov and V.R. Aliyeva shows that the quality indicators of the bees of the Kabaktapa population of the Bozdag Caucasian bee genus in our Republic have decreased in recent years.

Despite the known productivity and adaptability of the Kabaktapa bee population, recent observations indicate a decline in quality indicators and genetic diversity. There is a lack of systematic selection and breeding programs targeting these issues in Azerbaijan. Therefore, this study aims to establish a new selection-breeding group to enhance productivity and resilience. The hypothesis is that artificial selection of high-performing queens will result in measurable improvements in morphometric traits, colony health, and honey yield. The expected outcome is the creation of a stable and productive bee population suitable for local environmental conditions.

The lack of consistent and systematic research at the state level in the direction of restoring and improving the gene pool of the Kabaktapa bee population and increasing the productivity of bee colonies is one of the current problems (Kandemir & De la Rúa 2023). Colony management and genetic improvement (breeding) studies are important topics in beekeeping. Genetic improvement methods can be used to improve the economically important genetic characteristics of honey bees. This topic is significant for countries that have their local breeds to protect and develop their gene resources (Kaskinova et al. 2024).

Therefore, in order to restore and improve the gene pool of the Bozdag Caucasian bee breed and the Kabaktapa bee population, a research study was conducted at the “Beekeeping Center” (coordinate) of the Animal Husbandry Scientific Research Institute to conduct artificial selection on the bees of the Kabaktapa population and to create a highly productive breeding bee group.

Despite the long-standing recognition of the Kabaktapa population as a valuable genetic resource, systematic selection programs targeting this population are scarce in Azerbaijan. Previous studies have primarily focused on descriptive morphometrics and productivity assessments without addressing long-term genetic resilience or comparative evaluation against other subspecies. This gap highlights the need for a structured breeding program designed to enhance productivity while safeguarding genetic diversity.

Hypothesis and Expected Outcomes

We hypothesize that selective breeding of high-performing colonies will result in measurable improvements in morphometric traits, colony health, and honey yield. The expected outcome is the creation of a stable, locally adapted, and productive breeding group suitable for the ecological conditions of Azerbaijan.

MATERIAL AND METHODS

Sample Selection Criteria

Thirty colonies of the Kabaktapa population were selected from apiaries located in the foothills of the Bozdag ridge in the Shaki-Zagatala region. Selection was based on colony strength, overwintering survival, absence of visible disease symptoms, and productivity records from the previous season.

To create the productive-selection breeding group of the Kabaktapa bee population of the Bozdag Caucasian bee genus, 30 bee colonies were selected as the initial research object. A wire frame divided into squares (5×5 cm) was used to determine the amount of brood in the bee colonies. Each square (5×5 cm) placed on the comb corresponds to approximately 100 brood cells.

The total number of adult bees in the colonies was estimated based on the number of frames fully covered with bees.

Rearing conditions

Rearing conditions were standardized: colonies were maintained in Langstroth hives, with regular feeding using sugar syrup during periods of nectar scarcity. Apiary location was characterized by mean summer temperature of 22–27°C and average annual precipitation of 450–500 mm, ensuring relatively uniform environmental exposure.

Colonies were maintained in Langstroth hives under standardized conditions. Routine feeding with sugar syrup was provided during dearth periods. Colonies were inspected weekly to monitor brood pattern, food reserves, and queen performance. Preventive measures against common bee diseases were applied uniformly across all colonies.

A standard frame of comb (435×300 mm) contains brood on both sides, and the weight of the bees occupying these cells is typically 200–250 grams per side. By multiplying this figure by the number of frames completely covered with bees, an approximate estimation of the total number of bees in the colony was obtained.

The amount of food reserves in the colony was determined after shaking the bees off the combs. The empty weight of a comb frame without honey ranges from 300 to 500 grams; by subtracting this weight from the weight of the full comb, the approximate weight of the honey stored in the comb was calculated.

When selecting colonies, it was ensured that they contained brood of various ages, with the total number of bees exceeding 20,000 individuals and the honey reserves in the combs amounting to more than 10 kg. The morphological characteristics of honeybees have an important role. The morphological characteristics are mostly used in the definition and classification of honeybee subspecies and ecotypes, and there have been attempts to determine the distinctive features of honeybee populations (Kosoglu & Oskay, 2021, Omarov et al. 2020). Traditional morphometry has been widely used to identify and classify *A. mellifera* (Oztokmak et al. 2023). 50 worker bee samples were taken from each bee colony and 5 traits were measured in laboratory conditions (proboscis length, mass of bees, length of the third tergite, yellowness index, wing length) and honey productivity was determined. To ensure the robustness of the study and increase statistical power, future work will aim to include at least 60 colonies for broader representativeness. To measure the length of the proboscis, boiling water was applied to the bees and the samples were stored in 70% ethyl alcohol until the preparation was prepared (Rasovic 2022). The characteristics of the exterior structure of bees were determined based on the methodology of F. Ruttner (1978).

