Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension
Volume 8 Number 1 January 2009 pp. 31-37
ISSN 1119-7455

HETEROSIS FOR LITTER TRAITS IN NATIVE BY EXOTIC INBRED PIG CROSSES

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ABSTRACT

Inbred strains generated from native and exotic pigs were compared with their F_1 and F_2 backcross populations for a range of litter performance traits. Animals were intensively reared and at 81/2 months of age, the inbred genotypes from each strain were reciprocally mated to each other to generate F_1 crossbred genotypes; while gilts from each crossbred group were backcrossed to their male parents to obtain four backcross progeny groups. Results of the study showed that the litter performances were better in the crossbred groups than in the inbred parents and this improvement could be ascribed to the dominant genes from the exotic parents. Significant (P<0.05) heterosis was obtained in the crossbreds in most of the traits like prolificacy, nursing ability, sex-ratio, litter weight and gestation length. The heterosis observed in the litter traits was low and mostly non- significant. The backcross groups recorded residual heterosis in the litter traits monitored and the magnitude was higher in the exotic than in the native backcrosses. The results further indicate that the litter traits performance of the crossbred groups were mostly influenced by maternal, sex-linked, dominance and epistatic gene actions. It could be suggested that the litter traits of the native pig could be improved by cross-mating selected native and exotic backcross pigs. This could be followed by criss -crossing before group selection.

Keywords: Genotypes, heterosis, Exotic inbred, Litter traits, Pig.

INTRODUCTION

In Nigeria, government's policy on the ban of importation of inputs and services in the livestock sub sector has further exacerbated the plight of farmers in sourcing breeds and strains of livestock including pigs. What is found predominant in Nigeria today are basically several cross-bred generations abandoned here by the expatriates in the late 70's Litter production is an important aspect of commercial production in polytocous animals. It is an integral element in the short-term and long term sustainability of commercial pig production (Fayeye and Ayorinde, 2003).

Nwosu (1987), in his emphasis on how to form a formidable foundation for our pig and poultry farming in Nigeria, had harped on the need to involve the native pig or poultry as part of our seed stock development. Adebambo (1984), Olomu and Oboh (1995) and Williamson and payne (1992) had all maintained that, though our native pigs are noted to perform poorly in growth, they possess useful genetic attributes like tolerance to harsh weather and poor diets, diseases and parasites, good maternal qualities and nickability when crossed with the exotic breeds.

These are desirable genetic attributes that can be harnessed during crossbreeding for improvement of litter size and reproductive traits among native pig genotypes before they become extinct. Our native pigs, according to Marire *et al.* (1997), are noted to compare favourably in growth characteristics with their exotic counterparts and have the singular ability to transmit genes for early age at sexual maturity, good maternal ability, most probable producing ability (MPPA) and produce better heterosis in harsh conditions when crossed with the exotic breeds.

Female reproductive traits have low to moderate heritability. The most heritable traits are those depending solely on the genotype of the female i.e. age at puberty, ovulation rate and weaning to estrus interval. Conversely, litter size, conception and survival rates and to a lesser extent, litter weight, which result from complex interactions between sow, boar and embryo or piglet genotypes have low heritability and are therefore difficult to improve through selection (Ikeobi, 1998). Pig producers have long known that crossbreeding is an effective means of improving reproduction performance. This improvement called heterosis or hybrid vigour, comes from an increase in heterozygosity, which leads to better average genotypic values at dominant loci. As already mentioned, litter traits are controlled by the genes of both piglets and sows and enhanced performance may come from crossed piglets (i.e. direct or individual heterosis effect) or crossed dams (i.e. sow or maternal heterosis effects) (Weiner, 1994). Litter heterosis effects lead to slightly larger litter size at birth and to higher piglet survival and litter weights. This is why a study to evaluate the heterosis for litter size traits in the F_1 and the residual heterosis in the backcrosses of the native and two exotic pig breeds using a crossbreeding strategy known as the back and criss-cross heterosis evaluation technique (BAC - CET) utilized by Omeje (1989) is being investigated.

MATERIALS AND METHODS

Experimental Animals:- This comprised F_1 inbred strains generated from within strain mating of two exotic breeds of pigs (Large White and Landrace) and the Nigerian native pig established and maintained at the Piggery Breeding and Research Unit of Ebonyi State University Abakaliki, Nigeria.

