MINISTRY OF EDUCATION
AND TRAINING

MINISTRY OF AGRICULTURE
AND RURAL DEVELOPMENT

NATIONAL INSTITUTE OF ANIMAL SCIENCE

NGUYEN TIEN THONG

SELECTION AND CREATION OF GP LINES FROM IMPORTED LANDRACE AND YORKSHIRE

MAJOR: ANIMAL GENETICS AND BREEDING
CODE: 9 62 01 08

SUMMARY OF THE DISSERTATION

HA NOI, 2023

The work was completed at National Institute of Animal Science

Supervisors:
                    1. Prof. PhD. DANG VU BINH
                    2. Asscoc Prof. PhD. LE THI THANH HUYEN

Reviewer 1: Asscoc Prof. PhD. Tran Hue Vien

Reviewer 2: Asscoc Prof. PhD. Phan Xuan Hao

Reviewer 3: PhD. Pham Cong Thieu

The dissertation will be defended at the Institute – Level Doctoral Thesis Evaluation Council, at: National Institute of Animal Aciences, Thuy Phuong, NorthTu Liem, Hanoi at: …h,............. 2023

The dissertation can be found at:
1. National Library
2. Library of National Institute of Animal Aciences

PUBLICCATIONS RELATED TO THE THESIS

1. Nguyen Tien Thong, Trinh Hong Son, Pham Duy Pham, Trinh Quang Tuyen, Tran Phuong Nam, Le Thi Thanh Huyen and Dang Vu Binh, 2023. Creation of GP line on the basis of gene exchange between French and American Landraces and breeding through 3 generations. Journal of Animal Science and Technology – Institute of Animal Sciences, No 137, February 2023, pages 28-39.

2. Nguyen Tien Thong, Trinh Hong Son, Pham Duy Pham, Trinh Quang Tuyen, Tran Phuong Nam, Le Thi Thanh Huyen and Dang Vu Binh, 2023. Creation of GP line on the basis of gene exchange between French and American Yorkshires and breeding through 3 generations. Journal of Animal Science and Technology – Institute of Animal Sciences, No 137, February 2023, pages 40-51.

1. INTRODUCTION

1.1. Research reasons

Pig farming - occupying the number one position in the livestock industry in our country - has developed rapidly over the past decades. However, the quality of pig breeds in Vietnam is still very limited compared to countries with advanced husbandry such as the US, Canada, UK, France, the Netherlands, Denmark, Australia, even some countries in Asian regions such as Thailand or China. The reproductive performance of sows in farms is only 20.22 - 22.41 weaned/sow/year (Tran Thi Bich Ngoc et al., 2019), ADG is 700 - 750 g/day and FCR is 2.7 - 2.9 kg/kg in market hog.

In order to develop pig industry, pure Landrace, Yorkshire and Duroc breeds were imported from different countries for many years, in which Landrace and Yorkshire are the main objects to create dam line sows in hybrid combinations. In 2015, Thuy Phuong Pig Research Center - National Institute of Animal Science - imported GGP herds of Landrace and Yorkshire from France and the US in order to improve, promote productivity and provide high quality pig breeds for the livestock industry. Trinh Hong Son *et al.* (2020) evaluated the results of adaptive raising of these pig herds. A number of studies have been conducted to evaluate the growth ability and semen quality of Landrace and Yorkshire pigs which were imported from French (Nguyen Thi Hong Nhung et al., 2020a; Nguyen Thi Hong Nhung et al., 2020b); Heritability and breed value for weight gain and lean rate of Landrace boars imported from France and the US were estimated (Trinh Hong Son and Le Van Sang, 2018), as well as Yorkshire boars imported from France and America (Trinh Hong Son et al., 2017). Reproductive performance of Landrace and Yorkshire sows imported from French which raised at Thuy Phuong Pig Research Center has also been surveyed over 3 generations (Nguyen Thi Hong Nhung et al., 2020c).

However, improving the productivity of the GGP pig herd is limited due to a number of factors such as: the size of the imported pig herd, farming conditions, worker qualifications and breeding methods. Therefore, some research in the direction of genetic exchange has been carried out at Thuy Phuong Pig Research Center (Trinh Hong Son and Pham Duy Pham, 2020) as well as at Binh Thang Pig Research and Development Center. (Trinh Hong Son et al., 2020). The obtained results show that many reproductive productivity indicators have increased quite clearly. Starting from there, gene exchange research between Landrace and Yorkshire herds imported from France and the US has been carried out at Thuy Phuong Pig Research Center in recent years. Pig herds formed by genetic exchange have also provided research directions for continuing self-crossing and selection through generations to create new GP lines with high growth and reproductive productivity.

The project was carried out to evaluate the process of selecting and creating two new GP lines on the basis of gene exchange between two groups of Landrace imported from France, US and between two groups of Yorkshire imported from France and US.

1.2. Objectives of thesis

1.2.1. General objective

Select and create two Vietnamese GP dam lines with high reproductive performance and growth from Landrace and Yorkshire pigs imported from France and the US.

1.2.2. Specific objectives

- Two groups of exchanged genes GP Landrace pigs were self-crossed over 3 generations, evaluate and select male and female pigs of each generation to create a GP Landrace dam line with high reproductive performance and good growth ability;

- Two groups of exchanged genes GP Yorkshire pigs were self-crossed over 3 generations, evaluate and select male and female pigs of each generation to create a GP Yorkshire dam line with high reproductive performance and good growth ability;

- Evaluate the genetic potential and breeding value of NBA trait of 2 GP dam lines in the 3rd generation pig herd that were selected to create conditions for continued selection to improve productivity of those GP dam lines.

1.3.The scientific and practical value of the study

1.3.1. The scientific value

Addition research documents on gene exchange; Selected and created 2 high-yield pig lines; Providing information on growth ability, semen quality and productivity performance of 2 GP dam lines LVN and YVN Vietnam.

1.3.2. Practical value

Two GP dam lines with high reproductive performance and growth ability were created. These lines have been recognized as Technical Advances according to Decision No. 241/QD-CN-GVN, dated November 30, 2021 of the Department of Livestock Production - Ministry of Agriculture and Rural Development that contributes to improving the productivity of the pig herd at Thuy Phuong Pig Research Center and providing good breeds in the process of transferring breeds and technical advances into production.

1.4. The novelty of thesis

- The thesis is a systematic scientific research work. Growth ability, boar semen quality and sow reproductive performance in the Landrace and Yorkshire grandparent pig herds exchanging genetic resources from France and the US were evaluated over 3 generations of self-crossing;

- Two Vietnamese GP dam lines (LVN and YVN) were selected and created with good growth and reproductive performance. Genetic parameters and breed values were estimated which are the basis for selection to improve reproductive performance of these two pig lines.

2. LITERATURE REVIEW

2.1. SCIENTIFIC BASIS OF THE THESIS

The project is based on the scientific basis of growth traits, boar semen quality, reproductive performance of sows and influencing factors.

2.2. RESEARCH IN VIETNAM AND OTHER COUNTRIES

The thesis has evaluated the state of domestic and foreign research on pig selection and breeding, studies on breeding selection according to BLUP and breed value.

Based on the analysis of domestic and foreign research on pig selection and breeding and evaluation of imported Landrace and Yorkshire pig herds raised in Vietnam, it shows that Landrace and Yorkshire are high-yielding pig lines that bring high productivity, economic efficiency and competitive advantage in pig farming. However, the imported pig herd has not adapted well to the livestock environment in Vietnam. Due to the hot weather, the number of stillbirths and mummifieds is high, the number of pigs born alive and the number of weaned pigs per litter is lower than expected. In addition, due to the limited number of imported pig herds, breeding and selecting pure herds faces many difficulties in terms of improving the productivity of herds. Therefore, research on selecting and stabilizing good genetic values in Vietnam's hot and humid climate is very necessary for imported pig herds.

