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Phenotypic Characterization of Macherla Sheep- A Lesser-Known Sheep Breed of Andhra Pradesh

P. Panduranga Reddy[1]*, R. Vinoo[1], M. Muralidhar[1], Ch. Venkatasesaiah[2], K. Aswani Kumar[3] and Krovvidi Sudhakar[1]

[1]Department of Animal Genetics and Breeding, NTR College of Veterinary Science, Gannavaram, Andhra Pradesh, INDIA
[2]Livestock Farm Complex, NTR College of Veterinary Science, Gannavaram, Andhra Pradesh, INDIA
[3]Department of Veterinary biochemistry, NTR College of Veterinary Science, Gannavaram, Andhra Pradesh, INDIA

**Corresponding author: P Reddy; E-mail: panduvet@gmail.com*

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ABSTRACT

The status of lesser-known sheep cannot be ignored as they comprise 75 Per cent of the total Indian sheep population. The Macherla sheep is one of the lesser-known sheep breeds of Andhra Pradesh with medium to heavy sized body. Because of superior performance over Nellore and the characteristics such as good resistance and adaptability to local climatic conditions, the Macherla sheep attained considerable importance among sheep herders. A stratified random sample survey was conducted in Andhra Pradesh and Telangana states populated with huge number of Macherla sheep. The data was measured on 1279 sheep from 27 villages of nine mandals in four districts of two states. The predominant colour pattern in Macherla sheep was bicolour with combinations of white and black or brown and white. Rams are horned and ewes are polled. A gradual increase in the body measurements was observed from milk tooth to full mouth stage. Males recorded significantly higher body measurements than females. District has significant influence on the body measurements with higher recordings in Guntur district. The influence of district on body weight of Macherla sheep are found to be significant at all ages studied except for two-toothed and six-toothed ages. Among sexes, males recorded heavier body weights compared to females. The reproductive performance of Macherla sheep was ideal and within the range of species. The lambing Percentage was quite good in Macherla sheep. The Phenotypic correlations of body weight with the linear body measurements were positive and high.

HIGHLIGHTS

- Macherla sheep breed has superior performance compared to Nellore sheep breed of Andhra Pradesh.
- Guntur district recorded higher body weight during birth, three months, six months, and four-toothed age.
- The lambing percentage observed in Macherla sheep (97.4 per cent) was higher than the other hairy sheep.

Keywords: Macherla Sheep, body measurement, body weight, reproductive performance

The diversity of geo-climate over the ages has manifested into diversity of sheep breeds providing a total of 44 sheep breeds in different agro-climatic zones of India. However, there are several sheep genetic groups distributed across India whose characterization is either under process or completed and waiting for approval or yet to be characterized. These are of late called as lesser-known sheep genetic groups. According to FAO watch list (2000), 60 sheep breeds exist in India, which include well-recognized lesser-known breeds along with some wild species. Lesser-known genetic group of livestock adapted to certain geographical regions has a vital role in sustainability of farming community. The diversity of Indian sheep is evident by the presence of the heaviest Muzaffarnagari, tallest Nellore, and prolific Garole, to name

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a few. Indigenous sheep have developed a local adaptation by developing superior heat tolerance, resistance to some of the tropical diseases etc. (Hyder *et al*., 2017). Hence, conservation of indigenous sheep's germplasm is viewed as an essential function to conserve the genetic traits of valuable species. In addition, information on the origin, distribution, adaptability, morphological characteristics and production and reproduction performances of lesser-known animal genetic resources will be useful to design strategies for their sustainable management (Firas *et al*., 2015).

