ACTA SCIENTIARUM POLONORUM

Acta Sci. Pol. Zootechnica 22(2) 2023, 43–52

www.asp.zut.edu.pl pISSN 1644-0714 eISSN 2300-6145 DOI: 10.21005/asp.2023.22.2.05

ORIGINAL PAPER

Received: 16.09.2023
Accepted: 30.11.2023

ANALYSIS OF VARIABILITY IN REPRODUCTIVE TRAITS AND BREEDING EFFICIENCY IN RABBITS (*ORYCTOLAGUS CUNICULUS* L. 1758) OF THE POPIELNO WHITE AND TERMOND WHITE BREEDS

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ABSTRACT

In the study, the variability of reproductive traits (the number of born and weaned young) and the efficiency of breeding work were assessed and estimated in rabbits (*Oryctolagus cuniculus* L. 1758) of the Popielno White and Termond White breeds. Phenotypic trends of reproductive traits were estimated over a period of ten years in farms included in the analysis. The research material included data on the performance of 1836 female rabbits of the Termond White breed and 1237 female rabbits of the Popielno White breed, maintained on reproductive farms over a period of ten years. Analysis of variance for reproductive traits showed that sources of variability (farm, calendar year, and breed) had a statistically significant impact on the number of born and weaned rabbits. The average litter size obtained from female Termond White rabbits ranged from 2.89 to 3.54 within one year. For female Popielno White rabbits, this average was 3.44. The average number of born and weaned kits per litter during the analyzed period was 8.99 and 8.29, respectively. The reproductive results obtained regarding the number of born and weaned rabbits can be considered very good. The phenotypic trend line for the number of born and raised rabbits of the white Popielno breed showed an increasing tendency, while in the case of rabbits of the white Termond breed, it exhibited a decreasing trend. Clear fluctuations in the number of born and raised rabbit kits in the Termond white breed throughout the research period indicate the need to improve the reproductive traits of this breed through intensified selection. In the light of our own research, it can be stated that rabbit breeding in both farms is conducted properly, and the obtained results are satisfactory.

Key words: rabbit, Termond White, Popielno White, reproductive traits, breeding efficiency

INTRODUCTION

The domestic rabbit is a versatile species kept for various purposes, including meat, fur, wool, and also utilized as a laboratory animal and in amateur breeding [Cholewa et al. 2003]. This is associated with a high rate of fertility and prolificacy. In large-scale farms, a breeder can obtain 9 litters from a single female. This is due to the relatively quick mating of the female after giving birth [Barabasz and Bielański 2004]. However, a drawback of excessive exploitation is a decline in fertility, which occurs after approximately 12 litters. The most popular use for rabbits is meat, which is highly valuable and extremely nutritious. Achieving satisfactory results in meat production is facilitated by selecting the appropriate genetic material. Properly conducted selection allows for obtaining exceptionally meaty lines, characterized by a high meat content in the carcass, although this has resulted in a slight deterioration in its quality [Maj 2005]. Among the popular breeds kept for rabbit meat production are the white Popielno and white Termond breeds. Both of these breeds are characterized by a snow-white fur coat and red eyes [Niedźwiadek 1981, Weremczuk 2017].

Fig. 1 illustrates the number of female Popielno White and Termond White rabbits included in the evaluation of their performance and breeding value in Poland in 2012–2019 [KCHZ 2019].

From 2012 to 2019, the number of females varied. The largest number of female rabbits of both the Popielno White and Termond White breeds was in 2013. A year

