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The effect of industrial crossbreeding with terminal line boars on the growth and development of young pigs

Andrii Karatieiev
Postgraduate Student
Mykolaiv National Agrarian University
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine
https://orcid.org/0009-0008-3345-0450

Olena Karatieieva*
PhD in Agricultural Sciences, Associate Professor
Mykolaiv National Agrarian University
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine
https://orcid.org/0000-0002-0652-1240

Michael Gill
Doctor of Agricultural Sciences, Professor
Mykolaiv National Agrarian University
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine
https://orcid.org/0000-0001-7353-9865

Abstract. One of the most effective methods of genetic improvement in pigs is crossbreeding, which, when based on carefully selected breed combinations, contributes to increased productivity and reduced costs in pig production. The aim of the study was to assess the influence of different maternal genotypes, when crossed with terminal boars of the MaxGrow line, on growth parameters, weight gain, final live weight of piglets and the level of heterosis under commercial pig farming conditions. Experimental studies were conducted on three groups of pigs comprising purebred, crossbred (½ Large White × ½ Landrace of English selection) and specialised sows from Genesus, using terminal boars of the MaxGrow line. This approach ensured an objective assessment of the influence of the maternal genotype on the growth parameters of the offspring under conditions of a standardised paternal component. It was established that the sows' genotype is a determining factor in growth rate, daily weight gain and final live weight of the piglets. The highest values for absolute (107.37 kg), average daily (596.5 g) and relative (32.3%) weight gains throughout the entire rearing period were observed in pigs of the Genesus × MaxGrow genotype, indicating the effective realisation of the heterosis effect. Crossbred animals occupied an intermediate position (104.6 kg; 578.7 g and 32.0% respectively), demonstrating a consistent advantage over the purebred control (100.82 kg; 560.1 g and 30.5% respectively). The results of the growth index assessment and two-way analysis of variance confirmed the dominant role of genotype (38.0-56.0%) in the formation of productive traits and the high reliability of the data obtained. It was concluded that the use of MaxGrow terminal boars in combination with specialised and crossbred maternal lines is a scientifically sound and technologically feasible approach to improving breeding programmes in commercial pig farming. It can be utilised by breeding specialists and pig farm technologists to optimise industrial crossbreeding schemes with the aim of increasing the growth rate of young stock and the efficiency of pork production

Keywords: breeding programmes; terminal boars; heterosis effect; hybrid vigour; specialised lines; growth rate

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**Corresponding author (karateeva1207@gmail.com)*

INTRODUCTION

Rational improvement of breeding programs in pig farming is a necessary condition for ensuring the stable development of the industry and increasing its economic efficiency. In the system of artificial insemination of pigs at production complexes, the leading role belongs to breeding boars, since they largely determine the level of realisation of the hereditary potential of the offspring. In this regard, the scientifically substantiated selection of boars for use in crossbreeding schemes is of decisive importance for obtaining competitive products and meeting modern market requirements.

According to S. Vaishnav *et al*. (2025), selection and mating systems are integral components of improvement programs for any pig breed. Various parameters, such as the choice of traits, their number, and genetic properties, especially the level of heritability, must be taken into account when making decisions regarding selection in the breeding herd. The choice of breeds for the breeding method, namely purebred breeding or crossbreeding, is also a very important technique. Different crossbreeding systems are practiced in order to utilise the effects of heterosis and complementarity in pig farming. As indicated by S.P. Turner *et al*. (2024), optimisation of pig breeding programs is an important prerequisite for achieving sustainable and economically efficient pork production. In artificial insemination technologies for pigs, the role of breeding boars is undoubtedly key, since they are an integral factor of genetic potential. Therefore, the correct selection of boars for crossbreeding is important for maintaining high-quality pork production and adapting to constantly changing market requirements. Y. Steyn *et al*. (2021) concluded that crossbreeding is one of the key tools in pig breeding. When properly applied, it allows pork producers to genetically increase production efficiency and, accordingly, reduce production costs. The widespread use of crossbreeding is due to the fact that offspring obtained from mating animals of different breeds are usually characterised by higher viability, faster growth rates, and better productivity indicators compared with purebred animals. The advantage of crossbred offspring over the average indicators of its purebred parents is defined as heterosis, or hybrid vigour.

According to P. Nevrkla *et al*. (2021), pig breeding is influenced by a number of factors, among which one of the most important is the genotype of sows, which is half determined by terminal boars. The selection of appropriate genotypes for mating is one of the decisive factors. The criteria for choosing an appropriate breeding combination are the results of testing hybrid populations. Their main principle is the selection of genetically optimal populations for specific conditions. In addition, the phenotypic level of expression of parameters of live weight and growth intensity of young pigs is also significantly influenced by sows – the maternal genetic effect. According to M.C. Fabbri *et al*. (2024), crossbreeding can be an effective strategy for increasing the value of local pig breeds as well. Since it can reduce homozygosity and, as a consequence, provide hybrid vigour to improve physical condition and productive traits. In addition, P. Duenk *et al*. (2021) proved that the crossbreeding system can be used to reduce the level of inbreeding in offspring. Another advantage of crossbreeding is the manifestation of heterosis, also known as hybrid vigour. Hybrid vigour is a phenomenon in which the performance of crossbred individuals exceeds the average performance of the parental lines. Hybrid vigour is the opposite of inbreeding depression, and inbreeding generally leads to a greater number of gene pairs in an individual being homozygous. Crossbreeding, on the contrary, generally leads to a greater number of gene pairs being heterozygous. Crossbreeding is regularly used in many commercial pig farming systems because, in general, the offspring are more robust, with better indicators of growth and development.