3. MATERIALS, CONTENTS AND RESEARCH METHODS

3.1. Research Materials

The research materials are 4 GP pig herds created by cross-breeding in the same breed between pure Landrace and Yorkshire herds imported from France and the US, including:

- LVN1: created from cross-breeding 5 French Landrace boars with 60 American Landrace sows;

- LVN2: created from cross-breeding 10 American Landrace boars with 40 French Landrace sows;

- YVN1: created from cross-breeding between 5 French Yorkshire boars and 60 American Yorkshire sows;

- YVN2: created from cross-breeding between 10 American Yorkshire boars and 40 French Yorkshire sows.
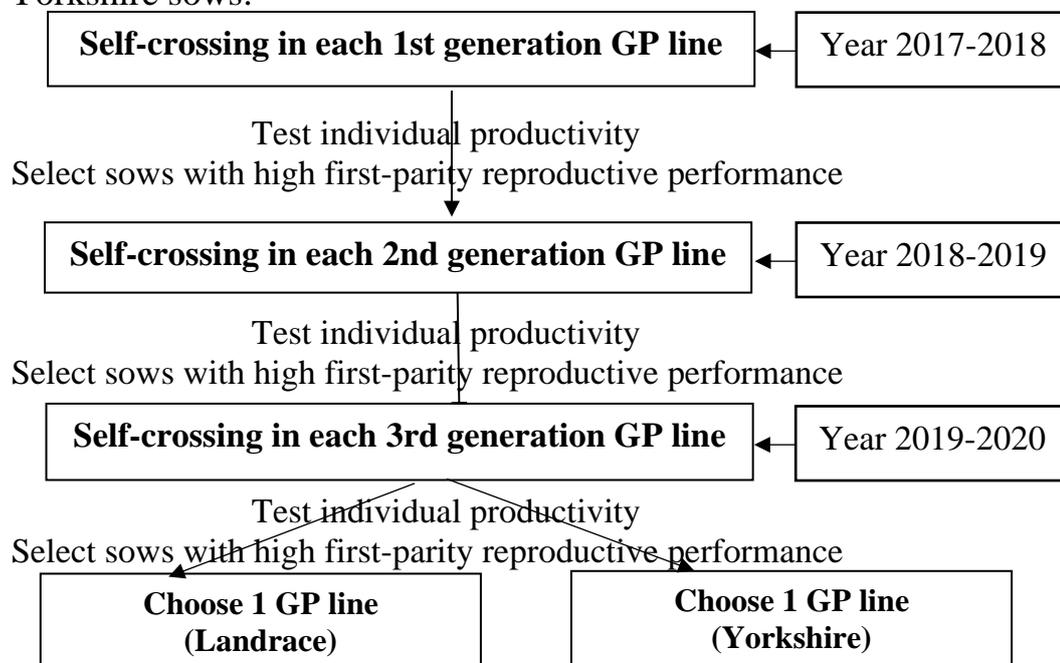
Figure 3.1. Diagram of self-crossing and selection of GP lines

3.2. Research contents

The study has three main contents:

- Selecting LVN1 and LVN2 herds through 3 generations;
- Selecting YVN1 and YVN2 herds through 3 generations;
- Evaluating genetic ability and breeding to improve two selected GP dam lines.

3.3. Research methods

3.3.1. For research content 1 and 2: Selecting LVN1, LVN2 and YVN1, YVN2 herds through generations

In each generation, self-crossing is carried out in each GP dam line. Use productivity testing method to evaluate and select offspring born from self-crossing generations. Gilts that were included in the performance test are offspring born from the first litter of sows of the previous generation.

Each GP herd is divided into 5 blood groups, each group includes 2 males and at least 10 females, cross-breeding is performed between blood groups to avoid inbreeding.

Evaluate the production ability of GP herds over 3 generations. Based on the results of testing productivity, semen quality of boars and reproductive performance in the 3rd generation, 1 GP line of the Landrace breed and 1 GP line of the Yorkshire breed that have high reproductive performance and good growth ability are selected.

3.3.1.1. Productivity testing method

Implement productivity testing methods according to Vietnamese Standards (TCVN 11910-2018) and uniformly apply the management system, housing, and care regime, according to the procedures of Thuy Phuong Pig Research Center;

Table 3.1. The number of individuals productivity test over 3 generations

Generation	LVN1		LVN2		YVN1		YVN2	
	Male	Female	Male	Female	Male	Female	Male	Female
1	100	200	100	200	100	200	100	200
2	100	200	100	200	100	200	100	200
3	100	240	100	240	100	240	100	240
Total	300	640	300	640	300	640	300	640

Monitor the following indicators: Age at start of testing (days); Test starting mass (kg); Age at the end of testing (days); Mass at the end of the test (kg); Average daily gain/day of testing (g/day); Back fat (mm); FCR in male pigs (kg/kg); Lean percentage (%).

3.3.1.2. Breeding methods for gilts

Data monitoring each individual's performance in terms of 3 indicators: ADG, lean percentage and FCR are processed using Excel. Select male and female gilts from performance tested individuals with ADG and lean percentage in the highest 50% of

individuals and regulations of Thuy Phuong Pig Research Center at the same time were born from previous generation sows have the best first-generation reproductive performance. In each generation, each potential GP herd needs to select at least 10 male pigs and 50 female pigs to be included in the self-crossing process.

3.3.1.3. Method for semen quality testing

After finishing the individual performance test, the male pigs in each generation were selected to be put into jumping training and colecting semen to check semen quality. Boars are cared and raised according to the procedures of Thuy Phuong Pig Research Center.

The number of male pigs colection semen is 10 individuals/herd/generation, the number of semen collection times to test semen quality is 30 different times/individual. The semen extraction process, age of male pigs and extraction frequency are carried out according to the procedures of Thuy Phuong Pig Research Center.

Evaluation criteria: semen volume (V, ml), sperm activity (A, %), sperm concentration (C, million/ml), total sperm count (VAC, billion) and semen pH value.

3.3.1.4. Methods of monitoring reproductive performance

Sows are artificially inseminate to the technical regulations of Thuy Phuong Pig Research Center. The first-generation reproductive performance of individual sows of potential GP herds is the basis for selecting gilts for self-crossing in the next generation. At the same time, reproductive performance indicators in the next generations continue to be collected to evaluate breed value in the following stages.

Table 3.2. The number of sows and litters

Generation	LVN1		LVN2		YVN1		YVN2	
	Sows	Litters	Sows	Litters	Sows	Litters	Sows	Litters
1	58	243	79	282	82	325	82	320
2	84	328	63	278	73	291	135	627
3	62	166	66	173	51	151	113	388
Total	204	737	208	733	206	767	330	1335

Sows are cared for, raised and protect to prevent diseases according to the technical procedures of Thuy Phuong Pig Research Center.

Monitoring criteria for sows' physiology and reproductive performance include: age at first service (days); age at first farrowing (days); total number borns/litter (piglets/litter); number born alive/litter (piglets/litter); birth weight/litter (kg/litter); average birth weight/pig (kg/pig); number of weaned pigs/litter (piglets/litter); number of weaning days (days); average weaning weight/pig (kg/pig); number of litters/sow/year and number of weaned pigs/sow/year;

3.3.1.5. Method for evaluating and selecting high performance GP lines

The results of growth ability, semen quality and reproductive performance between 2 herds LVN1, LVN2 and YVN1, YVN2 in generation 3 were compared. Choose 1 GP line of LVN and 1 GP line of YVN have higher productivity by the method: priority is given to reproductive performance indicators, but growth indicators and semen quality must meet the level prescribed by National Standard TCVN 11910:2018 on imported pig breeds.

3.3.2. For research content 3: Evaluating genetic ability and breeding to improve two selected GP dam lines

3.3.2.1. Method for estimating genetic parameters of reproductive performance traits

Use the GLM procedure of SAS 9.0 to evaluate the influencing factors on the reproductive performance traits. The statistical model is as follows:

$$Y_{ijklm} = \mu + G_i + L_j + S_k + B_l + e_{ijklm}$$

Where: Y_{ijklm}: phenotypic value of the trait; μ: population mean; G_i: fixed effect of generation (i=3: 1, 2, 3); L_j: fixed effect of parity (j=6: 1, 2, 3, 4, 5 and ≥6); S_k: fixed effect of farrowing year - season (k=12: 2 season (Winter-Spring and Summer-Autumn crop) x 6 years (2017 - 2022)); (Winter-Spring: October, November, December, January, February and March; Summer-Autumn: April, May, June, July, August and September); B_l: fixed effect of boar (l=30: 10 boars/generation x 3 generations); e_{ijklm}: random error.

From the collected data and the results of analyzing influencing factors, the data was coded using SAS 9.0 software. Heritability and genetic correlation coefficients were estimated using VCE software version 6.0.2 (Groeneveld et al., 2008).

The statistical model estimates the heritability coefficient and genetic correlation coefficient as follows:

$$Y_{ijkl} = \mu + F_i + S_j + D_k + e_{ijkl}$$

Where: Y_{ijkl}: phenotypic value of the trait; F_i: influence of fixed factors (depending on the results of evaluating the influence of fixed factors in the model mentioned above); S_j: the influence of random factors (sire); D_k: the influence of random factors (dam); e_{ijkl}: random error.

