MATERIALS AND METHODS

Location and Environmental Conditions:

The Institute is located at 26° 17' north latitude and 75° 22' 30" east longitude. The maximum summer temperature goes up to 45°C, while in winter the temperature goes down to 3°C. The area is exposed to hot dry winds from April to June with lot of dust in the atmosphere. During winter light frost is observed. Diurnal temperature variation is large throughout the year. Relative humidity starts rising in the later part of June or early July. The average annual rainfall based on the data from 1966 to 1977 is about 95 cm. The distribution of rain over different months is highly erratic but usually the larger part of it is received in the months from July to September. Winter rains are rather uncommon.

Management of Flock:

All the animals under the project were maintained at one sector. The housing and general management including grazing and supplementary feeding was similar to all animals.

a) Housing: The animals were housed in asbestos roofed sheds of 20 metres x 7 metres with 20 metres x 10 metres chain linked fenced corrals.

b) Grazing and supplementary feeding: Grazing was done from July to November in the forest area on natural vegetation most of which comprised of Aristida ascensionis, Ergroatis ciliaris, Perotis lordaiformis, Digitaria
adscendens, Cenchrus biflorus, Ziziphus numularia. Indigofera linnert etc., and was considered satisfactory. After harvesting of rainfed cultivated fodders mainly Cowpea and grasses from reseeded Cenchrus pastures, the flocks were allowed to graze on the Cowpea stubble and the grass pasture. Some irrigated cultivated fodder was also given to supplement grazing especially to younger stock and pregnant and lactating ewes. The period from February to June was observed to be the lean period when natural grazing was very scanty and some hay (Cenchrus, Cowpea and Dolichos) and Pela (dry leaves of Ziziphus numularia) were given to supplement grazing and top feeding. Ewes were given 1/2 kg and rams 1 kg of hay per day.

During lean months, lopping of Prosopis cineraria (Khejri), Acacia arabica, Acacia tortilis (Babool), Acacia senegal (Kheri), Gymnosporia spinosa (Kankera) and Azadirachta indica (Neem) was done and fed to the animals. Rams during the breeding season were given 300 g of concentrate mixture (Maize 50 %, Oats 8 %, Groundnut cakes 30 %, Wheat bran 10 % and Mineral mixture 2 %) having 68 % T.D.N. and 18 % D.C.P. The ewes in the last month of pregnancy and first month of lactation were given 350 g of concentrate mixture (given above) per head per day and during second and third months of lactation were given 250 g of concentrate. Lambs were given 50 g to 100 g of concentrate during first month and 250 g during second and third months of life. From weaning (90 days) to six months (180 days) of age 350 g of concentrate was given.
c) **Care and management of lambing ewes and lambs:** The ewes about to lamb were separated and kept in individual pens of approximately 1 sq. metre to have proper identification of the lambs and to avoid mis-mothering and disowning of lambs. This also helped in checking the milk yield and mothering instinct of ewes. All lambs were ear-tagged for identification.

d) **Health coverage:** The animals were dipped in one of the following medicinal dips:

0.15% Carathion, 0.5% D.D.T., 0.25% Malathion/Sumithion solutions, approximately 15 days after shearing in a cemented tank having 4000 litres capacity.

The general diseases encountered were sheep pox, enterotoxaemia, pneumonia, mange and gastro-intestinal helminthiasis. A regular vaccination and drenching schedule was followed throughout the year. Vaccination was done against sheep pox and clostridial group of organisms using a multicomponent vaccine. Post-mortem examination was performed on all the dead animals to determine the probable cause of death.

e) **Docking and shearing:** Docking of all the lambs was done during the first month of their life. Shearing of flock was done twice a year (Autumn and Spring) with electrical shearing machines.

f) **Feed lot management:** After weaning, almost all males were transferred to feed lot experiment. The male lambs were put in individual feed lot pens of 1 sq.m on 91st day and were offered *ad libitum* concentrate mixture and hay
till they attained 180 day of age. In the year 1973, the animals were given ad libitum concentrate mixture in form of mash and Pala leaves separately. During the year 1974 the animals were grouped into three groups and were given high, low and medium energy crushed concentrate mixture and Pala leaves separately and thereafter these animals were fed on medium energy ration upto 1977 with concentrate roughage ratio of 70:30. Prior to putting them in the experiment all the lambs were vaccinated against enterotoxaemia and were dewormed.