As indicated by R. Pereira-Pinto *et al*. (2025), pig growth indicators, expressed by daily gain, feed conversion efficiency, and lean meat content, have significantly improved due to selection and continue to improve thanks to available genetic and breeding approaches. In addition, pig crossbreeding has a progressive effect on such characteristics as growth rate, feed efficiency, and reproductive indicators due to hybrid vigour (heterosis). A.S. Kramarenko *et al*. (2024) report that the origin of boars and sows affects not only the productive traits of pigs but also reproductive qualities, stillbirth rate, and piglet mortality after farrowing. The authors note that boars of the Pietrain breed, which are used as terminal sires, have better fertilising ability and a higher number of piglets at birth. The studies of P. Nevrkla *et al*. (2021) describe the effect of crossbreeding on the growth intensity of piglets, mainly on live weight at birth and subsequent growth energy. Nevertheless, studies analysing the influence of terminal boars on the growth intensity of piglets before and after weaning are rare, although their influence may be significant, since they account for 50% of the genetic potential of piglets. This is what aroused interest in determining the influence of the use of terminal boars on the growth intensity of piglets during the suckling period and after weaning, in particular on indicators of live weight at birth and subsequent growth dynamics, taking into account their contribution to the realisation of the genetic potential of the offspring. Therefore, the aim of the study was to determine the effect of using terminal boars of the MaxGrow line in combination with different maternal genotypes on the live weight of piglets at birth, growth intensity during the suckling period and after weaning, as well as on the level of realisation of genetic potential and the heterosis effect under conditions of industrial pig farming.

MATERIALS AND METHODS

The studies were conducted on the facilities of Agricultural LLC "Promin" in Pervomaisk Raion during the period of 2025. For this purpose, three groups of pigs were formed using purebred sows, crossbred sows of the Large White breed (LW) and Landrace (L) obtained from English selection (1/2LW × 1/2L), and sows of the Genesus company; the breeding scheme is presented in Table 1. The selection of the studied breeds was determined by their availability at the specific farm on the basis of which the research was conducted. The formation of experimental groups was carried out according to the principle of analogous groups with random distribution of animals, while feeding and housing conditions for all groups were identical. The used genotypes MaxGrow and Genesus belong to commercial terminal lines; their exact breed composition and genetic structure are a commercial secret. In the practice of breeding research, such genotypes are identified by trade names, and comparative analysis is carried out in order to determine their productive efficiency.

Table 1. *Scheme of formation of experimental groups of pigs*

Indicator	Group		
	I (control)	II (experimental)	III (experimental)
n	50	50	50
Sow breed	LW	1/2LW×1/2L	Genesus
Boar breed	MaxGrow	MaxGrow	MaxGrow

Source: *developed by the authors*

The control group (I) consisted of the offspring of Large White (LW) sows, while the II experimental group included crossbred animals (½ Large White × ½ Landrace of English selection), and the III group consisted of pigs of the Genesus genotype. In all groups, boars of the MaxGrow line were used for insemination, which made it possible to objectively assess the influence of the paternal factor and the role of crossbreeding in the formation of productive traits of the offspring. The experimental groups were formed according to the principle of analogous groups by random assignment, and their feeding and housing conditions were completely identical. The growth intensity of the experimental piglets was monitored by individual weighing at birth, at one month of age, and at 60-, 90-, 150-, and 180-day ages using platform industrial scales TV1 "Tekhnovahy". According to the generally accepted methodology, absolute, average daily, and relative gains in the live weight of piglets were calculated. The main indices of the intensity of organism formation were evaluated according to the methods described in K.V. Harmatiuk (2022). The index of organism formation intensity (Δt) according to the formula:

$$\Delta t = \frac{W_2 - W_1}{0.5(W_2 + W_1)} - \frac{W_3 - W_2}{0.5(W_3 + W_2)}, \quad (1)$$

where W_1, W_2 i W_3 are live weight at a certain age; 0.5 is a coefficient. The index of uniformity of pig growth (I_u) according to the formula:

$$I_u = \frac{1}{1 + \Delta t} \times DG, \quad (2)$$

where Δt is the intensity of organism formation; *DG* is the average daily gain for different age intervals; 1 – coefficient, in calculations shows how much the index deviates from 100%. The index of growth tension (I_t) of the pigs according to the formula:

