Peculiarities of breeding work with red foxes obtained as a result of dominant color mutations

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Abstract. The proportion of the silver-black breed population in the fox gene pool by 2019 was 89.3%, the Vyatka ognevka accounted for 9.9%, so only 0.8% remained for the entire colored population. However, it is no secret that the market does not tolerate uniformity. One of the most effective ways to increase sales of any product, including fur products, is to expand the assortment. The fox industry has something to offer the consumer; in the niche of fur farming by the variety of colorful forms with it can be compared only with mink. Unfortunately, despite the fact that the history of "color" fox breeding dates back to the 30s of the last century, at present there is a lack of systematized information in Russian on various aspects of breeding mutant color forms of the fox. This work is devoted to determining the optimal breeding methods for obtaining the maximum number of young foxes of original coloration obtained as a result of dominant mutations. Research objective is to reveal and generalize the peculiarities of breeding work with foxes of snow, white-marbled, platinum and marbled colors. To this end, the following tasks have been set: to analyze the reproduction rates of female and male foxes of the above colors; to compare the results of reproduction depending on age; to identify the most productive type of crossbreeding for the breeding of the foxes presented. The article presents the results of various interbreeding of silver-black, snow, marbled and red foxes. Analysis of mating of animals of different ages has been carried out. The optimal combinations of parental pairs are revealed.

1. Introduction
In fur farming purebred breeding is mainly applied, but in some cases another method of breeding - cross-breeding – is also used [1]. It is implemented for different purposes: to improve the quality of animals, to obtain animals of new colors, to increase the number of animals [2,3]. In animal breeding, this type of crossbreeding is more often used to work with dominant coloring types. For example, when breeding animals that carry lethal genes in the homozygous state: snow and marbled foxes. In this case heterozygotes carrying lethal genes are crossed with foxes that do not have them, and of the resulting offspring, the pups with desirable coloration are left for breeding. A number of dominant mutations involving a series of allelic genes have been obtained in the silver-black fox population. This series includes the following types - the white-haired, platinum-haired, snow-haired, and arctic marbled. On April 5, 1943, at the height of the war, in the Georgian fur farm "Bakurian" in a litter of 6 puppies was born a female puppy that differed from the usual silver-black foxes. The snow-white pup had black ears on the outside and white on the inside; it had a black stripe on the back and small dark spots on its paws. Thus appeared a fox, later called "snow fox" by author Georgidze V.K. The snow fox (bbW^Gw), aka
Bacurian, aka Georgian, is white with black spots on its muzzle, the ends of its legs and back, where they form a black band. The ears are always black [4]. It has been established that the \( W^G \) gene determining the coloration of this fox is in the same alleloform with the white muzzle and platinum coloration genes [5]. Homozygous snow foxes can be born, which differ from heterozygotes by the weakened pigment on the dark spots and have a reduced viability - they die in the first 2 months of life [6]. Compounds of snow foxes with white muzzle and platinum foxes also have a weakened pigment and sometimes a purely white coloration and also, like snow foxes, die in the first months after birth. The \( W^G \) gene can be combined with any other basic coloring genes. When it is combined with genes defining red (BB), in white foxes the dark spots can be both black and red, depending on their location [7]. In 1945, in a litter of silver-black foxes from Norwegian fur trapper Sverre Omberg, an unusual snow-white pup with a dark rim around the eyes and a blurred band across the ridge appeared. The coloring is named Arctic Marble. The Arctic Marble is similar in appearance to the Snow Fox, but the belt on the back is wider and sort of blurred. Denoted by the symbol \( W^M \). The genes determining this color are not lethal: homozygotes are called white Arctic Marble (or atom) and they are distinguished by less development of black spots. The \( W^M \) gene can also be combined with other basic colorations [8, 9]. The red variation of the Arctic marble is called "sunglow". The breed types under consideration are also unusual in that they can be superimposed on any basic colors: both dominant and recessive. Well-known are pearl-marble and snow foxes, marbled burgundies, pearl whites, cream marbles, and plenty of others. Animals of such colors are rare, so they are highly prized at auctions [10, 11]. Difficulties in breeding these foxes require new research, so this work is devoted to the study of reproductive qualities of foxes obtained as a result of dominant mutations in various combinations of parental pairs.

2. Materials and methods

The studies were conducted in the fur farms of FSUE "Russkiy Sobol" and JSC "Saltykovsky". The material for the studies was the data on the results of rutting and pupping of female foxes for: 2012-2014 and 2016-2019 FSUE "Russky Sobol" and 2015-2019 JSC "Saltykovsky".

A total of 547 different crosses involving silver-black, snow and marbled foxes were analyzed. Animals were compared in their reproductive ability depending on the combination of different breeds and types by coloring, sex and age.