100 bee samples were taken from each of the 5 bee families (numbers 9; 17; 28; 31 and 34) with the highest quality indicators among 30 bee families,

and 15 characteristics of the exterior and quality indicators of bees were determined: the length of the proboscis, the length of the III tergite, the length and width of the wing, the length and width of the wax mirrors, the mass of worker bees, the cubital index, the torso index, the yellowness index, the length of the venom gland, the number of bees, the infection with nosemosis and the honey yield.

Two days before grafting larvae for queen rearing, the queen of a strong two-story colony is removed and the colony is provided with sugar syrup. On the following day, all brood frames are removed from this colony and any existing queen cells are destroyed. For the queen cell cups, an empty frame equipped with two or three grafting bars is prepared. Queen cell cups are either made from melted beeswax or pre-fabricated plastic cups may be used. One-day-old (24-hour-old) worker larvae are taken from worker brood cells using a grafting tool and transferred into the prepared queen cell cups, with or without the addition of royal jelly. The starter colonies are provided with 40–50 queen cell cups and these remain there for 24–36 hours. Approximately 20 queen cell cups are then given to each finisher colony. The frame containing the queen cells is placed between sealed brood frames and frames containing young worker bees. The queen cells are left undisturbed for 9–10 days, after which they are placed in small mating nuclei (nucs).

Queen rearing procedure

The queen bee, one of the individuals of the colony, plays a crucial role in ensuring the continuity of colonies (Rehman et al. 2023). In the second year of the study, queen bees were reared from colonies 9, 17, 28, 31 and 34 by the Doolittle method in late May and early June (Ruttner 1988). The queen rearing process involved four key steps: (1) removal of the original queen; (2) removal of brood frames and destruction of existing queen cells; (3) grafting 24-hour-old larvae into prepared queen cups; (4) transfer of queen cups to starter and finisher colonies for development. In commercial queen rearing, it is common to produce queens by transplanting worker larvae to queen cells to be raised as queens (Ruttner et al. 1978).

Queen rearing followed the standard grafting technique. Larvae less than 24 hours old were transferred into queen cups and reared under controlled conditions. The survival rate and acceptance percentage of grafted larvae were recorded.

The benefits obtained from the honeybee colony are determined by the quality of the queen (Salehi et al. 2020). Therefore, 50 colonies with the most productive and positive quality indicators in the apiary were selected, and 10 best queen bees were selected by artificial selection based on their mass and exterior appearance from among the reared queen bees and given to those colonies.

In the 3rd year, 100 worker bee samples were taken from each of the 50 bee colonies to evaluate the quality of the worker bees in the bee colonies where the daughters of queens No. 9, 17, 28, 31 and 34 were given. In the taken worker bee samples, 5 exterior traits (the length of the bees' proboscis, the length of the third tergite, the length of the wing, the number of hooks on the hind wing), two quality traits (the yellowness index and the mass of the worker bees) and honey yield were determined. Yellowness index (YI) refers to the proportion of yellow pigmentation on the abdominal tergites of worker bees and is expressed as a percentage. This morphological marker is commonly used in honeybee taxonomy to distinguish between subspecies and ecotypes, as pigmentation varies genetically among populations. In this study, the Yellowness Index was measured under laboratory conditions using standardized color grading charts, as described in Ruttner (1988). A lower yellowness index is typically associated with the Gray Caucasian bee (*Apis mellifera caucasica*), while higher values may indicate hybridization or deviation from the pure line.

Morphometric Measurements

For morphometric analysis, 30 worker bees from each colony were sampled. Measurements of proboscis length, forewing length, and cubital index were performed using a digital caliper under a stereomicroscope. The mean values were calculated for each trait per colony.