$$I_t = \frac{\Delta t}{RG} \times DG, \quad (3)$$

where Δt is the intensity of organism formation; *AD* – average daily gain for different age intervals; *RG* – relative gain for different age intervals. The role of the presented indices of organism formation intensity, growth uniformity, and growth tension lies in the objective assessment of the characteristics of growth processes of animals at different stages of their development. These indicators make it possible to determine the rate of organism formation, establish the uniformity of live weight increase, and assess the degree of growth tension during individual age periods. The use of these indices allows a more complete characterisation of the biological features of animal growth, identification of the influence of genotypic factors on the intensity of their development, and substantiation of the effectiveness of the applied technological solutions in the system of rearing and fattening. Such indicators are important criteria in evaluating productivity and predicting the further growth and development of animals. All statistical processing was carried out based on the methodologies presented in the manual by R.R. Sokal & F.J. Rohlf (1995), using the free-ware software JAMOVI v. 2.6.19 (Navarro & Foxcroft, 2025).

To evaluate the strength of the influence of different factors – genotype (factor A) and age period (factor B) – on the growth and development of young pigs, a two-factor analysis of variance (ANOVA) was used with subsequent post-hoc analysis based on Fisher's criterion for multiple comparisons. The Shapiro-Wilk test was applied to verify normality: for group 1 – $p = 0.011$, for group – 2 $p = 0.017$, for group 3 – $p = 0.0067$. In all three groups p is greater than 0.05. Therefore, it was concluded that all samples have a normal distribution. Taking into account that the paternal factor (MaxGrow boar) was constant, the variation was formed due to the maternal genotype and age period. The evaluation was performed using the values of the sum of squares of deviations (*SS*), mean squares (*MS*), the actual value of Fisher's criterion (F_{crit}), the level of significance (*p*), and the proportion of factor influence (η^2) (Kramarenko *et al.*, 2019). Animal handling procedures fully complied with European legislation (Council Directive No. 98/58/EC, 1998; Nalon & Stevenson, 2019). The research protocol was approved by the bioethics committee in accordance with the standards of good clinical practice regarding the protection and humane treatment of experimental animals.

RESULTS AND DISCUSSION

The dynamics of the live weight of pigs of different genotypes during the rearing period from birth to 6 months of age were studied. It was established that at birth piglets of all groups were characterised by almost identical live weight, which ranged within 1.56-1.59 kg, and the difference between the indicators was statistically insignificant. This indicates the homogeneity of the experimental population at the start of the experiment and the validity of further comparisons (Table 2).

Table 2. *Dynamics of live weight of piglets of different genetic origin, kg*

Age, months	Group					
	I (control)		II (experimental)		III (experimental)	
Sow breed	LW		1/2LW × 1/2L		Genesus	
Boar breed	MaxGrow		MaxGrow		MaxGrow	
At birth	155	1.56 ± 0.033	160	1.58 ± 0.041	158	1.59 ± 0.013
1 month	153	9.04 ± 0.335	157	9.15 ± 0.329	147	9.37 ± 0.364
2 months	147	21.92 ± 0.434	155	22.65 ± 0.335	143	23.37 ± 0.401*
3 months	145	37.93 ± 0.539	150	38.69 ± 0.581*	138	39.38 ± 0.563*
5 months	144	78.46 ± 0.84	146	80.12 ± 0.79*	137	82.35 ± 0.88*
6 months	142	102.38 ± 1.12	146	105.74 ± 1.08*	135	108.96 ± 1.15*

Note: ** = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$*
Source: *developed by the authors*

At one month of age, the live weight of piglets in all experimental groups increased 5.7-5.9 times compared to birth weight, which indicates a high intensity of growth during the suckling period. During this period, animals obtained as a result of crossbreeding, as well as piglets from specialised meat maternal forms, tended to have higher live weight indicators; however, the difference compared with the control animals remained statistically insignificant. This indicates a limited manifestation of genetic differences in the early postnatal period under the conditions of using MaxGrow terminal boars. Beginning from two months of age, when the role of the animal's own genotype in the formation of growth processes increases, intergroup differences intensified significantly. Piglets of the III experimental group (Genesus × MaxGrow) significantly ($p < 0.05$) exceeded the control group in live weight, which indicates the effective realisation of the genetic potential of the specialised meat genotype under the conditions of the rearing period and confirms the expediency of using terminal crossbreeding. At three months of age, both piglets of group II ((½LW × ½L) × MaxGrow) and those of the III experimental group already demonstrated a statistically significant advantage over the control animals. This indicates a positive effect of combining maternal forms with terminal boars, which is manifested in higher rates of live weight gain during the phase of intensive growth. The most pronounced intergroup differences were recorded in the final period of rearing – at 5-6 months of age. At 6 months, the live weight of pigs of the II experimental group exceeded the control by 3.36 kg (3.3%), while animals of the III group exceeded it by 6.58 kg (6.4%) with a statistically significant difference ($p < 0.05$). The obtained results convincingly confirm the higher genetically determined growth potential of pigs of the Genesus genotype and the effectiveness of using terminal crossbreeding with MaxGrow boars, as well as the expediency of involving crossbred maternal forms (½LW × ½L) under industrial pork production conditions (Fig. 1).

