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The analysis of chinchilla (*Chinchilla lanigera, M.*) male reproduction. The case of a leading polish breeding farm

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Abstract

Research into the chinchilla male fertility concerned mainly semen quality. Little attention has been paid to lifetime reproductive performance, essential from the economical point of view. Thus, the aim of this study was to analyze factors affecting the intensity of breeding use and lifetime performance of male chinchillas. After data transformation, the analysis of variance was performed to evaluate the effect of male birth litter size and age at the first effective mating. Additionally, the correlation coefficients for both litter sizes and litter rearing efficiency were calculated. For all traits, the linear regression on the sire's age at the first effective mating was found non-significant. Litter sizes differed slightly between seasons. The length of sire reproductive use was highly correlated (about 0.8) with the total number of litters and kits born and weaned. The total rearing efficiency was low, and in some cases negatively correlated with other traits, that is, with the total number of litters and kits born and weaned. Most sires were mated up to six dams; they were used in one polygamous set each. In total, the males sired about 60 litters each, hence the conclusion is that they could be extensively used and produce more benefits to chinchilla breeders.

KEYWORDS
chinchilla, length of reproductive use, males, reproduction traits

1 | INTRODUCTION

Chinchilla rarely features as a research object. The research on chinchillas to date concerned their origin, current status, and possibilities of protecting this species in the wild (Cortés et al., 2002; Jiménez, 1995, 1996; Spotorno et al., 2004) as well as the seasonality of the reproduction of captive chinchillas (Nistal & Di Masso, 2009) and the feeding of chinchillas kept as companion animals (Wolf et al., 2001).

Unlike other rodents, chinchilla is a peculiar species, in which the litter size is usually limited to 1–3 kits, rarely more. Low fertility of chinchillas is a big problem in their reproduction in farm conditions. From the economic point of view, that is the point of view of the breeder, the number of obtained offspring is an extremely important trait. In chinchilla breeding, as in other branches of animal breeding, the breeders want to have not only reimbursement of incurred expenses of the rising of the young breeding stock or of costs of maintaining breeding animals at the farm, or even of costs of purchasing males for reproduction, but also they want their animals to generate them an income, because they live off it. The final product of the chinchilla breeding is the progeny, so the more kits have been obtained per male or/and female parent the lower will be the costs of maintaining them and the higher will be the income for the breeder. On chinchilla farms, polygamous mating is typically used, with 5–10 females per one male. Newborn kits are raised mainly by their mothers. Therefore, most fertility studies of this species focus on the analysis of reproductive traits in females only. The research to date concerned the impact of various physiological factors (Sulik & Seremak, 2005; Semik et al., 2008) and of environmental factors (Felska, 2003; Felska & Brzozowski, 2004; Felska-Błaszczyk & Brzozowski, 2005) on the fertility of female chinchillas. The influence of seasonality on reproduction results for females (Bieniek et al., 2001) and for males (Szeleszczuk et al., 2017) was investigated.

Also, the differences in fertility in different color varieties of chinchillas (Felska-Błaszczyk et al., 2008; Seremak & Sulik, 2004b; Socha et al., 2009) were examined. The length of use of female chinchillas and factors affecting it were also analyzed (Bieniek et al., 2003; Brzozowski & Nyrek-Koczkodaj, 2007; Dzierżanowska-Góryń et al., 2011). Reproduction results were also studied depending on the type and behavior of female chinchillas and the age of the mother (Ślaska & Rozempolska-Rucińska, 2010a, 2010b; Święcicka et al., 2018). The influence of genetic factors on chinchilla fertility was also considered in several papers (Rozempolska-Rucińska et al., 2006).

