IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372.Volume 5, Issue 6 (Nov. - Dec. 2013), PP 63-71
www.iosrjournals.org

Factors influencing growth performance and estimation of genetic parameters in crossbred pigs

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Abstract: *Piggery is an important livelihood for a large number of resource-poor rural households in India. Growth is an important trait of interest in any meat producing animal and body weight (BW) measurements are good indicators of growth rate. The present study focuses on identifying the factors influencing pre and post weaning BW and average daily gains (ADG) in Large White Yorkshire-Desi crossbred pigs (50% and 75%) using weekly BW measurements from birth to 8 weeks of age and monthly BW from 3rd to 9th month from 1,405 piglets born during the years 2002-2011. The overall least squares mean BW (kgs) at birth, 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, 12th, 16th, 20th, 24th, 28th, 32nd and 36th week were 1.090, 1.93, 2.76, 3.76, 4.518, 5.461, 6.591, 7.584, 8.670, 12.959, 18.211, 24.254, 34.052, 41.970, 48.414 and 59.889 respectively. The overall least squares mean ADG (kgs) during 0-1, 1-2, 2- 3, 3-4, 4-5, 5-6, 6-7, 7-8, 0-8, 8-12, 12-16, 16-20, 20-24, 24-28, 28-32, 32-36, 8-36 weeks were 0.123, 0.118, 0.117, 0.137, 0.138, 0.152, 0.155, 0.191, 0.135, 0.119, 0.164, 0.180, 0.318, 0.249, 0.201, 0.272 and 0.255 respectively. Heritability estimated using full-sib analysis for BW at various ages varied from 0.577 to 0.966. Estimated genetic correlations among pre-weaning BW were positive and low in magnitude whilst among post-weaning BW, genetic correlations were high positive. The findings suggest that 12th week BW can be used for selecting increased BW at 36th week. The findings indicate scope for improvement through selection.*

Keywords: *Average daily gain, body weight, crossbred pigs, genetic correlation, heritability*

I. Introduction

Exotic-desi crossbred pigs are rich source of animal protein. Bodyweights (BW) and growth rates are important indicators for animal breeders for evolving strategies for higher productivity. The pre and post weaning BW and growth rates in pigs are influenced by various genetic and non-genetic factors such as genetic group, sex, parity, litter size at birth, season and period of birth. Genetic analysis of BW through heritability and genetic correlation in crossbred pigs at different ages is essential to find out the scope for increasing the BW during slaughter age of pig through indirect selection and thus maximizing the profit of pig farms. Heritability estimates of growth traits establish the genetic potential of a herd and helps in its possible exploitation through selection [1]. In this work, an attempt was made to study the effect of various genetic and non-genetic factors affecting pre-weaning and post-weaning body weights and average daily weight gains (ADG) in half-bred (50%CB) and graded progenies (75%CB) of Large White Yorkshire (LWY) and Desi pigs. The genetic parameters, namely heritability, genetic correlations and phenotypic correlations have also been computed.

II. Materials and Methods

2.1 Data description

Data pertaining to 1,405 piglets belonging to two genetic groups i.e. 50% and 75% LWY – Desi crossbreds born during the years 2002-2011 were used in the present investigation. Piglets were weaned at 8 weeks of age. The data on year of birth were grouped into two periods, viz. period 1 (2002-2005) and period 2 (2006-2011). Month of birth was assigned to one of the four seasons viz. summer (Mar-May), pre-monsoon (Jun-Aug), monsoon (Sep-Nov) and winter (Dec-Feb). The litter size at birth (LSB) was classified into 4 groups viz. 1-3, 4-6, 7-9, 10+.

2.2 Preliminary environment effects analysis

The effects of genetic and non-genetic factors viz. genetic group, sex, parity, liter size at birth, season and period of birth on pre and post weaning growth traits were studied by least squares method followed by pair wise comparison of means. General linear model procedure was used to identify the effect of genetic and non-genetic factors on the observed body weights recorded at birth, 1, 2, 3, 4, 5, 6, 7, 8, 12, 16, 20, 24, 28, 32 and 36 weeks of age. The fixed model

$$Y_{ijklmno} = \mu + G_i + S_j + LS_k + P_l + SB_m + PB_n + \varepsilon_{ijklmno}$$

was used where $Y_{ijklmno}$ is the adjusted BW of the o^{th} piglet, μ is the overall mean, G_i is the fixed effect of the i^{th} genetic group (i=50%CB, 75%CB), S_j is the j^{th} gender (j = male, female), LS_k is the k^{th} litter size at birth group (k= 1-3, 4-6, 7-9, 10+), P_l is the l^{th} Parity (l=1, 2+), SB_m is the m^{th} season of birth (m=summer, pre-monsoon, monsoon, winter), PB_n is the n^{th} period of birth (n=2002-05, 2006-11) and ε_{ijklmo} is the error attributed to the o^{th} piglet.

2.3 Estimation of genetic parameters

The scope for genetic improvement in an economically important trait of pig depends on its magnitude of heritability and genetic variance. Heritability, denoted by h^2, is one of the most important concepts in animal breeding as it is used to help plan breeding programs, determine management strategies, estimate breeding values of individual animals, and predict response to selection. It is a measure of the degree (0 to 1) to which offspring resemble their parents for a specific trait and indicates how much confidence to place in the phenotypic performance of an animal when choosing parents of the next generation. For highly heritable traits where h^2 exceeds 0.40, the animal's phenotype is a good indicator of genetic merit or breeding value. If however, h^2 is estimated low, the trait under study can only be improved by better feeding and management rather than by selection. Genetic correlation which studies the association between two traits due to additive gene effect, tells us how pairs of traits "co-vary" or change together. When genetic correlation is different from 0, then more of the same genes affect both traits. Selection for one trait will increase/decrease the other depending on whether the genetic correlation is positive or negative. The phenotypic covariance is the sum of genetic and environmental covariances.