The male progeny in the feed lot were either slaughtered or culled excepting those selected as replacement breeding stocks. Female lambs were generally not culled unless weak, debilitated or off type and this generally did not exceed 5 percent.

f) Data: The data of the present investigation pertains to the experimental breeding flock under the All India Coordinated Research Project (AICRP) on Sheep Breeding (for mutton) unit located at CSWRI, Avikanagar. 400 Malpura ewes were available for breeding during Autumn, 1971 and subsequently another 300 Malpura and 700 Sonadi animals were purchased from their home tracts between 1973 and 1976. Majority of the animals were of 1½ to 2½ years of age and were purchased on the basis of their conformity to the breed characteristics and being free from any physical defect or any apparent ill health. They were purchased from a number of flocks spread over a large part of the breeding tract to have a good representation of the breed and a broad genetic base.
The lambs belonging to Malpura and Sonadi breeds born during Spring, 1972 through Autumn, 1976 lambing seasons were included in the growth studies. Animals born from Spring, 1973 through Spring, 1977 were included in the carcass studies and animals born from Spring, 1974 through Spring, 1977 were included in the feed efficiency studies. In all, data on 1110 Malpura and 425 Sonadi lambs representing progenies of 38 and 15 sires, respectively, were available. The distribution of animals in different years and seasons of birth of the two breeds is presented in Table 12.

The breeding was restricted to Spring (February-March) and Autumn (August-September) seasons. Majority of the ewes got tupped in the Autumn season. Hand-mating was practiced. The heat detection was carried out daily for about one hour both in morning and evening by using aproned entire rams. The breeding seasons ran usually over three oestrous cycles. Allotment of ewes to the rams was done at random and in a manner that maximum sires could be used. Generally sires were used consecutively for two to three breeding seasons only.

Experimental Procedures:

Recording, sampling and generation of data:

1) Body weights: Ewes were weighed at the time of breeding and within 24 hours after lambing. Birth weight was recorded within 24 hours of lambing usually after the lambs coat had dried up. Subsequently the lambs were weighed at weekly intervals up to six months of age. The
Table 12: Year, season and sex wise distribution of animals of Malpura and Sonadi breeds.

<table>
<thead>
<tr>
<th>Year</th>
<th>Growth Malpura</th>
<th>Sonadi</th>
<th>Carcass studies Malpura</th>
<th>Sonadi</th>
<th>Feed efficiency Malpura</th>
<th>Sonadi</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1110</td>
<td>428</td>
<td>212</td>
<td>110</td>
<td>146</td>
<td>84</td>
</tr>
<tr>
<td>1972</td>
<td>261</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1973</td>
<td>386</td>
<td>61</td>
<td>84</td>
<td>14</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1974</td>
<td>276</td>
<td>188</td>
<td>80</td>
<td>30</td>
<td>95</td>
<td>34</td>
</tr>
<tr>
<td>1975</td>
<td>95</td>
<td>81</td>
<td>10</td>
<td>9</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>1976</td>
<td>92</td>
<td>98</td>
<td>23</td>
<td>30</td>
<td>30</td>
<td>33</td>
</tr>
<tr>
<td>1977</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>27</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>Season I</td>
<td>1050</td>
<td>377</td>
<td>195</td>
<td>97</td>
<td>132</td>
<td>76</td>
</tr>
<tr>
<td>Season II</td>
<td>60</td>
<td>48</td>
<td>17</td>
<td>13</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>Males</td>
<td>581</td>
<td>217</td>
<td>212</td>
<td>110</td>
<td>146</td>
<td>84</td>
</tr>
<tr>
<td>Females</td>
<td>529</td>
<td>208</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
weights were recorded in the morning before turning the animals out for grazing and before they were offered any supplementary feed or water. Weights were recorded closest to 0.025 kg in case of lambs less than 20 kg and 0.050 kg for animals weighing more than 20 kg.

ii) Greasy fleece weight: Immediately after shearing, the total fleece of the animals was weighed. The fleece weight was recorded closest to 0.025 kg in the shearing shed. The animals were not washed prior to shearing.

iii) Survivability: The survivability was recorded from birth to 90 days and 91 days to 180 days of age of lamb. Some of the animals were excluded from the study as their survival could not be known, mainly because of sale, auction, culling, slaughter etc.

iv) Growth: Average daily pre-weaning gain was observed as the difference between weaning weight and birth weight divided by 90. Similarly average daily post-weaning gain was obtained as the difference between six months weight and weaning weight divided by 90.

v) Efficiency of feed conversion and carcass studies: Male lambs included in the study were put in the individual feed lot pens on 91st day. Their initial body weight was recorded. Then these males were weighed at fortnightly intervals upto 180 days. The daily feed offered was recorded. The left over feed was also weighed along with body weights at fortnightly intervals. These animals were let out into a large open corral for about two hours.
Water was offered thrice a day. These animals were finally weighed on 181st day and were shorn and the weight after shearing was recorded.

Method of Slaughter:

On 181st day all the males excepting those which were selected for breeding were slaughtered. The animals were slaughtered by "Halal method". Stunning was not done prior to slaughter. Animals were fasted for 24 hours prior to slaughter but had access to water.