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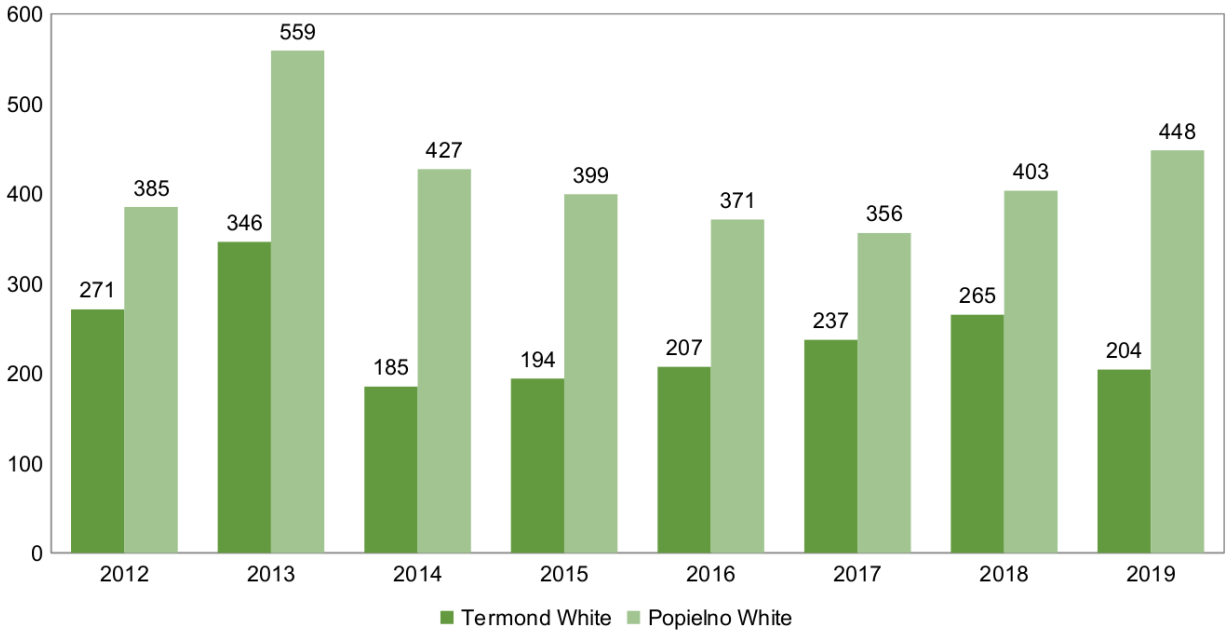

Fig. 1. Number of the basic herd evaluated for utility and breeding value in Poland

later, the number of female rabbits of the Termond White breed dropped significantly and was the lowest during the entire study period. In contrast, the number of female Ashland White rabbits decreased until 2017, after which an increase in the number of females was observed in these rabbits.

Within the framework of the Program for the Conservation of Farm Animal Genetic Resources, work has been carried out to preserve the population of the White Ashland rabbit since 1989 [Bielański and Kowalska 2010, Bielański and Kowalska 2011]. The goal of the program is to increase the number of females in the breeding stock, maintain the breed standard, breed specific traits (high fertility and prolificacy, fast growth rate, low feed consumption), and preserve genetic variability. According to Kowalska [2016], 9 herds of rabbits of this breed were maintained in Poland in 2015.

Rabbits belong to polyestrous animals, meaning those in which estrus occurs several times a year. Estrus in females can be induced by the presence of a male and lasts from 12 to 36 hours. Before mating individuals, a selection should be carried out. Its purpose is to eliminate animals that are sick or have defects in external structure. Additionally, attention should be paid to the size of litters, maternal care towards the young, and the traits that parents pass on to their offspring [Fijał et al. 1997]. Another crucial factor for selecting animals for breeding is their conformation. In Poland, the Standard developed by the Central Animal Breeding Station (2000) in Warsaw is in force. The information included in it pertains to each of the individual rabbit breeds. Thanks to this data, the assessment of conformation traits is carried out meticulously, and each trait receives a specific number of points [Barabasz and Bieniek 2003].

In rabbit breeding, three reproduction systems are distinguished. The extensive system, allowing females a rest period of 6 weeks between litters, is typically used by hobbyist breeders. The moderately intensive system allows the female to be bred again approximately 12 days after kindling, and the young stay with the mother for up to 5 weeks. In the intensive system, employed in commercial farming, mating takes place 2 days after giving birth, and the young stay with the mother for around 30 days. The duration of the reproductive use of females will depend mainly on the breeder's needs and the condition of the females [Barabasz and Bieniek 2003, Bielański and Kowalska 2007, Weremczuk 2017].

Using the natural method of reproduction, there should be 10 females per male. In rabbit breeding, both natural and artificial mating methods can be used. As is well known, individuals must exhibit good health, as well as overall physical appearance. During the natural method of reproduction, it is the female that is moved to the cage of the male, this is due to the fact that he feels more secure at his place and is not distracted by other smells [Weremczuk 2017]. It is recommended that the male be older and slightly larger than the female, while younger males may be intended for older females.