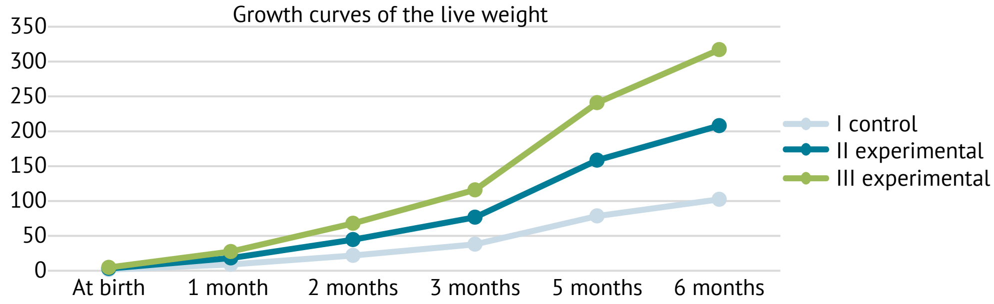

Figure 1. *Growth curves of live weight of piglets of different genetic origin*
Source: *developed by the authors*

The constructed graph clearly demonstrates the parallel nature of growth in animals of all groups at an early age and the gradual divergence of the curves starting from 2-3 months of age. The curve of the III experimental group is positioned above the others throughout the entire rearing period, visually confirming the advantage of the Genesus crossbred genotypes in terms of live weight. The II experimental group occupies an intermediate position between the control and the III group, demonstrating consistently higher growth rates compared to purebred Large White pigs. Live weight gain is one of the key indicators characterising growth intensity and the efficiency of realising the genetic potential of pigs during the rearing process. The analysis of absolute, average daily, and relative gains allows for an objective assessment of the influence of genotype on the formation of productive traits. The data presented in Table 3 reflect the dynamics of absolute, average daily, and relative live weight gains of pigs of different genotypes during the rearing period from birth to 6 months of age.

Table 3. *Dynamics of live weight gains of piglets of different genetic origin*

Age, months	Group					
	I (control)		II (experimental)		III (experimental)	
Sow breed	LW		1/2LW × 1/2L		Genesus	
Boar breed	MaxGrow		MaxGrow		MaxGrow	
			Absolute gain, kg			
birth-1 month	155	7.48 ± 0.34	160	7.57 ± 0.32	158	7.78 ± 0.31
1-2 months	153	12.88 ± 0.41	157	13.50 ± 0.38	147	14.00 ± 0.36*
2-3 months	147	16.01 ± 0.52	155	16.04 ± 0.49	143	16.01 ± 0.47
3-5 months	145	40.53 ± 0.87	150	41.43 ± 0.81*	138	42.97 ± 0.79*
5-6 months	144	23.92 ± 0.69	146	25.62 ± 0.65*	137	26.61 ± 0.63*
The whole period	149	100.82 ± 1.12	154	104.16 ± 1.09*	145	107.37 ± 1.15*
			Average daily gain, g			
birth-1 month	155	249.3 ± 11.3	160	252.3 ± 10.7	158	259.3 ± 10.3
1-2 months	153	429.3 ± 13.7	157	450.0 ± 12.6	147	466.7 ± 12.0*
2-3 months	147	533.7 ± 17.3	155	534.7 ± 16.4	143	533.7 ± 15.7
3-5 months	145	675.5 ± 14.5	150	690.5 ± 13.5*	138	716.2 ± 13.2*
5-6 months	144	797.3 ± 23.0	146	854.0 ± 21.7*	137	887.0 ± 21.0*
The whole period	149	560.1 ± 6.2	154	578.7 ± 6.1*	145	596.5 ± 6.4*
			Relative gain, %			
birth-1 month	155	479.5 ± 18.2	160	479.1 ± 17.6	158	489.3 ± 16.9
1-2 months	153	142.5 ± 5.1	157	147.5 ± 4.8	147	149.4 ± 4.6*
2-3 months	147	73.0 ± 2.6	155	70.8 ± 2.4	143	68.5 ± 2.3
3-5 months	145	106.9 ± 3.8	150	107.1 ± 3.6	138	109.1 ± 3.4*
5-6 months	144	30.5 ± 1.1	146	32.0 ± 1.0*	137	32.3 ± 0.9*

Note: ** = p < 0.05; ** = p < 0.01; *** = p < 0.001*
Source: *developed by the authors*

