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Genetic and Non-Genetic Factors Impacting Growth and Feed Efficiency in Egy-Line Rabbits Compared to Their Parents

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Abstract

THE THREE genotypes of growing rabbits; NMER, Giant Flander, and Egy-line were used to estimate heritability (h^2), the common litter effect (c^2) and error (e^2) in relation to phenotypic variance. In total, 1230 rabbits were produced from four litters in four seasons. Estimates of h^2 were moderate for all ages studied (5, 8, 14, and 20 weeks). NMER had the highest h^2 for body weight except at 5 weeks and had a higher h2 for daily weight gain (5-20). NMER had the lowest h2 for feed conversion in the periods 5-8 and 8-14. Estimates of c2 of body weight and daily gain ranged from moderate at 8 and at 8- 14 weeks of age in Egy-Line to high at 20 and at 14- 20 weeks of age in Giant Flander. Egy-Line has been shown to be superior to NMER in body weight at older ages (14 and 20 weeks); it is also greater than Giant Flander and NMER in daily weight gain. Better feed conversion values were observed in Egy-Line. The heaviest weaning weight of rabbits was recorded in autumn for the three genotypes. Body weights increased with the parity order until the third parity. Feed conversion in the second parity was preferred at early ages (5 and 8 weeks), but the best value in the third parity was at older ages. Differences in body weight between Egy-Line and its parents were significantly negative at early ages but significantly positive at older ages. Egy-Line outperformed its parents positively and significantly (P<0.01) in daily weight gain and daily feed consumption. Egy-Line excelled at improving feed conversion. It is concluded that the new synthetic line (Egy-Line) has proven its superiority and good performance genetically over its parents in all the studied traits.

Keywords: Heritability; Common litter effect, Growth traits, NMER, Giant Flander, Egy-Line.

Introduction

Animal production serves as the primary source of animal protein, which is essential for human nutrition. It constitutes a significant portion (37%) of the agricultural sector [1]. Additionally, rabbit meat is recognized as a viable alternative to traditional meats for consumers due to its high protein content, low fat, and cholesterol levels [2]. Rabbit meat production relies on selectively bred pure breeds known for their meat characteristics and crossbreeding. Among the commonly used medium-sized breeds in commercial rabbit farming are the New Zealand White and Californian [3-4]. However, small-scale farm owners have found these rabbits unsuitable for their production systems. Despite this, rabbits exhibit promising potential as meat-producing animals, particularly when considering their productive and reproductive abilities [5-6]. The improvement of Egyptian rabbits involved several generations of crossbreeding with the Flemish Giant (FG) [7]. This effort resulted in enhanced strains, including the Baladi Red (BR) and Baladi Black (BB), which was further used in crossbreeding with the V-line a synthesized line developed by selecting APRI, Alexandria, and Mashtohour rabbits [8]. In 2009, the Animal Production Research Institute (APRI) established a nucleus herd of rabbits from three governorates in Middle Egypt, naming them NMER (Native of Middle Egypt Rabbits) [9]. NMER exhibits reduced sensitivity to negative summer conditions compared to local and foreign breeds in Egypt, although their weight remains relatively low [10]. Subsequently, in 2021, a four-year crossbreeding program between NMER and Giant Flander created a new synthetic line called Egy-Line [11]. The authors observed that Egy-Line rabbits outperformed their parents regarding growth rate, but further studies are needed to evaluate this new line fully. Therefore, this study aimed to evaluate the genetic estimates of the new the synthesized line (Egy-line) and compare it with the purebred NMER

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and Giant Flander rabbit breeds in terms of genetics and productivity. In addition to determine the heritability (h2), the common litter effect (c^2) and error (e^2) in relation to phenotypic variance on the productive performance and feed efficiency of growing rabbits.

Material and Methods

Animals and Experimental design

This study was conducted at the Sakha Research Fram (Kafr El-Sheikh), which falls under the purview of the Animal Production Research Institute (APRI) at the Agricultural Research Center in Egypt. Over a period of 4 years, the study investigated three genotypes of growing rabbits: NMER, Giant Flander, and Egy-Line (a synthetic line created by crossing bucks of Giant Flander with does of NMER). A total of 72 sires and 351 dams (24 sires and 117 dams for each genotype) were utilized to produce 1230 growing rabbits (410 rabbits per group) for data collection. All treatments and rabbit care procedures adhered to Institutional Animal Care guidelines.

Animal Management

The rabbits were housed in windowed cages designed with a single level and galvanized wire. Breeding rabbits were kept individually, while growing rabbits were raised in collective cages after weaning to minimize the impact of group size on body weight and daily gain. Each breeding rabbit had its own metal cage (40 × 50 × 60 cm) was equipped with nipple watering and metal feeders. Does were introduced to the buck's cage, and service dates were recorded. Approximately 14 days after service, the does were palpated. Three days before the expected kindling date, positively palpated does were provided nest boxes (40 × 40 × 40 cm) with clean rice straw. Negatively palpated does were reintroduced to the buck's cage. Kits were weaned at thirty days of age and transferred to fattening cages (40 × 50 × 50 cm) with metal feeders and a nipple watering system. Each kit was identified by a metal number in the ear. The rabbits were fed ad libitum with commercial pelleted diets containing 17.5% crude protein, 14-16% crude fibers, and 2300-2500 kcal/kg digestible energy. Daily cleaning of cages involved removing manure while maintaining optimal ventilation and temperature. During winter, a minimum temperature of 10°C was maintained, while summer temperatures could reach up to 40°C. Relative humidity remained around 60% ± 10%. The rabbits received 14-16 hours of daylight per day. All management practices were consistent across the entire flock in terms of environment, hygiene, and care.