Due to the use of polygamous mating in farm conditions, the influence of the sire on the number of his offspring is quite difficult to study. However, a greater number of offspring after a given sire reduces the cost of maintaining that sire at the farm, and that is another economically important aspect from breeders' viewpoint. Unfortunately, there has been little research on the latter topic. Studies of male fertility concern mainly semen quality and factors affecting it, because the quality of male sperm undoubtedly influences the number of offspring born after the sire. Also, the research concerning male chinchilla reproduction deals with the possibility of introducing modern techniques, such as artificial insemination, into their breeding (Busso et al., 2012). The possibilities of semen collection from males by means of electroejaculation and their impact on sperm parameters were investigated as well (Barnabe et al., 1994; Busso et al., 2005; Busso et al., 2005; Ponzio et al., 2011). The effect of various diluents on the DNA integrity of male chinchilla spermatozoa was also analyzed (Niedbała et al., 2015). Further, seasonal changes in androgen metabolites and the quality of semen of male chinchillas with natural photoperiod were addressed (Dominchin et al., 2014) as well as seasonal changes in the structure of male testicles (Surmacki et al., 2011). Joint chinchilla male and female reproductive performance and fertility have also been studied (Călămar et al., 2008; Galeano et al., 2014; Morales et al., 2000; Novikov & Shumilina, 2015). However, relatively little attention has been paid so far to the reproductive life performance of male chinchillas and their length of use in reproduction. Therefore, the aim of the present study was to perform the retrospective analysis of the factors affecting the intensity of breeding use and lifetime reproductive efficiency of male chinchillas, which should be recognized as economically important to chinchilla breeders.

2 | MATERIALS AND METHODS

The material included data on the reproductive performance of 174 male chinchillas born in 1995–2008 were used as sires at a leading breeding farm located in southern Poland. The farm was founded in 1991 with chinchillas and breeding technology that originated from a reputable German farm. In addition, the farm has chinchilla lines from Canada, Denmark, and Finland. Since 1996, it has been a breeding farm, applying the evaluation of breeding value. For many years, animals from the farm in question won champion titles at National and International Animal Exhibitions. This farm offers not only breeding animals, but also self-made fodders for chinchillas (complete mixtures) and cages with equipment. The owner also conducts training courses for future chinchilla breeders, and the farm serves as a teaching base for students of Polish agricultural universities.

In the years 1996–2010, a total of 4,390 litters were obtained from the aforementioned males. The material for this study was a portion of data obtained in a long-term project concerning the analysis of chinchilla reproduction in Poland. The animals were kept in a closed room with cage batteries, air conditioning, and partially artificial light, and they were fed with complete feed (pellets), hay, and water. The males were managed in polygamous sets with six females in combined cages with free access to each female in the set to allow for natural mating. The cage area was about 0.5 m^2. The male body weight ranged between 470 and 560 g.

Three classes of male birth litter size, that is, 1, 2, and 3 or more heads (3 + class) were created. Data were classified into two litter birth seasons: from March to August or from September to February. The seasons were defined as is conventionally performed for the Polish population, according to a previous study conducted by Bieniek et al. (2001). Because natural mating in polygamous sets was used on the farm, in our data, we have only litter birth dates and the birth date of each sire, obtained from breeding documentation. Therefore, we have estimated the length of reproductive use of sire [days] (LURS) as the difference between the effective mating date of the last recorded litter and the effective mating date of the first recorded litter. Both effective mating dates were calculated as follows: litter birth date—111 days of pregnancy. Whereas, the sire age at the first effective mating was expressed as the difference between the birth date of the first recorded litter and the birth date of its sire minus 111 days of pregnancy.

Characteristics of the material are shown in Table 1.

The total number of litters born per sire (TNLBS), the total number of litters weaned per sire (TNLWS), the total number of kits born per sire (TNKBS), the total number of kits weaned per sire (TNKWS), the ratio of the total number of kits reared to the number of kits born per sire (TRE), and the length of reproductive use of sire (LURS) were checked for normal distribution with the Kolmogorov–Smirnov test using the SAS software (SAS, 2014). The TNLBS, TNLWS, TNKBS, TNKWS, and LURS were log transformed and TRE was transformed using the transformation proposed by Box and Cox (1964). The Box-Cox transformation of the variable x is indexed by λ parameter and is defined as:

$$x'_\lambda = \frac{x^\lambda - 1}{\lambda}$$

In this paper, in the case of TRE, the λ parameter was equal 2.