Mating Arrangement:- At 8½ months of age, inbred genotypes from each strain N x N, LW x LW and LR x LR representing native, Large White and Landrace inbreds, respectively were reciprocally mated to one another to generate F_1 crossbred populations. The mating arrangement, which is a part of the BAC - CET design already mentioned is shown in Fig 1. Similarly, at 8½ months of age, gilts from each crossbred group were backcrossed to the male parents to obtain four backcross progeny genotypes or groups as shown in Fig 1. Artificial insemination was the system adopted in mating of the gilts by the boars to forestall the problems of size differences associated with hand mating.

Management of the Animals:- The animals were intensively reared in standard pens according to their litter groups. Piglets were brooded and fed *ad libitum* for eight weeks with a commercial pig starter diet containing 22% crude protein and 2900kcal ME/kg. From two to eight months, they were fed commercial growers mash containing 2750kcal ME/kg and 17% crude protein while commercial breeders' mash containing 2850kcal ME/kg and 20% crude protein was provided from 8 months to 18 months of age.

Water for drinking was provided *ad libitum* throughout the period. The animals were dewormed on routine basis and other therapeutic treatments provided as the need arose. Legumes (such as *Centrosema*) and fresh forages (from Elephant grass- *Pennisetum purpureum,* and *Calapogonium mucunoides)* were provided as supplements.

Data Collected and Analysis:- Data were collected on litter size at birth and at weaning, age at puberty, litter weight at birth and at weaning, gestation length and sex- ratio at birth and at weaning. For the inbred progeny data, an analysis of variance (ANOVA) for a completely randomized design (CRD) using unequal cell number as outlined by Wiener (1971) was used as follows:- $Y_{ijk} = u + g_i + tij + e_{ijk}$ where Y_{ijk} = the K^{th} observation on litter size between the j^{th} strain and within the i^{th} strain.
u= population mean. gi = Effect of i^{th} strain tij= Random variable (e.g. litter size) due to the effect of the j^{th} strain within and between them ^{e}ijk = error or individual piglet differences. For the F_1, crossbred and the backcross, data were analysed by means of a one-way analysis of variance $^{Y}ij = u + gi + eij$ in a completely randomized design (Steel and Torrie 1980) with the various breeding groups as main source of variation. Duncan's new multiple range tests (Duncan 1955) was used to separate the mean differences.

Estimation of Heterosis:- Heterosis among the F_1 piglets was estimated as the mean crossbred deviation expressed in percentage of mid - parent performance. Backcross heterosis was computed from the average additive merit E (Bx) expected of each backcross as outlined by Omeje and Nwosu (1988). $E(Bx_1) = P + ½ [P_1-P]$ for a backcross to P_1 parent. $E(Bx_2) = P + ½ [P_2-P]$ for a backcross to P_2 parent. Heterosis = $Bx_1 - E(Bx_1)$ = Heterosis by the Bx_1 backcross and . $(Bx_2) – E(Bx_2)$ = Heterosis by the Bx_2 backcross. A simple t-test was used to compare the crossbred data with their mid parent for significance of heterotic performance using procedures outlined by Yule and Kendall (1968) and Omeje, (1985).

Genetic Analysis of Heterosis:- The heterosis obtained from the backcross groups were respectively compared with the F_1 heterosis by expressing the mean heterosis of the backcross group as a percentage of F_1. The results of the backcross heterosis relative to F_1 were matched against the complete dominance and parental epistasis model postulated by Sheridan (1981) as shown in Table 1 below.

RESULTS

In this model, Table 1, the F_1 heterosis relative to itself is 100% whether it is complete dominance or epistatic gene action that is operating. The relative performance of the backcross group was compared with the figure expected of the family or mating arrangement under any of the gene actions. If a particular result was of the same or nearly the same magnitude with the corresponding predicted value in this model, then it will be taken that the experimental data fitted well into the particular model of gene action responsible for heterosis.

Figure 1:- The crossbreeding strategy (BAC-CET) involving the inbred native by exotic inbred crosses[1].