Studied traits (Genetics and growth parameters)

Individual body weights (BW) were recorded at 5, 8, 14, and 20 weeks of age. Additionally, we measured daily weight gain (DWG), daily feed consumption (FI), and feed conversion ratio (FCR) during the following periods: 5-8, 8-14, 14-20, and 5-20 weeks. Subsequently, we estimated heritability (h^2), the common litter effect (c^2), and error (e^2) in relation to phenotypic variance. These estimates, along with considerations of seasons and parity, were noted in the materials section. Furthermore, we investigated the interaction between breed and season, the impact of breed and parity, and assessed the improvement of the Egy-Line (a synthetic line) compared to purebred lines across all the aforementioned traits.

Statistical analysis

The weighed least-squares means method in the SAS [12] procedure GLM was used to complete the statistical analysis and obtain least squares. The means were then compared using the Duncan's [13] multiple range tests to develop the body weights, weight gains, daily feed consumption, and conversion of the rabbits.

$Y_{ijk} = \mu + B_i + P_j + S_k + BS_{ik} + BP_{ij} + e_{ijk}$. (Mode1).

Where: Y_{ijk} = the observation on the i body weights, weight gains, daily feed consumption, and conversion, μ = the overall mean, Bi = the fixed effect of the i breed (i=NMER, Gaint Flander and Egy-Line), P_j = the fixed effect of the j^{th} parity (l=1^{st} , 2^{nd} , 3^{rd} and $\geq 4^{th}$), S_k = the fixed effect of the k^{th} season (kth = Autumn, Winter, Spring and Summer), BS_{ik} = the interaction between the i th breeds and the k th seasons, BP_{ij} = the interaction between the i th breeds and the jth parities and e_{ijkl} = the random deviation of all the other effects no specified the model.

Using the following multi-trait animal model of MTDFREML [14], estimates of genetic parameters for body weights, weight gains, daily feed consumption, and conversion were produced.

$y = Xb + Z1a + Z2c + e$ (Model 2)

Where, y = Vector of observation, X= Incidence matrix of fixed effects; b = vector of fixed effects including breed (NMER, Gaint Flander and Egy-line), parity (1^{st}, 2^{nd}, 3^{rd} and $\geq 4^{th}$) and season (autumn, winter, spring and summer); Z1 and Z2= incidence matrices corresponding to random effects of additive (a) and common litter effect.

Results and Discussion

Heritability and common litter effects

In our study, we explored heritability (h^2), the common litter effect (c^2), and error (e^2) in relation to phenotypic variance across body weights, daily weight gains, daily feed consumption, and feed conversion in growing NMER, Giant Flander, and Egy-Line rabbits. The summarized results are presented in Tables 1, 2, and 3. Notably, NMER exhibited moderate h^2 estimates for body weight, ranging from 0.04 to 0.22 across different age groups

(5, 8, 14, and 20 weeks). Daily body weight gain (BWG) displayed a decreasing h^2 trend from 5 to 14 weeks, followed by an increase at 5-20 weeks. During the 5-8 weeks, daily feed intake (FI) demonstrated higher h^2. The estimates for feed conversion ratio (FCR) varied across study periods, spanning from 0.02 to 0.21. Meanwhile, Giant Flander showed low to moderate h^2 estimates for body weight (ranging from 0.05 to 0.09), with the highest h^2 observed in daily BWG at 5-20 weeks. Egy-Line exhibited h^2 estimates ranging from 0.06 to 0.12 for body weight and 0.02 to 0.11 for BWG. Notably, the common litter effect (c^2) was pronounced, particularly for BW and BWG. While it decreased with age in Egy-Line, it persisted in Giant Flander. Our findings align with previous research, emphasizing the significance of genetic and maternal effects in shaping rabbit growth traits [11, 15, 16]. These insights contribute to our understanding of rabbit breeding and selection strategies. Additionally, heritability estimations for average daily gain (ADG) and feed conversion ratio (FCR) under ad-libitum feeding is moderate in rabbits (around 0.30), predicting successful trait selection [17]. Furthermore, heritability estimates ranged between 0.14±0.06 and 0.33±0.07 for growth traits and between 0.40±0.07 and 0.47±0.06 for feed intake and efficiency traits [18]. Some estimations of heritability for FCR fall within the range of 0.19 to 0.48 [19]. The relatively low heritability values estimated in our study for these traits can be attributed to the specific composition of our experimental population that are three genetically distinct interconnected populations.

Breed effect

We can summarize the findings from Table 4 regarding body weight (BW), body weight gain (BWG), feed intake (FI), and feed conversion ratio (FCR) for NMER, Giant Flander, and Egy-Line rabbits. Giant Flander consistently had the highest body weight across all ages studied. NMER outperformed Egy-Line in body weight at young ages (5 and 8 weeks), while Egy-Line showed superiority over NMER at older ages (14 and 20 weeks). Egy-Line surpassed both NMER and Giant Flander in BWG throughout all weeks of age. Egy-Line exhibited significantly higher feed intake (FI) compared to other genotypes in all study periods. The crossbred (Egy-Line) had a preferred FCR compared to purebreds. Better FCR values were observed in Egy-Line, followed by Giant Flanders, across all studied periods. These results align partially with previous studies [20-22], which also highlighted the benefits of crossbreeding for improved performance. Crossbred rabbits tend to yield higher litter weights and show better growth rates. The impact of genotype on FI and FCR further emphasizes the importance of breeding strategies in rabbit production. Feed efficiency was first improved by crossing heavy strains crossed with maternal lines. Overall, strains with a high growth rate improve the FCR of meat rabbits [23].