TABLE 1 Characteristics of the analyzed data

	No. of sires	No. of litters
Sire birth litter size class		
1	23	604
2	74	1,700
3+	77	2,086
Sire age at first effective mating		
<7 month	5	130
7–10 month	37	1,047
11–13 month	49	1,086
14–16 month	34	874
17–19 month	18	493
20–22 month	9	289
>22 month	22	471
Litter birth season		
March to August		2,516
September to February		1,874

After the transformation, the distribution of all analyzed traits, that is, TNLBS, TNLWS, TNKBS, TNKWS, and LURS did not deviate from the normal distribution. The actual mean values, that is, before transformations are listed in the tables. The analysis of variance was performed using the GLM procedure of SAS (2014) and the following linear model:

$$Y_{ij} = \mu + S_i + \beta_1 A_{ij} + \beta_2 BY_{ij} + e_{ij}$$

where:

Y_{ij} – the total number of litters born per sire (TNLBS), the total number of litters weaned per sire (TNLWS), the total number of kits born per sire (TNKBS), the total number of kits weaned per sire (TNKWS), the total number of kits reared to the number of kits born per sire (TRE) or the length of reproductive use of sire (LURS).

μ – overall mean.

S_i – fixed effect of i-th size of the male birth litter (i = 1, 2, 3).

$\beta_1 A_{ij}$– linear regression on male age at the time of the first effective mating (from 193 to 2,614 days).

$\beta_2 BY_{ij}$ – linear regression on male birth year (from 1995 to 2008).

e_{ij} – residual effect.

The R-squared values for such a model were about 0.2 for all tested traits (TNLBS, TNLWS, TNKBS, TNKWS, and LURS).

Three additional traits: litter size born (LSB), litter size weaned (LSW), and the ratio of the number of kits reared to those born in a given litter (LRE) were also described in this study. The litters with different numbers of kits born (LSB) and weaned (LSW), as well as the ratio of the number of kits reared to those born in a given litter (LRE) were analyzed using Marascuillo procedure for testing equality of proportions (Wagh & Razvi, 2016).

Additionally, Pearson's correlation coefficients for the transformed traits, that is, TNLBS, TNLWS, TNKBS, TNKWS, LURS, and TRE and Spearman's correlation for LSB, LSW, and LRE were calculated using the CORR procedure of SAS (2014).

TABLE 2 Means, standard errors (SE), and medians of the reproduction traits for 174 chinchilla males

Trait	Mean	SE	Median
TNLBS [No][1)]	25.2	21.1	19.0
TNLWS [No][2)]	23.0	19.4	18.0
TNKBS [heads][3)]	47.2	40.8	34.5
TNKWS [heads][4)]	39.4	34.2	29.5
LSB [heads][5)]	1.87	0.81	2.0
LSW [heads][6)]	1.56	0.83	2.0
LURS [days][7)]	1,927.0	984.7	1,716.0
TRE [%][8)]	83.5	11.4	85.1
LRE [%][9)]	84.8	30.8	100.0

Abbreviations: [1)] TNLBS – total number of litters born per sire [No]; [2)] TNLWS – total number of litters weaned per sire [No]; [3)]TNKBS – total number of kits born per sire [heads]; [4)]TNKWS – total number of kits weaned per sire [heads]; [5)] LSB – litter size born [heads]; [6)]LSW – litter size weaned [heads];[7)] LURS – length of reproductive use of sire [days] estimated as the difference between the effective mating date of the last recorded litter and the effective mating date of the first recorded litter. Both effective mating dates were calculated as follows: litter birth date – 111 days of pregnancy; [8)] TRE – total number of kits reared to the number of kits born per sire [%]; [9)] LRE – ratio of the number of kits reared to those born in a given litter [%]

3 | RESULTS AND DISCUSSION

Data regarding male reproductive performance are presented in Table 2. The examined sires were used in reproduction for about 5 years. During this time they sired over 25 litters with about 47 kits on average.

Most of the sires at the time of the first effective mating were at the age of 7 to 16 months, and they produced the overwhelming majority of litters (see: Table 1). The sires that were the oldest at the first effective mating were those used at the beginning of the farm's activity, and probably they had been imported from abroad (i.e., Denmark, Germany).