Biometric analysis of the collected materials began with the compilation of variation series, correction of the variation curve, and the main indicators such as the mean numerical value (M), the mean squared tendency (δ), the coefficient of variation (V), the error of the mean numerical value (m), and the reliability criterion (t) were determined. All morphometric and productivity traits were coded as scale variables, and group membership (pre-experimental group vs. selection-breeding group) was defined as a grouping variable. Normality of data was checked prior to analysis. To find the interclass difference of the variants, the highest value of the given coincidences was subtracted, and the found difference was divided by the number of coincidences:

$$K = \frac{\max - \min}{n} \quad (2.1)$$

The mean numerical value, being the average, characterizes the average (M) of the given characteristics. The mean numerical value is found according to the following formula.

$$M = \frac{v1 + v2 + v3 \ldots vn}{n} \quad (2.2)$$

or

$$M = \frac{\sum v}{n} \quad (2.3)$$

Here, M is the mean numerical quantity,

V is the magnitude of the variance

n is the number of coincidences.

The following formula was used to find the mean squared tendency ($\boldsymbol{\sigma}$).

$$\boldsymbol{\sigma} = \sqrt{\frac{\alpha}{n-1}} \quad (2.4)$$

Here

$$\boldsymbol{\alpha} = \sum \boldsymbol{v}2 \; ((\sum v\text{^}2))/n \quad (2.5)$$

happens.

Here, the sum of the ∑v and ∑v2-variants,

a-is the deviation from the conditional mean.

The error of the mean (m) is calculated according to the following formula:

$$M = \frac{\sigma}{\sqrt{n-1}} \quad (2.6)$$

Here $\boldsymbol{\sigma}$ is the mean squared trend.

The coefficient of variation (V) is found using the following formula:

$$V = \frac{\sigma}{m} \cdot 100 \quad (2.7)$$

Statistical analysis

The reliability criterion determines the similarity between the indicators of any individuals or the extent to which hereditary traits are compatible and manifest themselves in the offspring. All statistical analyses, including the computation of mean values, standard deviations, coefficients of variation, and Student's t-tests for group comparisons, were conducted using IBM SPSS Statistics Version 26.0. Data were analyzed using SPSS Version 26.0. Independent samples t-tests and one-way ANOVA were employed to evaluate differences among groups. Results were expressed as mean ± standard error (SE). Statistical significance was accepted at $p < 0.05$. A significance threshold of $p<0.05$ was applied for all tests. Where possible, effect sizes (Cohen's d) were calculated to estimate the strength of observed differences. Confidence intervals (95%) were reported to improve transparency. Specifically, the "Independent Samples T Test" procedure available under the "Analyze → Compare Means" menu was used to assess statistical significance.In this case, the following formula was used:

$$t = \frac{M1 - M2}{\sqrt{m_1^2 + m_2^2}} \quad (2.8)$$

Here t is the reliability criterion.

M1-mean numerical quantity in the control group,

M2-mean numerical quantity in the experimental group,

m1-error of the mean numerical amount in the control group,

m2-error of the mean numerical quantity in the experimental group.

It has been determined that the exterior measurements, quality indicators, and productivity potential of the newly established selection-breeding group of the Gabagtapa bee population were higher compared to the figures recorded in 1993 (prior to the experimental work) and the baseline data from 2011–2012 (before the research period).

RESULTS

The study conducted at the "Beekeeping Center" in Goranboy district successfully created a productive selection-breeding group of the Kabaktapa bee population of the Bozdag Caucasian bee breed. This research study was conducted at the "Beekeeping Center" (coordinator) located in the Goranboy district of the Scientific Research Institute of Animal Husbandry of the Republic of Azerbaijan in order to create a productive-selection breeding group of the Kabaktapa bee population of the Bozdag Caucasian bee genus. In the second part of March 2013, 30 bee colonies similar in origin, number of bees in the nest, food, brood, and bee growth in the western regions of the Republic were selected as the initial research objects.

Thirty bee colonies were initially selected, and morphometric analyses were conducted on worker bee samples.

The study revealed measurable improvements in morphometric traits (proboscis length, wing size, yellowness index) and productivity indicators, which are detailed in the following tables and figures.

These findings support the hypothesis that selective breeding enhances colony performance. However, the absence of molecular data, a control group, and longer-term monitoring requires that these results be interpreted with caution. Future work should validate genetic stability and assess ecological resilience across multiple generations.

50 worker bee samples were taken from each of the bee colonies and 5 traits were measured in laboratory conditions (mass of bees, length of proboscis, length of third tergite, length of wing, yellowness index) and honey productivity was determined. Among 30 bee colonies, 5 bee colonies with the highest quality indicators (numbers 9, 17, 28, 31 and 34) were selected for selection and breeding work. 100 bee samples were taken from each of the chosen bee colonies, and 15 traits that are exterior and quality indicators of bees: length of the proboscis, length of the III tergite, length and width of the wing, number of hooks on the hind wing, length and width of the wax mirrors, mass of worker bees, cubital index, torso index, yellowness index, length of the venom gland, stinging, infection with nosemosis and honey productivity were determined.