Season effect

Table 5 reveals significant variations ($P < 0.001$) in body weight (BW), body weight gain (BWG), daily feed intake (FI), and feed conversion ratio (FCR) across different seasons. Notable findings include (1) Autumn recorded the heaviest weaning weight for rabbits (549.3 g at 5 weeks, 835.44 g at 8 weeks, 470.08 g at 14 weeks, and 1977.70 g at 20 weeks), (2) Summer had the lowest body weight (523.46 g at 5 weeks, 787.54 g at 8 weeks, 1392.03 g at 14 weeks, and 1873.66 g at 20 weeks), (3) The highest increase in daily gain weight occurred during the autumn season (ranging from 11.39 g to 15.11 g). Seasonality impacts weaning weights, likely due to variations in milk production by suckling dams and subsequent growth performance [24]. Climatic changes over seasons may contribute to differences in BW [25]. Lower daily feed intake during summer and spring explains reduced growth rates [26, 27]. Thermal stress becomes detrimental to rabbit performance when temperatures exceed the thermal neutral zone (15°C to 25°C). Extreme heat (above 35°C) negatively affects BW and FCR, emphasizing the importance of favorable environmental conditions [28]. The autumn season exhibits the best feed conversion ratio, leading to improved BWG and FCR. These findings underscore the significance of seasonality and environmental factors in rabbit production.

During natural summer conditions, a more unfavourable feed conversion ratio (FCR) is achieved compared to winter, despite the lower growth rate. Conversely, at low temperatures, higher growth rates are observed but with poorer FCRs.

Parity

In Table 6, we present the least square means and standard errors (LSM+SE) for body weights, weight gains, daily feed consumption, and feed conversion of growing rabbits as a function of parity. The data in Table 6 indicates that body weight (in grams) at 5, 8, 14, and 20 weeks of age, as influenced by parity, is statistically significant ($P \leq 0.001$). Specifically, body weight increases with parity order up to the third parity, which records the heaviest body weight (551.89 g, 828.74 g, 1455.68 g, and 1965.26 g) at 5, 8, 14, and 20 weeks of age, respectively. Conversely, the lowest body weight is observed in the fourth parity or beyond at 8, 14, and 20 weeks of age. These findings align with similar trends reported by previous studies [29- 31], indicating that body weight increases with advancing parity until reaching a maximum at a certain parity and subsequently decreases. However, it’s worth noting that other studies have reported inconsistent effects of parity on body weight [32, 33].

Regarding daily weight gain (DWG), the third parity exhibits higher values compared to the first one across all age periods, except for ages 5-8 weeks. During the 5-8 weeks period, the second parity records the highest mean daily gain weight (13.75 g). In other periods (8-14, 14-20, and 5-20 weeks), the third parity shows the highest means (14.93 g, 12.13 g, and 13.46 g, respectively). Conversely, the lowest means are observed in the fourth parity and beyond throughout the study periods, consistent with trends reported by previous research [30, 34].

Parity order significantly affects daily feed consumption in all studied periods, with consumption decreasing as parity increases. The lowest level of feed consumption is observed in the fourth parity or beyond (as shown in Table 6). These findings align with those reported by Xiccato [35] and Rebollar [36]. Additionally, the daily feed consumption of growing rabbits at 5-8 weeks of age decreases with increasing parity order, averaging 60.6 g per kit. Notably, this value is higher than that described by Fortun-Lamothe [37] and Rebollar [36] (around 35 g and 58.7 g, respectively) at 25 to 35 days of age. From 5 to 14 weeks of age, kits consume approximately 91.32 g/day of feed, which is lower than the value reported by Xiccato et al. [35] (around 109 g) at 35 to 60 days of age.

Furthermore, the best feed conversion ratio (FCR) is observed in the second parity during the 5-8 and 8-14 weeks periods. However, during the 14-20 and 5-20-weeks periods, FCR reaches its optimal level in the third and fourth parities. This suggests that feed conversion is preferable in the second parity at early ages, while the third parity performs better at older ages.

The interactions

In terms of body weight gain, Giant Flanders exhibited the highest values during spring (634 g) at 5 weeks of age and autumn (2027 g) at 20 weeks of age (Table 8). Across all four seasons, Egy-Line consistently recorded the highest average daily weight gain and the most efficient feed conversion compared to the other two breeds.

The data presented in Table 8 revealed a significant effect ($P < 0.0001$) resulting from the interaction between breed and parity for body weights, daily weight gains, daily feed consumption, and feed conversion during the growing period (5-20 weeks) in rabbits. Specifically, Giant Flanders achieved its heaviest body weight in the third parity (637 g) at 5 weeks and in the second parity (2046 g) at 20 weeks of age (Table 8). Conversely, Egy-Line exhibited the lowest average body weight in the first parity (467 g) at 5 weeks and Giant Flanders in the fourth parity or beyond (1788 g).