Andhra Pradesh ranks second in India regarding the sheep population and exhibited a 30% increase in sheep population in 2019 compared to 2012 census from 13.6 million to 17.6 million. Nellore is the only sheep breed that is recognized by ICAR in Andhra Pradesh. In adjacent regions to Krishna River in Guntur, Prakasam, and Krishna districts of Andhra Pradesh and Nagar Kurnool and parts of Nalgonda district of Telangana, there is a locally adopted lesser-known sheep genetic group, locally called as Macherla sheep. These sheep are known for their better adaptability to hot and humid climatic conditions prevailing in this region. As a pilot project, we have evaluated the socio-economic Status, sheep husbandry practices and morphological patterns of Macherla Sheep breed (Reddy *et al*., 2020). Another preliminary study indicated that Macherla sheep have distinct phenotypic characters from Nellore and having higher productive performance (Choudary, 2013). Hence the present study was conducted with an objective to establish breed characteristics of Macherla sheep by studying morphological and morphometric traits and to assess the production and reproduction potentials under the existing managemental conditions.

MATERIALS AND METHODS

The study employs a stratified random sample survey based on the potential of sheep production in the geographical area. The survey was conducted in 27 villages of nine mandals and four districts (Guntur, Prakasam and Krishna districts in Andhra Pradesh and Nagar Kurnool district in Telangana) from February 2018 to December 2018. Visual observations of qualitative traits were recorded based on the breed morphological characteristics descriptor list of NBAGR (2018) for phenotypic characterization of sheep. Further, three villages were selected in each mandal based on the potential sheep population for recording body weights and body measurements of different age groups. About three to six sheep farmers with ten to twelve sheep per farmer were chosen randomly to record data. Apart from this, discussions were held with mandal, zonal, and district veterinary officials and developmental agencies to collect the required information. The Morphological descriptions such as coat color pattern, hair, horn, head profile, wattles, tail type were recorded. The body weights at different ages, biometrical measurements *viz*: Body Length (BL), Height at Withers (HW), Chest Girth (CG), Paunch Girth (PG), Face Length (FL), Face Width (FW), Ear Length (EL) and Tail Length (TL)) and data on reproductive performance (Age at First Estrus (AFE), Age at First Mating (AFM), Age at First Lambing (AFL), Lambing Interval (LI) and Litter Size (LS)) were recorded on a total of 1279 (153 males and 1126 females) sheep. The data was collected early in the morning before they were let out for grazing.

The age groups of birth, 3 months, 6 months, 2 tooth, 4 tooth, 6 tooth, and full mouth were considered for recording various traits. Age of the sheep was assessed based on dentition. All the animals having two permanent incisors were considered as one and half to two-year-old, four incisors as three-year-old, six incisors as four-year-old and those with eight permanent incisors were regarded as five years and above in age (Banerjee, 1991). Bodyweight (BW) was measured using a hanging scale having 100 kg capacity. Linear body measurements were measured with a tailor's tape following the standard procedure reported by FAO (2012). The data were classified according to district, sex, and age groups.

Statistical analysis

The basic statistics consisting of mean, standard deviation, and standard error were computed as per Snedecor and Cochran (1989). The data collected were scrutinized, edited, collated, and grouped according to the districts, age group, and sex. Procedure frequency was used to analyze qualitative traits and general linear model was used to interpret quantitative traits in Statistical Package for Social Sciences (SPSS Vs.23). The model used for least square mean analysis was:

$$Y_{ijkl} = \mu + D_i + S_j + A_k + e_{ijkl}$$

Where,

Y_{ijkl} = l^{th} observation of i^{th} district, j^{th} sex, k^{th} age group

D_i = Effect of i^{th} district (i = 1 to 4)

S_j = Effect of j^{th} sex (j = 1, male and 2, female)

A_k = Effect of k^{th} age group (k = 1 to 7, birth, 3 months, 6 months 2- teeth, 4- teeth, 6- teeth and 8-teeth)

e_{ijkl} = Random error

Duncan's multiple range tests as modified by Kramer (1957) was employed to make pair wise comparisons of least-square means.

Correlation and Regression analysis

Data was analyzed for the statistical correlation (two tailed test of significant) of body weight with biometrical measurements by using Pearson coefficient. Stepwise multiple regressions were used to predict body weight from linear measurements having positive correlations with body weight. Variables that best fitted the model were selected using R^2. One may define the "best model" as that which has a highest R^2 value.

