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THE BASIS FOR PIG HYBRIDIZATION: EVALUATION METHOD FOR THE COMBINING ABILITY OF LINES

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Abstract:

Single commercial cross breeding widely used in animal husbandry does not always guarantee heterosis, since each breed has a fairly wide range of genetic variability. This is what makes the cross breeding different from hybridization.

The purpose of these studies was to develop a method for calculating the combination heritability of traits exemplified by specific lines of herd boars of the Large White breed. The research work was based on the results of a long breeding experiment to obtain Large White pigs conducted in breeding farms of the Krasnodar Territory, i.e., Gulkevichsky, Ventsy-Zarya, Caucasus and Industrialny genetic selection centre. The breeding work on these farms was aimed at genetic differentiation of the existing lines according to the Maligonov-Libizov's method of intrastrain combination. This method has been used in breeding since 1963. Thus, unrelated factory lines have been created within more than 10-15 lines of ancestors.

For processing, there were selected only linear boars and sows that had at least 5 lines of the breed the animal was related to. Only linear pigs were investigated. The materials presented have proved that there is no reason to expect a general combining ability (GCA) in terms of traits with a high degree of the hereditary determination. The research has found a high proportion of specific combining ability (SCA) being noted in the reproductive fitness in the range of from 32.78 to 82.90% and in fattening and meat indices from 18.4 to 25.8%. The influence of reciprocal effects was significant in reproductive traits and ranged from 6.16 to 65.2%. The GCA manifestation can be predicted and used in a combining system of structural elements of crossing breeds according to additive effects.

The hereditary deposits are apparently consolidated by the additive interaction, which determines the heritability estimate of the selection trait. This indicated the probability of a heterosis effect guaranteed with respect to the reproductive traits between the group genotypes with consolidated heredity.

The studies presented are relevant and necessary for development of software in pedigree pig breeding aimed at evaluating the combining ability of the lines. Only then it is possible to quantify and guarantee the heterosis effect during the hybridization of pigs.

Key Words: *combining ability, crossing variants, GCA and SCA effects, genetic population indices, hybridization.*

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INTRODUCTION:

The pig industry is fast growing all over the world. This is due to pigs' advantageous specific traits, such as prolificacy, milking ability, early maturity, etc. that allow quick increasing of the pork production. The largest producers of pork are China, European Union countries, Brazil, Russia, Vietnam, Canada, Japan, the Philippines, Mexico and South Korea (Costa E.P., Amaral W.S., Costa A.H.A., Carvalho F.F., Santos A.K. & Silva A.F., 2004; Gorlov I.F., Slozhenkina M.I., Nikolaev D.V. & Fedorov Yu.N., 2017)

The Large White pig breed is the most common in the world. Among the total pig population, the share of the Large White breed in Russia accounts for more than 85%, in France and Finland about 63%, Poland 60%, and England 50%. It should be noted that the level and orientation of the selection and breeding work on a specific population of pigs have a considerable impact on the production level (Zinovyeva N.A., Kharzinova V.R., Sizareva E.I. et al., 2012).

In pig breeding, there is a breeding-by-lines-method that is used for combination of pigs of different potential traits with respect to a well-known trait of the line (M.P. Libizov, 1973). More than 100 years ago, Maligonov A.A. proved that the lines in pig breeding have not only high productivity, but also stable heritability, i.e. are homozygous. So, when breeding, the scientists had to take into account the combining ability of lines and synthetic selection (Malinovsky A.A., 1980).

The principles set out by A.A. Maligonov were implemented in the south of the Ukraine by academician M.F. Ivanov. He created a clear vertical pyramid of hybridization with an intrastrain combination system. For the first time in the world, M.F. Ivanov carried out hybridization as crossing of lines that were combined for the heterosis effect (Gorin V.T., 1973).

In 1965, Professor M.P. Libizov put the Maligonov-Ivanov's ideas into practice in a long-term breeding experiment on breeding relatively homozygous lines of pigs and their crossing in the system of commercial pig breeding in the North Caucasus (Tretiakova O.L., Mikhailov N.V., Sidorenko L.I., & Tolpekoyu G.A., 2001).
Based on this, a breeding technique in specialized lines was developed. It was followed from the B. Griffing's work on the evaluation of the combining ability and aimed at increasing the overall level of productivity (Tretiakova, O.L., 2001, 2017).