Egy-Line also excelled in daily weight gain during the second parity, recording an average of 14.6 g (Table 8). Furthermore, Egy-Line consistently outperformed the other breeds, with higher values (14 g, 13.4 g, and 13.3 g during the first, third, and fourth parities, respectively). Overall, Egy-Line demonstrated superior weight gain and feed conversion ratios compared to the other breeds. In summary, Egy-Line exhibited favorable interactions between breed and season as well as breed and parity, surpassing both NMER and Giant Flanders in these aspects.

Improvement a synthetic line comparing to its purebreds

Table 9 reveals notable differences in body weight between Egy-Line and its parent breeds (NMER and Giant Flander). These differences are significantly negative at early ages (5 and 8 weeks) but become significantly positive at older ages (14 and 20 weeks). Egy-Line consistently outperforms its parents in terms of daily weight gain, achieving statistically significant improvements ($P < 0.01$). Specifically, compared to NMER, Egy-Line exhibits weight gains of 1.21, 1.47, 1.33, and 1.36 during the 5-8, 8-14, 14-20, and 5-20 week periods, respectively. Similarly, when compared to Giant Flander, Egy-Line demonstrates gains of 1.57, 1.43, 0.88, and 1.23 in the same respective periods.

Furthermore, Egy-Line maintains consistent trends in daily feed consumption across all study periods. Additionally, it excels in improving feed conversion compared to its parent breeds. The superiority of Egy-Line as a synthetic line over purebreds may be attributed to its better adaptation to Egyptian conditions

Conclusions

Crossbreeding experiments enhance genetic diversity between local breeds (NMER) and exotic breeds (Giant Flander) with the goal of improving growth and feed efficiency. Crossbreeding serves as a rapid tool for breeders to enhance various qualities, achieve performance gains, increase production, and create superior crosses by combining different characteristics. These crossed breeds often exhibit premium traits due to the phenomenon of heterosis. In our study, we conducted a comprehensive assessment of genetic estimates for the newly developed synthetic rabbit line, Egy-Line. Remarkably, Egy-Line has demonstrated superiority over its purebred progenitors, NMER and Giant Flander, in terms of both genetic potential and overall productivity. Additionally, Egy-Line exhibits robust performance and adaptability, effectively acclimating to the specific environmental conditions prevalent in Egypt. Consequently, Egy-Line emerges as a preferable alternative to NMER. However, further studies are necessary to evaluate the performance of Egy-Line and its crosses in diverse contexts, including with smallholders in Upper Egypt.

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Conflicts of interest

The authors declared no competing interests.

Declarations

Availability of data and materials

The underlying research data can be obtained from the corresponding author, who can be reached by email: sayedabdkaffy@yahoo.com

Ethical consideration

Ethical approval number: 20210612323429 to this study by Research and animal care committee of the Animal Production Research Institute (APRI).

Author's contributions

Conceptualization, El-Sayed M. Abdel-Kafy and A. Farid; formal analysis, Amira S. El-Deighadi; Data curation, Shama H. A. Morsy, Samah M. Abde-Rahman; Methodology, Wael H. A. Ali, Zain El-Abdeen A. Sabra; Writing , Hoda M. Shabaan and Wael H. A. Ali; Reviewing, El-Sayed M. Abdel-Kafy and Amira S. El-Deighadi.

All authors have read and agreed to the published version of the manuscript.

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TABLE 1. Heritability (h^2), the common litter effect (c^2), and error (e^2) in relation to phenotypic variance for body weights, weight gains, daily feed intake, and conversion of growing NMER rabbits

Traits	h^2± SE	c^2± SE	e^2± SE
Body weights			
5 weeks	0.04 ± 0.08	0.31 ± 0.06	0.65 ± 0.07
8 weeks	0.21 ± 0.18	0.40 ± 0.11	0.38 ± 0.12
14 weeks	0.22 ± 0.03	0.47 ± 0.08	0.31 ± 0.06
20 weeks	0.21 ± 0.03	0.44 ± 0.09	0.35 ± 0.07
Daily gain weight			
5-8 week	0.10 ± 0.15	0.39 ± 0.10	0.51 ± 0.10
8-14 week	0.06 ± 0.16	0.36 ± 0.12	0.69 ± 0.11
14-20 week	0.05 ± 0.16	0.39 ± 0.11	0.56 ± 0.12
5-20 week	0.19 ± 0.22	0.40 ± 0.13	0.41 ± 0.14
Daily feed consumption			
5-8 week	0.24 ± 0.10	0.75 ± 0.06	0.01 ± 0.05
8-14 week	0.16 ± 0.07	0.79 ± 0.05	0.04 ± 0.05
14-20 week	0.19 ± 0.10	0.80 ± 0.06	0.01 ± 0.05
5-20 week	0.22 ± 0.12	0.77 ± 0.06	0.01 ± 0.07
Feed conversion			
5-8 week	0.02 ± 0.14	0.29 ± 0.09	0.69 ± 0.10
8-14 week	0.14 ± 0.18	0.16 ± 0.11	0.70 ± 0.14
14-20 week	0.21 ± 0.43	0.37 ± 0.17	0.42 ± 0.30
5-20 week	0.15 ± 0.44	0.44 ± 0.20	0.41 ± 0.28

TABLE 2. Heritability (h^2), the common litter effect (c^2), and error (e^2) in relation to phenotypic variance for body weights, weight gains, daily feed intake, and conversion of growing Ganit Flander rabbits