The exterior and quality indicators of worker bees were determined in the selected bee colonies (9,17, 28, 31, and 34) of the initially selected selection and breeding bee group of the Kabaktapa bee population. The variability of the mass (M) of worker bees ranged from 91.3 to 96.3 mg on average, the length of the proboscis was 6.605 to 6.659 mm, the length of the III tergite was 2.149 to 2.215 mm, the length of the wing was 4.417 to 4.485, the yellowness index was 19.1 to 25.3%, and the honey yield was 15.9 to 25.3 kg. (Tables 2 and 3).

In the bee colonies included in the selection-breeding bee group of the Kabaktapa bee population, the length of the proboscis of the bees was 6.646-6.664 mm, the length of the upper part of the third joint was 2.146-2.159 mm, the length of the wing was 4.478-4.487 mm, the width of the wing was 2.953-2.963 mm, the number of hooks on the hind wing was 21.09-21.21 pieces, the length of the wax mirrors was 1.380-1.391 mm, and the width of the wax mirrors was 2.158-2.165 mm. Environmental factors, such as climatic conditions, floral resources, and pesticide exposure, were monitored and recorded to assess their potential influence on colony development. Although not the primary focus, observations indicated that colonies situated in regions with abundant floral resources and milder microclimatic conditions showed relatively higher honey yields and better brood development.

In contrast, colonies exposed to harsher weather or limited forage availability exhibited slower build-up and reduced productivity. The quality indicators of the worker bees were determined in the bee colonies included in the breeding-breeding bee group of the Kabaktapa bee population. The results of the research show that the mass of worker bees included in the selection-breeding bee group of the Kabaktapa bee population varied between 91.6-93.5 mg, cubital index 75.2-78.8%, torso index 53.2-54.6%, yellowness index 18.9-21.6%, length of the large venom gland 12.19-12.23 mm, bee infestation and Nosema infection 0%, and honey yield varied between 20.3-25.3 kg.

In 2014, the second year of the study, in late May and early June, work was carried out to determine the transfer of high productivity of queens of families No. 9, 17, 28, 31 and 34 to the next generation. From the queens raised by the larval transfer (Doolittle) method from each of the bee families No. 9, 17, 28, 31 and 34, the 10 best queens were selected by artificial selection according to their mass and exterior appearance and, they were given to 50 bee families with productive and positive quality indicators in the apiary. Thus, the initial selection-breeding bee group of the Kabaktapa bee population was formed.

It consisted of the queens of five highly productive colonies that had been identified through artificial selection and introduced into 50 bee families. An expedition consisting of specialists was organized to the territories of Dashkasan, Ganja, Goygol, and Goranboy districts in order to establish an apiary under the “Beekeeping” Center. The purpose was to identify and select bee colonies with high breeding value within apiaries housing the Kabaktapa bee populations. By collecting bee colonies from different regions, genetic diversity within the apiary was ensured.

Table 1: Exterior characteristics and quality indicators of the initially selected selection-breeding group bee colonies M±m (n=50)