In the practical selection of large complexes, this approach is not used, which is due to the lack of appropriate genetic material and qualified analysis of the genetic parameters of real populations under industrial production conditions. The heterosis manifestation is influenced by differences in the inherited abilities of the lines and their compatibility in the crosses, that is, their combining ability. Its value can vary to a great extent depending on crossing variants. However, the creation of "group" or specialized genotypes should include the hereditary identity of all representatives of the line.

The combination ability can be general (GCA) and specific (SCA). The general combining ability is usually understood as the average productivity of a line in combinations with other lines. The SCA is manifested in the fact that a certain combination turns out to be better or worse than it should be expected on the basis of the GCA. The heterosis manifestation is evaluated by the deviation value of the productivity index when crossing with any specific line from the average values for all hybrid combinations (Gorin V.T. & Nikitchenko I.N., 1974).

A significant SCA effect can be expected only if the lines used for the crosses have high overall performance in their "pure" breeding. At the same time, it is possible to expect the SCA manifestation only at significant differences in the genetic construction of the material (Mikhailov N.V., 1980; Shakhbazova O.P., 2010, 2011).
One of the most effective methods in modern pig breeding is the molecular genetic method. Of particular interest are the studies aimed at the research of genotype sites (DNA) that are responsible for the development of indicators such as meatiness, growth rate, prolificacy etc.

(Mamontov S.N., Tretiakova O.L., Getmantseva L.V., Leonova M.A., Kolosov A.Yu. & Bakoyev S.Yu., 2015). Many researchers noted that the early diagnosis of these traits is of great importance for practical pig breeding (Marzanov N.S., Samorukov Yu.V., Eskin G.V. et al., 2006). The combination of pigs for increasing the growth rate and meatiness of carcasses by traditional methods is known to be handicapped by low heritability of traits, therefore identifying the alleles of individual genes responsible for these traits, as well as studying the relationship between these traits and actual productivity of pigs are of special interest (Melnikov V.A., Bardukov N.V., Fornara M.S., Kostyunina O.V., Sermyagin A.A. and Zaitsev A.M., 2018).

In this regard, the studies aimed at studying the combining ability of lines using new methods and approaches to evaluate the heritability of traits are promising.

The purpose and objectives of the research: The purpose of these studies was to develop a method for calculating the combining ability of specific lines of the Large White breed and other breeds, determine the most effective variant of crossing lines and establish the best variants for combining various traits.

MATERIAL AND RESEARCH METHODS

The experimental work was carried out according to the results of a long breeding experiment to produce Large White pigs. The experiment was conducted on Duroc and Landrace breeds in breeding farms of the Krasnodar Territory, i.e., Gulkevichsky, Ventsy-Zarya, Caucasus and Industrialny genetic selection centre. The breeding work in the farms was aimed at genetic differentiation of the existing lines according to the Maligonov-Libizov's method of intrastrain combination. This breeding method has been applied since 1963. Thus, unrelated commercial lines were created within more than 10-15 lines of ancestors. The long-term genetic experiment covered a period of about 35 years.

To automate the calculations of the GCA and SCA effects, the staff of the laboratory of the theoretical foundations of the livestock selection at the Don State Agrarian University developed Excel spreadsheet templates based on two experimental Savchenko's methods (Libizov M.P. & Polyanichko Ya.I., 1982). In terms of the materials of the breeding plants, the calculations in the templates were checked and the combining ability of the pig lines was evaluated (Svinarev I.Ju., Kolosov Ju.A., Tretiakova O.L.& Fedin G.I., 2015).

The structure of the genetic variability of traits was studied in various crossing variants according to the scheme presented in Table 1.

Table 1 - Scheme for assessing crossing variants

Mating type	Lines			
	Pure breeding		Crossbreeding	
	♂	♀	♂	♀
Intrastrain combination	Svat, Venets	Svat, Venets	Artist, Ronal	Artist, Ronal
	Secret, Shablon	Secret, Shablon	Lorhat, Giant	Lorhat, Giant
	Smaragd, Record	Smaragd, Record	Ult, Ural	Ult, Ural
Direct cross	Svat, Venets	Secret, Shablon	Artist, Ronal	Ronal, Artist
	Secret, Shablon	Smaragd, Record	Lorhat, Giant	Giant, Lorhat
	Smaragd, Record	Svat, Venets		Giant, Artist
Reciprocal cross	Secret, Shablon	Svat, Venets	Ronal, Artist	Artist, Ronal
	Svat, Record	Secret, Shablon	Giant, Lorhat	Lorkhat, Giant
	Svat, Shablon	Smaragd, Record	Giant, Artist	Artist, Giant