Table 1. Arithmetic means of litter numbers obtained from one doe in a calendar year, depending on breed and farm

Breed*	Farm	Average litter number obtained from one doe in each calendar year									
		2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
1	A	4.1	3.6	2.8	4.2	3.3	4.2	3.3	3.2	3.2	3.54
2		3.6	3.5	3.5	3.6	3.2	4.1	3.1	3.2	3.2	3.44
1	B	2.5	3.3	3.2	2.6	2.0	4.1	3.4	2.5	2.4	2.89

* 1 – Termond White Breed (TB); 2 – Popielno White Breed (PB)

Table 2. Analysis of variance for the number of born young rabbits

Source of variability	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Significance level Pr.>F
Calendar year	9	378.816	42.091	19.91	<0.0001
Breed	1	637.509	637.509	301.50	<0.0001
Farm	1	1303.803	1303.803	616.61	<0.0001
Error	3061	6472.359	2.115		<0.0001

This is related to the ease of mating for older females. Insemination as a part of reproductive biotechnology is a more commonly used method in rabbit breeding. In practice, almost exclusively fresh or liquid-preserved semen is used [Lucas et al. 2000]. The use of insemination has several benefits, namely, the reproductive capacity of males and females can be controlled, the transmission of infectious and parasitic diseases is reduced, and it provides an opportunity to transport semen obtained from outstanding males [Gogol 1996, 2012, Gogol and Wierzchoś-Hilczer 2014].

The aim of the study was to evaluate and analyze the variability of reproductive traits (number of young born and reared) and breeding efficiency in rabbits (*Oryctolagus cuniculus* L.1758) of the Popielno White and Termond White breeds. In the study, the variability of traits in herds of animals was determined. Phenotypic trends of reproductive traits over ten years in the farms included in the analysis were estimated.

MATERIAL AND METHODS

Research material

The research material concerning the reproductive performance of female rabbits originated from two reproductive farms. The first one (Farm A) is located in the southeast part of Poland in the Podkarpackie province. This farm specializes in the production of rabbit livestock based on breeding the Popielno White and Termond White breeds. The second farm (referred to as B in the study) is located in the Opole province. Various breeds of rabbits, including the Termond White breed, are kept there.

Farms A and B are built in the form of a monoblock. In this type of construction, the livestock pavilions are illuminated only with artificial light, which is turned on at 6:00 AM and turned off at 9:00 PM. This causes the length of light day to remain constant at 15 hours.. The cages, where various animal groups are housed, are tailored to their needs and constructed from galvanized, spot-welded metal mesh. The basic herd is kept in single-level cages equipped with feeders and automatic waterers. Pregnant females additionally have specially prepared stalls in their cages. Furthermore, all cages are placed on specially designed racks, under which there is a fully automated drainage channel. Additionally, each farm undergoes disinfection, insect control, and rodent control.

Rabbits are fed with nutrient-rich pelletized feeds that meet all the nutritional requirements of the animals [Gugołek 2011]. Farms A and B source rabbit feed from nearby feed mills. The basic herd receives feed with the addition of coccidiostat. Feed is administered to the rabbits twice a day, and the animals have constant access to drinking water.

Breeding documentation on the farms is meticulously maintained, and all activities related to rabbit breeding and utilization are recorded. The study was developed based on the performance results of rabbits for the period 2009–2018. The analysis focuses on reproductive traits of animals, encompassing a total of 3073 female rabbits.

The study covered two rabbit breeds that were utilized in farms subject to utility assessment. The Termond White (Breed 1, TB) is a breed originally developed in Belgium and first imported to Poland in 1977 [Bielański et al. 2011]. Females of this breed are characterized by a very good maternal instinct, achieving an average litter size of 7.78 individuals [Pałka et al. 2017]. On the other hand, rabbits of the Popielno White breed (Breed 2, PB), bred in Popielno, are included in the native breeds protection program. They can be bred in breed purity as well as hybrids [Gebler 2007]. Additionally, they are characterized by high prolificacy and fertility, and the low weaning weight is associated with high litter sizes [Kowalska et al. 2011]. Both breeds are classified into the group of medium-sized breeds.