3.3.2.2. Method for predicting the breeding value of the NBA trait

Base on the estimated genetic parameters, use the BLUP method of Henderson (1973, 1975) to predict the breeding value of the NBA trait of each individual using Pest software (Groeneveld et al., 2002).

The statistical model predicts values as follows:

$Y_{ijk} = \mu + SD_i + CD_j + e_{ijk}$

Where: Y_{ijk}: phenotypic value of the trait; μ: population mean; SD_i: the influence

of random factors (sire and dam in pedigree chart); CD_j: influence of fixed factors (same as in the genetic parameter estimation model); e_{ijk}: random error.

The accuracy of the EBV is calculated according to the formula:

$$r_{u',u} = \sqrt{(1 - \frac{PEV}{\sigma_A^2})}$$

4. RESULTS AND DISCUSSION

4.1.SELECTING LVN1 AND LVN2 HERDS THROUGH 3 GENERATIONS

4.1.1. Select LVN1 and LVN2 pigs according to performance test results over generations

LVN1 gilts and boars were selected based on performance test results, specifically shown in table 4.1:

Table 4.1. Select LVN1 pigs in the 1st generation (Mean±SD)

Traits	Boars		Gilts	
	Selected boars (n=10)	All boars (n=100)	Selected gilts (n=58)	All gilts (n=200)
Average daily gain (g/day)	850.14[a]±29.19	830.68[ab]±48.49	823.74[b]±28.84	793.90[c]±42.79
Backfat (mm)	11.36[b]±0.27	11.69[b]±0.51	11.68[b]±0.61	12.21[a]±0.79
Loin muscle thicknes (mm)	48.76[c]±1.21	48.86[bc]±1.18	49.99[a]±1.34	49.49[bc]±1.43
Lean percentage (%)	59.03[a]±0.28	58.71[a]±0.57	58.97[a]±0.6	58.29[b]±0.88
FCR	2.51[b]±0.02	2.54[a]±0.03	-	-

Note: Mean values in the same row with different letters are statistically different (P<0,05).

The 1st generation LVN1 boar herd was selected to include 10 pigs with the best performance in terms of weight gain, lean rate and FCR. The results were 850.14 g/day, 59.03% and 2.51 kg, respectively. The selected 1st generation LVN1 gilt herd includes 58 pigs with higher productivity than the average female herd with ADG and lean percentage of 823.74 g/day and 58.97%, respectively.

The results of selecting the 2nd generation LVN1 herd are shown in table 4.2.

Table 4.2. Select LVN1 pigs in the 2nd generation (Mean±SD)

Traits	Boars		Gilts	
	Selected boars (n=10)	All boars (n=100)	Selected gilts (n=84)	All gilts (n=200)
Average daily gain (g/day)	880.89[a]±9.28	841.11[b]±37.81	850.44[b]±28.71	814.12[c]±45.2
Backfat (mm)	11.10[b]±0.2	11.41[b]±0.4	12.06[a]±0.69	12.26[a]±0.77
Loin muscle thicknes (mm)	49.4[b]±0.72	49.11[b]±0.76	51.91[a]±1.4	51.64[a]±1.48
Lean percentage (%)	59.46[a]±0.16	59.06[b]±0.45	59.02[b]±0.64	58.74[b]±0.85
FCR	2.50±0.02	2.51±0.03	-	-

Note: Mean values in the same row with different letters are statistically different (P<0,05).

The selected 2nd generation LVN1 boar herd includes 10 pigs with higher productivity than the average of the entire LVN1 male pig herd with ADG, lean rate

and FCR reaching 880.89 g/day, 59.46% and 2.50 kg, respectively.

The selected 2nd generation LVN1 female pig herd includes 84 gilts with higher productivity than the average LVN1 female herd with ADG and lean rate of 850.44 g/day and 59.02% respectively.

Table 4.3. Select LVN1 pigs in the 3rd generation (Mean±SD)

Traits	Boars		Gilts	
	Selected boars (n=10)	All boars (n=100)	Selected gilts (n=62)	All gilts (n=240)
Average daily gain (g/day)	927.40[a]±15.16	881.42[b]±46.72	872.05[b]±39.46	836.19[c]±51.68
Backfat (mm)	11.19[c]±0.26	11.35[bc]±0.33	11.62[b]±0.43	12.38[a]±0.88
Loin muscle thicknes (mm)	54.33±1.95[b]	53.43±2.27[c]	55.2[a]±1.17	54.89[b]±1.17
Lean percentage (%)	60.49[a]±0.44	60.11[a]±0.65	60.24[a]±0.43	59.36[b]±0.97
FCR	2.46[b]±0.01	2.48[a]±0.02	-	-

Note: Mean values in the same row with different letters are statistically different (P<0,05).

The selected 3rd generation LVN1 male pig herd includes 10 boars with higher productivity than the average of the entire male pig herd with ADG, lean percentage and FCR meet 927.40 g/day, 60.49% and 2.46 kg respectively.

The selected 3rd generation LVN1 female pig herd includes 62 gilts with higher productivity than the average LVN1 female herd with ADG and lean rate of 872.05 days and 60.24% respectively.

Preliminary comparison of the results in table 4.3 with table 4.2 shows that the LVN1 productivity of the 3rd generation is higher than the 2nd generation.

The results of selecting the 1st generation LVN2 are shown in table 4.4.

Table 4.4. Select LVN2 pigs in the 1st generation (Mean±SD)

Traits	Boars		Gilts	
	Selected boars (n=10)	All boars (n=100)	Selected gilts (n=80)	All gilts (n=200)
Average daily gain (g/day)	876.07[a]±15.08	842.59[b]±54.96	827.04[b]±31.17	799.59[c]±40.22
Backfat (mm)	11.34[b]±0.42	11.58[b]±0.57	11.99[a]±0.64	12.31[a]±0.86
Loin muscle thicknes (mm)	48.85[b]±1.38	48.77[b]±1.16	50.81[a]±1.89	50.37[a]±2.02
Lean percentage (%)	59.08[a]±0.48	58.8[ab]±0.63	58.83[ab]±0.69	58.4[b]±1
FCR	2.51[b]±0.02	2.53[a]±0.03	-	-

Note: Mean values in the same row with different letters are statistically different (P<0,05)

The selected 1st generation LVN2 male pig herd includes 10 boars with higher productivity than the average of the entire LVN2 male pig herd with ADG, lean rate and FCR reaching 876.07 g/day, 59.08% and 2.51 kg respectively.

The 1st generation LVN2 female pig herd was selected to include 80 gilts with the best productivity compared to the entire LVN2 female pig herd with ADG and lean rate of 827.04 g/day and 58.83% respectively.

The results of selecting the 2nd generation LVN2 pig herd are shown in table

4.5. The selected 2nd generation LVN2 male pig herd includes 10 boars with higher productivity than the average of the entire male pig herd with ADG, lean rate and FCR reaching 891.94 g/day, 59.64% and 2.48 kg, respectively. Comparison with the results in table 4.4 shows that the productivity of the selected 2nd generation LVN2 boars is higher than that of the selected 1st generation LVN2 boars.

Table 4.5. Select LVN2 pigs in the 2nd generation (Mean±SD)

Traits	Boars		Gilts	
	Selected boars (n=10)	All boars (n=100)	Selected gilts (n=65)	All gilts (n=200)
Average daily gain (g/day)	891.95[a]±16.95	849.42[b]±40.7	849.54[b]±29.52	818.15[c]±42.38
Backfat (mm)	11.11[c]±0.25	11.34[c]±0.36	11.88[b]±0.64	12.38[a]±0.84
Loin muscle thicknes (mm)	50.26[b]±0.99	49.58[b]±1.08	53.17[a]±1.78	52.75[a]±1.9
Lean percentage (%)	59.64[a]±0.31	59.24[ab]±0.5	59.49[a]±0.69	58.87[b]±1.06
FCR	2.48±0.01	2.50±0.03	-	-

Note: Mean values in the same row with different letters are statistically different (P<0,05)

The selected 2nd generation LVN2 female pig herd includes 65 gilts with higher productivity than the average female herd with ADG and lean rate of 849.54 g/day and 59.49%, respectively. The productivity results of the 2nd generation LVN2 female pig herd were higher than the corresponding results of the 1st generation LVN2 herd.