In species like pig, each male is mated to several females and each mating produces several offspring (multiple births) resulting in larger full sib families. Hence, full-sib method is used for the computation of genetic parameters in pigs. The observation Y_{ijk} on the k^{th} progeny from j^{th} dam mated to i^{th} sire is denoted by the following statistical model $Y_{ijk} = \mu + s_i + d_{ij} + e_{ijk}$, where μ is the population mean, s_i is the effect of i^{th} sire, d_{ij} is the effect of the j^{th} dam mated to i^{th} sire and e_{ijk} is the environmental deviations attributed to individuals due to uncontrolled environmental and genetic factors. All the effects are assumed to be random, normal and independent with $E(s_i) = 0$, $E(d_{ij}) = 0$, $E(e_{ijk}) = 0$ and $E(s_i^2) = \sigma_s^2$, $E(d_{ij}^2) = \sigma_D^2$, $E(e_{ijk}^2) = \sigma_e^2$.

The estimate of heritability from the full-sib analysis using the sire and dam component can be obtained as $h^2_{S+D} = \dfrac{2(\hat{\sigma}_s^2 + \hat{\sigma}_D^2)}{\hat{\sigma}_P^2}$ where $\hat{\sigma}_P^2 = \hat{\sigma}_S^2 + \hat{\sigma}_D^2 + \hat{\sigma}_e^2$ is the estimated total phenotypic variance, $\hat{\sigma}_s^2$ is the additive genetic variance due to sire, $\hat{\sigma}_D^2$ is the additive genetic variance due to dam and $\hat{\sigma}_e^2$ is the environmental variance. Standard error of heritability was approximated using the formula due to [2] and is given by $SE(h^2_{S+D}) = \dfrac{16h^2_{S+D}}{T}$, where T = n*N, n is the average half sib family size and N is the total half sib families. The formula for genetic correlation between two traits x and y and its SE are given by $r_g = \dfrac{\mathrm{cov}_s(xy)}{\sqrt{\sigma^2_{s(x)}\sigma^2_{s(y)}}}$ and $SE(r_g) = \dfrac{1-r_g^2}{\sqrt{2}}\sqrt{\dfrac{SE(h_x^2)SE(h_y^2)}{h_x^2 h_y^2}}$ [3]. The formula for phenotypic correlation between two traits x and y is $r_p = \dfrac{\mathrm{cov}_p(xy)}{\sqrt{\sigma^2_{p(x)}\sigma^2_{p(y)}}} = \dfrac{\mathrm{cov}_g(xy) + \mathrm{cov}_e(xy)}{\sqrt{(\sigma^2_{g(x)} + \sigma^2_{e(x)})(\sigma^2_{g(x)} + \sigma^2_{e(y)})}}$

Body weights recorded at birth, 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, 12th, 16th, 20th, 24th, 28th, 32nd and 36th week and the Average Daily Gains (ADG in gms) during 0-1, 1-2, 2- 3, 3-4, 4-5, 5-6, 6-7, 7-8, 0-8, 8-12, 12-16, 16-20, 20-24, 24-28, 28-32, 32-36, 8-36 weeks were used to estimate heritability and genetic correlation. The variance components used for the estimation of heritability and genetic correlation of each trait were obtained by Variance Components Procedure of SPSS software [4] using Restricted Maximum Likelihood (REML) method after adjusting for significant fixed effects.

III. Results and Discussion

Out of a total of 1405 piglets used for the study, 27.3% belong to 50%CB and 72.7% belong to 75%CB. There were 54.7% males and the rest females. The litter size at birth for 50%CB varied from 1 to 11 with a mean of 6.50 while that of 75%CB varied from 1 to 15 with a mean of 8.34. The distribution of piglets in the various litter size groups were 5% (1-3), 24.9% (4-6), 47.6% (7-9) and 22.5% (10+). While 34.4% and 42.8% of piglets were born during summer and monsoon season, 19.7% and 3.0% were born during pre-monsoon and winter seasons. The pattern of birth during different seasons was similar for both the genetic groups. With regard to period of birth, 46.5% of animals were born during 2002-05 while the rest 53.5% were born during 2006-11. There were 64.2% of piglets belonging to parity 1 while the rest 35.8% belonged to parity 2 & 3. Parity 2 and 3 have been combined as the number of piglets belonging to parity 3 is very small.