Traits	h^2± SE	c^2± SE	e^2± SE
Body weights			
5 weeks	0.05 ± 0.20	0.35 ± 0.10	0.60 ± 0.16
8 weeks	0.09 ± 0.01	0.48 ± 0.09	0.44 ± 0.08
14 weeks	0.02 ± 0.01	0.47± 0.04	0.51 ± 0.04
20 weeks	0.04 ± 0.01	0.62 ± 0.01	0.34 ± 0.01
Daily gain in weight			
5-8 week	0.06 ± 0.28	0.41 ± 0.16	0.53 ± 0.17
8-14 week	0.11 ± 0.45	0.50 ± 0.26	0.39 ± 0.24
14-20 week	0.10 ± 0.07	0.62 ± 0.01	0.34 ± 0.01
5-20 week	0.20 ± 0.04	0.59 ± 0.84	0.39 ± 0.80
Daily feed consumption			
5-8 week	0.15 ± 0.27	0.56 ± 0.15	0.28 ± 0.14
8-14 week	0.15 ± 0.44	0.61 ± 0.25	0.24 ± 0.23
14-20 week	0.07 ± 0.12	0.29 ± 1.25	0.64 ± 1.13
5-20 week	0.26 ± 0.28	0.17 ± 0.93	0.57 ± 0.68
Feed conversion			
5-8 week	0.11 ± 0.17	0.35 ± 0.11	0.54 ± 0.12
8-14 week	0.30 ± 0.34	0.50 ± 0.19	0.19 ± 0.18
14-20 week	0.17 ± 0.87	0.21 ± 4.18	0.63 ± 3.31
5-20 week	0.12 ± 0.37	0.45 ± 1.65	0.42 ± 1.28

TABLE 3. Heritability (h^2), the common litter effect (c^2), and error (e^2) in relation to phenotypic variance for body weights, weight gains, daily feed intake, and conversion of growing Egy-line rabbits

Traits	h^2± SE	c^2± SE	e^2± SE
Body weights			
5 weeks	0.06 ± 0.07	0.59 ± 0.06	0.35 ± 0.08
8 weeks	0.12 ± 0.32	0.22 ± 0.14	0.66 ± 0.22
14 weeks	0.09 ± 0.26	0.27 ± 0.13	0.64 ± 0.19
20 weeks	0.07 ± 0.23	0.54 ± 0.15	0.39 ± 0.13
Daily gain in weight			
5-8 week	0.03 ± 0.14	0.32 ± 0.11	0.65 ± 0.12
8-14 week	0.02 ± 0.16	0.29 ± 0.12	0.70 ± 0.13
14-20 week	0.09 ± 0.25	0.58 ± 0.16	0.33 ± 0.14
5-20 week	0.11 ± 0.25	0.39 ± 0.15	0.50 ± 0.19
Daily feed consumption			
5-8 week	0.28 ± 0.01	0.57 ± 0.01	0.16 ± 0.01
8-14 week	0.17 ± 0.01	0.71 ± 0.01	0.12 ± 0.01
14-20 week	0.16 ± 0.42	0.83 ± 0.20	0.01 ± 0.21
5-20 week	0.24 ± 0.45	0.75 ± 0.23	0.01 ± 0.23
Feed conversion			
5-8 week	0.25 ± 0.21	0.27 ± 0.11	0.48 ± 0.15
8-14 week	0.21 ± 0.31	0.49 ± 0.19	0.31 ± 0.18
14-20 week	0.16 ± 0.25	0.42 ± 0.15	0.42 ± 0.16
5-20 week	0.29 ± 0.30	0.47 ± 0.16	0.23 ± 0.17

TABLE 4. Least square means and standard errors (LSM±SE) for body weights, weight gains, daily feed consumption, and feed conversion of growing rabbits as a function of genetic groupings

Traits	NMER LSM ± SE	Giant Flander LSM ± SE	Egy – Line LSM ± SE
Body weights (g)			
5 weeks	533.67 ± 6.21[b]	608.21 ± 7.21[a]	477.84 ± 7.23[c]
8 weeks	798.79 ± 7.97[b]	873.47 ± 9.27[a]	773.62 ± 9.28[c]
14 weeks	1379.28 ±12.46[c]	1468.82 ± 14.49[a]	1427.82 ± 14.50[b]
20 weeks	1838.39 ± 15.09[b]	1956.50 ± 17.54[a]	1951.43 ± 17.56[a]
Daily gain weight (g)			
5-8 week	12.62 ± 0.20[b]	12.63 ± 0.24[b]	14.08 ± 0.24[a]
8-14 week	13.80 ± 0.18[b]	14.17 ± 0.21[b]	15.58 ± 0.21[a]
14-20 week	10.95 ± 0.13[c]	11.61 ± 0.15[b]	12.47 ± 0.15[a]
5-20 week	12.43 ± 0.13[b]	12.04 ± 0.15[b]	14.03 ± 0.15[a]
Daily feed consumption (g)			
5-8 week	59.64 ± 0.64[a]	57.81 ± 0.74[b]	60.70 ± 0.74[a]
8-14 week	62.95 ± 0.46[b]	63.78 ± 0.53[a]	65.74 ± 0.53[a]
14-20 week	62.85 ± 0.50[b]	63.36 ± 0.59[a]	65.36 ± 0.59[a]
5-20 week	62.25 ± 0.38[b]	62.58 ± 0.44[b]	64.58 ± 0.44[a]
Feed conversion			
5-8 week	4.98 ± 0.07[a]	4.82 ± 0.08[a]	4.45 ± 0.08[b]
8-14 week	4.76 ± 0.06[a]	4.71 ± 0.07[a]	4.34 ± 0.07[b]
14-20 week	5.67 ± 0.06[a]	5.59 ± 0.07[b]	5.40 ± 0.07[c]
5-20 week	5.10 ± 0.04[a]	5.01 ± 0.05[a]	4.67 ± 0.05[b]

[a, b, c,] Means in the same row with different letters differ significantly from each other using Duncan's Multiple Range test (P≤ 0.01 or P≤0.001).