During the suckling period (birth-1 month), the absolute live weight gain of piglets in all groups was practically the same and ranged from 7.48 to 7.78 kg, while intergroup differences did not reach the level of statistical significance. This indicates similar initial growth conditions and the absence of a significant genotype effect at an early age. Beginning from the period of 1-2 months, animals of the III experimental group (Genesus × MaxGrow) showed a significantly higher absolute gain (+1.12 kg; $p < 0.05$) compared with the control, indicating a faster realisation of the genetically determined growth potential after weaning. At the age of 3-5 and 5-6 months, pigs of groups II and III also significantly exceeded the control values, with the greatest intergroup differences observed in animals of the Genesus genotype. Over the entire rearing period from birth to 6 months of age, the absolute gain in the control group was 100.82 kg, while in animals of the II and III experimental groups it amounted to 104.16 and 107.37 kg, respectively, which is 3.3% and 6.5% higher compared with the control group ($p < 0.05$). The analysis of average daily gains revealed a similar pattern in the growth dynamics of pigs when crossbreeding schemes using MaxGrow terminal boars were applied. During the suckling period, no significant intergroup differences were found, indicating a relatively similar realisation of growth potential at the early stages of postnatal development regardless of genotype.

However, already at the age of 1-2 months, pigs of the III experimental group (Genesus × MaxGrow) were characterised by significantly higher average daily gains compared with the control animals (466.7 vs. 429.3 g; $p < 0.05$), which indicates a more effective interaction between the maternal meat genotype and the terminal paternal component during the post-weaning period. During the phase of intensive growth (3-5 months), the average daily gains of pigs in the II ((½LW × ½L) × MaxGrow) and III experimental groups significantly exceeded those of the control group by 15.0-40.7 g ($p < 0.05$). The obtained data indicate a positive effect of industrial crossbreeding and a better ability of crossbred and specialised meat genotypes to efficiently utilise feed nutrients during the period of maximum growth intensity. In the final fattening period (5-6 months), the advantage of animals obtained through terminal crossbreeding schemes became even more pronounced, confirming the stability of the heterosis effect at later stages of ontogenesis. On average, for the entire rearing period, the average daily gain of pigs in the control group was 560.1 g, whereas in animals of the II and III experimental groups it amounted to 578.7 and 596.5 g, respectively, which significantly exceeded the control value ($p < 0.05$).

The analysis of relative live weight gains also confirmed the established patterns. At an early age, intergroup differences were insignificant, indicating a limited manifestation of genetic advantages during the suckling period. However, during the periods of 1-2 and 3-5 months, pigs of the III experimental group, obtained from specialised maternal forms in combination with terminal MaxGrow boars, significantly exceeded the control group in relative gains ($p < 0.05$). At the age of 5-6 months, both the II and III groups maintained significantly higher indicators of relative gain, which indicates a prolonged and stable advantage of crossbreeding schemes using terminal boars throughout the entire rearing period. The index-based evaluation of growth indicators represents a generalised approach to analysing the intensity, tension, and uniformity of body formation in animals during ontogenesis. The application of indices makes it possible to comprehensively characterise the course of growth processes at different age periods. Therefore, the indices of body formation intensity, growth tension, and growth uniformity were studied in crossbred pigs of different maternal origins. It is important to note that all experimental animals, except those of the control group, were obtained from crossbred sows and inseminated with boars of the MaxGrow line, which ensured the uniformity of the paternal genotype and made it possible to objectively assess the effect of crossbreeding and hybridisation on the characteristics of growth processes (Table 4).

Table 4. *Intensity of body formation in young pigs*

Age, months	Group					
	I (control)		II (experimental)		III (experimental)	
Sow breed	LW		1/2LW × 1/2L		Genesus	
Boar breed	MaxGrow		MaxGrow		MaxGrow	
index of organism formation intensity						
0-3 months	152	0.55 ± 0.02	157	0.53 ± 0.02	149	0.52 ± 0.02*
0-6 months	149	0.55 ± 0.02	154	0.53 ± 0.02	145	0.52 ± 0.02*
index of growth tension						
0-3 months	152	2.14 ± 0.09	157	2.12 ± 0.09	149	2.06 ± 0.08*
0-6 months	149	1.82 ± 0.06	154	1.87 ± 0.06	145	1.91 ± 0.06*
index of growth uniformity						
0-3 months	152	0.47 ± 0.02	157	0.47 ± 0.02	149	0.49 ± 0.02*
0-6 months	149	0.55 ± 0.02	154	0.53 ± 0.02	145	0.52 ± 0.02*