3.1 Least Squares Analysis

Body Weights

The method of unequal subclass analysis of variance was used to test the significance of the fixed effects. The overall least squares mean body weights(kgs) ± SE at birth, 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, 12th, 16th, 20th, 24th, 28th, 32nd and 36th weeks were 1.090 ± 0.008, 1.937 ± 0.032, 2.764 ± 0.045, 3.767 ± 0.056, 4.518 ± 0.077, 5.461± 0.077, 6.591 ± 0.070, 7.584 ± 0.126, 8.670 ± 0.119, 12.959 ± 0.210, 18.211 ± 0.330, 24.254 ± 0.478, 34.052 ± 0.617, 41.970 ± 0.741, 48.414 ± 0.941, and 59.889 ± 0.828 respectively (Table 1 and 2). The values were in close agreement with the values reported by [5, 6]. Genetic group did not affect the pre-weaning body weights except birth weight and weaning weight. However, significant effect of genetic group was observed on all the post-weaning body weights. Significant effect of genetic group on all body weights except birth weight was reported by [6]. The 75% CB recorded heavier body weights at all age groups indicating their superiority over 50% CB, a finding concurred by authors [5, 7] in such similar studies. Even though males were slightly heavier than females during pre-weaning period and up to 5 months of age, females were slightly heavier from the 6th month. However, most of the differences were found to be non-significant. Significant effect of sex on post-weaning weights was reported by [8]. Litter size at birth significantly influenced both the pre and post weaning body weights at all ages. The mean body weight decreased as the litter size at birth increased and possibly due to competition for the resources within the litter. Parity significantly influenced the pre-weaning body weights except at birth and at weaning. The mean body weight of piglets of parity 1 was more than the mean body weight of piglets of parity 2 during pre-weaning period. Similar finding was reported by [7]. As far as post-weaning body weights were concerned, the difference in mean body weights were not significant after 5 months of age. Period of birth had a significant effect on both the pre-weaning and post-weaning mean body weights. The mean body weight increased as the period increased for all ages indicating clearly the constant improvement in management practices over the years yielding good results. Season of birth had a significant effect on the mean body weight of all ages except during first and second week of age. Significant effect of season of birth on the pre-weaning body weights were reported by [6, 9].

Average Daily Gain

The overall least squares mean Average Daily Gains (ADG in kgs.) ± SE during 0-1, 1-2, 2- 3, 3-4, 4-5, 5-6, 6-7, 7-8, 0-8, 8-12, 12-16, 16-20, 20-24, 24-28, 28-32, 32-36, 8-36 weeks were 0.123 ± 0.004, 0.118 ± 0.004, 0.117 ± 0.005, 0.137 ± 0.006, 0.138 ± 0.006, 0.152 ± 0.006, 0.155 ± 0.007, 0.191 ± 0.10, 0.135 ± 0.002, 0.119 ± 0.005, 0.164 ± 0.006, 0.180 ± 0.007, 0.318 ± 0.010, 0.249 ± 0.009, 0.201 ± 0.012, 0.272 ± 0.010 and 0.255 ± 0.005 respectively (Table 3 and 4) with the maximum average daily gain of 318 gms during 5th to 6th month of age. The effect of genetic group was not significant during pre-weaning periods except during 0-1 and 0-8 weeks while the genetic group had a significant effect during most of the post-weaning periods. The 75% CB recorded faster growth of 140 gms/day and 282 gms/day during pre-weaning (0-8 weeks) and post weaning (8-36 weeks) periods as against 130 gms/day and 229 gms/day for 50% CB during the corresponding periods. There was no significant difference in ADG observed between the two sexes during the pre-weaning period and some of the post-weaning periods. However, there was no clear association between gender and ADG. Parity significantly influenced ADG for most of the pre and post-weaning periods except 6-7 and 0-8. The ADG during birth to weaning was 136 gms for parity 1 and 135 gms for parity 2+. Similarly, the ADG during 8-36 weeks was 267 gms for parity 1 and 244 gms for parity 2. Season and Period of birth had a significant effect on the ADG during most of the age periods studied.

3.2 Heritability, Genotypic and Phenotypic correlations

The mixed full-sib model considering genetic group, sex, parity, season of birth, litter size at birth as fixed effects were used to estimate the heritability ± SE for body weights recorded at birth, 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, 12th, 16th, 20th, 24th, 28th, 32nd and 36th week. The results obtained are represented in the diagonal elements of Table 5. The heritability estimates using sire and dam component for the body weights at birth, 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, 12th, 16th, 20th, 24th, 28th and 36th week were 0.718, 0.834, 0.683, 0.691, 0.577, 0.597, 0.647, 0.632, 0.880, 0.851, 0.966, 0.907, 0.889 and 0.854. The estimate obtained for 32nd week was outside the range. The estimates of heritability indicate that post-weaning body weights are more heritable than pre-weaning body weights. Selection for body weights may be very effective from 3rd month.

The estimates of genetic and phenotypic correlation between the bodyweights recorded at various ages obtained through full-sib mixed model are given in upper and lower diagonals respectively of Table 5. The general trend is that as the time gap increases, both the genetic and phenotypic correlation decreases. Estimated genetic correlations among pre-weaning bodyweights were positive and low in magnitude while among post-weaning body weights, genetic correlations were high positive. The genetic correlation between birth weight and 3rd month is 0.422 and between 3rd month and 36th month is 0.553. The finding suggests that birth weight together with 12th week body weight can be used for selection to bring about increased body weight at 36th week.

IV. Tables

Table 1: Least-squares mean ± standard error of pre-weaning body weight (kg) of crossbred pigs (Number of observations in parentheses)