Generation	Genotypes			
	Strain I		Strain II	Strain III
Po (inbreds /purebreds)	LR x LR		N x N	LW x LW
	1		2	3
F_1 (Crossbreds)	LR x N	N x LR	LW x N	N x LW
	Main crossbred	**Reciprocal** crossbred	**Main** crossbred	**Reciprocal** crossbred
	4	5	6	7
Bx (Backcrosses)	N x (N.LR)	LR x (LR. N)	N x (N.LW)	LW x (LW. N)
	8	9	10	11

Po:- Base Population
N x N:- native; LR x LR – Landrace; LW x LW – Large White breeds. F_1 – First filial generation (Crossbreds), B x- Backcross generation (Second Filial generation)[1]. Adapted from Omeje, (1989).

Table 1: Comparison of percentage heterosis expected under various mating schemes for the dominance and parental epistasis models with complimentary loci (Sheridan, 1981).

Mating Schemes	Dominance Hypothesis	Parental 2 loci	Epistasis 3 loci
Purebred	0.00	0.00	0.00
F_1	100.00	100.00	100.00
F_2 (two breed synthetic)	50.00	12.50	-15.60
Backcross	50.00	25.00	25.00
Three way cross	100.00	50.00	25.00
Four way cross	100.00	0.00	-50.00
Rotational cross (2 breeds)	66.70	44.40	29.60
Rotational cross (3 breeds)	85.70	40.80	21.00

The percentage values are relative to F_1

Table 2: Means ±S.E for litter size traits of the inbred genotypes belonging to the native and exotic pig strains.

a, b, c:- For each trait and within each strain, means superscripted with different letters are significantly different (P<0.05). Note: Standard

Traits	Strains		
	LR X LR 1	**N x N 2**	**LW x LW 3**
Litter Size at birth	8.50^a	6.50^c	7.50^b
	(0.05)	(0.02)	(0.30)
Litter Size at weaning	7.50^a	5.50^c	6.50^b
	(0.21)	(0.15)	(6.50)
Age at puberty	267	245	262
	(2.0)	(3.0)	(2.1)
Litter weight at birth	1.30^a	0.85^b	1.50^a
	(0.20)	(0.15)	(0.25)
Litter weight at weaning	27.00^a	18.50^b	24.10^a
Gestation length	118	111	122
	(2.0)	(1.0)	(2.0)
Sex-ratio at birth	1.25	0.85	1.10
	(0.25)	(0.15)	(0.15)
Sex-ratio at weaning	1.05	0.65	1.00
	(0.02)	(0.05)	(0.01)

errors are in parentheses.

Table 2 shows the litter traits of inbred native and two exotic inbred pig genotypes used for the cross breeding. Significant differences (P<0.05) were observed among the inbred genotypes in all the traits, except for gestation length, age at puberty and sex-ratio. The Landrace and Large White were superior to the native counterparts in some of the traits. The Landrace genotypes were superior to the Large White in their litter size at birth and at weaning, whereas the two inbred exotic genotypes did not differ (P>0.05) in age at puberty which was longer than the native genotypes. Litter weight at birth was higher in the Large White than the Landrace. The litter size traits of the F_1 crossbred and the backcross groups are presented in Table 3 and 4 respectively.

Litter size at birth was higher among the crossbred groups when compared with their parental averages (Table 2), the only exceptions being the main crossbreds involving the Large White and native (LW x N) whose litter size at birth (6.00 piglets) were less (P>0.05) than their native (6.50 piglets) parents. The letter sizes at birth of the backcrosses were similar to the F_1 mean values in most of the groups (table 4).

Table 3: Means ± S.E for litter size traits characteristic of the F_1 crossbred group.

Traits	Crossbred Groups			
	LR x N 4	N x LR 5	LW x N 6	N x LW 7
Litter Size at birth	10.00[a]	8.00[b]	6.00[c]	6.50[c]
	(0.60)	(0.60)	(0.60)	(0.50)
Litter size at weaning	5.50[b]	7.50[a]	5.00[b]	4.00[b]
	(0.50)	(0.51)	(0.10)	(0.10)
Age at puberty	255	258	250	254
	(1.20)	(2.00)	(2.00)	(1.80)
Litter weight at birth	1.80	1.17	1.10	1.30
	(0.03)	(0.02)	(0.10)	(0.10)
Litter weight at weaning	19.05	19.99	18.54	17.39
	(1.55)	(1.29)	(1.46)	(1.29)
Gestation length	122[a]	117[b]	1175[b]	123[a]
	(2.0)	(2.50)	(2.50)	(2.00)
Sex – ratio at birth	0.69	0.78	0.71	0.63
	(0.12)	(0.03)	(0.04)	(0.13)
Sex – ratio at weaning	0.59	0.65	0.67	0.59
	(0.09)	(0.15)	(0.10)	(0.09)
No of pigs providing data	128	122	120	121