Note: Large White breed involves 6 lines: Svat, Secret, Smaragd, Venets, Shablon and Record; Landrace breed involves 4 lines: Artist, Lorhat, Ural and Ult; Duroc breed involves 2 lines: Ronal and Giant

In general, the experimental work took into account the data obtained in evaluating various cross variants of the Large White, Landrace and Duroc breeds.

RESULTS AND DISCUSSION:

To confirm the hypothesis of the differentiation between the specific lines within the Large White, Landrace and Duroc breeds, a comparative analysis of changes in indicators of the pigs' reproductive fitness was carried out in breeding farms of the Krasnodar Territory.

The research results on the number of live pigs obtained for one farrow from linear Large White sows in the Gulkevichsky breeding plant are given below. 70 boars and 255 sows were evaluated with respect to the GCA and SCA effects using the spreadsheet templates developed (Table 2).

Table 2 – The prolificacy indices of sows in the direct cross variant (P1)

♀	♂	A	B	C	D	E	F	n
	n	10	16	17	8	9	10	70
a	42	11.9	11.5	12.4	11.6	11.8	11.3	70.5
b	38	11.7	11.6	11.4	11.6	11.6	11.1	69
c	54	11.8	11.8	11.1	11.8	12.4	11.1	70
d	36	10.6	11.2	11.1	10.8	10.5	10.3	64.5
e	45	10.9	11.4	10.7	10.9	10.6	10.3	64.8
f	40	11.0	10.8	10.9	11.0	10.7	10.4	64.8
n	255	67.9	68.3	67.6	67.7	67.6	64.5	403.6

Note: Large White breed (A is Svat, B is Secret, S is Smaragd, D is Venets, E is Shablon and F is Record)

The maximum number of live piglets calculated for one case of farrowing was 12.4 pigs obtained in the cross variants of ♂ C x ♀a and ♂ E x ♀c. The minimum prolificacy was 10.3 piglets in the cross variants of ♂F x ♀d and ♂F x ♀e.

Table 3 shows the evaluation of the GCA lines of the direct and reciprocal cross variants. Line A when crossing with the lines A, B and C shows a positive effect on prolificacy in both direct and reciprocal cross variants.

Table 3 – Evaluation of the effects of ACS

direct cross variant of the lines		reciprocal cross variant of the lines	
lines ♂		lines♀	
A	0.28	A	0.27
B	0.24	B	0.15
C	0.07	C	0.18
D	-0.31	D	-0.37
E	-0.27	E	-0.22
F	0.31	F	-0.33

Note: Large White breed (A is Svat, B is Secret, S is Smaragd, D is Venets, *E is Shablon and F is Record)*

The results of processing linear cross data indicated various positive and negative effects, which explained the failures in commercial crossing of pig lines without pre-estimation of their compatibility.

The data obtained allowed concluding that it is possible to improve the indices of the pigs' reproductive fitness by the methods of intrastrain combination and also selecting positive variants of the intrastrain crosses for improving traits according to the requirements of the maternal lines combination.

The effectiveness of hybridization largely depends on the compatibility of the breeds, types and lines used in crossing. In this regard, we conducted a comparative analysis of the crossbreeding of specialized breeds (Landrace and Duroc). Table 4 shows the changes in the number of live piglets obtained per one farrow in crossing pigs in the Industrialny Center.

Table 4 – The prolificacy indices of sows in the direct cross variant (P1)

	♂	G	H	I	J	K	L	N
♀	n	8	10	12	8	10	10	58
g	48	9.7	9.6	9.5	9.0	9.0	8.7	55.5
h	32	9.6	9.3	9.8	9.6	9.6	8.1	56
i	45	9.0	9.8	8.5	9.7	9.4	9.1	55.5
j	38	9.4	9.6	9.0	9.3	9.3	8.3	54.9
k	42	9.0	8.5	8.7	8.9	8.7	8.3	52.1
l	36	8.9	8.3	8.2	8.0	8.2	8.4	50
n	241	55.6	55.1	53.7	54.5	54.2	50.9	324

Note: Landrace breed (lines: Artist, Lorkhat, Ural and Ult), Duroc breed (Ronal and Giant)

The objectives of the genetic selection center include the production and breeding of hybrid young stock with genetically guaranteed high productivity. To solve this task, it was necessary to test the lines for the combination ability effect, that is, evaluate their GCA and SCA. The spreadsheet templates allowed automatical evaluating the combinability effects, with the data being imported from the ASPP software (Automated Systems in Pig Production). The evaluation results are shown in Table 5.