Research Methods (Statistical Analysis)

In the study, a statistical analysis of traits – reproductive indicators of the Popielno White and Termond White rabbit breeds was conducted. Statistical analyses were performed using the SAS statistical package v. 9.4 [SAS Institute Inc. 2000] and Statistica v. 13.1 STATISTICA [2012].

To assess the impact of individual effects on the level of analyzed traits, the GLM (General Linear Models) procedure was employed. Multifactorial analyses of variance were conducted using the model:

$$Y_{ijkl} = \mu + R_i + P_j + F_k + E_{ijk}$$

where:

Y_{ijkl} – analyzed traits: the number of individuals born, the number of individuals raised,
μ – mean of the trait,
R_i – constant influence of the calendar year,
P_j – constant influence of the breed,
F_k – constant influence of the farm,
E_{ijk} – the part unexplained by the experiment (error).

The significance of differences between means for constant effects was determined using Tukey's test and the LSMean test, with a significance level of $\alpha = 0.01$.

RESULTS AND DISCUSSION

Over the period of nine years (from 2009 to 2017), a total of 3603 females were used for reproduction in the analyzed herds. During this time, a total of 50928 individuals of the White Termond rabbit breed and 30217 individuals of the White Popielno rabbit breed were born in the two farms. In total, 81145 rabbits were obtained, out of which 70671 were raised, constituting 87.09% of the born offspring. The highest percentage of offspring raised occurred in 2012, while the lowest was in 2009.

When applying moderately intensive reproduction from one female within a year, it is possible to achieve even 8 litters or more. There is a possibility of obtaining up to 10 litters within a year; however, the consequence of such breeding is the replacement of 80% or even 90% of the basic herd [Bielański et al. 1996, Bielański et al. 2011].

The reproductive utilization intensity of the examined breeds' females ranged from 2.0 to 4.2 litters per year (Table 1). Among the analyzed rabbits, females of the White Termond breed achieved the highest average number of litters – 3.54 on Farm A, while the lowest – 2.89, was recorded for females of the same breed on Farm B.

The analysis of variance for the number of litters born showed a statistically highly significant influence of all variables on this trait (Table 2). Both the calendar year and the breed had a statistically highly significant impact on the number of born young rabbits.

Average numbers of offspring varied in the range of 6.83 to 10.38 individuals (Table 3). The lowest average was observed in Termond White rabbits on Farm B (Opole province) in the sixth year of assessment. The highest average (10.38) was recorded in the same assessment year, for the same breed, but on Farm A (Podkarpackie province). Considering the farm, it is noteworthy that Termond White rabbit females on Farm A exhibited higher average numbers of births compared to females on Farm B. The highest average number of rabbit offspring on Farm B was in the second year of analysis, amounting to 8.86 individuals. In the subsequent years (2011–2018), these averages were lower, ranging from 6.83 (2014) to 7.76 (2017) individuals. On the other hand, on Farm A, the lowest average of offspring born was 9.28, significantly differing from the average for females on Farm B.

As demonstrated by the analysis of variance, the breed also had a statistically significant impact on the number of newborn rabbit offspring (Table 2). White Termond rabbits exhibited higher average numbers of births compared to averages for the White Popielno breed (Table 3). This relationship was observed in each year of assessment.

The analysis of variance for the number of offspring raised in a litter showed a highly significant influence of all sources of variability affecting this trait (Table 4).

The highest average number of raised rabbit offspring (9.61) was characteristic of the White Termond breed, while the lowest average (6.29) for this trait occurred in the first year of assessment for rabbits of the White Popielno breed (Table 5). Similar to the number of births, the influence of the breed was significantly evident here as well. Specifically, White Termond rabbits exhibited higher averages for the number of raised offspring compared to those averages for the White Popielno breed throughout the entire study period.