a, b, c:- means for each trait and strain not followed by same superscript are statistically (P<0.05) different. Note: standard errors are in parenthesis. LR x N = Landrace x native (Main crossbred), N x LR=Native x Landrace (Reciprocal crossbred. LW x N = Large white x Native (main crossbred); N x LW = Native x Large White (Reciprocal crossbred).

Table 4: Means ± S. E for litter size traits of the Backcross progeny groups.

(Traits) (LW. N)	Backcross N x (N . LR) 8	Progeny LR x (LR. N) 9	Groups N x (N.LW) 10	LW x 11
Litter size at birth	8.50[c]	6.50[a]	7.50[b]	6.00[a]
	(0.86)	(0.80)	(0.80)	(0.40)
Litter size at weaning	4.50[a]	4.00[a]	7.50[c]	6.00[b]
	(0.50)	(0.80)	(0.80)	(0.20)
Age at Puberty (days)	240	250	230	235
	(1.60)	(2.0)	(2.10)	(2.50)
Litter weight at birth	1.05	1.15	1.25	1.20
	(0.05)	(0.06)	(0.07)	(0.10)
Litter weight at weaning	18.02	15.75	17.40	17.70
	(1.42)	(1.55)	(1.20)	(1.30)
Gestation length	121.50[b]	118.00[a]	118.00[a]	122.00[b]
	(2.50)	(2.00)	(2.00)	(2.50)
Sex –ratio at birth	0.70	0.64	0.68	0.50
	(0.10)	(0.14)	(0.18)	(0.21)
Sex –ratio at weaning	0.84	0.59	0.68	0.46
	(0.16)	0.19)	(0.18)	(0.21)
Number of Animals	124	118	211	231

a, b, c:- mean values along the same row with different superscripts are significantly different (P<0.05). Note:- Standard errors are in parenthesis.

However, the reciprocal backcross involving the N x (N.LW) also did not differ from the F_1 main crossbred LW x N. For litter size at weaning, the reciprocal crossbred N x LR and main Backcross LW x (LW.N) with an average of 7.50 piglets were the most superior (P<0.05) followed by their reciprocal backcross N x (N.LW) with 6.00 piglets and main crossbred LR x N with 5.50 piglets. The least were from the reciprocal crossbred N X LW and backcross N x (N.LR) with 4.00 piglets each.

Results also show significant differences (P<0.05) in the litter size at weaning involving F_1 native and Landrace crossbreds to the crossbreds of native and Large White. The reverse is the case in the Litter size at weaning involving the backcrosses where superior performance was obtained from the backcrosses involving native and Landrace. Non-significant (P>0.05) differences were observed for age at puberty, gestation length and sex-ratio at birth and at weaning of the F_1 crossbred genotypes. However, significant differences (P<0.05) were observed for gestation length of the backcross genotypes with the main backcross (LR x (LR.N) and having Longer periods of days. (Table 4).

The exotic crossbred genotypes were superior to their native counterparts in the litter weight at birth and weaning (Table 3) but did not show any significant (P>0.05) differences. In the same vein, the backcross genotypes did not show any significant (P>0.05) differences in their litter weight at birth and at weaning (Table 4).

Table 5 and 6 present the heterosis for litter size traits of the F_1 crossbred and the backcross groups, respectively. The results showed that the highest heterosis in litter size at birth and at weaning was obtained from the reciprocal crossbreds and backcrosses with 62.52% and 23.07% for litter size at birth and 53.60% and 17.35% for litter size at weaning respectively. The F_1 crossbred groups recorded non- significant (P>0.05) heteroses in litter weight at birth and at weaning (Table 5) whereas, heteroses for litter weight for the backcrosses were mostly negative and Non- significant. The negative heterosis implies that the crossbred performance was less than the mid-parent average in litter weight at birth and at weaning. A similar trend was observed for the backcross heterosis for litter weight (Table 6) except for the reciprocal backcross N x (N.LW) which shared highly significant (P<0.05) heterosis of 2.03%. The reciprocal crossbred and backcross groups registered higher heteroses in both traits compared with the main crossbred and main backcross groups. Heterotic performance for gestation length was significant (P<0.05) and positive for the F_1 crossbred group but non-significant for the backcross groups except reciprocal backcross N x (N.LW)