Fixed Effect	**Birth Weight** (1405)	**BW1** (967)	**BW2** (965)	**BW3** (1071)	**BW4** (954)
Overall	1.091± .012	1.979± .034	2.827± .046	3.845± .059	4.628± .073
Genetic Group	**	NS	NS	NS	NS
50% CB	1.028± .015^{a}(388)	1.986± .039(357)	2.805± .053(356)	3.804± .070(357)	4.591± .084(357)
75% CB	1.154± .013^{b}(1022)	1.972± .037(610)	2.849± .051(609)	3.886± .066(714)	4.666± .081(597)
Sex of Piglet	*	NS	NS	NS	NS
Male	1.106± .013^{a} (768)	2.003± .036 (498)	2.847± .050 (496)	3.836± .066 (540)	4.662± .080 (485)
Female	1.076± .013^{b} (637)	1.955± .038 (469)	2.807± .052 (469)	3.854± .065 (531)	4.595± .083 (469)
Litter Size at Birth	NS	NS	**	**	**
1-3	1.121± .027^{a}(70)	2.077± .068(66)	3.092± .093^{a}(64)	4.360± .129^{a}(63)	5.449± .149^{a}(63)
4-6	1.102± .015^{a}(350)	1.981± .041(259)	2.868± .056^{a}(259)	3.929± .073^{b}(279)	4.825± .088^{b}(257)
7-9	1.084± .013^{a}(669)	1.981± .034(508)	2.757± .047^{ba}(508)	3.667± .061^{c}(551)	4.342± .074^{c}(501)
10+	1.057± .016^{a}(316)	1.878± .054(134)	2.592± .073^{b}(134)	3.422± .089^{d}(178)	3.898± .115^{d}(133)
Parity	*	**	**	**	**
1	1.095± .012(902)	2.080± .039^{a}(636)	3.042± .053^{a}(635)	4.270± .062^{a}(745)	5.106± .085^{a}(626)
2+	1.087± .014(503)	1.878± .041^{b}(331)	2.612± .056^{b}(330)	3.419± .078^{b}(326)	4.150± .089^{b}(328)
Season of Birth	**	NS	NS	**	NS
Summer(3-5)	1.086± .014^{a} (484)	1.889± .053 (397)	2.770± .072 (397)	3.266± .071^{a} (392)	4.429± .113 (394)
Pre-Monsoon(6-8)	1.062± .017^{a} (277)	2.004± .063 (142)	2.840± .086 (142)	4.070± .101^{b} (142)	4.659± .135 (142)
Monsoon (9-11)	1.158± .012^{b} (602)	1.979± .045 (386)	2.790± .061 (385)	4.022± .059^{b} (502)	4.563± .096 (380)
Winter(12-2)	1.058± .036^{a} (42)	2.044± .089 (42)	2.908± .122 (41)	4.020± .172^{b} (35)	4.863± .198 (38)
Period of Birth	NS	**	**	**	**
2002-2005	1.081± .013^{a}(654)	1.823± .042 (528)	2.600± .057^{a}(526)	3.087± .064^{a} (515)	4.035± .090^{a} (518)
2006-2011	1.101± .016^{b}(751)	2.136± .070 (439)	3.054± .094^{b}(439)	4.602± .084^{b} (556)	5.222± .149^{b} (436)

NS – not significant; * significant (P<0.05); ** significant (P<0.01)

Means with different superscripts under each effect within the column differ significantly.

Table 1 (cont.): Least-squares mean ± standard error of pre-weaning body weight (kg) of crossbred pigs (Number of observations in parentheses)

Fixed Effect	**BW5** (1089)	**BW6** (1099)	**BW7** (1055)	**BW8** (1405)
Overall	5.641± .077	6.598± .087	7.823± .105	9.264± .119
Genetic Group	NS	**	NS	**
50% CB	5.581± .094(357)	6.567± .106^{a}(357)	7.750± .128(357)	9.046± .150^{a}(383)
75% CB	5.702± .085(732)	6.628± .098^{b}(742)	7.896± .116(698)	9.483± .130^{b}(1022)
Sex of Piglet	NS	NS	NS	*
Male	5.648± .087 (559)	6.618± .097 (604)	7.858± .118 (550)	9.385± .133^{a} (768)
Female	5.635± .087 (530)	6.577± .101 (495)	7.789± .120 (505)	9.143± .136^{b} (637)
Litter Size at Birth	**	**	**	**
1-3	6.845± .171^{a}(66)	7.907± .195^{a}(66)	9.195± .233^{a}(66)	10.509 ± .281^{a}(70)
4-6	5.863± .098^{b}(280)	6.908± .110^{b}(291)	8.002± .136^{b}(268)	9.521 ± .152^{b}(350)
7-9	5.247± .081^{c}(564)	6.207± .093^{c}(557)	7.408± .113^{c}(530)	8.805 ± .130^{c}(669)
10+	4.611± .122^{d}(179)	5.368± .139^{d}(185)	6.688± .162^{d}(191)	8.222 ± .167^{d}(316)
Parity	**	**	**	NS
1	6.243± .081^{a}(759)	7.279± .091^{a}(769)	8.413± .114^{a}(702)	9.381± .129(902)
2+	5.040± .104^{b}(330)	5.916± .117^{b}(330)	7.233± .138^{b}(353)	9.147± .148(503)
Season of Birth	**	NS	*	**
Summer(3-5)	5.272± .097^{a}(396)	6.331± .111(446)	7.237± .140^{a} (419)	8.597± .146^{a}(484)
Pre-Monsoon(6-8)	5.640± .138^{ab}(142)	6.487± .144(162)	8.064± .192^{b}(142)	9.523± .177^{b}(277)

Monsoon (9-11)	5.627± .080[b](509)	6.543± .099(449)	7.817± .116[b] (452)	9.500± .122[b](602)
Winter(12-2)	6.026± .217[b](42)	7.030± .249(42)	8.174± .297[b](42)	9.437± .369[ab](42)
Period of Birth	**	**	**	**
2002-2005	4.826± .088[a] (528)	5.686± .103[a] (528)	6.637± .123[a] (528)	8.367± .133[a] (654)
2006-2011	6.457± .113[b] (561)	7.509± .132[b] (571)	9.009± .169[b] (527)	10.162± .166[b] (751)

NS – not significant; * significant (P<0.05); ** significant (P<0.01)
Means with different superscripts under each effect within the column differ significantly.