Table 5 – Evaluation template of the cross variants effects.

direct cross variant of the lines		reciprocal cross variant of the lines	
♂lines		♀lines	
G	-0,1	G	0,17
H	0,9	H	0,85
I	1,8	I	0,2
J	0,4	J	0,37
K	-2,1	K	1,6
L	-0,9	l	0,32

Note: Landrace breed (lines: Artist, Lorhat, Ural and Ult), Duroc breed (Ronal and Giant)

The direct crossing variant between the Artist's Line and sows of Landrace and Duroc lines was noted for a decrease in prolificacy by 0.1 head, while the Ural’s line crossing had this indicator increased by 1.8 live piglets per one farrow. Intrastrain analysis showed that in the Ural line, the value of the breeding fitness index was 34.2 points. In the Artist line, it was 20.6 points. The average value of the Landrace breeding index was 19.1 points.

An important point of the research was the study of the diversity and variability of breeding traits in the intrastrain combination (Table 6).

Table 6 - Breeding traits indices in the intrastrain combination *)

Indicator	Code of trait										
	X1***	X2**	X3***	X4**	X5*	X6***	X7***	X8**	X9***	X10***	X11***
Smaragd x Smaragd (n=102)						Smaragd x Smaragd (n=19)					
$\overline{X}$ ±m	11.28	62.70	10.39	205.84	47.18	183	3.68	2.8	734	95.3	10.6
σ±m	0.79	4.39	0.57	13.52	42.58	4.93	0.078	0.06	31.8	1.23	0.14
Cv±m	6.97	7.00	5.49	6.57	90.25	2.693	2.11	2.14	4.33	1.29	1.32
Svat x Svat (n=126)						Svat x Svat (n=9)					
$\overline{X}$ ±m	11.13	61.20	10.30	205.00	36.60	182.5	3.68	2.79	734.5	95.3	10.6
σ±m	0.31	2.92	0.35	12.90	26.30	10.5	0.033	0.10	37.1	0.51	0.20
Cv±m	5.43	7.92	6.00	8.66	112.6	5.75	0.89	3.69	5.05	0.53	1.88
Secret x Secret (n=120)						Secret x Secret (n=8)					
$\overline{X}$ ±m	11.10	61.60	10.30	205.00	36.80	175	3.57	2.82	773	95.5	10.6
σ±m	0.51	6.18	0.59	15.50	37.70	5.79	0.03	0.05	36.8	1.53	0.24
Cv±m	10.26	13.61	10.67	11.92	103.3	3.25	0.84	1.77	4.76	1.60	2.26

Note: X_1 is the prolificacy, X_2 is the milkiness, X_3 is the number of piglets to weaning, X_4 is the weight of the 2 months outlet, X_5 is the breeding reproduction index, X_6 is the early maturity, X_7 is the feed costs, X_8 is the lard thickness 100 kg, X_9 is the average daily gain, X_{10} is the length of the carcass, and X_{11} is the weight of the back third part of the half carcass.

All values are reliable, i.e., X_1, X_3, X_6, X_7, X_9, X_{10}, and X_{11} *** 0.999; values X_2, X_4, and X_8 ** 0.99; and values X_5 * 0.95

The production level in the Large White lines was quite high, but the deviation of the average values of the studied traits X_1 ... X_{11} between the lines was insignificant, which indicated a high consolidation in the lines. The Svat line was universal; the variability of traits was not significant. The Svat line had high values of the meat and fattening traits. The Smaragd and Secret lines specialized in indicators of maternal traits; their reproductive fitness indices were 47.18 and 36.8 points, respectively. However, along with high maternal traits, the Secret line combines good indices of growth and development of pigs. The value of the breeding index of reproductive traits in all lines was established to have a high variability compared with the traits included into its composition.