Table 5: - Heterosis of litter size traits among F_1 Crossbred groups

Traits	F1 Crossbred Groups			
	LR x N 4	N x LR 5	LW x N 6	N x LW 7
Litter size at birth	48.50**	52.96**	50.69**	62.52**
	(3.10)	(2.36)	(2.86)	(2.29)
Litter size at weaning	43.60**	48.67**	46.40**	53.60**
	(2.50)	(2.30)	(2.20)	(2.41)
Litter weight at birth	2.45^{NS}	3.81*	2.41^{NS}	3.51*
	(0.17)	(0.51)	(0.38)	(0.56)
Litter weight at weaning	1.42^{NS}	1.15^{NS}	1.21^{NS}	1.31^{NS}
	(0.03)	(0.06)	(0.02)	(0.06)
Gestation length	16.56*	12.43*	15.50*	13.10*
	(1.42)	(1.01)	(0.95)	(1.15)

Note:- Standard errors are in parenthesis
- P<0.05, NS:- Not significant (P>0.05), **P<0.01.

Table 6:- Mean ± S.E for heterosis in litter size traits of the backcross progeny groups[1].

	backcross progeny group			
	N x (N. LR) 8	LR x (LR. N) 9	N x (N.LW) 10	LW x (LW. N) 11
Litter size at birth	19.29**	21.12**	21.45**	23.07**
	(1.67)	(1.19)	(1.67)	(1.19)
Litter size at weaning	13.30**	14.70**	15.60*	17.35**
	(1.34)	(1.43)	(1.23)	(1.48)
Litter weight at birth	-0.38^{NS}	-0.80^{NS}	-1.20^{NS}	-1.32^{NS}
	(0.15)	(0.20)	(0.40)	(0.35)
Litter weight at weaning	-0.92^{NS}	-0.99^{NS}	1.42*	2.03**
	(0.40)	(0.52)	(0.30)	(0.92)
Gestation length	0.08^{NS}	0.10^{NS}	0.12*	0.15**
	(0.01)	(0.02)	(0.06)	(0.04)

Note:- Standard errors are in parenthesis.
*P<0.05, NS:- Not significant (P>0.05), **P<0.01.
[1]:- Measured in actual deviation from the average additive merit E (Bx) expected of each backcross.

Table 7:- Summary of the backcross heterosis in litter size traits expressed as a percentage of F1 to ascertain modes of gene action[1].

Mating Scheme	Litter size at birth: Complete dominance	Litter size at birth: Parental epistasis (2loci)	Litter size at weaning: Complete dominance	Litter size at weaning: Parental epistasis (2loci)	Litter weight at birth: Complete dominance	Litter weight at birth: Parental epistasis (2loci)	Litter weight at weaning: Complete dominance	Litter weight at weaning: Parental epistasis (2loci)	Gestation length: Complete dominance	Gestation length: Parental epistasis (2loci)
Type of cross:										
F1 cross	100	100	100	100	100	100	100	100	100	100
Back crosses										
LRx(LR.N)	11.82		13.10		10.05		18.20		18.16	
N x (N.LR)		-19.15		-18.40		3.19		10.18		14.50
LWx(LW.N)	10.14		11.32		-18.50		-16.50		14.40	
(Nx LW) x N		-18.63		-16.36		-19.50		17.17		10.49

Source: [S1] After Sheridan 1981

had highly significant improvement. The main crossbred genotype LR x N showed the highest heterosis in gestation length with 16.56%. Table 7 is a summary of the backcross heterosis for litter size traits expressed as a percentage of the F_1 to ascertain the mode of gene action responsible for heterosis.