Table 2: Least-squares mean ± standard error of post-weaning body weight (kg) of crossbred pigs (Number of observations in parentheses)

Fixed Effect	**BW12** (981)	**BW16** (874)	**BW20** (773)	**BW24** (716)
Overall	13.244± .214	18.276± .352	24.256± 0.509	34.458± 0.660
Genetic Group	**	**	**	**
50% CB	12.763± .273[a](260)	17.427± .454[a](246)	22.501±0.659[a](224)	32.531±0.860[a](200)
75% CB	13.725±.240[b](721)	19.125±.394[b](628)	26.011±0.568[b](549)	36.386±0.746[b](516)
Sex of Piglet	NS	NS	*	NS
Male	13.246± .236 (536)	18.461± .392(461)	24.917± 0.575(392)	34.070± 0.754(353)
Female	13.242± .247 (445)	18.090± .411(413)	23.595± 0.592(381)	34.847± 0.770(363)
Litter Size at Birth	**	NS	NS	NS
1-3	13.831± .536[a](48)	18.399± 0.888(45)	25.605± 1.309(40)	36.741± 1.758(36)
4-6	13.683± .28[ab](244)	18.290±0.467(222)	23.954±0.665(207)	33.031±0.885(186)
7-9	12.816± .24[ac](459)	17.821± .398(404)	23.114 .573(360)	32.839± 0.745(343)
10+	12.645± .29[ac](230)	18.593± .497(203)	24.351±.737(166)	35.222±0.975(151)
Parity	**	**	**	NS
1	12.754± .221[a](704)	17.062± .369[a](612)	22.744± .558[a](520)	34.270± 0.738(464)
2+	13.734± .282[b](277)	19.489± .466[b](262)	25.768± .661[b](253)	34.647± 0.852(252)
Season of Birth	**	**	**	**
Summer(3-5)	12.473± .32[ab](194)	17.005± .529[a](187)	24.129±0.789[a](156)	37.595±1.086[a](128)
Pre-Monsoon(6-8)	13.678± .298[b](273)	19.630± .519[b](230)	25.454±0.811[a](195)	35.278±1.066[a](194)
Monsoon (9-11)	14.257± .209[b](476)	19.789± .351[b](420)	27.177±0.511[ba](387)	37.241±0.687[a](358)
Winter(12-2)	12.568± .605[ab](38)	16.68± 0.990[a](37)	20.265± 1.413[ab](35)	27.720±1.802[b] (36)
Period of Birth	**	**	**	**
2002-2005	11.540± .230[a](547)	15.918± .382[a](494)	21.724±0.557[a](456)	31.836±0.733[a](429)
2006-2011	14.948± .300[b](434)	20.634± .507[b](380)	26.788±0.750[b](317)	37.081±0.979[b](287)

NS – not significant ; * significant (P<0.05); ** significant (P<0.01).
Means with different superscripts under each effect within the column differ significantly.

Table 2 (contd.): Least-squares mean ± standard error of post-weaning body weight (kg) of crossbred pigs (Number of observations in parentheses)

Fixed Effect	**BW28** (692)	**BW32** (603)	**BW36** (445)
Overall	42.411±0.789	48.491± 1.018	59.936± 0.983
Genetic Group	**	**	**
50% CB	40.262±1.030[a](192)	45.019±1.319[a](164)	53.912±1.352[a](123)
75% CB	44.560±0.877[b](500)	51.964±1.107[b](439)	65.959±1.100[b](322)
Sex of Piglet	**	NS	NS
Male	41.006± 0.904[a](339)	47.637±1.183[a](290)	59.419±1.224(220)
Female	43.816± 0.915[b](353)	49.346±1.152[b](313)	60.452±1.138(225)
Litter Size at Birth	**	*	NS
1-3	45.481± 2.084[a](34)	51.620±2.691[a](28)	63.923±3.254(17)
4-6	39.939±1.038[a](184)	45.681±1.293[ab](167)	57.829±1.259(114)
7-9	40.172± 0.895[a](326)	46.164±1.143[a](282)	58.117±1.003(210)
10+	44.051±1.143[ab](148)	50.501±1.441[ac](126)	59.874±1.454(104)
Parity	NS	NS	*
1	43.179± 0.882[a](446)	49.469±1.135(373)	61.789±1.252[a](241)
2+	41.643± 1.011[b](246)	47.513±1.283(230)	58.082±1.194[b](204)
Season of Birth	**	**	**
Summer(3-5)	46.554±1.269[a](127)	49.571±1.573[a](120)	57.247±1.720[a](98)
Pre-Monsoon(6-8)	47.700±1.247[a](194)	54.418±1.524[a](188)	58.842±1.733[a](161)
Monsoon (9-11)	45.440±0.815[a](338)	53.918±1.058[a](267)	63.718±1.172[b](186)
Winter(12-2)	31.950±2.171[b](33)	36.058±2.786[b](28)	-
Period of Birth	**	**	**
2002-2005	38.480±0.869[a](420)	43.573±1.117[a](380)	56.676±1.286[a](261)
2006-2011	46.342±1.174[b](272)	53.409±1.523[b](223)	63.195±1.479[b](184)

NS – not significant ; * significant (P<0.05); ** significant (P<0.01).
Means with different superscripts under each effect within the column differ significantly

Table 3: Least-squares mean ± standard error of pre-weaning Average Daily Gains (kgs.) of crossbred pigs (Number of observations in parentheses)