The phenotypic diversity of breeding traits was due to the interaction of the hereditary (σ_γ) and environmental (σ_π) diversity. The hereditary diversity (σ_γ), genotypic variation consisted of additive and non-additive parts. The additive genetic variation was the result of the cumulative effects of allelic, polymeric genes. In a general sense, the additive part of the genotypic variation determined the breeding value of the animal.

Non-additive genetic variability was responsible for the development of the specific combination ability, especially in cross lines. A considerable proportion in non-additive manifestations was occupied by epistasis that was the interaction of nonallelic genes. In this regard, the key direction of the breeding work was the study of the genotypic variability structure by the variance analysis of a two-factor complex. The producer boars were taken for the gradations of the first factor in the two-factor dispersion complex; sows were taken for the gradations of the second factor. The variance analysis model provided for the determination of the genotypic variability in variants of linear breeding (intrasrtain combination) and line crosses. The indicators of reproductive fitness and fattening and meat traits were taken as effective traits. Mathematical calculations were carried out using a set of M. Excel spreadsheets.

The results of determining the structure of genotypic variability with intrastrain combination and line crosses are shown in Table 7.

It should be noted that the greater proportion in the variability structure was occupied by the GCA from 61.7 to 69.5% that was significantly manifested in the fattening and meat traits; by maternal traits, it ranged from 0.84 to 23.6%. The reverse is true for the SCA; a high proportion was noted for the reproductive traits, from 32.78 to 82.9%; low were fattening and meat indices, from 18.4 to 25.8%. The influence of the reciprocal effects was significant in reproductive traits and ranged from 6.16 to 65.2%.

The analysis performed made it possible to determine the relative difference of individual genetic variant components that affected the phenotypic diversity of the trait in the hybrid progeny. There was found a manifestation regularity of the general combining ability in the traits that have high rates of heritability, i.e. are affected by additive genes. The effects of the specific combinative ability were established to manifest in traits with low heritability, that is, are subject to the influence of dominance, epistasis and interaction of genes and environmental conditions. The dependence of the combining ability on the heritability coefficient of traits in the Large White breed is shown in Figure 1.

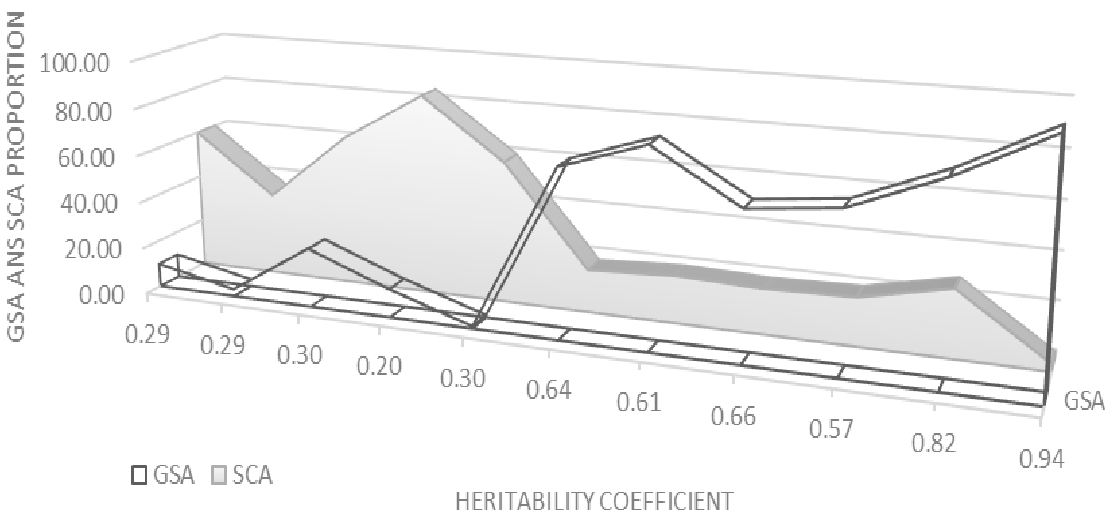

Figure 1 – The effect of the heritability coefficient of traits on the general and specific abilities of the lines

The biological meaning of this phenomenon, apparently, lies in the consolidation of the inherited abilities in terms of additive interactions that influences the magnitude of the heritability of a selection trait. This indicates the possibility of a guaranteed heterosis effect on the basis of reproductive fitness traits in terms of differentiated group genotypes with consolidated heredity.