TABLE 5. Least square means and standard errors (LSM+SE) for body weights, weight gains, daily feed onsumption, and feed conversion of growing rabbits as a function of season

Traits	Season			
	Autumn	Winter	Spring	Summer
	LSM ± SE	LSM ± SE	LSM ± SE	LSM ± SE
Body weights (g)				
5 weeks	549.31 ± 13.18[a]	528.93 ± 7.99[b]	557.91 ± 5.63[a]	523.46 ± 6.76[b]
8 weeks	835.44 ± 16.92[a]	809.14 ± 10.27[bc]	829.06 ± 7.23[ab]	787.54 ± 8.67[c]
14 weeks	1470.08 ± 26.45[a]	1415.40 ±16.05[b]	1422.37±11.30[b]	1392.03± 13.56[b]
20 weeks	1977.70± 32.03[a]	1909.83± 19.43[b]	1900.59± 13.68[b]	1873.66± 16.42[b]
Daily gain weight (g)				
5-8 week	13.62± 0.43[a]	13.34 ± 0.26[ab]	12.91 ± 0.18[b]	12.58 ± 0.22[b]
8-14 week	15.11 ± 0.39[a]	14.43 ± 0.23[b]	14.13 ± 0.17[b]	14.39 ± 0.19[b]
14-20 week	12.09 ± 0.27[a]	11.77 ± 0.17[b]	11.39 ± 0.12[b]	11.47 ± 0.14[b]
5-20 week	13.60 ± 0.27[a]	13.15 ± 0.16[b]	12.79 ± 0.11[b]	12.86 ± 0.14[b]
Daily feed consumption (g)				
5-8 week	57.72 ± 1.35[b]	61.04 ± 0.82[a]	59.15 ± 0.58[ab]	59.63 ± 0.69[ab]
8-14 week	65.34 ± 0.97[a]	64.22 ± 0.59[ab]	63.79 ± 0.41[ab]	63.27 ± 0.50[b]
14-20 week	65.22 ± 1.07[a]	63.61 ±0.65[ab]	62.75 ± 0.46[b]	63.84 ± 0.55[ab]
5-20 week	63.76 ± 0.81[a]	63.34 ± 0.49[ab]	62.45 ± 0.34[b]	62.77 ± 0.41[ab]
Feed conversion				
5-8 week	4.40 ± 0.15[b]	4.77 ± 0.09[a]	4.81 ± 0.06[a]	5.03 ± 0.08[a]
8-14 week	4.49 ± 0.13[b]	4.62 ± 0.08[ab]	4.71 ± 0.06[a]	4.59 ± 0.07[ab]
14-20 week	5.56 ±0.13	5.58 ± 0.08	5.64 ± 0.05	5.70 ± 0.06
5-20 week	4.80 ± 0.10[b]	4.91 ±0.06[ab]	4.99 ± 0.04[a]	5.01 ± 0.05[a]

[a, b, c,] Means in the same row with different letters differ significantly from each other using Duncan's Multiple Range test (P≤ 0.01 or P≤0.001).

TABLE 6. Least square means and standard errors (LSM±SE) for body weights, weight gains, daily feed consumption, and feed conversion of growing rabbits as a function of parity

Traits	Parity order			
	1 LSM ± SE	2 LSM ± SE	3 LSM ± SE	≥4 LSM ± SE
Body weights (g)				
5 weeks	531.12 ± 7.68^{c}	538.66 ± 7.85^{bc}	551.89 ± 7.71^{a}	537.94 ± 7.86^{ab}
8 weeks	812.01 ± 9.86^{b}	827.42 ± 10.08^{a}	828.74 ± 9.90^{a}	793.01 ± 10.09^{b}
14 weeks	1427.40±15.42^{ab}	1452.61± 15.76^{a}	1455.68± 15.47^{a}	1364.20±15.78^{b}
20 weeks	1924.90± 18.67^{a}	1938.37± 19.08^{a}	1965.26±18.74^{a}	1833.25± 19.11^{b}
Daily gain weight (g)				
5-8 week	13.38 ± 0.25^{a}	13.75 ± 0.26^{a}	13.18 ± 0.25^{a}	12.15 ± 0.26^{b}
8-14 week	14.65 ± 0.23^{a}	14.89 ± 0.23^{a}	14.93 ± 0.23^{a}	13.60 ± 0.23^{b}
14-20 week	11.85 ± 0.16^{a}	11.57 ± 0.16^{ab}	12.13 ± 0.16^{a}	11.17 ± 0.16^{b}
5-20 week	13.27 ± 0.16^{ab}	13.33 ± 0.16^{a}	13.46 ± 0.16^{a}	12.34 ± 0.16^{b}
Daily feed consumption (g)				
5-8 week	60.60 ± 0.79^{a}	60.05 ± 0.80^{ab}	58.67 ± 0.79^{ab}	58.22 ± 0.80^{b}
8-14 week	64.18 ± 0.56^{ab}	63.31 ± 0.58^{ab}	64.52 ± 0.57^{a}	62.62 ± 0.58^{b}
14-20 week	64.84 ± 0.62^{a}	64.59 ± 0.64^{a}	63.76 ± 0.63^{ab}	62.22 ± 0.64^{b}
5-20 week	63.73 ± 0.47^{a}	63.97 ± 0.48^{a}	63.05 ± 0.47^{a}	61.58 ± 0.48^{b}
Feed conversion				
5-8 week	4.71 ± 0.09^{ab}	4.37 ± 0.09^{b}	4.45 ± 0.09^{b}	5.03 ± 0.09^{a}
8-14 week	4.56 ± 0.08^{b}	4.25 ± 0.08^{b}	4.32 ± 0.08^{b}	4.86 ± 0.08^{a}
14-20 week	5.62 ± 0.07	5.58 ± 0.07	5.26 ± 0.07	5.73 ± 0.07
5-20 week	4.91 ± 0.06^{b}	4.80 ± 0.06^{b}	4.68 ± 0.06^{b}	5.13 ± 0.06^{a}