Fixed Effect	**ADG01** (967)	**ADG12** (965)	**ADG23** (948)	**ADG34** (946)
Overall	0.128± .004	0.121± .004	0.122± .005	0.139± .005
Genetic Group	**	NS	NS	NS
50% CB	0.137± .005[a](357)	0.117± .005(356)	0.121± .006(356)	0.137± .006(357)
75% CB	0.119± .005[b](610)	0.125± .005(609)	0.124± .005(592)	0.141± .006(589)
Sex of Piglet	NS	NS	NS	NS
Male	0.130± .005 (498)	0.121± .005 (496)	0.122± .005 (479)	0.143± .006 (477)
Female	0.126± .005 (469)	0.122± .005 (469)	0.123± .005 (469)	0.135± .006 (469)
Litter Size at Birth	NS	**	**	**
1-3	0.137± .008(66)	0.145± .009[a](64)	0.165± .010[a](62)	0.181± .010[a](63)
4-6	0.126± .005(259)	0.127± .005[a](259)	0.130± .006[b](257)	0.152± .006[b](257)
7-9	0.129± .004(508)	0.111± .004[b](508)	0.113± .005[c](496)	0.117± .005[c](493)
10+	0.120± .007(134)	0.102± .007[b](134)	0.082± .008[d](133)	0.105± .008[c](133)
Parity	**	**	**	**
1	0.140± .005[a](636)	0.138± .005[a](635)	0.140± .006[a](623)	0.158± .006[a](620)
2+	0.117± .005[b](331)	0.105± .005[b](330)	0.105± .006[b](325)	0.120± .006[b](326)
Season of Birth	NS	NS	NS	**
Summer(3-5)	0.115± .007 (397)	0.126± .007(397)	0.127± .007 (392)	0.113± .008[a] (392)
Pre-Monsoon(6-8)	0.135± .008 (142)	0.119± .008(142)	0.125± .009 (142)	0.135± .009[a] (142)
Monsoon (9-11)	0.120± .006 (386)	0.116± .006 (385)	0.127± .006 (379)	0.126± .007[a] (377)
Winter(12-2)	0.143± .011 (42)	0.124± .012 (41)	0.112± .013 (35)	0.182± .014[b] (35)
Period of Birth	**	NS	**	**
2002-2005	0.107± .005[a](528)	0.111± .005(526)	0.103± .006[a](514)	0.107± .006[a](512)
2006-2011	0.149± .009[b](439)	0.131± .009(439)	0.141± .010[b](434)	0.171± .010[b](434)

NS – not significant ; * significant (P<0.05); ** significant (P<0.01).
Means with different superscripts under each effect within the column differ significantly.

Table 3 (contd.): Least-squares mean ± standard error of pre-weaning Average Daily Gains (kg) of crossbred pigs (Number of observations in parentheses)

Fixed Effect	**ADG45** (953)	**ADG56** (1023)	**ADG67** (966)	**ADG78** (1055)	**ADG08** (1405)
Overall	0.152± .006	0.156± .006	0.162± .007	0.204± .010	0.146± .002
Genetic Group	NS	*	NS	NS	*
50% CB	0.147± .007(357)	0.163± .007 [a] (357)	0.157± .008(357)	0.199± .012(357)	0.143± .003[a](383)
75% CB	0.157± .006(596)	0.149± .007 [b] (666)	0.167± .008(609)	0.209± .011(698)	0.149± .002[b](1022)
Sex of Piglet	NS	NS	NS	NS	NS
Male	0.150± .006 (485)	0.154± .007 (528)	0.158± .008 (498)	0.211± .011 (550)	0.148± .002 (768)
Female	0.155± .006 (468)	0.158± .007 (495)	0.166± .008 (468)	0.197± .011 (505)	0.144± .002 (637)
Litter Size at Birth	**	NS	**	NS	**
1-3	0.213± .012[a](63)	0.171± .013(66)	0.179± .014[a](66)	0.197± .022 (66)	0.168± .005[a](70)
4-6	0.158± .007[b](256)	0.151± .008(270)	0.178± .009[a](258)	0.209± .013 (268)	0.150± .003[b](350)
7-9	0.141± .006[b](501)	0.158± .006(543)	0.156± .007[ab](508)	0.204± .011 (530)	0.138± .002[c](669)
10+	0.096± .009[c](133)	0.143± .010(144)	0.136± .011[ab] (134)	0.204± .015 (191)	0.128± .003[d](316)
Parity	**	**	NS	*	NS
1	0.175± .007[a](626)	0.168± .007 [a] (693)	0.168± .008(636)	0.188± .011[a](702)	0.148± .002(902)
2+	0.129± .007[b](327)	0.144± .008 [b](330)	0.156± .009(330)	0.219± .013[b](353)	0.144± .003(503)
Season of Birth	**	**	**	**	**
Summer(3-5)	0.101± .009[a] (393)	0.111± .008 [a](396)	0.116± .011[a] (396)	0.113± .013 [a](419)	0.134± .003[a](484)
Pre-Monsoon(6-8)	0.152± .011[b](142)	0.182± .011 [b](142)	0.192± .013[b](142)	0.215± .018 [b](142)	0.151± .003[b](277)
Monsoon (9-11)	0.163± .008[b](380)	0.156± .007 [b](443)	0.183± .010[b](386)	0.269± .011 [cb](452)	0.149± .002[b](602)
Winter(12-2)	0.191± .016[b](38)	0.175± .017 [b](42)	0.156± .019 [ab](42)	0.218± .028 [c](42)	0.150± .006[ab](42)
Period of Birth	**	**	**	**	**
2002-2005	0.101± .007[a](518)	0.110± .007[a](528)	0.112± .009[a](528)	0.157± .012[a](528)	0.130± .002[a](654)
2006-2011	0.203± .012[b](435)	0.202± .010[b](495)	0.211± .015[b](438)	0.250± .016[b](527)	0.162± .003[b](751)

NS – not significant; * significant (P<0.05); ** significant (P<0.01)
Means with different superscripts under each effect within the column differ significantly.