Note: ** = p < 0.05; ** = p < 0.01; *** = p < 0.001*

Source: *developed by the authors*

The analysis of the body formation intensity index indicates that during the period of 0-3 months its value in pigs of the control group was 0.55, whereas in animals of the II and III experimental groups it was 0.53 and 0.52, respectively. The decrease in the body formation intensity index in pigs of the Genesus genotype was statistically significant ($p < 0.05$), which indicates relatively more intensive growth rates during the post-weaning period compared with the early stage of ontogenesis. A similar pattern was observed over the entire rearing period (0-6 months), where the lowest value of the body formation intensity index was also characteristic of the III experimental group (Genesus × MaxGrow). This indicates an earlier and more pronounced shift in growth phases in pigs of this genotype. The growth tension index during the period of 0-3 months was the highest in animals of the control group (2.14), while in crossbred pigs of the II (½LB × ½L × MaxGrow) and III (Genesus × MaxGrow) groups it decreased to 2.12 and 2.06, respectively. The significantly lower value observed in pigs of the Genesus genotype ($p < 0.05$) indicates less abrupt fluctuations in growth intensity within the early postnatal period. At the same time, during the 0-6 month period an opposite trend was observed: the growth tension index in animals of the III group was significantly higher than in the control (1.91 vs. 1.82; $p < 0.05$). This indicates a more intensive course of growth processes on average throughout the entire rearing period and confirms the higher genetically determined growth potential of pigs of this genetic combination. The growth uniformity index during the period of 0-3 months was practically identical in pigs of the I and II groups (0.47), whereas in animals of the III experimental group it was significantly higher and amounted to 0.49 ($p < 0.05$). This indicates a more uniform course of growth processes at an early age in pigs of the Genesus genotype. However, over the entire rearing period (0-6 months), the growth uniformity index in pigs of the III group was the lowest (0.52), which, in combination with the increased growth tension index, indicates a more intensive but less uniform pattern of growth on average throughout the entire ontogenetic period.

To evaluate the influence of genotype (factor A) and age period (factor B) on the main growth indicators of pigs, a two-factor analysis of variance was performed. The results indicate that the genotype of the animals had a statistically significant effect on the live weight of pigs. The F_{crit} value for factor A was 21.69 at $p = 0.044$, confirming the significance of differences between the groups. The share of genotype influence in the total variability of the trait was high and amounted to 56.0%, indicating the leading role of hereditary factors in the formation of live weight under conditions of identical paternal origin (Table 5).

Table 5. *Two-factor analysis of variance of the influence of genotype and age period on pig growth indicators*

Factor	SS	df	MS	F_{crit}	p	η_x^2
Live weight						
A – genotype	1,844,431.343	2	883,749.134	21.68857442	0.044035832	56.0
B – age	31,230.13548	1	28,361.1527	0.663452385	0.563954488	35.0
Random factors	64,518.44444	2	35,161.1462			9.0
Total variability	1,738,817.721	5				
Absolute gain (0-6 months)						
A – genotype	0.066633333	2	0.03431557	288.5613127	0.003778430	55.0
B – age	0.001066667	1	0.00114448	7.135886421	0.088169365	37.0
Random factors	0.000233333	2	0.00011337			8.0
Total variability	0.066633333	2	0.03431557	221.5613127	0.003778430	
Average daily gain (0-6 months)						
A – genotype	3,728.553333	2	2,927.26668	35.64455364	0.038136508	38.0
B – age	2,411. 662211	1	5,946.13287	0.533442532	0.632297979	21.3
Random factors	0.11100317	2	5,551.24856			40.7
Total variability	3,969.333333	5				

Source: *developed by the authors*

The influence of the age period (factor B) on the live weight indicator under conditions of using MaxGrow terminal boars proved to be statistically insignificant ($F_{crit} = 0.66$; $p = 0.564$), and its share in the structure of total variability amounted to 35.0%. This indicates that within the analysed age intervals, changes in live weight were less pronounced compared with intergenotypic variability caused by the characteristics of maternal origin. The small share of random factors in the total variability (9.0%) indicates high uniformity of the experimental livestock and the correctness of the experimental design under conditions of a standardised paternal factor. The analysis of absolute gain over the entire rearing period showed a very high and statistically significant influence of genotype when using terminal crossbreeding schemes. The value of F_{crit} for factor A (genotype) was 288.56 at $p = 0.0038$, and the share of its influence reached 55.0% of the total variability of the trait. The obtained results convincingly confirm the decisive role of the maternal genotype in the formation of growth intensity in offspring under conditions of using MaxGrow terminal boars, which ensures the maximum realisation of the genetic growth potential. The influence of the age period was less pronounced and statistically insignificant ($F_{crit} = 7.14$; p = 0.088), although its share in the total variability amounted to 37.0%, which indicates the presence of a tendency toward age differentiation of gains within the studied period. The minimal share of random factors (8.0%) indicates the stability of trait manifestation and the high repeatability of results within the terminal crossbreeding system.