After completely bleeding, the animals were again weighed to record the weight of the blood. Then the animals were skinned and after removing all the non-edible portions the carcasses were weighed. This gave hot carcass weight of the animals.

Empty live weight of the animals was recorded as the live weight of the animals minus the weight of ingesta. The ingesta was removed from the gastrointestinal tract and the tract was weighed before and after the removal of ingesta to record the weight of the ingesta. The dressing percentages were calculated as follows:

Dressing percentage on live weight basis

\[ \text{Dressing percentage on live weight basis} = \frac{\text{Weight of the hot carcass}}{\text{Live weight of animal}} \times 100 \]

Dressing percentage on empty live weight basis

\[ \text{Dressing percentage on empty live weight basis} = \frac{\text{Weight of the hot carcass}}{\text{Empty live-weight of animal}} \times 100 \]

Feed efficiency was calculated as:

\[ \frac{\text{gain}}{\text{feed consumed (T.D.N.)}} \times 100 \]
Statistical analysis:

The data was processed on Burroughs 3600 computer at the Indian Agricultural Statistical Research Institute, New Delhi.

As the effects were non-orthogonal due to unequal and disproportionate subclass frequencies, least squares method of fitting constants (Harvey, 1960) was employed for the analysis of variance for studying the contribution to the variance by the non-genetic factors.

Observations on Sonadi lambs were not available for Spring, 1972 and similarly the lambs were not available in Autumn, 1972 for both the breeds.

The interactions were included in the model along with other effects excepting sires. It was observed that most of the two way interactions were non-significant and hence were not included in the subsequent models.

Model I-Malpura breed: The following characters were studied:

1. Birth weight
2. Four weeks weight
3. Weaning weight
4. Six months weight
5. First six monthly greasy fleece weight
6. Pre-weaning average daily gain
7. Post-weaning average daily gain
8. Pre-weaning survival
9. Post-weaning survival

The following mathematical model was assumed:

\[ Y_{ijklm} = \mu + t_i + p_j + g_k + s_l + b_1(n-m) + e_{ijklm} \]
where, \( i = 1,2...5; j = 1,2; k = 1,2 \) and \( l = 1,2...38 \).

\( Y_{ijklm} \) is the observation on the \( m \)th lamb, sired by the \( i \)th sire of the \( k \)th sex and born in the \( j \)th season of the \( i \)th year.

\( \mu \) = overall population mean common to all the observations assuming equal subclass frequency.

\( t_i \) = the effect due to the \( i \)th year of lambing,

\( p_j \) = the effect due to \( j \)th season of lambing,

\( q_k \) = the effect due to the \( k \)th sex of lamb,

\( s_l \) = the effect due to \( i \)th sire,

\( b_1 \) = the regression of the lamb traits on the ewes' body weight at lambing (w)

\( e_{ijklm} \) is the random error assumed to be independently and normally distributed with mean zero and variance \( \sigma_e^2 \).

Year, season and sex were assumed to be fixed effects and sires as random effect. The interactions having been found to be non-significant in preliminary analyses were not included in the model.

In order to obtain unique solution, the following constrain was imposed:

\[
\sum_i t_i = \sum_j p_j = \sum_k q_k = \sum_l s_l = 0
\]

**Model II:** In the Sonadi breed same analysis was carried out. However, data of four years and 15 sires were used.

**Carcass characters:** The following characters were studied:

1. Six months weight
2. Carcass weight
3. Dressing percentage on live weight basis
4. Dressing percentage on empty live weight basis.
The following mathematical model was assumed:

\[ Y_{ijkl} = \mu + t_i + p_j + g_k + e_{ijkl} \]

where, \( Y_{ijkl} \) is the record of the \( i \)th lamb, progeny of the \( k \)th sire, born in the \( j \)th season of the \( i \)th year,

\( \mu \) = the overall population mean,

\( t_i \) = the effect due to \( i \)th year of lambing, \((i = 1, ..., 5)\)

\( p_j \) = the effect due to \( j \)th season of lambing, \((j = 1, 2)\).

\( g_k \) = the effect due to the \( k \)th sire \((k = 1, ..., 35)\) in Malpura and \((1, ..., 15)\) in Sonadi.

\( e_{ijkl} \) is the random error and was assumed to be normally distributed with mean zero and variance \( \sigma^2 \). Year and season were fixed effects and sire as random effect. The same constrain was used as in the earlier model.

**Feed lot characters:** In the Malpura and Sonadi breed following characters were studied:

1. Six months weight
2. Feed-lot average daily gain
3. Total digestible nutrients (TDN) consumed
4. Efficiency of feed conversion
5. Dressing percentage on live weight basis
6. Dressing percentage on empty live weight basis

The following mathematical model was assumed:

\[ Y_{ijkl} = \mu + t_i + p_j + g_k + e_{ijkl} \]

where, \( Y_{ijkl} \) is the record of the \( i \)th lamb, progeny of the \( k \)th sire, born in the \( j \)th season of the \( i \)th year.