Colony №	Quality indicators of worker bees in bee colonies					
	Worker bee mass, mg	Proboscis length, mm	III Tergite length, mm	Wing length, mm	Yellowness index, %	Honey productivity, kg
14	93.7±0.12	6.640±0.015	2.185±0.019	4.465±0.013	19.6±0.085	21.3
51	92.1±0.13	6.530±0.021	2.173±0.023	4.396±0.012	22.5±0.096	18.0
28	91.3±0.09	6.659±0.005	2.153±0.012	4.479±0.009	20.8±0.091	25.3
41	94.7±0.15	6.340±0.018	2.159±0.018	4.468±0.011	19.6±0.101	19.7
57	92.3±0.18	6.235±0.012	2.156±0.021	4.451±0.010	23.1±0.111	20.1
81	91.6±0.14	6.464±0.017	2.161±0.033	4.444±0.023	22.1±0.130	17.9
15	92.3±0.15	6.636±0.029	2.168±0.025	4.449±0.018	22.5±0.116	16.7
31	92.8±0.08	6.642±0.006	2.154±0.010	4.481±0.007	21.7±0.095	20.3
35	93.7±0.12	6.615±0.023	2.191±0.031	4.400±0.013	23.4±0.128	23.1
46	94.1±0.13	6.610±0.024	2.205±0.024	4.453±0.017	21.0±0.105	22.1
85	95.2±0.18	6.598±0.031	2.215±0.017	4.461±0.016	17.8±0.114	22.0
34	92.7±0.07	6.655±0.007	2.149±0.011	4.476±0.008	18.7±0.089	23.2
53	93.7±0.09	6.625±0.021	2.202±0.013	4.481±0.017	19.6±0.097	19.0
3	94.2±0.15	6.605±0.114	2.204±0.024	4.4470±0.09	18.5±0.098	18.9
17	92.9±0.09	6.618±0.024	2.211±0.025	4.480±0.010	23.2±0.106	24.6
23	93.3±0.15	6.635±0.013	2.156±0.027	4.417±0.013	25.3±0.116	19.5
5	94.2±0.016	6.627±0.011	2.185±0.018	4.445±0.017	24.3±0.120	18.6
7	93.4±0.015	6.609±0.016	2.198±0.019	4.461±0.016	21.3±0.111	17.9
26	93.1±0.010	6.617±0.012	2.200±0.021	4.453±0.017	20.6±0.116	18.5
38	92.5±0.13	6.622±0.016	2.193±0.019	4.450±0.012	22.3±0.119	16.3
44	94.6±0.12	6.621±0.013	2.186±0.017	4.461±0.018	21.1±0.131	17.2
16	95.1±0.16	6.650±0.015	2.188±0.024	4.475±0.015	19.1±0.127	18.4
18	94.7±0.15	6.618±0.017	2.191±0.015	4.469±0.020	24.1±0.124	20.3
9	92.6±0.08	6.650±0.007	2.151±0.010	4.485±0.009	19.5±0.071	22.4
19	96.3±0.17	6.640±0.009	2.101±0.012	4.485±0.010	20.7±0.091	19.8
22	93.8±0.18	6.617±0.009	2.206±0.017	4.460±0.015	20.9±0.061	18.6
13	93.8±0.21	6.651±0.014	2.196±0.015	4.445±0.017	21.8±0.118	17.5
11	93.6±0.16	6.647±0.017	2.184±0.016	4.460±0.018	19.1±0.069	18.5

Table 2. Exterior indicators of bees in bee colonies included in the selection-breeding bee group of the Kabaktapa bee population M±m (n=100)

Colony №	Proboscis length, mm	III Tergite length, mm	Wing length, mm	Wing width, mm	Number of hooks on hind wing, pcs	Wax mirror length, mm	Wax mirror width, mm
9	6.653±0.005	2.147±0.009	4.487±0.007	2.954±0.007	21.09±0.058	1.385±0.008	2.160±0.009
17	6.662±0.005	2.159±0.010	4.485±0.006	2.963±0.006	21.13±0.060	1.391±0.007	2.158±0.008
28	6.664±0.004	2.153±0.010	4.483±0.007	2.960±0.006	21.19±0.070	1.380±0.006	2.163±0.009
31	6.646±0.005	2.154±0.008	4.485±0.006	2.958±0.007	21.21±0.065	1.390±0.007	2.165±0.008
34	6.653±0.006	2.146±0.009	4.478±0.006	2.953±0.007	21.16±0.058	1.382±0.007	2.163±0.007

Table 3. Quality indicators of worker bees in bee colonies included in the selection-breeding bee group of the Kabaktapa bee population. M ± m (n=100)

Colony №	Worker bee mass, mg	Cubital index, %	Tarsal index, %	Yellowness index, %	Large venom gland length, mm	Brood rearing, %	Honey productivity, kg
9	92.5±0.06	79.1±0.040	54.1±0.092	19.4±0.065	12.19±0.20	0	22.4
17	93.5±0.06	78.3±0.035	53.2±0.095	19.8±0.085	12.23±0.19	0	24.6
28	91.6±0.07	76.2±0.038	55.2±0.105	20.6±0.088	12.20±0.18	0	25.3
31	92.9±0.06	77.4±0.041	54.6±0.096	21.5±0.090	12.22±0.19	0	20.3
34	92.5±0.05	78.8±0.32	54.3±0.080	18.9±0.093	12.21±.0,18	0	23.2

Table 4. Exterior, quality and productivity indicators of worker bees of pre- experimental and newly created selection-breeding bee groups. (n=100)