For breeders, litter size at birth (LSB) is an essential consideration. In the present study, the average litter size equaled 1.87 (see: Table 2), which is consistent with the previously obtained results. For example, Dzierżanowska-Góryń et al. (2011) found that chinchilla litter size at birth varied from 1.76 to 2.20. Earlier, Socha et al. (2001) reported a similar—or slightly higher than in our study—litter size at birth (from 1.80 to 1.90). However, Felska and Brzozowski (2004) reported higher values of LSB that ranged from 1.84 to 2.25 in most of the analyzed groups. And also Călămar et al. (2008) obtained higher mean LSB value—over 2.22, with the range from 2.16 to 2.27. In all research studies, as well as in breeding practice, the litter size of about 2 or 2.5 kits was considered a good result. Moreover, the possibility to obtain more kits in one litter in chinchillas is slim, because the typical litter size in this species ranges between 1 and 3 kits. Even if the sire could produce more kits, their number in one litter is limited by female capacity for reproduction, because in one heat the female has only four mature follicles in both ovaries. Furthermore, the potential for larger litters has been modified by various genetic and environmental factors. The genetic factors include higher embryo and fetus mortality due to genetic defects. The environmental factors would include, for example, cage illumination, as was found by Felska and Brzozowski (2004).

Each sire was mated to 1 up to 17 dams. Most of the sires were mated to 1 up to 6 dams, which means that each of them was used in one polygamous set (68.4% of sires). Further 31.6% were used in two to maximum six polygamous sets (20.1%, 5.7%, 2.9%, about 1% and 1.7%, respectively). The sires born between 1995 and 2002 were mated either to 7–10 dams or to 11–17 dams throughout their lifetime (37.9% and 17.2% of sires, respectively), and they were probably exchanged between polygamous sets.

Seremak and Sulik (2004a) found that chinchilla males should be mated with more than four or six females. They mentioned that in Danish farms chinchilla males were mated, with good effects, to as many as 16 females in one polygamous set. Thus, although the number of females mated to one male in our study was sufficient, most of the examined males were not so intensively used.

The reproductive performance of sires, expressed as the total number of litters per sire, was not high; over 29% of the sires had up to 10 litters, followed by a group of about 24% sires, which had up to 20 litters. Slightly more than 16% of the sires had nearly 30 litters, and little more than 10% – up to 40 litters. It can be observed that only about 21% of sires contributed more than 40 litters to the herd. About 2.3% of sires left 80 or more litters in the herd.

The number of litters born and weaned per sire is the essential parameters for the reproduction results of the farm. The sires aged about 1.0–1.5 years at the time of their first effective mating contributed from 30 to 60 litters per sire, but the higher number of litters did not depend on the sire's age at the time of the first effective mating. To some extent, the results similar to ours were found by Bieniek et al. (2003). They found that chinchilla females were effectively mated first time at the age of about 1.5 years, with the range from 7.7 months to 1.75 years, and their lifetime reproductive performance ranged from 1 to 14 litters. In fact, in chinchilla breeding, the number of litters higher than 6–8 for females and 30–60 for males rarely occurs, because only the animals with high genetic quality, good health, and reproduction ability can be used longer and are able to produce more litters.

Table 3 shows the means, standard errors, and medians for all examined traits in different classes of sire's birth litter size (1, 2, and 3+). There were no significant differences ($p > .05$) between the male birth litter classes for all analyzed traits, that is, TNLBS, TNLWS, TNKBS, TNKWS, LURS, and TRE. What is interesting, the highest values of the total number of litters born (TNLBS) and weaned (TNLWS) per sire, total number of kits born (TNKBS) and weaned (TNKWS) per sire, as well as the length of reproductive use of sire (LURS) were observed for sires in the 3 + class (3 and more kits born in sire's birth litter).

The linear regression of the number of litters born (TNLBS) and weaned (TNLWS) per sire as well as of the number of kits born (TNKBS) and weaned (TNKWS) per sire on male birth year was highly significant ($p < .01$). The corresponding linear regression coefficient for TRE was close to zero and non-significant ($p > .05$). In the case of the length of reproductive use of the sire (LURS), the linear regression coefficient on male birth year was highly significant. It indicates that males used longer in reproduction produced much more litters and kits during their lives, and generated more income for the breeder, despite the loses of kits.

