Genetic parameters of production traits for Debrecen White Rabbit

A debreceni fehér nyúl termelési tulajdonságainak genetikai paraméterei

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SUMMARY

The Debrecen White rabbit is a medium-sized breed highly suited for intensive meat production. To evaluate its genetic potential, our study analysed 18,885 production records from 2019 to 2025. The research focused on three primary growth traits: weight at 6 weeks, weight at 10 weeks, and average daily weight gain during the four-week fattening period. The rabbits averaged 1.17 kg at 6 weeks and more than doubled their mass to 2.50 kg by 10 weeks. The average daily weight gain reached 47.42 g, comfortably exceeding the standard 40 g benchmark for high-yielding strains. Growth parameters were significantly influenced by birth year, birth month and sex. While no sexual dimorphism was present at 6 weeks, males became significantly heavier than females by week 10 due to superior daily weight gains. Seasonality also played a major role; rabbits born in March achieved peak performance compared to autumn cohorts. Interestingly, annual data highlighted a compensatory growth mechanism, where cohorts entering the fattening period with lower 6-week weights achieved the highest daily gains to catch up by week 10. Heritability estimates were remarkably low, ranging from 0.02 to 0.08. This suggests that phenotypic variation is heavily dominated by environmental factors and maternal influences rather than additive genetics, likely due to decades of intense selection within a closed population. These near-zero heritabilities make direct mass selection highly inefficient, so transition to family-based BLUP models, genomic selection, or crossbreeding schemes to achieve further genetic progress might be favourable.

Keywords: heritability, genetic correlation, growth traits

ÖSSZEFOGLALÁS

A debreceni fehér nyúl egy intenzív hústermelésre kiválóan alkalmas, közepes testű fajta. A fajta genetikai potenciáljának felmérése érdekében tanulmányunkban 18885 termelési adatot értékeltünk a 2019 és 2025 közötti időszakból. A kutatás három elsődleges növekedési tulajdonságra összpontosított: a 6 hetes kori testtömegre, a 10 hetes kori testtömegre, valamint a négyhetes hizlalási időszak átlagos napi testtömeg-gyarapodására. A nyulak átlagos tömege 6 hetesen 1,17 kg volt, ami 10 hetes korra több mint a duplájára, 2,50 kg-ra nőtt. Az átlagos napi testtömeg-gyarapodás elérte a 47,42 grammot, ami meghaladta a nagy hozamú vonalaknál elvárt 40 grammos standard referenciaértéket. A növekedési paramétereket jelentősen befolyásolta a születési év, a születési hónap és az állatok ivara. Bár 6 hetes korban még nem volt tapasztalható ivari dimorfizmus, a bakok a jobb napi súlygyarapodásuknak köszönhetően a 10. hétre szignifikánsan nehezebbek lettek a nőstényeknél. A szezonalitás szintén meghatározó szerepet játszott: a márciusban született nyulak érték el a jobb teljesítményt az őszi állomá-

nyokhoz képest. Érdekesség, hogy az éves adatok rávilágítottak egy kompenzációs növekedési mechanizmusra is, miszerint az alacsonyabb 6 hetes testtömeggel hizlalásba vont csoportok érték el a legnagyobb napi gyarapodást, így a 10. hétre felzárkóztak a többiekhez. Az örökölhetőségi értékek rendkívül alacsonyak voltak, 0,02 és 0,08 között mozogtak. Ez arra utal, hogy a fenotípusos varianciát az additív genetikai hatások helyett sokkal inkább a környezeti tényezők és az anyai hatások dominálják, ami valószínűleg a zárt populáción belüli, évtizedeken át tartó intenzív szelekció következménye. Mivel ezek a nullához közeli örökölhetőségi értékek csak alacsony hatékonyságú egyedszelekciót tesznek lehetővé, a további genetikai előrehaladás elérése érdekében célszerű lehet a családi adatokon alapuló BLUP-modellekre, a genomikus szelekcióra vagy a keresztezési sémákra való átállás.