Table 4.6. Select LVN2 pigs in the 3rd generation (Mean±SD)

Traits	Boars		Gilts	
	Selected boars (n=10)	All boars (n=100)	Selected gilts (n=66)	All gilts (n=240)
Average daily gain (g/day)	939.62[a]±17.96	892.48[b]±43.3	888.05[b]±38.79	850.36[c]±55.85
Backfat (mm)	11.16[c]±0.26	11.23[c]±0.33	11.79[b]±0.48	12.4[a]±0.82
Loin muscle thicknes (mm)	54.79[b]±1.6	53.25[c]±2.36	55.64[a]±0.87	55.59[a]±0.88
Lean percentage (%)	60.63[a]±0.44	60.2[b]±0.64	60.16[b]±0.52	59.5[c]±0.89
FCR	2.46[b]±0.01	2.47[a]±0.01	-	-

Note: Mean values in the same row with different letters are statistically different (P<0,05)

The selected 3rd generation LVN2 male pig herd includes 10 boars with higher productivity than the average of the entire male pig herd with ADG, lean rate and FCR reaching 939.62 g/day, 60.63% and 2.46 kg respectively. The productivity of the selected 3rd generation LVN2 male pig herd was higher than the corresponding results in the 2nd generation, especially the ADG met 939.62 g/day compared to 891.95 g/day of the 2nd generation.

The selected 3rd generation LVN2 female pig herd includes 66 gilts with higher productivity than the average female herd with ADG and lean rate of 888.05 g/day and 60.16%, respectively. The productivity of the selected 3rd generation LVN2 female pigs is higher than that of the 2nd generation, with ADG met 888.05g/day compared to 849g/day.

4.1.2. Semen quality of LVN1 and LVN2 boars over 3 generations

- Semen quality of LVN1 boars over 3 generations

Results on semen quality of LVN1 boars over 3 generations are shown in table 4.7.

Table 4.7. Semen quality of LVN1 boars over 3 generations (Mean±SD)

Traits	The 1st gen (n=10)	The 2nd gen (n=10)	The 3rd gen (n=10)
Semen volume (ml)	221.00[b]±29.73	228.55[a]±27.2	230.62[a]±29.84
Sperm activity	0.85[b]±0.03	0.86[a]±0.03	0.85[b]±0.03
Sperm concentration (million/ml)	255.55[b]±20.35	258.96[ab]±16.36	260.02[a]±17.9
VAC (billion)	47.94[b]±7.73	50.64[a]±6.93	51.19[a]±7.84
pH	7.40±0.15	7.41±0.15	7.41±0.14

Note: Mean values in the same row with different letters are statistically different (P<0,05).

The semen volume of LVN1 boars over 3 generations is 221.00, 228.55 and 230.62 ml respectively. In generation 3, LVN1 boars have semen volume equivalent to generation 2 (P>0.05). Sperm activity of LVN1 boars is highest in generation 2 (reaching 0.86) and lowest in generation 1 (reaching 0.85).

Sperm concentration in 3 generations of LVN1 boars reached 255.55, 258.96 and 260.02 million/ml, respectively. The sperm concentration of LVN1 pigs reached the highest level in 3rd generation (260.02 million/ml), higher than 1st generation and 2nd generation (P<0.05). This shows that the semen quality of LVN1 boars has improved over 3 generations.

- Semen quality of LVN2 boars over 3 generations

Results on semen quality of LVN2 boars over 3 generations are shown in table 4.8.

Table 4.8. Semen quality of LVN2 boars over 3 generations (Mean±SD)

Traits	The 1st gen (n=10)	The 2nd gen (n=10)	The 3rd gen (n=10)
Semen volume (ml)	225.03±26.20	225.69±26.08	228.30±28.87
Sperm activity	0.86[b]±0.04	0.87[a]±0.04	0.87[a]±0.04
Sperm concentration (million/ml)	257.52±21.43	260.88±17.46	260.11±17.86
VAC (billion)	50.00[b]±7.85	51.41[ab]±7.24	52.11[a]±7.81
pH	7.41±0.14	7.41±0.14	7.40±0.14

Note: Mean values in the same row with different letters are statistically different (P<0,05).

Research results on semen volume of LVN2 male pigs over 3 generations show that LVN2 boars have similar semen volume in 3 self-crossing generations (P>0.05). Sperm activity of LVN2 boars over 3 generations is 0.862, 0.873 and 0.877 respectively. Sperm activity of LVN2 male pigs in 2nd generation and 3rd generation is similar (P>0.05). Thus, the sperm activity of LVN2 boars has been stable in 2nd and 3rd generations.

4.1.3. Reproductive performance of LVN1 and LVN2 sows over 3 generations

- Reproductive performance of LVN1 sows over 3 generations

The reproductive performance results of LVN1 sows over 3 generations are shown in table 4.9.

Table 4.9. Reproductive performance of LVN1 sows over 3 generations

Traits	The 1st gen (n=243)		The 2nd gen (n=328)		The 3rd gen (n=166)	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Age at first service (days)	242.02	17.38	253.23	17.80	249.74	18.23
Age at first farrowing (days)	364.17	24.95	377.79	23.52	373.95	26.74
Total number borns (pigs/litter)	12.62[b]	2.50	12.77[ab]	2.80	13.16[a]	2.67
Number born alive (pigs/litter)	11.63[b]	2.79	11.86[ab]	2.66	12.14[a]	2.30
Average birth weight (kg/pig)	1.42	0.22	1.41	0.19	1.43	0.20
Birth weight/litter (kg/litter)	16.50	3.90	16.57	3.76	17.18	3.06
Number of weaning days (days)	21.52[b]	6.71	22.93[a]	6.51	20.74[b]	9.20
Number of weaned pigs (pigs/litter)	11.04	4.30	11.39	4.40	11.76	5.91
Average weaning weight (kg/pig)	6.42[b]	0.77	6.48[ab]	0.69	6.57[a]	0.61
Weaning weight (kg/litter)	71.05	29.33	73.43	28.80	76.57	39.13
Farrowing index (litters/sow/year)	2.31	-	2.3	-	2.32	-
Number of weaned pigs/sow/year	25.51	-	26.20	-	27.28	-

Note: Mean values in the same row with different letters are statistically different (P<0,05).

The TNB trait reached the highest in generation 3 with 13.16 pigs/litter (P<0.05). The NBA trait of LVN1 sows increased from generation 1 to generation 3 (P<0.05). Specifically, the NBA in generations 1, 2, and 3 is 11.63, 11.86 and 12.14 respectively. The difference in the TNB and the NBA between generations of the LVN1 herd shown in table 3.11 is also consistent with the results of comparing LSM values using the GLM procedure on the software. SAS 9.0.

The number of weaned pigs/litter of LVN1 sows over 3 generations reached 11.04, 11.39 and 11.76 respectively (P>0.05).

- Reproductive performance of LVN2 sows over 3 generations

The results in table 4.10 show that the indicators of the TNB trait of LVN2 sows tend to increase from the 1st generation to 3rd generation (P<0.05). Specifically, the TNB in 1st generation is 12.81 pigs, 2nd generation is 13.14 pigs and 3rd generation is 13.84 pigs. The NBA of LVN2 sows is highest in 3rd generation (12.65) and lowest in 1st generation (11.82) (P<0.05).

After 3 generations of self-crossing, the number of weaned pigs/litter of LVN2 sows in 3rd generation is higher than that in 1st adn 2nd generations (P<0.05). The number of weaned pigs/litter of LVN2 pigs in 1st generation reached 11.33 pigs, 2nd generation reached 11.66 pigs and 3rd generation reached 12.22 pigs.

Table 4.10. Reproductive performance of LVN2 sows over 3 generations

Traits	The 1st gen (n=282) Mean	SD	The 2nd gen (n=278) Mean	SD	The 3rd gen (n=173) Mean	SD
Age at first service (days)	255.86	30.91	262.89	24.02	261.20	25.79
Age at first farrowing (days)	371.97	30.93	379.44	24.09	377.36	25.77
Total number borns (pigs/litter)	12.81[b]	3.04	13.14[b]	3.29	13.84[a]	2.56
Number born alive (pigs/litter)	11.82[b]	3.12	12.14[ab]	3.07	12.65[a]	2.35
Average birth weight (kg/pig)	1.47	0.24	1.46	0.21	1.46	0.18
Birth weight/litter (kg/litter)	17.09[b]	4.01	17.64[ab]	4.42	18.30[a]	3.43
Number of weaning days (days)	22.21	7.25	22.77	7.28	21.99	8.59
Number of weaned pigs (pigs/litter)	11.33[b]	3.42	11.66[ab]	4.61	12.22[a]	5.81
Average weaning weight (kg/pig)	6.50[a]	0.67	6.37[b]	0.68	6.59[a]	0.65
Weaning weight (kg/litter)	73.38[b]	22.51	74.08[b]	30.15	80.12[a]	37.89
Farrowing index (litters/sow/year)	2.32	-	2.32	-	2.33	-
Number of weaned pigs/sow/year	26.29	-	27.05	-	28.47	-

Note: Mean values in the same row with different letters are statistically different (P<0,05).