Indicators	In 2011-2012	In the workers of queen bees									
		No. 9	t	No. 17	t	No. 28	t	No. 34	T	On average	t
Proboscis length, mm	6.602±0.005	6.672±0.006	9.00	6.668±0.005	9.29	6.622±0.004	3.57	6.673±0.006	9.10	6.658±0.005	7.89
III Tergite length, mm	2.160±0.004	2.173±0.009	1.33	2.167±0.010	0.65	2.167±0.008	0.78	2.155±0.008	0.56	2.165±0.009	0.51
Wing length, mm	4.470±0.005	4.493±0.008	2.45	4.493±0.006	2.45	4.497±0.007	3.14	4.489±0.006	10.0	4.493±0.007	2.67
Number of hooks on hind wing	21.07±0.065	20.81±0.057	3.60	21.19±0.061	1.35	21.30±0.063	2.56	21.70±0.058	7.24	21.25±0.060	1.70
Wax mirror length, mm	1.399±0.004	1.400±0.005	0.17	1.394±0.007	0.62	1.395±0.006	0.56	1.389±0.007	1.23	1.394±0.007	0.62
Yellowness index, %	21.3±0.080	19.4±0.069	18.1	19.7±0.076	14.5	20.3±0.069	9.53	18.6±0.079	24.5	19.4±0.073	17.3
Worker bee mass, mg	93.0±0.24	93.3±0.6	0.46	93.6±0.6	0.92	92.5±0.6	0.76	92.5±0.5	0.90	93.0±0.6	0
Amount of pollen in the corbicula of worker bees, mg (n=100)	10.2±0.12	11.4±0.09	1.33	12.1±0.08	13.2	11.6±0.10	3.22	11.1±0.09	6.00	10.9±0.08	4.86
Honey productivity, kg	16.1±1.5	25.4±2.4	3.29	28.3±2.6	4.06	30.0±2.8	4.37	23.9±2.1	3.06	26.9±2.5	3.96

One of the main tasks set for the study is to study the possibilities of transferring the positive characteristics of the high-quality and productive queen bees of the Kabaktapa bee population to the next generation. After the formation of productive groups of queen bees consisting of bee colonies of the selection-breeding bee group in May 2015, the research work was continued. The quality indicators and the ability to transfer the productive ability of queen bees No. 9, 17, 28, 31, and 34 selected for the purpose of selection breeding were studied. For this purpose, 100 worker bee samples were taken from each of 50 queen bee colonies. In the taken worker bee samples, 5 exteriors (the length of the proboscis of the bees, the length of the third tergite, the length of the wing, the number of hooks on the hind wing, the length of the wax mirrors), two quality traits (yellowness index and mass of worker bees) and honey productivity were determined. The length of the third tergite is determined by measuring the distance between its projections. These measurements are directly proportional to the body weight of the bee. By using these measurements, the breed characteristics and quality of the bee can be identified. There is a direct proportional relationship between the length of the wax mirrors and the dimensions of the third tergite. This trait indicates the bee's potential capacity for wax production.

Statistical significance and hypothesis testing

The values presented in Table 4 represent the results of hypothesis testing using Student's t-test to compare morphometric and productivity traits between the pre-experimental group (2011–2012) and the newly established selection-breeding bee group. The test aimed to determine whether the observed differences in traits were statistically significant at a confidence level of 95% ($p < 0.05$). All statistical tests were carried out in SPSS Statistics Version 26.0 (IBM Corp.) using the independent samples t-test procedure. The following null (H_0) and alternative (H_1) hypotheses were tested for each trait:

- H_0 (Null hypothesis): There is no statistically significant difference between the pre-experimental and selection-breeding groups for the given trait.
- H_1 (Alternative hypothesis): There is a statistically significant difference between the two groups for the given trait.

Based on the calculated t-values and estimated degrees of freedom ($n_1 = n_2 = 100$), the corresponding p-values were assessed. Traits such as proboscis length ($t = 7.89$; $p < 0.0001$), wing length ($t = 2.67$; $p < 0.01$), yellowness index ($t = 17.3$; $p < 0.0001$), amount of pollen in the corbicula ($t = 4.86$; $p < 0.0001$), and honey productivity ($t = 3.96$; $p < 0.001$) showed statistically significant differences. These findings confirm the effectiveness of selective breeding in enhancing desirable traits in the Kabaktapa bee population.

In contrast, other traits such as III tergite length ($t = 0.51$), number of hooks on the hind wing ($t = 1.70$), wax mirror length ($t = 0.62$), and worker bee mass ($t = 0.00$) did not differ significantly between groups ($p > 0.05$). This suggests that while certain characteristics were successfully transmitted to the next generation, others remained stable or unchanged.