Kulcsszavak: örökölhetőség, genetikai korreláció, növekedési tulajdonságok

1 Introduction and literature review

The Debrecen White rabbit is bred for meat production. This medium-sized breed can be used for production in intensive systems as well as backyard conditions. The breeding population was 80 bucks and 1800 does in 2024 *(Juráskó, 2025)*. To avoid the mating of close relatives, a circular mating system is used during breeding, with five lines in the population. In addition to effective selection for meat production, the maintenance of genetic variability is also important. An understanding of genetic structure and information about population genetic parameters is important for commercial breeds as well as for breeds under gene conservation.

Rabbit reproduction parameters and growth-related traits are deeply research in the international literature. *Ezzeroug et al. (2020)* evaluated reproduction and growth for an Algerian synthetic rabbit line. *Ayyat et al. (2024)* estimated the genetic parameters (heritability as well as genetic and phenotypic correlations) for New Zealand White, Californian and Gabali rabbits in Egypt. They concluded that heritability estimates indicated potential genetic influences on these traits, with moderate heritability observed for BW.

Gyovai et al. (2012) concluded that computer tomography scan could be efficiently used to improve muscle volume. The also reported strong negative genetic correlation reported between the thigh muscle volume and 21 day litter weight. Reproduction traits and growth parameters were studied for Pannon White breed *(Nagy et al., 2011,2013)* in Hungarian rabbit sector.

The objective of the current research was to estimate genetic parameters of some production traits of Debrecen White rabbit breed.

2 Materials and Methods

The raw production data and the pedigree information were provided by the Debrecen White Rabbit Breeder Association. The dataset contained production records of pre-selected breeding candidate animals from 2019 up to 2025. The

evaluated traits were weight at 6 weeks old, weight at 10 weeks old and daily weight gain during the fattening period. Besides the previous production traits, selection criteria for the nucleus included conformation, health status, and dam productivity parameters (minimum 8 kits successfully reared per litter, optimal weaning weights, and litter mortality below 10%). The final dataset contained 18,885 production records and the pedigree records of these rabbits back to the founder individuals (34,410 rabbits).

Statistical analyses were performed using R statistical software *(R Core Team, 2024)*. The dependent variables (weight at 6 weeks old, weight at 10 weeks old and daily weight gain) were analysed using linear models (lm function). Sex, birth year and birth month of the rabbits were taken into account as fixed effects in the model. Estimated marginal means (EMMs, also known as least-squares means) and their associated standard errors (SE) were computed using the emmeans package *(Lenth et al., 2026)* to characterize group differences. The level of statistical significance was set $P < 0.05$. The significance of fixed effects is shown in *Table 1*. Sex effect was not significant for weight at 6 weeks old, but it was included in the model to allow the usage of the same evaluation model for each trait.

Table 1 Significant levels for traits and fixed effects of Debrecen White Rabbit

Traits (1)	Sex (2)	Birth Year (3)	Birth Month (4)	R^2
Weight at 6 weeks old (kg) (5)	P = 0.5596	P < 0.001	P < 0.001	0.2561
Weight at 10 weeks old (kg) (6)	P < 0.001	P < 0.001	P < 0.001	0.1024
Daily weight gain (g) (7)	P < 0.001	P < 0.001	P < 0.001	0.1150

tulajdonságok (1); ivar (2); születési év (3), születési hónap (4), hathetes kori élősúly (5); tízhetes kori élősúly (6); hízlalás alatti napi gyarapodás (7)

1. táblázat. A fix hatások tulajdonságonkénti szignifikancia szintjei debreceni fehér nyulaknál

Variance components, correlations and heritabilities were estimated with VCE-6 software *(Groeneveld et al., 2008)* for each trait using the following model:

$Y_{ijkl} = \mu + Sex_i + BirthYear_j + BirthMonth_k + Animal_l + e_{ijkl}$, where

Y_{ijkl}	=	the evaluated trait;
μ	=	the overall population mean;
Sex_i	=	sex of the rabbit;
$BirthYear_j$	=	birth year of the rabbit;
$BirthMonth_k$	=	birth month of the rabbit;
$Animal_l$	=	random effect of the rabbit;
e_{ijkl}	=	random residual term.