In the case of all the analyzed traits, that is,, TNLBS, TNLWS, TNKBS, TNKWS, LURS, and TRE the linear regression on the male age of the first effective mating was non-significant ($p > .05$).

TABLE 3 Means, standard errors (SE), and medians of the reproduction traits for 174 chinchilla males, by the size of the sire birth litter

	The size of the sire birth litter [heads]								
	1			2			3+		
Trait	Mean	*SE*	Median	Mean	*SE*	Median	Mean	*SE*	Median
TNLBS [No][1)]	26.3	24.9	18.0	23.0	18.8	19.0	27.1	22.0	20.0
TNLWS [No][2)]	24.1	23.1	18.0	21.1	17.5	16.0	24.6	20.0	19.0
TNKBS [heads][3)]	47.6	46.2	32.0	44.0	37.4	35.0	50.1	42.6	35.0
TNKWS [heads][4)]	40.3	39.8	28.0	36.9	31.8	28.5	41.5	35.1	30.0
LURS [days][5)]	1,930.1	1,223.0	1,438.0	1,810.6	892.7	1,585.0	2,037.9	991.5	1,906.0
TRE [%][6)]	82.4	18.1	87.5	83.9	10.1	84.9	83.3	10.0	84.3

Abbreviations: [1)] TNLBS – total number of litters born per sire [No]; [2)] TNLWS – total number of litters weaned per sire [No]; [3)]TNKBS – total number of kits born per sire [heads]. [4)]TNKWS – total number of kits weaned per sire [heads]; [5)] LURS – length of reproductive use of sire [days] estimated as the difference between the effective mating date of the last recorded litter and the effective mating date of the first recorded litter. Both effective mating dates were calculated as follows: litter birth date – 111 days of pregnancy; [6)] TRE – total number of kits reared to the number of kits born per sire [%]

However, what is interesting is that the sires, which were first effectively mated at the age of about one year, had lower TRE value, which could indicate that in this group the losses of the whole litters as well as individual kits occurred more often. The sires that were the youngest at the time of their first effective mating had the highest value of litter size born out of all groups, and the lowest LRE value of all groups, which means that, although they could potentially sire larger litters, the kits in those litters were probably weaker and the losses were more frequent.

For chinchilla breeding, it has been recommended that the young males be used for reproduction at the age of about 1 year. Younger animals would not be mature enough to be suited to reproduction. On the other hand, the males over 1 year old at the time of their first effective mating would not have enough time to produce a large number of progeny. In our study, the first assumption was confirmed, because the males that had their first effective mating at a younger age had poorer fertility. However, in those that were older at the time of their first mating the number of litters was more differentiated and seemed independent of the studied factor. Brzozowski and Nyrek-Koczkodaj (2007) found similar differences in litter sizes born and weaned between those females that were the youngest at the time of their first mating, and the older ones. They found that the females aged under 6 months had significantly higher mean litter sizes, both born and weaned, contributing more than two kits. Our results in these litter sizes, for males in different groups of age at the first mating, seem considerably similar; on average, almost two kits were born but only about 1.5 weaned.

The sires had their first effective mating at the youngest age (less than 7 months) were born in litters with two or more kits. All classes of the sire age at the time of first effective mating were represented in the first group made up by sire birth litter size (one kit in the litter) but this class was less numerous than others; presumably, the breeders preferred the sires that were born in the litters with higher size, as they believed them to be more fertile than others. However, in our research, the impact of birth litter size of the sire on the average values of most of the examined fertility traits was not found significant, despite visible differences in some traits (see: Table 3).

The few sires, which were the youngest at the time of the first effective mating, sired lower numbers of litters and demonstrated poor fertility parameters, except for the litter size born, and also the shortest length of reproductive use (about 2.4 years) compared to other groups. These sires were born in litters of different sizes, but their too early use in reproduction probably overloaded the young, still growing organism, and resulted in worse reproductive results (probably poor semen quality and weaker born kits with higher mortality, maybe due to the occurrence of hereditary diseases) and led to a shorter time of their reproductive use.