\( e_{ijkl} \) is the random error and was assumed to be normally distributed with mean zero and variance \( \sigma^2 \). Year and season were fixed effects and sire as random effect. The same constrain was used as in the earlier model.
Estimation of heritabilities, genetic and phenotypic correlations:

Data were adjusted for significant non-genetic effect using correction factors developed from model containing sire for computing estimates of heritability, genetic and phenotypic correlations among the different traits of interest.

The estimates of heritabilities and genetic correlation were computed from the sire components of variance and covariance.

\[ h^2 = \frac{4 \sigma^2_s}{\sigma^2_s + \sigma^2_e} \]

Genetic correlation:

\[ r_{g_1 g_j} = \frac{\sigma_{s_1 s_j}}{\sqrt{\frac{\sigma^2_s}{s_1} \cdot \frac{\sigma^2_s}{s_j}}} \]

The standard error for heritability was calculated using the formula of Swiger et al. (1964). The standard error of genetic correlation was calculated using the approximate formula given by Robertson (1959).

\[ \text{s.e. } h^2 = 4 \sqrt{\frac{2(N-1)(1-t^2)(1+(K-1)t)^2}{K^2(N-S)(S-1)}} \]

where, \( t \) is the intraclass correlation, \( s \) is the number of sires, \( N \) is the total number of observations, and

\[ K = \frac{1}{S-1} \left[ N - \frac{\sum_{i=1}^{S} h_i^2}{N} \right] \]

was satisfactory.

\[ \text{s.e. } r_{g_1 g_j} = (1-r_{g_1 g_j}) \left[ \frac{\sigma^2_{g_1} \cdot \sigma^2_{g_j}}{2(\sigma^2_{h_1}, \sigma^2_{h_j})} \right]^{1/2} \]
Selection Indices: Selection indices were computed following the procedure of Hazel (1943).

The selection index based on traits can be written as:

\[ I = \sum_{i=1}^{n} b_i x_i \]

where, \( b_i \)'s are the weights attached to the phenotypic value of each trait and are calculated so as to maximise \( R_{IH} \). The \( H \) is the aggregate genetic worth based on the additive genetic values of the traits under consideration and can be written as:

\[ H = \sum_{i=1}^{n} a_i g_i \]

where, \( a_i \)'s are the relative economic values and \( g_i \)'s are the additive genetic values for the traits included in the index. The maximisation of \( R_{IH} \) gives a set of \( n \) simultaneous equations. The solutions of these provide values of \( b \)'s. These simultaneous equation in matrix notation will be:

\[ X'Xb = a G'G \]

where, \( X'X \) is the matrix of size \( n \times n \) of phenotypic variances and covariances, \( b \) is the column vector of size \( n \), \( a \) is the row vector of size \( n \) and \( G'G \) is the matrix of size \( n \times n \) of genotypic variances and covariances. Solution of \( b \) can be obtained as:

\[ b = (X'X)^{-1} a G'G \]

\[ R_{IH} = \frac{\delta I}{\delta H} \]
\[ \sigma^2_I = V \left( \sum_{i=1}^{n} b_i x_i \right) = \sum_{i=1}^{n} b_i^2 \sigma^2 x_i + b_1 b_2 \sigma^2 x_i x_j \]

\[ \sigma^2_H = V \left( \sum_{i=1}^{n} a_i G_i \right) = \sum_{i=1}^{n} a_i^2 \sigma^2 G_i + \sum_{i \neq j} a_i G_i \sigma G_i G_j \]

The relative efficiency of indices combining different traits can be seen from the value of \( R_{IH} \) and genetic gains in the traits of interest. This will also need consideration of the effect on generation interval.

The expected genetic progress in each trait from index selection was calculated as:

\[ E \left( G_i - x_i \right) = b_{G_i} \cdot \frac{\sigma_i}{b} \sigma_i \]

The direct response to selection of each trait was calculated as:

\[ G_X = h_X^2 \cdot \frac{\sigma_i}{b} \sigma_x \]

The correlated response was calculated as:

\[ CR_{Y/X} = b_{G_Y} G_X \cdot \Delta G_X \]

\[ = r_{G_Y G_X} h_Y h_X x \sigma_y \]

Response in individual characters to index selection was calculated as:

\[ R_{x_i/I} = \frac{b_{x_i I} z/b \sigma_I}{\sigma I} \]

\[ = b_1 \sigma^2 G_1 + b_2 \sigma^2 G_1 G_2 \]

\[ \sigma I \]