Table 4: Least-squares mean ± standard error of post-weaning Average Daily Gains (kg) of crossbred pigs (Number of observations in parentheses)

Fixed Effect	**ADG812** (981)	**ADG1216** (871)	**ADG1620** (762)	**ADG2024** (705)
Overall	0.120± .005	0.163± .007	0.179± .008	0.318± .010
Genetic Group	NS	**	**	NS
50% CB	0.114± .006(260)	0.148± .009[a](246)	0.145± .010[a](221)	0.308± .014(197)
75% CB	0.126± .006(721)	0.178± .007[b](625)	0.213± .009[b](541)	0.327± .012(508)

Sex of Piglet	NS	NS	NS	**
Male	0.115± .005(536)	0.166± .007(458)	0.185± .009(384)	0.271± .012^{a}(348)
Female	0.125± .006(445)	0.160± .008(413)	0.173± .009(378)	0.365± .012^{b}(357)
Litter Size at Birth	**	**	**	NS
1-3	0.106± .012^{a}(48)	0.151± .017^{a}(45)	0.219± .020^{a}(40)	0.343± .028(35)
4-6	0.121± .006^{a}(244)	0.154± .009^{ab}(222)	0.172± .010^{a}(203)	0.286± .014(185)
7-9	0.116± .005^{ab}(459)	0.162± .007^{a}(404)	0.159± .009^{ba}(356)	0.311± .012(338)
10+	0.137± .007^{ac}(230)	0.185± .009^{ac}(200)	0.166± .011^{a}(163)	0.330± .015(147)
Parity	**	**	NS	**
1	0.109± .005^{a}(704)	0.133± .007^{a}(609)	0.169± .009(518)	0.345± .012^{a}(453)
2+	0.131± .006^{b}(277)	0.193± .009^{b}(262)	0.189± .010(244)	0.291± .013^{b}(252)
Season of Birth	**	NS	**	**
Summer(3-5)	0.092± .007^{b} (194)	0.158± .010 (187)	0.198± .013^{a} (147)	0.394± .017^{a} (128)
Pre-Monsoon(6-8)	0.145± .007^{a} (273)	0.180± .010(230)	0.165± .013^{ac} (195)	0.310± .017^{b} (194)
Monsoon (9-11)	0.149± .005^{a} (476)	0.178± .007(417)	0.240± .008^{b}(385)	0.325± .011^{bc}(351)
Winter(12-2)	0.093± .014^{b} (38)	0.136± .019 (37)	0.113± .022^{c}(35)	0.243± .029^{bd}(32)
Period of Birth	**	**	NS	NS
2002-2005	0.091± .005^{a}(547)	0.143± .007^{a}(494)	0.180± .009(456)	0.313± .011(425)
2006-2011	0.150± .007^{b}(434)	0.183± .010^{b}(377)	0.178± .012(306)	0.322± .015(280)

NS – not significant ; * significant (P<0.05); ** significant (P<0.01).
Means with different superscripts under each effect within the column differ significantly.

Table 4 (contd.): Least-squares mean ± standard error of post-weaning Average Daily Gains (kg) of crossbred pigs (Number of observations in parentheses)

Fixed Effect	**ADG2428** (686)	**ADG2832** (601)	**ADG3236** (445)	**ADG836** (445)
Overall	0.250± .010	0.195± .013	0.276± .012	0.255± .005
Genetic Group	NS	**	*	**
50% CB	0.243± .013(192)	0.173± .016^{a}(162)	0.251± .017^{a}(123)	0.227± .007^{a}(123)
75% CB	0.258± .011(494)	0.217± .014^{b}(439)	0.301± .014^{b}(322)	0.284± .005^{b}(322)
Sex of Piglet	**	*	NS	NS
Male	0.221± .011^{a}(338)	0.211± .015^{a} (288)	0.276± .015(220)	0.251± .006(220)
Female	0.280± .011^{b}(348)	0.179± .014^{b} (313)	0.276± .014(225)	0.259± .006(225)
Litter Size at Birth	NS	NS	NS	NS
1-3	0.282± .026(34)	0.186± .033(28)	0.297± .040(17)	0.269± .016(17)
4-6	0.227± .013(184)	0.185± .016(165)	0.275± .016(114)	0.242± .006(114)
7-9	0.237± .011(326)	0.188± .014(282)	0.277± .012(210)	0.249± .005(210)
10+	0.256± .014(142)	0.223± .018(126)	0.256± .018(104)	0.261± .007(104)
Parity	**	NS	**	**
1	0.273± .011(440)	0.210± .014(373)	0.302± .016^{a}(241)	0.266± .006^{a}(241)
2+	0.228± .012(246)	0.181± .016(228)	0.251± .015^{b}(204)	0.245± .006^{b}(204)
Season of Birth	**	**	NS	**
Summer(3-5)	0.316± .016^{a}(127)	0.169± .019^{a} (120)	0.296± .021(98)	0.238± .009^{a} (98)
Pre-Monsoon(6-8)	0.321± .015^{a}(194)	0.256± .019^{b} (187)	0.248± .021(161)	0.253± .009^{a} (161)
Monsoon (9-11)	0.260± .010^{b}(332)	0.277± .013^{b}(266)	0.285± .015(186)	0.275± .006^{b}(186)
Winter(12-2)	0.104± .027^{c}(33)	0.079± .034^{a}(28)	-	-
Period of Birth	**	NS	NS	**
2002-2005	0.226± .011^{a}(419)	0.208± .014(380)	0.295± .016(261)	0.241± .006^{a}(261)
2006-2011	0.275± .015^{b}(267)	0.182± .019(221)	0.257± .018(184)	0.269± .007^{b}(184)

NS – not significant ; * significant (P<0.05); ** significant (P<0.01).
Means with different superscripts under each effect within the column differ significantly.