The differences in the TNB, the NBA and the number of weaned pigs/litter between generations of the LVN2 herd shown in table 4.10 are similar to the results obtained when using the SAS 9.0 software for comparison by excluding the influence of some fixed factors.

The number of weaned pigs/sow/year of LVN2 sows gradually increased over 3 generations: 1st generation reached 26.29 pigs, 2nd generation reached 27.05 and 3rd generation reached 28.47 pigs. Thus, after 3 generations of self-crossing, LVN2 sows in the 3rd generation have stable and highest productivity.

4.1.4. Evaluate LVN1, LVN2 in the 3rd generation and choose the LVN GP line

Comparison results between LVN1 pigs and LVN2 pigs according to 3 selection criteria: growth, semen quality and reproductive performance are shown in table 4.11.

Table 4.11. Comprehensive assessment of LVN1 and LVN2 in 3rd generation

Traits	LVN1 n	Mean±SD	LVN2 n	Mean±SD
1. Growth and lean rate				
Average daily gain (g/day)	340	849.50[b]±54.28	340	862.75[a]±55.82
Lean percentage (%)	340	59.58±0.95	340	59.71±0.89
FCR	100	2.48±0.02	100	2.47±0.02

2. Semen quality				
Semen volume (ml)	10	230.62±29.84	10	228.30±28.87
Sperm activity	10	0.853[b]±0.03	10	0.877[a]±0.04
Sperm concentration (million/ml)	10	260.02±17.9	10	260.11±17.86
VAC (billion)	10	51.19±7.84	10	52.11±7.81
3. Reproductive productivity				
Total number borns (pigs/litter)	166	13.16[b]±2.67	173	13.84[a]±2.56
Number born alive (pigs/litter)	166	12.14[b]±2.30	173	12.65[a]±2.35
Average birth weight (kg/pig)	166	1.43±0.20	173	1.46±0.18
Birth weight/litter (kg/litter)	166	17.18[b]±3.06	173	18.30[a]±3.43
Number of weaned pigs (pigs/litter)	166	11.76±5.91	173	12.22±5.81
Average weaning weight (kg/pig)	147	6.57±0.61	151	6.59±0.65
Weaning weight (kg/litter)	166	76.57±39.13	173	80.12±37.89
Farrowing index (litters/sow/year)	166	2.32	173	2.33
Number of weaned pigs/sow/year	166	27.28	173	28.47

Note: Mean values in the same row with different letters are statistically different (P<0,05).

Table 4.11 shows that: In the 3rd generation, LVN1 pigs have lower ADG than LVN2 pigs, 849.50 g/day and 862.75 g/day, respectively (P<0.05).

The lean rate of 3rd generation LVN1 pigs reached 59.58%, equivalent to 59.71% of LVN2 pigs in 3rd generation (P>0.05). Thus, 3rd generation LVN1 and LVN2 pigs have good growth ability, in which LVN2 pigs are better than LVN1 pigs.

Regarding the semen quality of 3rd generation LVN1 and LVN2 boars, the results in table 4.11 show that LVN1 boars and LVN2 boars in 3rd generation have similar semen volume and semen concentration (P>0.05). However, the sperm activity of LVN2 boars was higher than that of LVN1 boars (P<0.05).

Thus, 3rd generation LVN1 and LVN2 boars have good and stable semen quality. The semen quality traits of 3rd generation LVN1 and LVN2 boars all meet the national standard TCVN 11910:2018 on Requirements for imported pig semen quality in artificial insemination.

Regarding the reproductive performance of 3rd generation LVN1 and LVN2 sows, table 4.11 shows: In 3rd generation, the TNB of LVN2 is higher than that of LVN1 (P<0.05). Specifically: The TNB of LVN1 and LVN2 pig herds are 13.16 and 13.84 respectively. The NBA of the 3rd generation LVN1 and LVN2 pig herds are 12.14 and 12.65 pigs, respectively. The NBA of the 3rd generation LVN2 pigs is higher than that of the 3rd generation LVN1 pigs, this difference is statistically significant (P<0.05).

The number of weaned pigs/sow/year of the 3rd generation LVN2 herd is higher than that of the 3rd generation LVN1 herd. The number of weaned pigs/sow/year of the 3rd generation LVN1 and LVN2 herds are 27.28 and 28.47 respectively. The difference of 1.19 weaned pigs/sow/year.

In summary, from the results of reproductive indicators, it shows that the third generation LVN1 and LVN2 pigs have high and stable reproductive performance, in which LVN2 pigs have higher reproductive productivity than LVN1 pigs.

- Selection results

From the results on growth ability, semen quality and reproductive performance of the LVN1 and LVN2 lines, it shows that the LVN2 pig line has most of the indicators higher than LVN1, in which it is superior in terms of the following traits:

+ Average daily weight gain in the gilt period reached 862.75 compared to LVN1 of 849.50 g/day (P<0.05);

+ LVN2 boars have sperm activity of 0.88 compared to LVN1 of 0.85 (P<0.05);

+ LVN2 sows have the TNB and the NBA reaching 13.84 and 12.65 respectively compared to LVN1 which have 13.16 and 12.14 respectively (P<0.05); Birth weight reached 18.30 kg/litter compared to LVN1 of 17.18 kg/litter (P<0.05). The number of weaned pigs/sow/year reached 28.47 compared to LVN1 which was 27.28 pigs.

Therefore, LVN2 was chosen as the GP line of genetically exchanged Landrace pigs.

4.2. SELECTING YVN1 AND YVN2 HERDS THROUGH 3 GENERATIONS

4.2.1. Select YVN1 and YVN2 pigs according to performance test results over generations

The 1st generation 1 YVN1 gilts and boars were selected based on performance test results, specifically shown in table 4.12.

Table 4.12. Select YVN1 pigs in the 1st generation (Mean±SD)

Traits	Boars		Gilts	
	Selected boars (n=10)	All boars (n=100)	Selected gilts (n=82)	All gilts (n=200)
Average daily gain (g/day)	870.80[a]±33.38	832.96[b]±49.66	825.09[b]±26.28	802.03[c]±34.81
Backfat (mm)	11.32[c]±0.26	11.60[bc]±0.47	11.77[b]±0.57	12.17[a]±0.78
Loin muscle thicknes (mm)	50.17±1.23	49.37±1.6	50.04±1.49	49.55±1.51
Lean percentage (%)	59.40[a]±0.30	58.92[b]±0.57	58.89[b]±0.62	58.35[c]±0.91
FCR	2.50[b]±0.02	2.53[a]±0.03	-	-

Note: Mean values in the same row with different letters are statistically different (P<0,05).

The selected 1st generation YVN1 boar herd includes 10 boars with higher productivity than the entire herd with ADG, lean rate and FCR reaching 870.80 g/day, 59.40% and 2.50 kg respectively.

The selected 1st generation YVN1 gilt herd includes 82 gilts with higher productivity than the average female herd with ADG and lean rate are 825.09 g/day and 58.89% respectively.

The results of selecting 2nd generation YVN1 gilts and boars are shown in table 4.13. The selected 2nd generation YVN1 boar herd includes 10 boars with higher productivity than the entire male pig herd with ADG, lean rate and FCR reaching 890.55 g/day, 59.67% and 2.49 kg respectively. Thus, the productivity of the selected 2nd generation YVN1 boar herd is not much different from the corresponding results of the 1st generation. However, the productivity of the selected 2nd generation YVN1 gilts was higher than the corresponding indicators of the 1st generation, specifically the ADG reached 844.22 compared to 825.09; Lean ratio reached 59.34 compared to 58.89.

Table 4.13. Select YVN1 pigs in the 2nd generation (Mean±SD)

Traits	Boars		Gilts	
	Selected boars (n=10)	All boars (n=100)	Selected gilts (n=74)	All gilts (n=200)
Average daily gain (g/day)	890.55[a]±17.72	847.97[b]±47.17	844.22[b]±30.69	820.03[c]±39.9
Backfat (mm)	11.02[d]±0.22	11.36[c]±0.35	11.78[b]±0.57	12.22[a]±0.73
Loin muscle thicknes (mm)	49.96[b]±0.86	49.63[b]±0.91	52.04[a]±1.33	51.73[a]±1.35
Lean percentage (%)	59.67[a]±0.2	59.23[b]±0.41	59.34[ab]±0.59	58.80[c]±0.83
FCR	2.49±0.02	2.51±0.03	-	-

Note: Mean values in the same row with different letters are statistically different (P<0,05).