What is interesting is that when analyzing the size of the sire birth litter (see: Table 3), in most cases, for the total number of litters born and weaned per sire as well as the total number of kits born and weaned per sire, the medians are lower than mean values. Also, for those traits in most of the males, the values were lower than the overall mean, and more variable. The opposite trend was observed in the case of efficiency trait, suggesting that the total rearing efficiency (TRE) was below the average for males that were older at the time of their first effective mating. Also, for the length of reproductive sire's use (LURS), a similar trend was observed for the sires aged 7–10 months at the time of the first effective mating, which was also used for reproduction longer than this group's average. That could be profitable for breeders.

The number of litters born and weaned per sire is the two essential parameters, influencing the annual reproduction results of the farm. In the present study, most of the litters were sired by relatively young males, aged between 1 and 8 years, in average, from about 10 up to 49 litters born from about 10 to about 46 litters weaned per sire. The youngest sires produced on average about four litters born, and over 3.5 litters weaned per sire, whereas the oldest sires produced almost six times as many, that is, over 72, born and about 65 weaned litters per sire.

In Figure 1, the numbers of litters with litter size from 1 kit to 4–6 kits born depending on the age of the sire are presented. The sires aged between 1 and 5 years produced litters with one to three kits born, in most cases. The young sires (in the age of up to 2 years) also produced large litters, mostly consisting of four kits, but also five or even six kits born in the litter. The older sires, over 7 years old, produced litters mostly with one or two kits, rarely more numerous. However, litter sizes obtained for older males suggest the possibility of using males in reproduction for longer time than until the age of 5 years, if they are healthy.

For chinchilla females, Bieniek et al. (2003) also found that most of them had litters with one to three kits. Also, Socha et al. (2009) obtained similar results; namely, they found that most litters consisted of one up to three kits. Higher litter sizes (4 or more kits in one litter) occurred rarely. In chinchilla breeding, the age between 1 and 5 years is regarded as optimal for males as well as females. The older animals usually had poorer fertility, but if they were valuable and healthy, and able to produce litters with a minimum of 1–2 kits, then the breeder could decide to use them longer. That can be concluded in some cases from our results.

The next studied aspect was the seasonal pattern of litter size born (LSB) and weaned (LSW), and the ratio of the number of kits reared to born in a given litter (LRE). Both litter sizes (LSB, LSW) and LRE were slightly higher in the season of March to August (1.94 ± 0.83 heads, 1.64 ± 0.85 heads, and 85.29 ± 29.85% for LSB, LSW, and LRE, respectively) than in the second season, that is, from September to February (1.77 ± 0.76 heads, 1.46 ± 0.80 heads and 84.15 ± 32.11% for LSB, LSW, and LRE, respectively). Interestingly, for all three studied traits, the mean values are lower than the medians (2 heads), with one exception, that is, litter size weaned for litters born between September and February (median = 1 head), which means that in the latter season the losses of kits occurred more often, and thus more litters with one kit were weaned.

The seasonal changes in different parameters of chinchilla male and female fertility were mentioned by numerous authors (Bieniek et al., 2001; Morales et al., 2000; Nistal & Di Masso, 2009; Szeleszczuk et al., 2017) as were the changes in the parameters of semen quality and testicular activity in chinchilla males (Busso et al., 2012; Busso, Ponzio, Fiol do Cuneo & Ruiz, 2005; Dominchin et al., 2014; Surmacki et al., 2011). Although Dierżanowska-Góryń et al. (2011) found some changes in chinchilla female fertility between winter and summer, they did not attribute those changes in the season itself but rather to the differences in farm management. The aforementioned seasonal changes in chinchilla reproduction occurred in the wild, in breeding populations both in South America and in Europe, although the seasons were quite different. In Polish conditions, the reproduction activity increases in spring and summer and decreases in autumn and winter, but the changes are relatively small, which is linked to the housing conditions of animals (cages in closed rooms with air conditioning, stable temperature, coupled with fully or partially artificial illumination).