Reproductive performance was analyzed as follows: in colored females, the percentage of unfortunate-born (NBR), empty individuals, fecundity, the percentage of puppy deaths before registration, and the yield of pups per successful and main female were evaluated. The reproductive ability of males was judged after evaluating the same parameters in the females they covered.

All data were processed by the method of variation statistics using Microsoft Office Excel program and presented in tables and graphs.

3. Study results

To study reproductive qualities of snow foxes, 131 pairs of "snow female x silver-black male" and 179 pairs of "silver-black female x snow male" were created. Studying the rutting and pupping results of snow foxes according to age, we divided all the studied foxes into the following groups: "young" (first time going into the rut), "two to four years old" and "five years and older".

Table 1. Indicators of reproductive qualities of snow foxes depending on the type of crossing and age of females and males.

| Indicators | Type of crossing | silver-black females x snow males |
|------------|------------------|----------------------------------|
|            | snow females x silver-black males |                        |
| age of females | young animals | 2–4 years old | 5 years old> | 45 | 94 | 40 |
| age of males | young animals | 2–4 years old | 5 years old> | 45 | 94 | 40 |
| Number of crosses | 28 | 80 | 23 | 45 | 94 | 40 |
From the data presented in the table, it follows that regardless of the type of commercial crossing, snow foxes have a fairly high yield of pups per primary female, although in crossing snow males with silver-black females this indicator is slightly higher than in crossing snow females with silver-black males.

From the data presented in the table, we see that the highest percentage of empty females is in young animals, and decreases with age. Young snow females have a higher percentage of young culls than older females. Fertility is highest among females five years of age or older, and the highest yield of young per safely pregnant female is among females two to four years of age. However, at their expense of skipped and unsuccessfully given birth females the yield per the main female is less than at old females by 0.51 heads. Based on these results, we can conclude that females older than five years old can and should be kept for breeding if the animal is healthy and consistently shows good reproductive qualities.

The results of the analysis of reproductive qualities of snow males show that after four years of breeding use their reproductive abilities decrease, which is reflected in the increased percentage of unsuccessful pregnancies and skipped females compared to the younger groups, a high departure of young animals before registration, although the fertility of covered females is consistently high. As for young snapping males: their rates are quite high, comparable to those of adult males.

Having analyzed how reproduction rates in snow foxes change depending on age, we now see that the type of crossbreeding plays a significant role in the breeding of foxes of this color. Thus, in snow females, reproductive ability increases with age: five-year-old and older females showed the highest results. On the other hand, snow-covered males were most fruitful during the first four years of life, and then the performance of females covered by them sharply decreased. On the basis of the results obtained, it can be stated that the most productive will be to use snowy males and silver-black females in breeding of animals of this color, as already from the first rut they show higher reproduction rates, as compared to snowy females.

When breeding snow-red foxes, there is one more, seemingly rather obvious moment in breeding work and color inheritance. When a silver-black fox is crossed with a red fox, one always expects to get a snow-red fox in the first generation. In order to get back to the red form, the sivodushkas are crossed with red individuals, obtaining in the offspring a split into sivodushkas again, bastards and reds proper. The first attempts to get a snow-red fox, they usually cross red foxes with snow foxes, which, relative to the basic coloring is the same as if we crossed a red fox with a silver-black fox. The first generation produces animals with unevenly distributed basic "sivodushnaya" coloration. It is reasonable to keep such animals for breeding for one year only, to cross them again with red foxes and to receive pure red coloring in offspring, and all intermediate forms should be killed off, as they cannot provide stable and uniform coloring.

The herd of snow-red foxes is too small to divide it into groups according to age, and snow-red males were not left for breeding at all, but we can still draw some conclusions about their reproductive ability.

Table 2. Reproductive capacity of snow-red females.

| Type of crossing | snow-red females x red males |
|------------------|-----------------------------|
| Number of crosses| 17                          |

From the data presented in the table, we see that the highest percentage of empty females is in young stock with young with black females this indicator is slightly higher than in crossing red females with silver.
% unsuccessfully given birth -  
Fecundity, head. X±Sₙ 6.29±0.34  
Young stock with withdrawal, % 2.89  
Exit to the main female, head. X±Sₙ 5.94±0.38

Snow-red females covered with red males had high fertility, among them there were no females without litter, and the departure of young to registration is extremely small, as a result we have a high yield of pups per the main female. On the basis of the data of this table, we see that the snow-red females exceed the snow-red females in the rate of yield of pups per the main female by 1,07 heads (the difference is reliable, P>0.95). It can be assumed that snow-red males, by analogy with females, will also have high reproduction rates.