Analyzing the reproduction results obtained by White Termond rabbits on Farms A and B, it can be observed that animals maintained on Farm A exhibited significantly higher indicators (Tables 3 and 5). Variability for the number of born and raised rabbits was also estimated. Variability was expressed by coefficients of variation (V) depending on breed, farm, and calendar year (Tables 3 and 5). The lowest variability in the number of born rabbits, 8.05, was characteristic of the TB breed on Farm A in the last year of assessment (2018), while the highest, 33.51, was for the same breed but maintained on Farm B in the sixth year (2014) of assessment. For the PB breed, the coefficient of variation was lowest in 2015, at 12.07, and the highest was observed in 2010, at 23.23 (Table 3). The coefficient of variation for the number of raised rab-

Table 3. Statistical characteristics of the number of born rabbits

Calendar year	Farm	Breed*	N	$\bar{X}$	SD	V
2009	A	1	317	9.43	1.554	16.48
		2	28	7.89	0.956	12.11
2010	A	1	97	8.95	1.503	16.79
		2	30	8.03	1.866	23.23
	B	1	22	8.86	1.552	17.51
2011	A	1	224	9.95	1.097	11.03
		2	72	7.76	1.157	14.90
	B	1	60	7.20	1.938	26.92
2012	A	1	114	10.24	1.332	13.02
		2	127	9.48	1.542	16.27
	B	1	50	6.88	2.144	31.20
2013	A	1	231	9.43	1.196	12.67
		2	245	9.11	1.407	15.43
	B	1	29	7.00	2.268	32.40
2014	A	1	102	10.38	1.186	11.42
		2	162	9.11	1.145	12.58
	B	1	12	6.83	2.290	33.51
2015	A	1	83	9.80	1.156	11.80
		2	101	9.00	1.086	12.07
	B	1	28	7.64	2.468	32.29
2016	A	1	139	9.57	1.064	11.12
		2	215	7.48	1.443	19.28
	B	1	49	7.45	1.733	23.26
2017	A	1	116	9.28	1.162	12.52
		2	147	8.91	1.685	18.93
	B	1	38	7.76	1.635	21.06
2018	A	1	79	9.37	0.754	8.05
		2	110	8.61	1.041	12.10
	B	1	46	7.46	2.030	27.22
Total			3073	8.99	1.656	18.42

* 1 – Termond White breed (TB), 2 – Popielno White breed (PB); N – number of does of each breed in consecutive years, $\bar{X}$ – average litter size for the breed in consecutive years, SD – standard deviation, V – coefficient of variation.

Table 4. Analysis of variance for the number of raised young rabbits

Source of variability	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Significance level Pr.>F
Calendar year	9	521.472442	57.941382	33.97	<0.0001
Breed	1	573.998859	573.998859	336.56	<0.0001
Farm	1	1044.841317	1044.841317	612.63	<0.0001
Error	3061	5220.563962	1.705509		<0.0001

bits on Farm A for the TB breed was lowest in 2016, 8.38; the highest was recorded in 2009, 16.08. The same coefficient for the PB breed occurred in 2015, 12.72, and the highest was noted in 2010, at 26.31. On Farm B, the lowest coefficient of variation was obtained in 2010, 21.22, and the highest was 36.69, recorded in 2013 (Table 5).

The results obtained in the research on the reproductive traits of rabbits differ slightly from the findings of other authors. According to Bielański et al. [2011], the White Popielno breed achieved an average litter size of 5.61 individuals, significantly less than in our own research. On the other hand, Bieniek et al. [2017] demonstrated that the White Popielno breed achieved an average litter size of 7.46, while the White Termond breed reached 7.78 individuals. Some studies [Gacek 1997, Gacek 2010] on the Termond breed, reveal an average number of births ranging from 7.3 to 7.5 individuals, with the number of offspring raised at 6.5. For the same breed, Barabasz and Gacek [2004] obtained a slightly higher average number of births (8.0), but a lower number of offspring raised (5.99). Kołodziejczyk et al. [2012] obtained results at a similar level – the White Termond breed had