Table 4 lists the litters with different sizes born (LSB), different sizes weaned (LSW), and different ratios of the number of kits reared to those born in a given litter (LRE). In the case of LSB, LSW, and LRE, highly significant differences were found between classes ($p < .01$). The sizes of litters born (LSB) ranged between 1 and 6. In the largest number of litters, one or two kits were born. The LSW varied from 0 to 5, and in the largest number of litters one or two kits was weaned. In most cases, the ratio of the number of kits reared to those born in a given litter (LRE) was equal to 100%, which means that all born kits were weaned. Moreover, the level of mortality of whole litters was low, about 8.7%, throughout the examined 14 years (0.62% per year of birth), which indicates high quality management in the examined farm.

TABLE 4 Characteristic of the reproduction traits for 174 chinchilla males

Trait	Number of litters	
	N	%
Total	4,390	100.00
Litter size born (LSB) [heads]		
1	1603	36.51^{A}
2	1896	43.19^{B}
3	769	17.52^{C}
4	111	2.53^{D}
5	10	0.23^{E}
6	1	0.02^{E}
Litter size weaned (LSW) [heads]		
0	383	8.72^{A}
1	1725	39.29^{B}
2	1759	40.07^{B}
3	485	11.05^{C}
4	36	0.82^{D}
5	2	0.05^{D}
Ratio of the number of kits reared to those born in a given litter (LRE) [%]		
0	383	8.72^{A}
25	11	0.25^{B}
33	57	1.30^{B}
40	3	0.07^{B}
50	300	6.83^{A}
67	234	5.33^{AC}
75	30	0.68^{B}
80	1	0.02^{B}
100	3,371	76.79^{D}

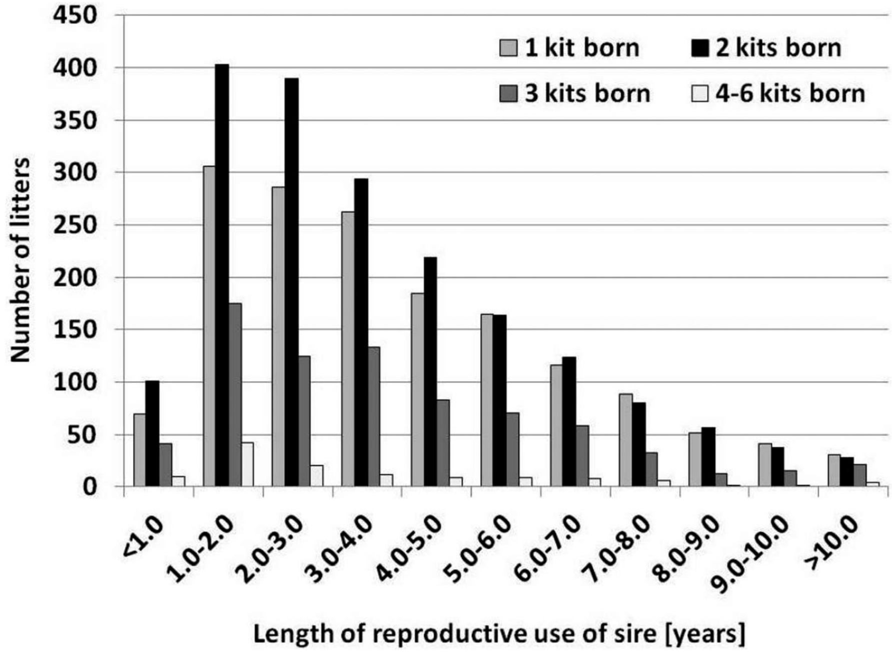
Note: $^{A, B, ..., E}$ values within the same trait with different superscripts differ significantly ($p < .01$).