3 Results and discussion

The estimated overall marginal means along with standard errors as well as the minimum and maximum values are summarized in *Table 2*. The data represents a robust sample size (N = 18,886) for the future parameter estimation. The average body weight at 6 weeks of age was 1.17 kg, with individual values ranging from a minimum of 0.90 kg to a maximum of 1.57 kg. By 10 weeks of age, the mean body weight more than doubled, reaching 2.50 kg ranging from 2.04 kg to 3.01 kg. During the four-week fattening period, the animals exhibited a mean daily weight gain of 47.42 g. While the lowest performing individuals gained only 24.29 g/day, the upper limit of the population reached a high growth rate of 58.21 g/day, indicating substantial phenotypic variation within the population. The results demonstrate that the Debrecen White Rabbit exhibits excellent growth performance, making it highly competitive with other commercial meat rabbit breeds. The very low standard errors (SE) across all traits underline the high uniformity of the population, which is a desirable trait in commercial livestock production. The mean body weight at 10 weeks (2.50 kg) is particularly significant, as it meets the optimal commercial slaughter weight standard for the European market. Achieving this weight within a 10-week timeframe is critical for maximizing economic efficiency and feed conversion ratios in intensive rabbit farming. The average daily weight gain of 47.42 g observed in this study is notably high. In rabbit husbandry, a daily gain exceeding 40 g during the fattening period is generally considered the benchmark for high-yielding meat strains. It is crucial that these animals represent a pre-selected nucleus herd rather than an unselected commercial cross-section. Consequently, the evaluated rabbits effectively constitute elite breeding candidates. This pre-selection truncated the additive genetic variance, explaining the near-zero h^2 estimates, and accounts for the 10–15% higher growth performance compared to commercial offspring. The wide range between the minimum (24.29 g) and maximum (58.21 g) weight gains suggests that while the population average is high, there is still significant phenotypic variability available. Overall, these baseline statistics confirm that the Debrecen White Rabbit possesses robust genetic potential for meat production, characterized by rapid post-weaning growth and excellent slaughter-weight viability at 10 weeks of age. Our calculated means were higher compared to *Dige et al. (2012)* and *Sakhtivel et al. (2017)* findings for weight traits as well as daily weight gain. The reason might be that their evaluation based on local New Zealand White populations and not intensive commercial genotypes.

Table 2 Basic statistics for production traits of Debrecen White Rabbit

Traits (1)	N	$\bar{X}$±SE	Min	Max
Weight at 6 weeks old (kg) (2)	18886	1.17 ± 0.002	0.90	1.57
Weight at 10 weeks old (kg) (3)	18886	2.50 ± 0.003	2.04	3.01
Weight gain (g) (4)	18886	47.42 ± 0.116	24.29	58.21

tulajdonságok (1); hathetes kori élősúly (2); tízhetes kori élősúly (3); hízlalás alatti napi gyarapodás (4)

2. táblázat. A termelési tulajdonságok leíró statisztikai jellemzői debreceni fehér nyulaknál

The estimated marginal means along with their standard errors of different factor levels were estimated for each trait and are shown in *Table 3*. At 6 weeks of age, body weight was identical between sexes (1.17 kg for both males and females). The lack of significant weight differences at 6 weeks suggests that sexual dimorphism in the Debrecen White Rabbit is minimal during early post-weaning life. However, by 10 weeks of age, males achieved a significantly higher body weight (2.56 kg) compared to females (2.44 kg) ($P < 0.05$). This divergence is driven by a significantly higher average daily weight gain in males (49.52 g) than in females (45.31 g) ($P < 0.05$). The substantial imbalance in sample sizes (18,508 females vs. 378 males) reflects standard commercial or nucleus herd management, where males are strictly selected and kept in smaller numbers.

Production traits fluctuated significantly across the years evaluated (2019–2025). The 6-week weight was the highest in 2019 (1.28 kg) and lowest in 2023 and 2024 (1.10 kg). The 10-week weight followed a similar pattern, peaking in 2019 (2.59 kg) and hitting its lowest point in 2022 (2.42 kg). Interestingly, the daily weight gain showed an inverse trend, reaching its highest values in 2024 (49.6 g) and 2023 (49.0 g), despite those years having lower initial 6-week weights. The compensatory growth phenomenon is clearly visible in the 2023 and 2024 cohorts: despite entering the fattening period with the lowest 6-week weights (1.10 kg), these cohorts achieved the highest daily weight gains (~49 g/day), allowing them to nearly catch up to standard 10-week market weights (2.47–2.49 kg).