$^{a, b, c,}$ Means in the same row with different letters differ significantly from each other using Duncan's Multiple Range test ($P \leq 0.01$ or $P \leq 0.001$).

TABLE 7. Interaction Breed and season effects for body weights, weight gains, daily feed consumption, and feed conversion of growing rabbits

Breed	Season	W5	Error	W20	Error	DWG5-20	Error	DFI520	Error	FCR5-20	Error
NMER	Autumn	590.5^{abd}	22.2	1985.5^{ab}	55.0	13.3^{bcd}	0.46	62.7^{ab}	1.36	4.8^{abc}	0.16
	Winter	519.6^{ed}	10.9	1849.4^{cd}	27.1	12.7^{cde}	0.23	62.8^{ab}	0.67	5.0^{ab}	0.08
	Spring	548.7^{dc}	9.4	1843.9^{cd}	23.3	12.3^{de}	0.19	63.1^{ab}	0.58	5.2^{a}	0.07
	Summer	513.3^{ed}	9.0	1793.1^{d}	22.3	12.2e	0.19	61.2^{bc}	0.55	5.1^{a}	0.07
Giant Flander	Autumn	614.4^{ab}	21.2	2027.3^{a}	52.7	13.5^{bc}	0.44	63.8^{ab}	1.30	4.8^{abc}	0.16
	Winter	579.8^{bc}	15.7	1943.1^{abc}	38.9	13.0^{cde}	0.33	63.6^{ab}	0.96	5.0^{ab}	0.12
	Spring	633.9^{a}	10.1	1899.3^{bcd}	25.1	12.1^{e}	0.21	59.8^{c}	0.62	5.1^{a}	0.07
	Summer	597.5^{ab}	12.7	1933.1^{abc}	31.5	12.7^{cde}	0.26	63.2^{ab}	0.78	5.1^{a}	0.09
Egy-line	Autumn	429.4^{g}	24.5	1947.2^{abc}	60.8	14.5^{a}	0.51	65.6^{a}	1.50	4.6c	0.18
	Winter	497.5^{ef}	14.7	1923.6^{abc}	36.5	13.6^{abc}	0.31	63.2^{ab}	0.90	4.7^{bc}	0.11
	Spring	493.0^{ef}	9.3	1926.2^{abc}	23.1	13.6^{abc}	0.19	63.6^{ab}	0.57	4.7^{bc}	0.07
	Summer	456.0^{gf}	14.1	1930.0^{abc}	35.1	14.0^{ab}	0.29	65.6^{a}	0.87	4.8^{bc}	0.10
		<.0001		<.0001		<.0001		<.0001		<.0001	

TABLE 8. Interaction Breed and parity effects for body weights, weight gains, daily feed consumption, and feed conversion of growing rabbits

Breed	Parity	W5	Error	BW20	Error	DWG520	Error	DFI520	Error	FCR 520	Error
NMER	First	513.9^{de}	9.8	1814.7^{ef}	23.6	12.4^{ef}	0.20	62.9^{bcd}	0.59	5.2^{abc}	0.07
	Second	537.1^{d}	9.7	1858.9^{def}	23.4	12.6^{def}	0.20	61.9^{cd}	0.59	5.0^{bcd}	0.07
	Third	534.5^{d}	10.9	1843.3^{def}	26.2	12.5^{def}	0.22	62.6^{bcd}	0.66	5.1^{abc}	0.08
	≥ Fourth	553.3^{dc}	15.7	1810.3^{ef}	37.7	12.0^{gf}	0.32	61.2^{ed}	0.95	5.2^{b}	0.11
Giant Flander	First	618.2^{ab}	15.8	1989.3^{abc}	38.1	13.1^{cde}	0.32	63.2^{bcd}	0.96	5.0^{bcd}	0.11
	Second	602.7^{ab}	18.6	2046.1^{a}	44.7	13.7^{bc}	0.37	66.7^{a}	1.12	4.9^{bcde}	0.13
	Third	637.0^{a}	11.8	2003.1^{ab}	28.4	13.0^{cde}	0.24	62.1^{cd}	0.71	4.9^{cde}	0.09