Table 5. Statistical characteristics of the number of raised rabbits

Calendar year	Farm	Breed*	N	$\bar{X}$	SD	V
2009	A	1	317	8.29	1.332	16.08
		2	28	6.29	1.243	19.77
2010	A	1	97	8.76	1.321	15.08
		2	30	7.63	2.008	26.31
	B	1	22	8.14	1.726	21.22
2011	A	1	224	9.39	0.926	9.86
		2	72	7.22	1.091	15.10
	B	1	60	6.78	1.795	26.47
2012	A	1	114	9.61	0.946	9.83
		2	127	8.92	1.138	12.76
	B	1	50	6.58	2.061	31.33
2013	A	1	231	8.68	1.079	12.43
		2	245	8.54	1.175	13.76
	B	1	29	6.41	2.353	36.69
2014	A	1	102	9.52	0.941	9.89
		2	162	8.36	1.073	12.83
	B	1	12	6.67	2.146	32.19
2015	A	1	83	8.72	1.130	12.95
		2	101	8.52	1.083	12.72
	B	1	28	7.00	2.553	36.47
2016	A	1	139	8.75	0.733	8.38
		2	215	6.93	1.251	18.06
	B	1	49	6.92	1.656	23.94
2017	A	1	116	8.83	0.980	11.11
		2	147	7.84	1.180	15.05
	B	1	38	7.45	1.796	24.12
2018	A	1	79	8.38	1.041	12.43
		2	110	7.88	1.038	13.17
	B	1	46	7.09	2.219	31.32
Total			3073	8.29	1.499	18.08

* 1 – Termond White breed (TB), 2 – Popielno White breed (PB); N – number of does of each breed in consecutive years, $\bar{X}$ – average litter size for the breed in consecutive years, SD – standard deviation, V – coefficient of variation.

an average litter size of 7.77 individuals, and the number of raised offspring fluctuated between 8 and 9 individuals. Different research results are presented by Gacek et al. [2013], who showed that the highest prolificacy was exhibited by White Popielno breed females, with an average of 8.49 individuals, while the lowest index was recorded for the Californian breed – 6.27 individuals. The White Termond breed achieved an average of 7.73 individuals.

The study also estimated the phenotypic trends of the analyzed traits (Figures 2–3). The trend values express changes over a unit of time, which in this study was one year. Over the examined period, fluctuations were observed in the number of births (Fig. 2) and the number of raised offspring (Fig. 3) for both the White Popielno and White Termond rabbit breeds.

Despite the variability in the fertility of White Popielno rabbit females in individual years of analysis, the phenotypic trend line for the number of born and raised offspring shows an upward trend. It is different in the case of White Termond rabbits. Phenotypic trend lines for reproductive traits exhibit a downward trend, which, given the distinct fluctuations in the number of born and raised offspring throughout the research period, may indicate the need for improvement in the reproductive characteristics of this breed.

Reproductive traits of both breeds showed significant variability in the values obtained over the study period (Figures 2–3), and phenotypic trends for the White Termond breed indicated a decreasing trend for both the number of born and raised offspring (Figures 2–3). On the other hand, for the White Popielno breed, there was an increasing trend in the analyzed period. In summary, it can be stated that there are potential opportunities for improving reproductive performance in both the White Popielno and White Termond breeds.

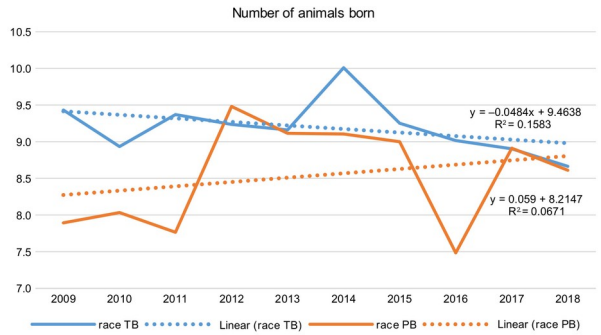

Fig. 2. Phenotypic trends of the number of born young in consecutive years of study, considering the rabbit breed

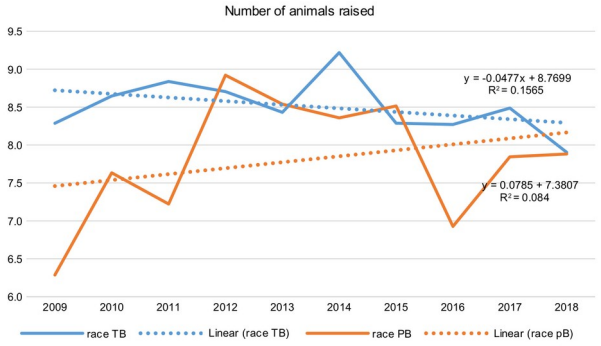

Fig. 3. Phenotypic trends of the number of raised young in consecutive years of study, considering the rabbit breed

SUMMARY AND CONCLUSIONS

Summarizing the analysis of reproductive traits (the number of born and raised offspring), it can be stated that statistically significant influences were observed from the calendar year, rabbit breed, and the animal farm. It should be noted that the average numbers of births and raised offspring showed variations in individual years (statistically significant influence). Although the influences of individual years were statistically significant, it can be considered that the final average numbers of births and raised offspring remained at a similar level to the initial averages.