The month of birth exerted a significant influence on all growth metrics. Rabbits born in March demonstrated the highest performance across all traits, leading to a 6-week weight of 1.19 kg, a 10-week weight of 2.54 kg, and the highest daily weight gain (48.16 g). Conversely, individuals born in September exhibited the lowest 6-week (1.15 kg) and 10-week weights (2.48 kg), while those born in April had the lowest overall daily weight gain (46.64 g). The superior performance of rabbits born in March compared to those born in late summer and autumn (August/September) underscores the well-documented effect of seasonality in rabbit production. Kits born in March undergo their primary fattening stage during April and May, benefiting from moderate ambient temperatures that promote optimal feed intake. Conversely, rabbits born in August and September often face

high summer temperatures during early life or are born to does that suffered from summer heat stress. Heat stress is known to reduce milk production in lactating does and suppress voluntary feed intake in growing kits, explaining the significantly lower weaning and finishing weights of the autumn-born cohorts. These seasonal trends suggest that environmental control systems within the housing facilities could be further optimized to mitigate the performance dips observed in the late summer and autumn rounds.

Table 3 The effect of different factors on the production traits of Debrecen White Rabbit

Traits (1)	N	Weight at 6 weeks old (kg) (2)	Weight at 10 weeks old (kg) (3)	Weight gain (g) (4)
Sex (5)				
–male (6)	378	1.17 ± 0.005	2.56 ± 0.006^{a}	49.52 ± 0.215^{a}
–female (7)	18508	1.17 ± 0.001	2.44 ± 0.002^{b}	45.31 ± 0.056^{b}
Birth year (8)				
–2019	1213	1.28 ± 0.004^{a}	2.59 ± 0.005^{a}	46.6 ± 0.169^{d}
–2020	3172	1.19 ± 0.003^{c}	2.51 ± 0.004^{c}	47.1 ± 0.132^{c}
–2021	2264	1.19 ± 0.003^{c}	2.50 ± 0.004^{c}	46.7 ± 0.141^{d}
–2022	2624	1.13 ± 0.003^{d}	2.42 ± 0.004^{f}	46.1 ± 0.136^{e}
–2023	2726	1.10 ± 0.003^{e}	2.47 ± 0.004^{e}	49.0 ± 0.139^{b}
–2024	3337	1.10 ± 0.003^{e}	2.49 ± 0.004^{d}	49.6 ± 0.133^{a}
–2025	3550	1.21 ± 0.003^{b}	2.52 ± 0.004^{b}	46.7 ± 0.141^{d}
Birth month (9)				
–March (10)	1190	1.19 ± 0.004^{a}	2.54 ± 0.005^{a}	48.16 ± 0.165^{a}
–April (11)	7810	1.18 ± 0.003^{a}	2.49 ± 0.003^{bc}	46.64 ± 0.114^{c}
–August (12)	333	1.17 ± 0.006^{a}	2.50 ± 0.008^{bc}	47.19 ± 0.257^{bc}
–September (13)	4801	1.15 ± 0.003^{c}	2.48 ± 0.004^{c}	47.58 ± 0.117^{b}
–October (14)	4752	1.17 ± 0.003^{b}	2.50 ± 0.004^{b}	47.52 ± 0.121^{b}

tulajdonságok (1); hathetes kori élősúly (2); tízhetes kori élősúly (3); hízlalás alatti napi gyarapodás (4); ivar (5); bak (6); nőstény (7); születési év (8); születési hónap (9); március (10); április (11); augusztus (12); szeptember (13); október (14)

3. táblázat. A különböző tényezők hatása a termelési tulajdonságokra debreceni fehér nyulaknál

The estimated heritabilities, genetic correlations, and phenotypic correlations for the production traits of the Debrecen White Rabbit are presented in *Table 4*. The heritability estimates (shown on the diagonal) for each trait were low. There were a strong, positive genetic correlation and a moderate positive phenotypic correlation between the two weights. The genetic correlation was strongly negative, along with a moderate negative phenotypic correlation between 6 weeks old weight and weight gain. Strong positive phenotypic correlation was observed between 10 weeks old weight and weight gain, while the genetic correlation was weak and negative having a large standard error.