Table 4.14. Select YVN1 pigs in the 3rd generation (Mean±SD)

Traits	Boars		Gilts	
	Selected boars (n=10)	All boars (n=100)	Selected gilts (n=51)	All gilts (n=240)
Average daily gain (g/day)	921.40[a]±16.47	883.15[b]±37.77	880.98[b]±31.01	830.46[c]±50.81
Backfat (mm)	11.08[c]±0.3	11.14[c]±0.24	11.83[b]±0.56	12.28[a]±0.89
Loin muscle thicknes (mm)	54.13[b]±1.97	52.64[c]±2.2	55.42[a]±1.03	55.06[a]±1.14
Lean percentage (%)	60.56[a]±0.23	60.15[ab]±0.54	60.07[b]±0.59	59.50[c]±0.98
FCR	2.47±0.01	2.47±0.02	-	-

Note: Mean values in the same row with different letters are statistically different (P<0,05).

The selected 3rd generation YVN1 boar herd includes 10 boars with higher productivity than the entire male pig herd with ADG, lean rate and FCR reaching 921.40 g/day, 60.56% and 2.47 respectively. That result is better than the productivity of the 2nd generation herd with corresponding results of 890.55 g/day, 59.67% and 2.49 kg.

The selected 3rd generation YVN1 female pig herd includes 51 gilts with higher productivity than the average female herd with ADG and lean rate of 880.98 g/day and 60.07% respectively. That result is higher than generation 2 with results corresponding

to ADG of 844.22 g/day and lean percentage of 59.34%.

Results of productivity testing and selection of the 1st generation YVN2 herd are shown in table 4.15. The selected 1st generation YVN2 male pig herd includes 10 boars with higher productivity than the average of the entire male pig herd with ADG, lean rate and FCR reaching 884.26 g/day, 59.57% and 2.50 kg respectively.

Table 4.15. Select YVN2 pigs in the 1st generation (Mean±SD)

Traits	Boars		Gilts	
	Selected boars (n=10)	All boars (n=100)	Selected gilts (n=82)	All gilts (n=200)
Average daily gain (g/day)	884.26[a]±31.71	841.69[b]±51.68	828.33[b]±33.9	805.55[c]±41.89
Backfat (mm)	11.13[c]±0.36	11.53[b]±0.55	11.86[b]±0.7	12.24[a]±0.86
Loin muscle thicknes (mm)	50.03[ab]±1.95	49.25[b]±1.93	50.97[a]±2	50.64[a]±1.96
Lean percentage (%)	59.57[a]±0.46	58.97[bc]±0.75	59.01[b]±0.76	58.53[c]±1.02
FCR	2.50±0.02	2.52±0.03	-	-

Note: Mean values in the same row with different letters are statistically different (P<0,05).

The selected 1st generation YVN2 female pig herd includes 82 gilts with higher productivity than the average of the entire female pig herd with ADG and lean rate of 828.33 g/day and 59.01% respectively.

The results of selecting 2nd generation YVN2 pigs are shown in table 4.16. The selected 2nd generation YVN2 male pig herd includes 10 boars with higher productivity than the average of the entire male pig herd with ADG, lean rate and FCR reaching 901.41 g/day, 59.94% and 2.48 kg respectively.

Table 4.16. Select YVN2 pigs in the 2nd generation (Mean±SD)

Traits	Boars		Gilts	
	Selected boars (n=10)	All boars (n=100)	Selected gilts (n=135)	All gilts (n=200)
Average daily gain (g/day)	901.41[a]±21.1	855.07[b]±43.46	843.14[b]±28.94	824.65[c]±39.63
Backfat (mm)	10.94[b]±0.23	11.3[b]±0.39	12.07[a]±0.82	12.19[a]±0.86
Loin muscle thicknes (mm)	50.75[b]±1.55	50.27[b]±1.94	52.29[a]±1.9	52.22[a]±1.84
Lean percentage (%)	59.94[a]±0.29	59.45[b]±0.64	59.09[bc]±0.89	58.95[c]±0.97
FCR	2.48±0.01	2.50±0.03	-	-

Note: Mean values in the same row with different letters are statistically different (P<0,05).

The selected 2nd generation YVN2 female pig herd includes 135 gilts with higher productivity than the average female herd with ADG and lean rate of 843.14 g/day and 59.09% respectively.

Comparing the results in table 4.16 and table 4.15 shows that the growth ability of the 2nd generation YVN2 herd is higher than that of the 1st generation, so initially, the selection of gilts gave good results.

The results of selecting the 3rd generation YVN2 pig herd are shown in table 4.17. The selected 3rd generation YVN2 male pig herd includes 10 boars with higher

productivity than the average herd with ADG, lean rate and FCR reaching 965.14 g/day, 60.77% and 2.46 kg respectively. This result is higher than the corresponding figures of 2nd generation.

Table 4.17. Select YVN2 pigs in the 3rd generation (Mean±SD)

Traits	Boars		Gilts	
	Selected boars (n=10)	All boars (n=100)	Selected gilts (n=113)	All gilts (n=200)
Average daily gain (g/day)	965.14^a±12.45	905.74^b±43.71	861.83^c±38.35	834.43^d±49.11
Backfat (mm)	11.10^b±0.24	11.08^b±0.24	12.03^a±0.71	12.26^a±0.79
Loin muscle thicknes (mm)	55.13^a±1.48	52.98^b±2.67	55.66^a±0.91	55.57^a±0.92
Lean percentage (%)	60.77^a±0.49	60.3^b±0.59	59.90^c±0.77	59.64^c±0.86
FCR	2.46±0.01	2.46±0.02	-	-

Note: Mean values in the same row with different letters are statistically different (P<0,05).

The selected 2nd generation YVN2 female pig herd includes 113 gilts with higher productivity than the average famale herd with ADG and lean rate of 861.83 g/day and 59.90%, respectively. The productivity results of the 3rd generation YVN2 gilt herd are consistent with the goal of selecting GP herds with good growth and reproductive performance.

4.2.2. Semen quality of YVN1 and YVN2 boars over 3 generations
- Semen quality of YVN1 boars over 3 generations
Results on semen quality of YVN1 boars over 3 generations are shown in table 4.18.

Table 4.18. Semen quality of YVN1 boars over 3 generations (Mean±SD)

Traits	The 1st gen (n=10)	The 2nd gen (n=10)	The 3rd gen (n=10)
Semen volume (ml)	223.60^b±30.29	227.99^{ab}±27.83	232.66^a±27.18
Sperm activity	0.86±0.03	0.85±0.03	0.86±0.04
Sperm concentration (million/ml)	252.70^c±20.71	258.23^b±20.93	262.36^a±19.53
VAC (billion)	48.40^c±7.95	50.25^b±7.65	52.67^a±7.51
pH	7.39±0.14	7.36±0.17	7.33±0.18

Note: Mean values in the same row with different letters are statistically different (P<0,05).

The semen volume of YVN1 pigs gradually increased over generations, resulting in generations 1, 2, and 3 reaching 223.60, 227.99 and 232.66 ml respectively. The difference in semen volume between generations is statistically significant (P<0.05).

The sperm concentration of YVN1 pigs through generations reached from 252.7 to 262.36 million/ml (P<0.05), the VAC of each generation reached 48.40, 50.25 and 52.65 billion/time respectively and meets TCVN 11910:2018 for Yorkshire boars.

Thus, the above results show that YVN1 pig semen has improved over generations and in all 3 generations, they meet the national standard TCVN 11910:2018 on productivity requirements of import breed pigs.

- Semen quality of YVN2 boars over 3 generations

Results on semen quality of YVN2 boars over 3 generations are shown in table 4.19:

Table 4.19. Semen quality of YVN2 boars over 3 generations (Mean±SD)

Traits	The 1st gen (n=10)	The 2nd gen (n=10)	The 3rd gen (n=10)
Semen volume (ml)	226.24[b]±27.18	231.27[ab]±28.73	234.94[a]±28.52
Sperm activity	0.87±0.04	0.86±0.03	0.87±0.04
Sperm concentration (million/ml)	255.80[b]±21.25	257.63[b]±21.25	261.93[a]±17.28
VAC (billion)	50.05[b]±7.23	51.46[b]±7.92	53.44[a]±7.69
pH	7.34[a]±0.18	6.79[b]±1.35	7.34[a]±0.17

Note: Mean values in the same row with different letters are statistically different (P<0,05).