The structure of genetic variability in the interbreed crossing of lines is shown in Figure 2.Considering the structure of genetic variability, it should be noted that there is a connection between the ACS and SCS and the heritability.

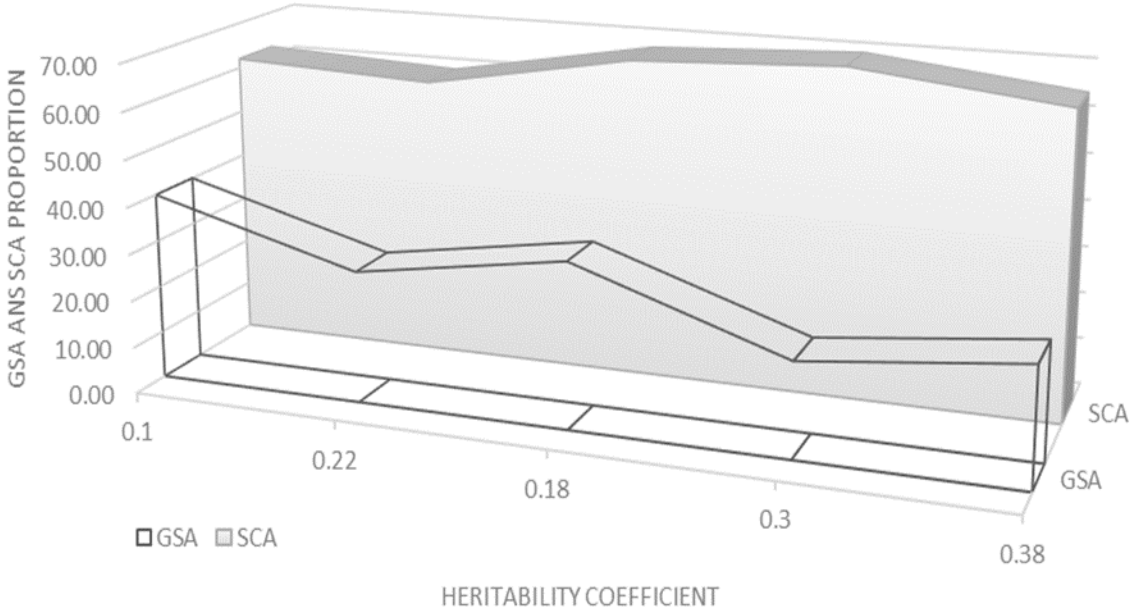

Figure 2 - Influence of the heritability coefficient of traits on the general and specific abilities of the lines in crossbreeding

The analysis of the relationship between the GCA and SCA and the heritability coefficients of traits in crossbreeding showed that despite the presence of antagonistic directions of correlation interrelations between the traits of reproductive, fattening and meat traits, it is possible to obtain a positive compatibility effect in crosses of specialized breed lines. This is explained by the fact that the low heritability traits that include reproductive traits usually have a heterosis effect and therefore surpass the initial forms on average. The fattening and meat traits in hybrid combinations received a sufficiently high development due to a large hereditary determination.

CONCLUSIONS:

The regularity revealed is an important point in the genetic confirmation of the heterosis hypothesis that claims, if a breed line specializes in a number of traits that have a high heritability coefficient, heterosis does not manifest itself.

The research is of particular importance in the conditions of large commercial pig production, when in a short time in already established pig breeds it is required to ensure the manifestation or strengthening of a number of properties and traits that allow increasing the strength of the constitution and adaptability of livestock to modern technologies. In linear breeding, it is easier to ensure greater specialization, while retaining sufficient space for the breeder to use the achieved animal production indices in other lines.

The purchase of imported livestock for the farms of the Russian Federation should be based on the guaranteed heterosis effect; it is necessary to check all livestock lines and breeds with respect to the effect of the combining ability. However, supplier firms are not ready for such an assessment, and when supplying pedigreed-stock they establish the value and terms of paying royalties for each livestock head that will be in production in any of the buyer's herds. These circumstances indicate the need for the development of domestic breeding base in pig breeding with the combination of specialized lines and testing their combining ability. Only then it is possible to guarantee an increase in the productivity of pigs and quality of their products.

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