According to the average daily gain indicator, a statistically significant influence of genotype was also established under the condition of using MaxGrow terminal boars. The value of F_{crit} for factor A was 35.64 at $p = 0.038$, which confirms the presence of significant intergenotypic differences in the realisation of growth potential. The share of genotype influence in this case was 38.0%, which indicates its substantial, although somewhat smaller role compared with absolute gain. The influence of the age period proved to be statistically insignificant ($F_{crit} = 0.53$; $p = 0.632$), and its share in the total variability amounted to 21.3%, which indicates the secondary nature of this factor in the formation of average daily gains within the analysed period. At the same time, the relatively significant share of random factors (40.7%) may be associated with individual characteristics of animal growth, physiological differences in the utilisation of feed nutrients, and adaptive responses of the organism during different phases of ontogenesis, even under conditions of a uniform paternal genotype. Improving productivity is a common goal of both practitioners and scientists in the field of animal husbandry and pig production in particular. This improvement is achieved through crossbreeding and the selection of the best predecessors (Dotché *et al.*, 2019). Piglets obtained as a result of crossbreeding become heterozygous at all loci, while their original parental breeds are homozygous for another allele. When crossbreeding is used to create a new synthetic line, two or more parental breeds can be mated in rotation. The resulting offspring can then be interbred in each generation. After several generations, the animals will become genetically uniform, and this population can be considered a new terminal line. The development of such terminal lines is an important aspect in the management of genetic diversity during the selection process (Ganteil *et al.*, 2021).

Positive effects of crossbreeding and the use of terminal boar lines are also indicated by M. Cao *et al.* (2026), who note that if there is a certain relationship between animal productivity and their genotype, then prolonged breeding of pigs in a closed population over several generations under strong selection pressure for a limited number of traits leads to lower genetic diversity and a higher deficit of heterozygotes, which may result in inbreeding depression. This can be avoided through the use of terminal lines in crossbreeding to increase herd heterozygosity. The use of hybrid pigs in the breeding process was investigated by J. Zhou *et al.* (2024), who found that the productive qualities of pigs significantly improved through the combination of Pietrain and Yorkshire populations and their reciprocal hybrid crossbreeding. The researchers note that the inclusion of the hybrid population in genomic prediction may improve the accuracy and reliability of prediction compared with the baseline model that uses only purebred animal data. The results of studies by L. De Prekel *et al.* (2025) emphasise the importance of selecting terminal sire lines when considering heat stress management, since the use of terminal lines in pig production can play a decisive role in improving strategies for mitigating the negative effects of heat stress on productivity.

In the studies of M. Kremez *et al.* (2024), it was established that hybrid piglets outperformed their crossbred counterparts from direct crossbreeding in average daily and absolute gains, live weight at the end of the rearing period, and survival rate. At the same time, they consumed more feed during the rearing period compared with their crossbred and purebred peers and had better feed conversion. This is also confirmed by the data of the present study. According to G. Kadirvel *et al.* (2023), in the pork production system of the Eastern Himalayan mountain region, crossbred pigs demonstrated better growth rates and larger litter size at birth and weaning than purebred local pigs. Therefore, the researchers believe that the application of crossbreeding and hybridisation will increase productivity and reproductive capacity of pigs.

D. Baranovskyi & O. Tkachuk (2024) established that pig production can be effective when pigs are used in different combinations. Thus, crossbred piglets had high growth energy indicators and were characterised by good slaughter and meat-fat qualities. The researchers recommend combining Large White sows with boars of the Landrace, Duroc, and Pietrain breeds. The improvement of growth indicators of local pigs in Benin through crossbreeding is also reported by C. Bankolé *et al.* (2025). The authors emphasise that the most productive exotic breeds adapted for use in tropical environments are Large White, Landrace, Duroc, and Pietrain. Among the mentioned breeds, Pietrain demonstrates a high potential for crossbreeding and exhibits the highest heterosis effect on live weight indicators. The obtained results demonstrate that Pietrain pigs can be used in crossbreeding schemes to improve the growth indicators of local pigs in Benin. H. Wen *et al*. (2026) also indicate the necessity of applying different crossbreeding models when developing breeding programs, since there are significant differences in genetic diversity, population structure, and origin within Duroc subpopulations and between Duroc and other pig breeds. The observed levels of inbreeding in Duroc subpopulations indicate the need for better management of genetic diversity within the breed and the application of different variants of crossbreeding and hybridisation when working with this population, which fully corresponds with the statements of previous researchers.

Thus, crossbreeding programs are widely used to improve the overall production performance of pigs while maintaining higher productivity only in F1 crossbred offspring. However, due to the breakdown of epistatic complexes in the F2 generation, improvement and stabilisation of the obtained heterosis based on additive and dominant breed effects is a significant challenge. Therefore, in order to ensure the most stable manifestation of heterosis over several generations or to create specialised hybrid lines, it is advisable to evaluate different breed combinations and implement the lower level of the hybridisation pyramid, which involves the use of three-breed commercial pigs obtained by inseminating two-breed sows with terminal boars.