Proper breeding practices, ensuring appropriate environmental conditions, including animal welfare, enable obtaining good reproductive performance results in rabbits [Kmiecik et al. 2020]. Our results allow for the following conclusions:

1. Analysis of variance for reproductive traits showed that all sources of variability (farm, calendar year, and breed) had a statistically highly significant impact on the number of born and raised rabbit offspring.
2. The average number of litters obtained per female varied within one year from 2.89 to 3.54. The average number of born and raised offspring in one litter during the analyzed period was 8.99 and 8.29, respectively. The obtained reproductive results for the number of born and raised offspring can be considered very good.
3. The phenotypic trend line for the number of born and raised offspring of the White Popielno rabbit breed showed an increasing trend, while for the White Termond rabbit breed, the phenotypic trend lines for reproductive traits exhibited a decreasing trend. Clear fluctuations in the number of born and raised offspring in the White Termond breed throughout the research period indicate the need to improve reproductive traits through intensified selection.
4. Based on our own research, it can be concluded that rabbit breeding in both examined farms is conducted correctly, and the obtained results are satisfactory in terms of reproductive traits. However, continuous breeding work should be carried out to further improve these traits.

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ANALIZA ZMIENNOŚCI CECH REPRODUKCYJNYCH I EFEKTYWNOŚCI ROZRODU KRÓLIKÓW (*ORYCTOLAGUS CUNICULUS* L. 1758) RAS POPIELNIAŃSKI BIAŁY I TERMONDZKI BIAŁY

STRESZCZENIE

W pracy oceniono i oszacowano zmienność cech rozrodu (liczbę urodzonych i odsadzonych młodych) oraz efektywność pracy hodowlanej w odniesieniu do królików (*Oryctolagus cuniculus* L. 1758) ras popielniański biały i termondzki biały. Trendy fenotypowe cech reprodukcyjnych oszacowano na przestrzeni dziesięciu lat w fermach objętych analizą. Materiał badawczy stanowiły dane dotyczące użytkowości 1836 samic królików rasy termondzki biały i 1237 samic królików rasy popielniański biały, utrzymywanych na fermach reprodukcyjnych w okresie dziesięciu lat. Analiza wariancji dla cech reprodukcyjnych wykazała, że źródła zmienności (ferma, rok kalendarzowy i rasa) miały statystycznie istotny wpływ na liczbę urodzonych i odsadzonych królików. Średnia wielkość miotu uzyskana od samic królików rasy termondzki biały wahała się od 2,89 do 3,54 w ciągu jednego roku. W przypadku samic królików popielniański biały średnia ta wynosiła 3,44. Średnia liczba urodzonych i odsadzonych młodych w miocie w analizowanym okresie wynosiła odpowiednio 8,99 i 8,29. Uzyskane wyniki rozrodu w zakresie liczby urodzonych i odsadzonych królików można uznać za bardzo dobre. Linia trendu fenotypowego dla liczby urodzonych i odchowanych królików rasy popielniański biały wykazywała tendencję rosnącą, natomiast w przypadku królików rasy termondzki biały wykazywała tendencję malejącą. Wyraźne wahania liczby urodzonych i odchowanych króliczą w rasie termondzki biały w całym okresie badań wskazują na potrzebę doskonalenia cech reprodukcyjnych tej rasy poprzez intensyfikację selekcji. W świetle badań własnych można stwierdzić, że hodowla królików w obu fermach prowadzona jest prawidłowo, a uzyskiwane wyniki są zadowalające.

Słowa kluczowe: królik, popielniański biały, termondzki biały, cechy reprodukcyjne, efektywność hodowli

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