The Arctic marbled fox looks similar to the snowy fox, but the belt on its back is wider and as if blurred. It is denoted by the symbol W⁵. The genes determining this color are not lethal: homozygotes are called white Arctic Marble (or atom) and are distinguished by less development of black spots. The W⁵ gene can also be combined with other basic colors.

**Table 3**: Reproductive performance of Marbled Foxes according to the type of crossing and age of females and males.

| Indicators | Type of crossing | Marbled females x silver-black males | silver-black females x marbled males |
|------------|------------------|--------------------------------------|--------------------------------------|
|            |                 | age of females | 2-4 years old | 5 years old | age of males | young animals | 2-4 years old |
| Number of crosses | 16 | 21 | 6 | 24 | 33 |
| % unsuccessfully given birth | 18.8 | - | 16.7 | 16.7 | - |
| % genct | - | 14.3 | - | 16.7 | 6.1 |
| Fecundity X±Sₙ | 4.08±0.6** | 6.06±0.3** | 6.80±0.106 | 5.88±0.4 | 7.13±0.3 |
| Young stock with withdrawal,% | 5.8 | 8.7 | 9.1 | 6.5 | 17.7 |
| Exit to the successful female | 3.77±0.5 | 5.28±0.4 | 6.00±1.01 | 5.38±0.4 | 5.71±0.3 |
| Exit to the main female X±Sₙ | 3.06±0.6 | 4.52±0.5 | 5.00±1.4 | 3.58±0.6 | 5.36±0.4 |

The most productive in breeding Arctic marbled foxes is the type of crossing in which a silver-black female is covered with a marbled male. In this type of crossbreeding all three indices - fecundity, yield of pups per successful and main female - are higher by 1.8 (the difference is reliable, P>0.99), 1.61 (P>0.99), 0.52 heads respectively in young females. Having analyzed the results of pupping of marbled females covered with silver-black males, we see that young animals have low fecundity compared to older groups, they also have a significant percentage of unfortunate-born females, but there are no empty females. Pre-registration culls in females of all three age groups are rather low. In general, reproductive performance of marbled females increases with age, a similar picture we observed in snow females. However, in this case young animals lose due to low fecundity and NBR. Females two to four years old have high fecundity - 2.01 heads higher than young females (difference is significant, P>0.95), but they also have a low yield of pups per main female due to stillborn pups and skips. The number of breeding marbled females of the older group is low, but there is a tendency to an increase in the yield of pups per successful and main female due to the high, in comparison with the younger groups, fecundity.

Similarly to young marbled females, young marbled males have a rather low yield of pups, but in this case it is associated with a high percentage of females that did not give birth. Adult males are very prolific, the females covered by them gave 1.25 head more pups than the females covered by them. pups more than females covered by young males (the difference is significant, P>0.95). However, two- to four-year-old males had a fairly high percentage of young cubs before registration, but even so, they had a high yield of pups per primary female, 1.78 head higher than young animals (difference valid, P>0.95). Only 4 heads of males 5 years old and older were found, a total of 29 live pups were obtained.
from them, 5 of which fell, probably even in old Marbled males good fecundity is preserved, but the departure of pups before registration increases.

Young and adult marbled males had higher reproductive rates than females by 0.52 and 0.84 goals, respectively. And although marbled females five years and older showed better results than females in the younger groups, while there were too few marbled males of this age to speak of reliable data, or at least a trend, it is nevertheless much more advantageous to use marbled males and to cover silvery-black females with them.

4. Conclusions

It was found that snow males already from the first rut demonstrate higher reproduction rates compared to snow females (males from the younger and middle age groups gave a higher yield of pups than snow females from similar groups by 0.86 and 0.52 heads, respectively). On this basis, it can be said that it would be most productive to cover snowy males with silver-black females when breeding animals of this color. It has been proved that snow-red females exceed snow-red females in the rate of pups yield per the main female by 1.07 heads (the difference is reliable, P>0.95).

Marbled females two to four years old have been shown to have high fecundity, 2.01 goals higher than young females (difference reliable, p>0.95), but they also have a low yield of pups per major female due to stillborn pups and omissions. Adult marbled males are also very prolific: the females covered by them gave 1.25 head more pups than the females covered by them. pups more than females covered with young marbled males (difference is significant, P>0.95), it was proved that they had a high yield of pups per main female, 1.78 head higher than young animals (difference is significant, P>0.95). Thus, it was

It has been established that the most productive in breeding Arctic Marbled Foxes is the type of crossing in which the silver-black female is covered with a marbled male. At such crossing all three indices - fecundity, yield of pups per successful and main female - are higher by 1.08 (the difference is reliable, P>0.99), 1.6 (P>0.99) and 0.52 heads respectively in young females.

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