CONCLUSIONS

The results of the conducted studies convincingly indicate that under the conditions of applying industrial crossbreeding schemes using terminal MaxGrow boars, the leading factor determining growth intensity, the pattern of gain formation, and the final live weight of young pigs is the maternal genotype. Standardisation of the paternal component made it possible to objectively assess genetically determined differences between the groups and to minimise the influence of random factors. The highest values of absolute (100.82 kg, which is 6.5% higher compared to the control), average daily (596.5 g, which is 6.5% higher than in the control group), and relative gains throughout the entire rearing period were characteristic of pigs of the Genesus × MaxGrow genotype, which confirms their high genetic growth potential and the effective realisation of the heterosis effect under terminal crossbreeding conditions. Crossbred animals (½LW × ½L)×MaxGrow occupied an intermediate position, demonstrating a stable advantage over the control pigs (3.3% and 1.5%, respectively), which indicates the expediency of using combined maternal forms in industrial pork production schemes. The results of the growth index evaluation according to the methodology of V.P. Kovalenko complement the obtained data and indicate a significant influence of maternal origin on the intensity (0.52-0.55), tension (1.82-1.91), and uniformity of offspring body formation (0.52-0.55). Pigs of the Genesus × MaxGrow genotype were characterised by more balanced growth at an early age (0.49) and higher intensity of growth processes on average (0.52) over the entire rearing period, which is biologically and technologically expedient for intensive fattening systems and confirms the effectiveness of its use for assessing growth intensity.

Two-factor analysis of variance confirmed that genotype is the leading factor in the variability of growth indicators (ηx^2 = 38.0-56.0%), whereas the age period within the experiment did not exert a statistically significant influence (ηx^2 = 21.3-37.0%), although in some cases a tendency toward an increase in its share in the structure of total variability was observed. The low or moderate share of random factors (ηx^2 = 8.0-40.7%) indicates the high reliability of the experiment and the correctness of the applied biometric methods. Summarising the obtained results, it can be concluded that the use of terminal MaxGrow boars in combination with specialised and crossbred maternal forms is an effective breeding-technological approach that ensures increased growth intensity of young pigs and promotes the maximum realisation of the genetic potential of pigs under conditions of intensive industrial pig production. A promising direction for further research is the combination of traditional zootechnical evaluation methods witeth molecular-genetic and bioinformatic approaches for identifying markers associated with growth intensity and the manifestation of the heterosis effect in the offspring of Genesus × MaxGrow and (½LW × ½L) × MaxGrow genotypes.

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CONFLICT OF INTEREST

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Вплив промислового схрещування з кнурами термінальної лінії на показники росту та розвитку молодняку свиней

Андрій Каратєєв
Аспірант
Миколаївський національний аграрний університет
54008, вул. Георгія Ґонґадзе, 9, м. Миколаїв, Україна
https://orcid.org/0009-0008-3345-0450

Олена Каратєєва
Кандидат сільськогосподарських наук, доцент
Миколаївський національний аграрний університет
54008, вул. Георгія Ґонґадзе, 9, м. Миколаїв, Україна
https://orcid.org/0000-0002-0652-1240

Михайло Гиль
Доктор сільськогосподарських наук, професор
Миколаївський національний аграрний університет
54008, вул. Георгія Ґонґадзе, 9, м. Миколаїв, Україна
https://orcid.org/0000-0001-7353-9865

Анотація. Одним із найбільш ефективних методів генетичного поліпшення свиней є схрещування, яке за обгрунтовано підібраних поєднань порід сприяє зростанню продуктивності та зниженню витрат на виробництво свинини. Метою досліджень було оцінити вплив різних материнських генотипів у поєднанні з термінальними кнурами лінії MaxGrow на показники росту, прирости, кінцеву живу масу молодняку та рівень прояву гетерозису за умов промислового ведення свинарства. Експериментальні дослідження проведено на трьох групах свиней, сформованих із чистопородних, помісних (½ велика біла × ½ ландрас англійської селекції) та спеціалізованих свиноматок компанії Genesus за використання термінальних кнурів лінії MaxGrow. Такий підхід забезпечив об'єктивну оцінку впливу материнського генотипу на показники росту потомства за умов стандартизованого батьківського компонента. Встановлено, що генотип свиноматок є визначальним чинником інтенсивності росту, формування приростів і кінцевої живої маси молодняку. Найвищі значення абсолютних (107,37 кг), середньодобових (596,5 г) і відносних (32,3 %) приростів упродовж усього періоду вирощування відзначено у свиней генотипу Genesus×MaxGrow, що свідчить про ефективну реалізацію гетерозисного ефекту. Помісні тварини займали проміжне положення (104,6 кг; 578,7 г та 32,0 % відповідно), демонструючи стабільну перевагу над чистопородним контролем (100,82 кг; 560,1 г та 30,5 % відповідно). Результати індексної оцінки росту та двофакторного дисперсійного аналізу підтвердили провідну роль генотипу (38,0-56,0 %) у формуванні продуктивних ознак і високу надійність отриманих даних. Зроблено висновок, що використання термінальних кнурів MaxGrow у поєднанні зі спеціалізованими та помісними материнськими формами є науково обґрунтованим і технологічно доцільним напрямом удосконалення селекційних програм у промисловому свинарстві. Дослідження може бути використано фахівцями з селекції та технологами свинарських господарств для оптимізації схем промислового схрещування з метою підвищення інтенсивності росту молодняку та ефективності виробництва свинини

Ключові слова: селекційні програми; термінальні кнурі; ефект гетерозису; гібридна сила; спеціалізовані лінії; інтенсивність росту