Table 5: Full-sib estimates of heritability and genetic correlation along with standard error for body-weight at several ages (weeks) of crossbred pigs (using REML method of estimation)

Week	0	1	2	3	4	5	6	7	8	12	16	20	24	28	32	36
0	**0.718** (0.009)	0.308 (.012)	0.386 (.0112)	0.393 (.010)	0.406 (.011)	0.293 (.011)	0.229 (.011)	0.230 (.012)	0.297 (.008)	**0.422** (.011)	0.363 (.014)	0.414 (.014)	0.366 (.016)	0.365 (.016)	0.355 (.020)	0.228 (.031)
1	0.427	0.834 (0.015)	0.809 (.005)	0.628 (.008)	0.543 (.009)	0.376 (.011)	0.344 (.011)	0.257 (.012)	0.115 (.013)	-0.106 (.022)	-0.058 (.024)	0.005 (.027)	0.052 (.030)	0.078 (.031)	0.004 (.037)	0.403 (.050)
2	.0.383	0.735	0.683 (0.01	0.880 (.003	0.824 (.004	0.618 (.008	0.619 (.008	0.578 (.009	0.472 (.010	-0.033	0.022 (.025	0.085 (.027	0.116 (.030	0.205 (.030	0.075 (.03	0.444 (.048

			2)	)	)	)	)	)	)	(.026)	)	)	)	)	6)	)
3	0.381	0.611	0.830	0.691 (0.011)	0.878 (.003)	0.705 (.006)	0.664 (.007)	0.562 (.008)	0.467 (.009)	0.200 (.019)	0.194 (.021)	0.226 (.022)	0.154 (.027)	0.175 (.029)	0.048 (.036)	0.388 (.050)
4	0.332	0.522	0.733	0.851	0.577 (0.011)	0.911 (.002)	0.815 (.004)	0.739 (.006)	0.578 (.009)	0.408 (.019)	0.277 (.022)	0.219 (.026)	0.069 (.031)	0.116 (.032)	0.033 (.037)	0.370 (.053)
5	0.291	0.435	0.624	0.752	0.879	0.597 (0.010)	0.910 (.002)	0.842 (.003)	0.711 (.006)	0.433 (.015)	0.293 (.020)	0.265 (.023)	0.055 (.027)	0.051 (.029)	0.035 (.036)	0.185 (.059)
6	0.265	0.412	0.587	0.676	0.796	0.868	0.599 (0.010)	0.915 (.002)	0.772 (.005)	0.418 (.016)	0.302 (.020)	0.290 (.024)	0.024 (.030)	0.121 (.031)	-0.071 (.036)	0.168 (.063)
7	0.251	0.357	0.530	0.616	0.718	0.804	0.882	0.647 (0.011)	0.863 (.003)	0.503 (.015)	0.298 (.021)	0.270 (.024)	0.035 (.028)	0.235 (.029)	0.001 (.036)	0.203 (.056)
8	0.270	0.300	0.464	0.535	0.625	0.682	0.760	0.861	0.632 (0.008)	0.609 (.007)	0.399 (.013)	0.303 (.016)	0.122 (.019)	0.154 (.019)	0.051 (.022)	0.065 (.032)
12	0.282	0.022	0.101	0.281	0.372	0.437	0.460	0.535	0.678	**0.880** (0.016)	0.917 (.002)	0.887 (.004)	0.744 (.008)	0.791 (.007)	0.772 (.009)	**0.553** (.024)
16	0.224	0.006	0.102	0.229	0.280	0.301	0.333	0.372	0.486	0.833	0.851 (0.018)	0.927 (.002)	0.838 (.006)	0.859 (.005)	0.838 (.007)	0.678 (.019)
20	0.221	0.016	0.090	0.198	0.201	0.229	0.250	0.271	0.377	0.744	0.858	0.966 (0.023)	0.958 (.002)	0.934 (.000)	0.941 (.003)	0.812 (.012)
24	0.159	0.022	0.082	0.162	0.135	0.125	0.157	0.188	0.258	0.587	0.707	0.868	0.907 (0.024)	0.952 (.002)	0.944 (.003)	0.913 (.006)
28	0.168	0.037	0.114	0.165	0.134	0.111	0.155	0.223	0.208	0.547	0.657	0.796	0.902	0.889 (0.024)	0.943 (.003)	0.929 (.005)
32	0.188	0.008	0.048	0.085	0.071	0.085	0.095	0.153	0.189	0.550	0.606	0.773	0.861	0.910	$	$
36	0.163	0.148	0.182	0.191	0.127	0.078	0.126	0.211	0.193	0.440	0.512	0.665	0.785	0.864	0.906	0.854 (0.042)

Diagonal elements represent heritability, above diagonal elements represent genetic correlation and below diagonal elements represent phenotypic correlation

V. Conclusion

In crossbred pigs, sex of piglet, genetic group did not show marked influence on all pre-weaning body weight measurements except at birth and weaning. Litter size, parity, season of birth and period of birth showed significant effect on the average body weights during pre-weaning periods. However, for post-weaning periods, except for gender, all other factors had a significant effect on average body weights. Similar pattern was observed even for the average daily gains during the pre and post weaning periods. The estimates of heritability indicate that post-weaning body weights are more heritable than pre-weaning body weights. Estimated genetic correlations among pre-weaning bodyweights were positive and low in magnitude while among post-weaning body weights, genetic correlations were high positive. The genetic correlation between birth weight and 3rd month is 0.422 and between 3rd month and 36th month is 0.553. The estimates of phenotypic correlation between different ages were positive. The finding suggests that birth weight together with 12th week body weight can be used for selection to bring about increased body weight at 36th week.

Acknowledgement

The authors are thankful to Tamil Nadu Veterinary and Animal Sciences University, Chennai, India for providing the research facilities for conducting this study.

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