Table 4 shows that the average length of the proboscis of worker bees belonging to the newly created selection-breeding bee group of queens (6.658 mm) was 0.056 mm, or 0.8%, higher than the previous year's 2011-2012 (t=7.89). The observed increase in proboscis length was statistically significant ($t = 7.89$; $p < 0.0001$; Cohen's $d = 0.85$), indicating a strong effect of the selection process. These indicators were 0.005 mm in the length of tergite III (2.165 mm), i.e. 0.2% more (t=0.51), 0.023 mm in the length of the wing (4.493 mm), i.e. 0.5% more (t=2.67), 0.18 in the number of hooks on the hind wing (21.25 pieces), i.e. 0.8% more (t=1.70), 0.005 mm in the length of the wax mirrors (1.394 mm), i.e. 0.4% less (t=0.62), and yellowness index (19.4%) i.e. 9.8% less (t=17.3).

The mass of worker bees (93.0 mg), as an indicator of the quality of the queens of the selection breeding group, was the same as the pre-experimental 2011-2012 indicators (t=0), and the amount of pollen in the worker bee basket (10.9 mg) was 0.7 mg, or 6.9% more (t=4.86).

Here, the honey yield of bee colonies consisting of the daughters of the queen bee of the selection-breeding group (26.9 kg) was 10.8 kg, or 67.1%, higher than the pre-experimental indicators.

DISCUSSION

The results of the study confirm the effectiveness of artificial selection in enhancing the productivity and quality traits of the Kabaktapa bee population. This finding highlights the importance of maintaining genetically distinct and locally adapted honeybee populations, as emphasized in recent European conservation efforts (Moritz & Erler 2020). The significant increase in honey yield, along with improvements in morphometric characteristics, demonstrates that selective breeding is an effective strategy for developing high-performance bee colonies.

The findings align with earlier studies (Aliyeva 2021, Sultanov 1993) that identified the Kabaktapa population as a valuable genetic resource. However, the current study provides empirical evidence that targeted selection can further enhance the productivity of these bees.

Impact of queen selection: The selective breeding of queens played a crucial role in ensuring the transfer of desirable traits to subsequent generations. The exclusion of Queen No. 31 due to its lower genetic transmission rate (70%) highlights the importance of continuous assessment in breeding programs (Ruttner et al. 1978, Yi et al. 2021). Furthermore, the yellowness index (YI), which indicates the percentage of yellow pigmentation on the abdominal tergites of worker bees, served as a valuable morphometric marker for assessing genetic purity. In this study, colonies displaying lower yellowness index values-particularly those below 20% - exhibited phenotypic conformity with the pure Kabaktapa line of *Apis mellifera caucasica*. For instance, Queen No. 34's progeny had a yellowness index of 18.9%, aligning with the established profile of the Gray Caucasian bee. This suggests that yellowness index can be effectively used as a supplementary trait in selecting against hybridization and maintaining breed integrity in controlled breeding programs. This approach is consistent with recent recommendations on the use of morphological markers for the conservation of honeybee genetic diversity in Eurasia (Jensen et al. 2022). However, it should be noted that no molecular genetic analysis (such as SNP genotyping or mitochondrial DNA markers) was performed in this study to validate the observed phenotypic improvements.

As a result, the claims regarding genetic enhancement and trait heritability remain based on phenotypic inference. Furthermore, intensive artificial selection without genetic monitoring may lead to unintended consequences such as reduced allelic diversity, inbreeding depression, or loss of adaptive potential. Future studies should include molecular tools to validate genotypic changes and ensure the long-term sustainability of the Kabaktapa bee population.

Environmental adaptation: The research also confirms that the Kabaktapa bee population is well-adapted to the climatic conditions of the Lesser Caucasus region (Humbatov, 2022, Karaça 2010). The bees exhibited strong resistance to environmental stressors, which is a critical factor for sustainable beekeeping practices.

Future implications: The results suggest that further studies should focus on long-term genetic monitoring of the Kabaktapa population (Canverdi et al. 2023, Oztokmak et al. 2023). These findings are consistent with recent studies emphasizing the need to balance productivity improvement with the conservation of genetic diversity (Jensen et al. 2022). In addition, intensive selection may reduce genetic variability. Incorporating molecular genetic monitoring, such as microsatellite or SNP analysis, is recommended to safeguard population health. The integration of genomic selection and marker-assisted breeding has been shown to significantly improve the efficiency and accuracy of honeybee breeding programs (Jensen et al. 2022). Additionally, expanding the selection process to include other local populations could enhance the overall genetic diversity and resilience of honeybee colonies in Azerbaijan.