Similar to YVN1 pigs, the semen volume of YVN2 boars gradually increased over generations, the results in generations 1, 2 and 3 reached 226.24, 231.27 and 234.94 ml respectively. The difference in semen volume between generations is statistically significant (P<0.05).

Sperm activity of YVN2 pigs in generations ranges from 86-87% and meets the requirements for Yorkshire boars according to TCVN 11910:2018.

The sperm concentration of YVN2 boars through generations reached from 255.80 to 261.93 million/ml (P<0.05), the average total number of straight forward sperm/time in all 3 generations reached over 50 billion and reaching TCVN 11910:2018 for Yorkshire boars.

4.2.3. Reproductive performance of YVN1 and YVN2 sows over 3 generations

- Reproductive performance of YVN1 sows over 3 generations

The reproductive performance results of YVN1 sows over 3 generations are shown in table 4.20.

Table 4.20. Reproductive performance of YVN1 sows over 3 generations

Traits	The 1st gen (n=325)		The 2nd gen (n=291)		The 3rd gen (n=151)	
	Mean	SD	Mean	SD	Mean	SD
Age at first service (days)	244.93[b]	14.99	249.29[b]	16.97	256.32[a]	16.80
Age at first farrowing (days)	367.67[b]	22.39	369.71[b]	23.43	381.00[a]	24.44
Total number borns (pigs/litter)	12.53	2.97	12.80	3.14	12.92	2.87
Number born alive (pigs/litter)	11.48[b]	3.05	11.76[ab]	3.01	12.07[a]	2.47
Average birth weight (kg/pig)	1.47	0.26	1.45	0.21	1.45	0.17
Birth weight/litter (kg/litter)	16.53[b]	3.99	16.82[ab]	3.94	17.30[a]	3.43
Number of weaning days (days)	21.11[b]	7.47	22.03[ab]	7.13	22.91[a]	7.25
Number of weaned pigs (pigs/litter)	10.97	4.22	11.26	5.62	11.64	6.28
Average weaning weight (kg/pig)	6.41	0.80	6.40	0.68	6.45	0.75
Weaning weight (kg/litter)	70.71	28.91	72.36	37.03	75.62	41.81
Farrowing index (litters/sow/year)	2.31	-	2.31	-	2.32	-
Number of weaned pigs/sow/year	25.33	-	26.02	-	27.01	-

Note: Mean values in the same row with different letters are statistically different (P<0,05).

The traits for the number of piglets of YVN1 sows gradually increase over generations, but the level of difference is different for each indicator. In generation 3, the TNB and the number of weaned pigs/litter of YVN1 pigs reached 12.07 and 11.64 pigs, respectively. This result meets the requirements for Yorkshire sows according to TCVN 11910:2018. In which, the number of weaned pigs/sow/year of 3rd generation YVN1 pigs is 27.01 pigs, this result meets the productivity requirements of the GP line.

The difference in the NBA trait between generations of the YVN1 herd shown in table 3.34 is also consistent with the results of comparing LSM values using the GLM procedure on SAS 9.0 software when eliminating remove the influence of some fixed factors.

Thus, YVN1 pigs have improved reproductive performance in terms of number of piglets over generations and these results are higher than other research results on Yorkshire pigs. At the same time, in the 3rd generation, YVN1 pigs have number of weaning pigs/sow/year meets the productivity requirements of the GP dam line.

- Reproductive performance of YVN2 sows over 3 generations

The reproductive performance results of YVN2 sows over 3 generations are shown in table 4.21.

Table 4.21. Reproductive performance of YVN2 sows over 3 generations

Traits	The 1st gen (n=320)		The 2nd gen (n=627)		The 3rd gen (n=388)	
	Mean	SD	Mean	SD	Mean	SD
Age at first service (days)	246.09[b]	17.06	254.46[a]	21.49	255.19[a]	15.84
Age at first farrowing (days)	371.84	29.75	379.29	30.80	378.92	26.29
Total number borns (pigs/litter)	12.42[b]	3.13	12.85[ab]	3.23	13.47[a]	2.78
Number born alive (pigs/litter)	11.73[b]	3.24	12.05[ab]	3.12	12.59[a]	2.83
Average birth weight (kg/pig)	1.46	0.22	1.46	0.22	1.43	0.18
Birth weight/litter (kg/litter)	16.87[b]	4.42	17.35[ab]	4.26	17.89[a]	3.99
Number of weaning days (days)	21.01	7.12	21.56	7.10	22.07	8.32
Number of weaned pigs (pigs/litter)	11.30[b]	4.04	11.57[ab]	5.05	12.20[a]	5.85
Average weaning weight (kg/pig)	6.36[b]	0.81	6.48[a]	0.73	6.58[a]	0.68
Weaning weight (kg/litter)	71.73[b]	26.99	74.83[ab]	33.60	79.89[a]	38.19
Farrowing index (litters/sow/year)	2.32	-	2.32	-	2.33	-
Number of weaned pigs/sow/year	26.21	-	26.85	-	28.42	-

Note: Mean values in the same row with different letters are statistically different (P<0,05).

The results in table 4.21 show that the indicators for the number of piglets of YVN2 sows gradually increase over generations and the difference is statistically significant (P<0.05). The results of YVN2 sows were also higher than those of YVN1

sows in the corresponding generations. In 3rd generation, the NBA and the number of weaned pigs/litter of YVN2 sows reached 12.59 and 12.20 pigs respectively. This result meets the requirements for Yorkshire sows according to TCVN 11910:2018. The number of weaned pigs/sow/year of 3rd generation YVN2 sows is 28.42 pigs, this result meets the project's target and is higher than that of YVN1 pigs.

4.2.4. Evaluate YVN1, YVN2 in the 3rd generation and choose the YVN GP line

Comparison results between YVN1 pigs and YVN2 pigs according to 3 selection criteria: growth, semen quality and reproductive performance are shown in table 4.22.

Table 4.22. Comprehensive assessment of YVN1 and YVN2 in 3rd generation

Traits	YVN1		YVN2	
	n	Mean±SD	n	Mean±SD
1. Growth and lean rate				
Average daily gain (g/day)	340	845.96[b]±53.06	340	859.47[a]±57.59
Lean percentage (%)	340	59.69±0.92	340	59.83±0.84
FCR	100	2.47±0.02	100	2.46±0.02
2. Semen quality				
Semen volume (ml)	10	232.66±27.18	10	234.94±28.52
Sperm activity	10	0.86±0.04	10	0.87±0.04
Sperm concentration (million/ml)	10	262.36±19.53	10	261.93±17.28
VAC (billion)	10	52.67±7.51	10	53.44±7.69
3. Reproductive productivity				
Total number borns (pigs/litter)	151	12.92[b]±2.87	388	13.47[a]±2.78
Number born alive (pigs/litter)	151	12.07[b]±2.47	388	12.59[a]±2.83
Average birth weight (kg/pig)	151	1.45±0.17	388	1.43±0.18
Birth weight/litter (kg/litter)	151	17.30±3.43	388	17.89±3.99
Number of weaned pigs (pigs/litter)	151	11.64±6.28	388	12.20±5.85
Average weaning weight (kg/pig)	131	6.45±0.75	336	6.58±0.68
Weaning weight (kg/litter)	151	75.62±41.81	388	79.89±38.19
Farrowing index (litters/sow/year)	151	2.32	388	2.33
Number of weaned pigs/sow/year	151	27.01	388	28.42

Note: Mean values in the same row with different letters are statistically different (P<0,05).
- Growth ability:

The results in table 4.22 show that the ADG trait of 3rd generation YVN2 pigs reached 859.47 g/day, 13.51 g/day higher than 3rd generation YVN1 pigs and this difference is statistically significant (P<0.05).

The lean rate in the 3rd generation YVN1 and YVN2 pigs had a small difference, not statistically significant (P>0.05), reaching 59.69 and 59.83%, respectively.

Thus, in generation 3, both YVN1 and YVN2 herds have the good growth ability and stably with respect to indicators such as ADG, lean rate and FCR. In particular, YVN2 pigs have better growth ability than YVN1 pigs.

- Semen quality:

The results show that the quality semen of 3rd generation YVN1 and YVN2 boars all meet the requirements for Yorkshire boar semen according to TCVN 11910:2018.