Breed	Parity	W5	Error	BW20	Error	DWG520	Error	DFI520	Error	FCR 520	Error
	≥ Fourth	589.2[bc]	11.3	1787.8[f]	27.3	11.4[g]	0.23	59.1[e]	0.68	5.4[a]	0.08
Egy-line	First	467.0[f]	13.9	1940.8[bcd]	33.5	14.0[ab]	0.28	64.3[bc]	0.84	4.7ef	0.10
	Second	472.9[f]	14.0	2001.1[ab]	33.8	14.6[a]	0.28	65.1[ab]	0.85	4.6f	0.10
	Third	484.6[fe]	15.0	1896.2[dec]	36.1	13.4[bc]	0.30	63.4[bcd]	0.91	4.8[edf]	0.11
	≥ Fourth	494.3[fe]	11.4	1889.6[ed]	27.4	13.3[bcd]	0.23	63.8[bcd]	0.69	4.9[cde]	0.08
		<.0001		<.0001		<.0001		<.0001		<.0001	

W5 = week 5 of age; W20 = week 20 of age; DWG = Daily weight gain; DFI= Daily feed intake; CFR 5-20= feed conversion ratio at 5-20 weeks.

TABLE 9. Improvement in Egy-Line as a synthetic line comparing to purebreds for body weights weight gains, daily feed intake, and conversion

	Improvement in Egy-line relative to	
Traits	**NMER**	**GanitFlander**
Body Weights:		
5 weeks	-50.00 ± 8.54**	-127.67 ± 9.40**
8 weeks	-21.80 ± 11.12*	-95.57 ± 12.24**
14 weeks	36.65 ± 18.22*	-34.09 ± 19.92[ns]
20 weeks	92.71 ± 21.18**	3.11 ± 23.34[ns]
Daily Gain in Weight:		
5-8 week	1.21 ± 0.28**	1.57 ± 0.31**
8-14 week	1.47 ± 0.26**	1.43 ± 0.28**
14-20 week	1.33 ± 0.18**	0.88 ± 0.20**
5-20 week	1.36 ± 0.18**	1.23 ± 0.20**
Daily Feed Consumption		
5-8 week	0.51 ± 0.90[ns]	3.55 ± 0.98**
8-14 week	2.40 ± 0.63**	2.09 ± 0.70**
14-20 week	1.83 ± 0.70**	2.00 ± 0.77**
5-20 week	1.80 ± 0.53**	2.26 ± 0.59**
Feed Conversion		
5-8 week	-0.50 ± 0.26[ns]	-0.89 ± 0.28**
8-14 week	-0.33 ± 0.09**	-0.36 ± 0.09**
14-20 week	-0.44 ± 0.08**	-0.19 ± 0.08*
5-20 week	-0.36 ± 0.06**	-0.34 ± 0.07**

Ns= not significant at P > 0.05; * = P < 0.05; ** = P <0.01.

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العوامل الوراثية وغير الوراثية المؤثرة على النمو وكفاءة التغذية في أرانب إيجي لاين مقارنة بآبائهم

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الملخص

تم استخدام ثلاثه انواع من الارانب (النمر والجاينت فلاندر والايجى لين) وذلك لتقدير المكافئ الوراثى (h^2) وتأثير عدد الخلفة (c^2) والخطأ (e^2) بالنسبة للتباين المظهري وتم إنتاج 1230 أرنبًا من أربعة بطون في خلال أربعة مواسم و كانت تقديرات h^2 معتدلة لجميع الأعمار التي تمت دراستها (5 و 8 و 14 و 20 أسبوعًا) ولقد سجل النمر أعلى h^2 لوزن الجسم باستثناء 5 أسابيع وكان لديه h^2 أعلى لزيادة الوزن اليومي 5-20) بينما كان لديه أقل h^2 لتحويل الأعلاف في الفترتين 5-8 و8-14وتراوحت تقديرات c^2 من وزن الجسم والزيادة اليومية من المعتدل عند 8 وعند 8-14 أسبوعًا من العمر في إيجي لاين إلى الأعلى عند 20 وعند 14-20 أسبوعًا من العمر في جاينت فلاندر. لقد ثبت أن إيجي لاين يتفوق على النمر في وزن الجسم في الأعمار الأكبر (14 و20 أسبوعًا) كما أنه أكبر من جاينت فلاندر والنمر في زيادة الوزن اليومية وقد لوحظت قيم تحويل أعلاف أفضل في إيجي لاين وتم تسجيل أثقل وزن فطام للأرانب في فصل الخريف للأنماط الجينية الثلاثة وزادت أوزان الجسم مع ترتيب التكافؤ حتى التكافؤ الثالث وكان تحويل العلف في التكافؤ الثاني مفضلا في الأعمار المبكرة (5 و 8 أسابيع) ولكن أفضل قيمة في التكافؤ الثالث كانت في الأعمار الأكبر وكانت الاختلافات في وزن الجسم بين إيجي لاين ووالديها سلبية بشكل ملحوظ في الأعمار المبكرة ولكنها إيجابية بشكل ملحوظ في الأعمار الأكبر ولقد تفوقت إيجي لاين على نظيراتها إيجاباً ومعنوياً ($P<0.01$) في زيادة الوزن اليومي واستهلاك العلف اليومي وتفوقت إيجي لاين في تحسين تحويل الأعلاف ونستنتج من ذلك أن السلالة التركيبية الجديدة (إيجي لاين) أثبتت تفوقها وحسن أدائها وراثيا على آبائها في جميع الصفات المدروسة.

الكلمات الدالة: المكافئ الوراثى و تأثير عدد الخلفة ، صفات النمو ، النمر ، الجاينت فلاندر ، الايجى لين.