Additionally, correlations between the analyzed traits (TNLBS, TNLWS, TNKBS, TNKWS, LURS, and TRE) were determined. The lowest correlation coefficients were those between TRE and other traits, and their absolute values varied from 0.00 to 0.07 ($p > .05$). The other traits were moderately or highly correlated (from 0.80 to 0.99, $p < .01$). In this group of traits, the correlation coefficients between LURS and other traits, that is, TNLBS, TNLWS, TNKBS, and TNKWS, were approximately 0.80. The highest correlation coefficients were calculated between each pair of the traitsTNLBS, TNLWS, TNKBS, and TNKWS (about 0.99). Only TRE with TNLBS or TNKBS were negatively correlated. Also, Spearman's correlations between LSB, LSW, and LRE were calculated. All correlations were low or moderate ($p < .01$). The correlation between LSB and LRE (with the absolute value of 0.20) was the lowest, while LSB and LSW showed the highest correlation (0.74). Only LSB and LRE were negatively correlated.

The correlation coefficients between the two efficiency parameters (TRE and LRE) and all other traits were negative and low, which means that the more litters or the larger size litters the chinchilla male sired, the lower were the efficiency parameter values for that male specimen. The moderate or high and positive correlations between TNLBS, TNLWS, TNKBS and TLKWS indicate strong connections among those four traits. Also, LURS was highly and positively correlated with those four traits. This confirms a close relationship between the length of use of a male in reproduction and its reproductive performance. The correlation between both litter sizes (LSB and LSW) was also high and positive (0.74), with a value slightly above the 0.64 obtained for chinchilla females by Socha et al. (2009).

To summarize the above results, the impact of the studied factors—such as sire's birth litter size, or sire's age at the time of the first effective mating—on the reproduction performance in terms of the total number of litters and kits born and weaned did not turn out to be statistically significant. However, visible differences in total reproduction performance for the studied sires do exist, especially for the age of the sire's first effective mating. The males, which were the youngest at the time of their first effective mating, had the poorest performance. Moreover, the noticeable differences in the total reproduction performance for the sire's birth litter size effect were small, although the breeders' conviction is that the sires, which were born in larger litters, are more fertile. The length of reproductive use of the sires had the same pattern of relevance, namely: all the examined effects were statistically non-significant, regardless of the visible differences in this trait, in some cases substantial, as for the

FIGURE 1 Number of litters born with different litter sizes (LSB) depending on the length of the sire's reproductive use



sire's age at the first effective mating. The sires being the youngest at the time of their first effective mating had the shortest length of reproductive use, which is unprofitable for breeders. In the case of both litter sizes, the influence of factors such as litter birth season was mentioned also in other studies. The males, which were the youngest at the time of their first effective mating, sired the litters, which were the largest in size at birth, but with more losses at weaning compared to older males. The males born in large litters sired litters with almost the same size as the males born in litters with one or two kits, but in their litters, there were higher losses of kits than in other groups.

4 | CONCLUSIONS

It can be concluded that the lack of differences between the sire's birth litter size classes did not support the breeders' belief that the males born in larger litters are more fertile than those born in litters with one kit. Most of the examined sires were used in one polygamous set (with up to six females) each and sired up to approximately 60 litters, which means that they could be more extensively used and mated to a larger number of females, and to produce more litters. That should produce more potential benefits for chinchilla breeders.

The high and positive correlations confirm a close relationship between the length of use of a male in reproduction and its reproductive performance. The males, which were used longer in reproduction, have produced, despite the losses of individual kits, much more litters and kits during their lives and generated more income for the breeder. However, the use very young males (under one year of age) in reproduction would be unprofitable for breeders, irrespective of the fact that such males are giving more numerous litters (but with heavy losses of kits). On the other hand, low and negative correlations of TRE and LRE with the number of litters or kits born and weaned and with the litter size, whether born or weaned, indicate unfavourable, though minor, dependence of rearing efficiency on other traits. Therefore, it can be concluded that the only possible way to improve the rearing efficiency is to take care of good health and maintenance conditions of the animals.

Our results indicated that, to some extent, the examined chinchillas still show seasonality of reproduction. The analysis of different litter sizes showed a species-specific number of kits per litter, ranging from 1 to 3 kits. Moreover, the level of mortality of the whole litters was low throughout the examined time period of 14 years (0.62% per year of birth), which indicates high quality management in the examined farm.

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