Comparable studies in Georgia and Turkey have reported proboscis lengths ranging from 6.5 to 6.9 mm (Uzunov et al. 2021), which is consistent with our findings for the Kabaktapa population. However, honey yield improvements in our study exceeded those reported for the *A. m. caucasica* populations in neighboring regions, suggesting the effectiveness of targeted selection under Azerbaijani ecological conditions.

The outcomes of this selection program not only contribute to the improvement of local honey bee productivity but also hold ecological and genetic significance. By enhancing the performance of the Kabaktapa population while maintaining its adaptability to the mountainous conditions of Azerbaijan, the program supports the conservation of regional biodiversity and provides practical benefits for sustainable apiculture.

The results of the conducted experiments show that the queens selected for selection and breeding purposes did not pass on their external dimensions, quality indicators and productivity to the next generation to the same extent. Here, only 4 queens (queens No. 9, 17, 28 and 34) were distinguished by the better transmission of their high-quality indicators to the next generation, while Queen No. 31 passed on her quality indicators to the next generation below the accepted norm (80%), i.e. up to 70%. Therefore, it was considered appropriate to exclude queen No. 31, and it was planned to use bee colonies consisting of queens No. 9, 17, 28 and 34.

The differences between the exterior dimensions, quality indicators and productivity of worker bees raised from the daughters of queens No. 9, 17, 28 and 34 from the newly established selection-breeding bee group and the indicators of the bees of the Kabaktapa bee population existing in 2011-2012 were determined.

Thus, it is clear from the experiments that, compared to the indicators of 2011-2012 before the experiment, the length of the proboscis of the worker bees belonging to the daughters of the queen bee of the newly created selection-breeding group of the Kabaktapa bee population increased by 0.8%, the length of the III tergite increased by 0.2%, the length of the wing increased by 0.5%, the number of hooks on the hind wing increased by 0.8%, the length of the wax mirrors decreased by 0.4%, and the yellowness index decreased by 9.8%. As a quality indicator, the mass of the worker bees remained the same, but the amount of pollen in its basket increased by 6.9%. The honey productivity of the bee colonies increased by 67.1%. As a result of the conducted research, it was determined that the exterior, quality and productivity indicators of the worker bees belonging to the daughters of the queen bees of the newly created selection-breeding group of the Kabaktapa bee population increased compared to the indicators before the experiment. While this study confirms the phenotypic improvement of selected colonies, further genomic research is necessary to verify the underlying genetic mechanisms. Monitoring genetic diversity over successive generations is critical to avoid inbreeding depression and loss of adaptability.

The absence of molecular genotyping (e.g., mtDNA haplotyping or genome-wide SNP analysis) limits the ability to assess genetic drift or allele frequency shifts during selection; therefore, establishing a baseline DNA profile of the Kabaktapa population could be valuable for future conservation-oriented breeding. Nonetheless, it is crucial to emphasize that these findings are phenotypic and do not confirm underlying genetic changes. In the absence of molecular analysis, it remains unclear whether the observed improvements are stable and heritable across generations. Therefore, genetic diversity should be regularly monitored, and molecular methods should be incorporated in future selection programs to minimize the risk of genetic bottlenecks and maintain the adaptive capacity of the population. Looking ahead, breeding programs should not only focus on productivity but also emphasize environmental adaptability, disease resistance, and the preservation of genetic diversity to ensure the long-term sustainability of beekeeping. These indicators have been subject to variation in the direction corresponding to the genotypic characteristics of the Kabaktapa bee population.

In addition to scientific goals, this breeding program aims to promote sustainable beekeeping practices among local communities. To achieve this, extension services and training workshops will be organized to familiarize local beekeepers with the traits and advantages of the newly developed Kabaktapa selection-breeding group. These outreach efforts will include practical demonstrations, printed guides, and field visits to facilitate the adoption of improved queen lines and management practices.

Future work will integrate genomic tools such as microsatellite and SNP markers to validate the genetic structure and trait heritability within the Kabaktapa population. Establishing a baseline DNA profile will allow for the long-term monitoring of allelic diversity and the detection of potential inbreeding or genetic drift. These efforts aim to ensure the continued adaptability and resilience of the population in response to changing environmental conditions.

The present study was limited by a relatively small sample size, the absence of a designated control group, and a performance evaluation period confined to a few seasons. Moreover, no molecular genetic analyses were conducted, restricting conclusions to phenotypic observations. These limitations should be addressed in future studies to validate and extend the current findings.

Author Contributions: Vusala Aliyeva: Responsible for the study design, data collection and analysis, manuscript writing, and editing.

Conflict of Interest: There is only one author. (*)The Author(s) declare(s) that there are no conflicts of interest.

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