DISCUSSION

The significant differences observed among the inbred lines of each exotic strain in some of these traits (Table 2) categorized them as distinct groups which can contribute to the improvement of the native pig. The data obtained in the crossbred groups indicate that while sire influence affected the litter size at birth and at weaning, non-additive genetic effects were responsible for the inheritance of the trait in the other crossbred groups. Gunset and Robinson, (1990) had earlier observed that sire influence as well as additive effects were important in the inheritance of prolificacy and better nursing ability of the crossbred genotypes. They posited that crossbred females have 2- 4% higher conception rates, slightly larger ovulation rates (+0.5ova) and 0.6to 0.7 more piglets at weaning. Post farrowing survival of piglets is higher for crossbred sows (5%) and litter weights are greater (+4.2kg at 21days). Litter heterosis effects lead to slightly larger litter size at birth (+0.24piglet per litter) and to a higher piglet survival (+5.8%) and litter weights. Also, in terms of sow heterosis, there is an average reduction in age at puberty of 11.3 days for crossbred sows.

It should be noted that heterosis values may differ according to breed combinations. For instance, Large White and Landrace crosses generally exhibit lower heterosis values than other crosses between European or American breeds. Haley *et al.* (1995) indicated that heterosis values in crosses between large white and Meishan breeds are higher than in two or threefold Large White and Landrace crosses. Bidanel (1993) and Lee and Haley (1995) had all noted that heterosis for age at puberty is around 40 – 50 days and that sow heterosis effects on litter size at birth and at weaning exceed two piglets per litter. On gestation length and sex-ratio at birth and at weaning, the LR x N (maincrossbred) and N x LW (reciprocal crossbred) showed longer gestation days as against other groups. Similarly, the sex- ratio of the crossbred groups portrayed the reciprocal genotype N x LR as the most superior though not significant among the groups.

The genetic superiority of the reciprocal crossbred to others in sex- ratio trait can be linked to the native genome which have been adjudged by Olomu and Oboh (1995) as unique. The higher significant heterosis recorded by the F_1 crossbred in traits related to prolificacy, nursing ability, litter weight at birth and weaning of the reciprocal crossbreds over the maincrossbreds may be as a result of maternal impact of the dams acquired from the dominant genes of the exotic parents.

The result of significant heterosis observed among the F_1 crossbreds is consistent with the report of Bidanel (1993) and Lee and Haley (1995). This indicates that significant improvement in these traits may be achieved by the reciprocal mating of the native and exotic pigs. The higher heterosis recorded by the reciprocal cross groups over their maincross groups implies that, maternal influence was more important than sex- linkage effect in the reproductive traits of Pig.

Earlier studies by Nwakpu and Omeje (2004) had reported positive and significant heteroses in the reciprocal crossbred but not on the maincrossbred. The researchers inferred that crossing the exotic boar with native sow would yield rapid improvement especially when the parents of the crossbreds are confined. The F_1 crossbred groups differed in their heterotic performance on litter size traits, which was due to the nature and the degree of gene frequency differences between the parental lines, since heterosis is directly proportional to heterozygosity (Falconer, 1989). The presence of these reciprocal cross differences will be useful in making decisions either to use the sire or dam of the superior strains in the improvement of litter size in pigs. The relatively low and negative heteroses for litter size traits at the backcross groups could suggest that the litter size traits of the base stocks used were mostly governed by additive and residual gene effects. This is consistent with the reports of Gunset and Robinson (1990) and Lee and Haley (1995) that heterosis for reproductive traits are low.

The results in Table 7 indicated that most of the mainbackcross groups retained far less than 50% of the F_1 heterosis in the litter size traits studied. However, some of the reciprocal backcross groups showed higher percentage values of the F_1 heterosis in the traits. This means that heteroses for litter size traits of the main and reciprocal backcross groups were influenced by complete dominance of allelic genes and parental epistasis involving complimentary genes. This also agrees with the earlier reports of Sheridan (1986) and Haley *et al.* (1995) that heterosis for litter size traits was variable but mostly influenced by dominance and epistatic gene effects. Finally, it can be noted that impressive levels of heteroses for litter size traits were observed in the crosses between the native and exotic pigs, which were more in some groups (especially the reciprocal crossbred groups) than in others. However, heterosis for litter size traits was low and mostly non- significant. The heterosis recorded in the backcross groups was residual and higher in the main than the reciprocal backcross groups.

It can be concluded that, the litter size traits performance in the native by exotic cross was influenced by maternal, sex- linred dominance and epistatic gene action. Selection involving the native and exotic backcrosses may be embarked upon to generate progenies which can be evaluated on litter size traits performance

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