In general, 3rd generation YVN1 and YVN2 boar semen have equally good qualities, stable with low coefficients of variation and meet the national standard TCVN 11910:2018 on Yorkshire boar semen quality requirements in artificial insemination.

- Reproductive productivity

The results in table 4.22 show that in the third generation, YVN2 sows have better indicators of number pigliets than YVN1 sows. Detaily: The TNB trait in YVN2 sows reached 13.47, 0.55 higher than YVN1 sows; The NBA trait of YVN2 sows reached 12.59, 0.52 piglets higher than YVN1 sows, and the number of weaned pigs/litter in YVN2 sows reached 12.20, 0.56 piglets higher compared to YVN1 sows. Specialy, the number of weaned pigs/sow/year in 3rd generation YVN1 and YVN2 sows reached 27.01 and 28.42 pigs, respectively. These results meet the requirements for reproductive performance of the grandparent sows.

In summary, the above results show that the 3rd generation YVN2 pigs have better reproductive performance than YVN1 pigs and both 3rd generation YVN1 and YVN2 sows have the number of weaned pigs/sow/year meeting the requirements of the project.

- Selection results

From the results on growth ability, semen quality and reproductive performance of the YVN1 and YVN2 pig lines, it shows that the YVN2 pig line has most of the indicators higher than YVN1, in which it is superior in terms of the following traits:

+ The ADG trait of YVN2 pigs in the growing period reached 859.47 compared to YVN1 which was 845.96 g/day (P<0.05);

+ YVN2 sows have the TNB trait and the NBA trait reached 13.47 and 12.59 pigs respectively compared to YVN1 which is 12.92 and 12.07 pigs respectively (P<0.05). The criteria number of weaned animals/sow/year of YVN2 sows reached 28.42 pigs compared to YVN1 which was 27.01 pigs.

The reproductive performance indicators of the YVN2 herd are superior to those of the unselected Yorkshire herd (France, USA) raised at the facility (Report on the results of implementing Technical Progress "Two GP dam lines LVN and YVN").

Therefore, YVN2 was chosen as the GP line of genetically exchanged Yorkshire pigs.

4.3. EVALUATING GENETIC ABILITY AND BREEDING TO IMPROVE TWO SELECTED GP DAM LINES

4.3.1. Genetic parameters of reproductive performance traits

Heritability coefficients, genetic correlations, phenotypic correlations of the traits total number born/litter (TNB), number born alive/litter (NBA), number of weaned pigs/litter (NW) of the LVN2 and YVN2 sow herds are shown in table 4.23.

Table 4.23. Genetic parameters of reproductive performance traits

GP lines	Traits	TNB	NBA	NW
LVN2 (n=733)	TNB	$0,22 \pm 0,05$	$0,96 \pm 0,02$	$0,45 \pm 0,24$
	NBA	0,86	$0,25 \pm 0,06$	$0,55 \pm 0,24$
	NW	0,25	0,28	$0,10 \pm 0,05$
YVN2 (n=1335)	TNB	$0,20 \pm 0,04$	$0,95 \pm 0,02$	$0,51 \pm 0,12$
	NBA	0,90	$0,18 \pm 0,04$	$0,53 \pm 0,12$
	NW	0,35	0,36	$0,18 \pm 0,04$

Note: *- The elements on the diagonal are the heritability coefficient ($h^2 \pm SE$);*

     - The elements above the diagonal are the genetic correlation coefficient (r_A);

     - The elements below the diagonal are the phenotypic correlation coefficients (r_P).

The results in table 4.23 show that the LVN2 herd has heritability coefficient of the number of weaned animals/litter trait reached 0.10 is the normal level but but the corresponding results for the TNB and NBA traits reached high levels, 0.22 and 0.25, respectively. The heritability of the reproductive productivity traits in the YVN2 herd also reached high levels, they are 0.20, 0.18 and 0.18, respectively.

In general, for both LVN2 and YVN2 lines, the genetic correlation coefficients between traits TNB, NBA and NW as well as between NBA and NW all have higher values than the corresponding phenotypic correlation coefficients. Detaily, for the LVN2 line, genetic correlation coefficients are respectively 0.96, 0.45 and 0.55 compared to the corresponding phenotypic correlation coefficients of 0.86, 0.25 and 0.28. For line YVN2, the genetic correlation coefficients were 0.95, 0.51, and 0.53 compared with the corresponding phenotypic correlation coefficients of 0.90, 0.35, and 0.36.

4.3.2. Predict the breeding value of the NBA trait

The results of predicting breeding values for the trait number born alive/litter of two GP dam lines LVN2 and YVN2 are presented in tables 4.24.

Table 4.24. Classify individuals according to EBV of NBA

Lines	Classify (Select percentage)	EBVs			Phenotype values		
		n	Mean	Accuracy	n	Mean	SD
LVN2	5% of herd	3	1,97	0,64	8	15,13	1,81
	10% of herd	7	1,72	0,65	22	14,18	2,06
	50% of herd	33	1,03	0,63	91	13,47	1,99
	100% of herd	66	0,50	0,64	173	12,65	2,35
YVN2	5% of herd	6	1,59	0,64	18	14,39	1,85
	10% of herd	11	1,47	0,66	40	14,40	1,84
	50% of herd	57	0,92	0,67	207	13,48	2,34
	100% of herd	113	0,39	0,66	388	12,59	2,83

The results in table 4.24 show that the average EBV of the trait NBA at 50% of best individuals of LVN2 herd is 1.03 with the accuracy is 0.63. The heritability coefficient of this trait on LVN2 herd is 0.25, so if only the phenotypic value of the individual is used for selection, the selection accuracy is $\sqrt[2]{0,25} = 0,50$. The BLUP method used to predict breeding value in this study increased the accuracy of breeding selection by about 13%.

The results in table 4.24 also show that the average EBV of the trait NBA of the YVN2 pig herd at 50% of best individuals is 0.92 with the average accuracy is 0.67. The heritability coefficient of this trait on the YVN2 herd is 0.18, so if only the phenotypic value of the individual is used for selection, the accuracy of selection is $\sqrt[2]{0,18} = 0,42$. The BLUP method increases the accuracy of breeding selection on YVN2 by about 25%.

According to the recommendations of the National Swine Improvement Federation (NSIF), the accuracy of breed value estimates should be higher than 0.45. If the accuracy is below 0.45, the data is unreliable and should not be used as a basis for selection. Thus, it is possible to use the EBV of two lines LVN2 and YVN2 as a basis for selecting breeds to continue improving the NBA trait for these grandparent lines.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

1. From the two GP lines LVN1 and LVN2, through a 3-generation self-crossing process, LVN2 was selected as the GP line of Landrace pigs with gene exchange from American male and French female sources with the following characteristics:

- Good growth ability with ADG meet 862.75g/day, lean rate meets 60.32%, FCR meets 2.47.

- Sows have high and stable reproductive productivity with the indicators of TNB, NBA, and number of weaned pigs/litter reaching 13.84, 12.65, and 12.22 pigs, respectively. The indicator of number of weaned animals/sow/year reached 28.47 animals.

- Boars have the indicators of semen volume, sperm activity and sperm concentration of 228.3 ml, 87.7% and 260.1 million/ml, respectively.

2. From the two GP lines YVN1 and YVN2, through a 3-generation self-crossing process, YVN2 was selected as the GP line of Landrace pigs with gene exchange from American male and French female sources with the following characteristics:

- Good growth ability with ADG meet 859.47g/day, lean rate meets 59.83%, FCR meets 2.46.

- Sows have high and stable reproductive productivity with the indicators of TNB reaching 13.47, the NBA reaching 12.59 and the number of weaned pigs/litter reaching 12.20 pigs. The indicator of number weaned pigs/sow/year reaching 28.42 animals.

- Boars have the indicators of semen volume, sperm activity and sperm concentration meet 234.94 ml, 0.87 and 261.93 million/ml, respectively.

3. The estimated heritability coefficients for the traits TNB, NBA and number of weaned pigs/litter for the LVN2 GP line are 0.22, 0.25 and 0.10 respectively. The corresponding results of the YVN2 line are 0.20, 0.18 and 0.18, respectively. The EBV of the NBA has the accuracy of 0.63-0.65 for LVN2 line and 0.64-0.67 for YVN2 line. These accuracies are 13% and 25% higher than the accuracy if using phenotypic values to select varieties.

5.2. RECOMMENDATIONS

Using YVN2 and LVN2 herds as grandparents lines to improve the productivity of pig herds at Thuy Phuong Pig Research Center, and at the same time as raw materials to create female parent pigs to serve herd replacement on farms outside.