Table 4 Estimated heritabilities (diagonal), genetic (upper triangle) and phenotypic correlations (lower triangle) for production traits of Debrecen White Rabbit (Standard errors within brackets)

Traits (1)	2	3	4
Weight at 6 weeks old (kg) (2)	0.08 (0.012)	0.73 (0.111)	-0.76 (0.108)
Weight at 10 weeks old (kg) (3)	0.48 (0.007)	0.02 (0.008)	-0.10 (0.264)
Weight gain (g) (4)	-0.32 (0.008)	0.66 (0.006)	0.02 (0.008)

tulajdonságok (1); hathetes kori élősúly (2); tízhetes kori élősúly (3); hízlalás alatti napi gyarapodás (4)

4. táblázat. A termelési tulajdonságok örökölhetőségi értékei (az átlóban), genetikai (az átló fölött) és fenotípusos (az átló alatt) korrelációk értékei, zárójelek között a standard hiba értékei debreceni fehér nyulaknál

The heritability estimates obtained in this study are remarkably low (0.02–0.08) compared to standard literature values for meat rabbits, which typically range from low-to-moderate (0.15–0.30) for post-weaning finishing weights and daily gains *(Castelline and Panella, 1988; Szendrő et al., 1988; Lukefahr et al., 1996; Matics et al., 2014; Sakhtivel et al., 2017)*. Even in strictly selected, closed terminal populations where genetic variance naturally narrows, heritability for daily weight gain has been consistently estimated at moderate levels, such as 0.23 *(Nagy et al., 2013)*, contrasting sharply with the 0.02 observed in the Debrecen White population. There are two primary biological and managerial reasons for this outcome: there could be high environmental variance. Given the large sample size (N = 18,886) and the significant annual and monthly fluctuations observed in *Table 3*, non-genetic factors (such as litter size at birth, maternal milk production, microclimate, and feed variations) dominate the phenotypic expression of these traits. In particular, early post-weaning traits are heavily influenced by the dam's maternal ability rather than the kit's own additive genetics. The genetical explanation could be the genetic homogeneity. The Debrecen White Rabbit is a highly selected closed breed. Decades of intense, targeted selection for growth performance within this nucleus herd may have substantially reduced the additive genetic variance, leading to a plateau in heritability estimates.

The strong positive genetic correlation between 6-week and 10-week body weights (r_g = 0.73) indicates that selection for heavier kits at 6 weeks will effectively improve market weights at 10 weeks. However, a critical biological trade-off is revealed by the highly negative genetic correlation between 6-week weight and subsequent weight gain (r_g = -0.76). This antagonistic relationship strongly suggests a compensatory growth mechanism driven by environmental and maternal constraints: kits that are phenotypically lighter at 6 weeks (often due to larger litter sizes or poorer maternal milk supply before weaning) exhibit accelerated growth rates during the standalone fattening period (weeks 6 to 10) once

they gain unrestricted access to commercial feed. Conversely, kits that are exceptionally heavy at 6 weeks experience a relative slowdown in their daily growth rate as they approach their physiological growth plateau.

The near-zero heritabilities for 10-week weight and weight gain ($h^2 = 0.02$) demonstrate that direct mass selection (selecting individuals purely based on their own phenotype) will yield very slow genetic progress. To bypass this hurdle and continue improving the meat performance of the Debrecen White Rabbit, the breeding program should transition from mass selection toward family-based selection (BLUP animal models utilizing pedigree data) or incorporate genomic selection tools. Furthermore, optimizing crossbreeding schemes (using the Debrecen White as a maternal or paternal line crossed with a highly complementary breed) can capitalize on heterosis to maximize commercial growth rates despite low purebred heritabilities.

4 Conclusions

The Debrecen White rabbit has a genetic potential for meat production, with growth performance, with elite breeding candidates fully meeting European commercial slaughter-weight standards. The low heritability estimates ($h^2 = 0.02 – 0.08$) for growth traits might be the result of genetic homogeneity due to long-term intensive selection. Furthermore, the strong negative genetic correlation ($r_g = –0.76$) between 6-week weight and daily weight gain confirms a pronounced compensatory growth mechanism during the fattening period.

To achieve further genetic progress, future breeding programs should transition to family-based BLUP animal models, incorporate genomic selection tools, or implement structured crossbreeding schemes to exploit heterosis in commercial production.

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Received/Érkezett: 2026. augusztus 4.
Accepted/Elfogadva: 2026. szeptember 1.

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