RESULTS AND DISCUSSION

Origin, habitat and distribution

The sheep genetic group is popularly known as Macherla sheep and attained its local name based on the native tract i.e., Macherla area of Guntur district. The locals informed that the animals existing from a long time and its legacy was known for the past 30-50 years. Total geographical area of Macherla sheep was 51790 km^2. The average flock size of Macherla sheep in the present study is 134.31±4.6 and the minimum flock size of the genetic group is 50. The demographic survey revealed that a total of 5,32,393 Macherla sheep were distributed across the breeding tract. Based on the demographic survey, Macherla sheep constitutes about 3.02% of total sheep population of Andhra Pradesh and 0.7% of total sheep population of India (DAHD 2019).

Morphological characters

The coat color and other morphological characters of Macherla sheep are distinct from the other sheep genetic groups of Andhra Pradesh *viz.* Nellore sheep (Brown, Jodipi and Palla strains) and North Coastal sheep. The predominant coat color pattern in Macherla sheep was bi-color of black and white (44.41%) followed by brown and white (35.65%), brown (18.64%) and black (1.88%). Similar to Nellore sheep breed, Macherla sheep is also a hairy type sheep but the hair is relatively more in this genetic group. A thick and dense bundle of hair growth, predominantly on neck and dewlap regions followed by brisket, back and thigh region was evident in adult rams providing elegant look. The predominant head profile in both sexes is prominently convex and ears were pendulous. The males are horned and females are polled.

Body measurements

Body measurements are useful for the description of a breed objectively and to study the growth pattern of the breed. Biometric measurements indicate the skeletal growth of the animals. The least-squares means for BL, HW, CG, and PG at birth, three-months, six-months, two-toothed, 4-toothed, 6-toothed, and full mouth age groups pooled over sex of the animals and district showed an increasing trend and least square means of various body measurements are presented in Table 1.

The least square means compared between sexes at different ages revealed significant influence on all four body measurements with higher ($P<0.01$) values in males. Similar differences were noted in Nellore Palla sheep (Harini, 2017) and North coastal sheep of Andhra Pradesh (Gangaraju, 2010). The variation in measurements between the males and females increased with age, which might be due to the differences in body weights, sex hormones, and sexual dimorphism. Influence of district was significant on body length at all age groups except at four-toothed, six-toothed, and full mouth age. Guntur district recorded significantly higher body length at birth, three months, and four-toothed age while Prakasam district recorded higher body length at six months and two-toothed age. District has significant effect on height at withers at all age groups. Guntur district recorded higher HW during birth, three months, six months, and four-toothed age, Prakasam district recorded higher HW at six-toothed and full mouth age, whereas Krishna district recorded higher WH at two-toothed age. District has significant effect on chest girth at all

Table 1: Least squares mean (±SE) of body measurements (cm) of Macherla lambs

Effects	Birth	Three months	Six months	two teeth	four tooth	six tooth	Full mouth
Body length (cm)							
Overall	34.80 ± 0.34 **(215)**	53.53 ± 0.38 **(155)**	63.13 ± 0.48 **(156)**	72.90 ± 0.33 **(166)**	73.00 ± 0.38 **(179)**	73.04 ± 0.40 **(152)**	74.22 ± 0.56 **(256)**
Sex	**	**	**	**	**	**	**
Male	35.98 ± 0.62^{a} (61)	55.08 ± 0.63^{a} (18)	65.04 ± 0.64^{a} (13)	73.94 ± 0.73^{a} (16)	76.33 ± 0.70^{a} (13)	74.41 ± 0.79^{a} (17)	75.99 ± 0.87^{a} (15)
Female	33.61 ± 0.46^{b} (154)	52.05 ± 0.43^{b} (137)	61.22 ± 0.44^{b} (143)	69.84 ± 0.39^{b} (150)	69.68 ± 0.38^{b} (166)	71.69 ± 0.41^{b} (98)	72.42 ± 0.4 ^{b} (241)
District	**	**	**	**	**NS**	**NS**	**NS**
Guntur	37.02 ± 0.59^{a} (47)	60.19 ± 0.6^{a} (37)	64.46 ± 0.62^{a} (34)	71.57 ± 0.20^{a} (41)	73.98 ± 0.41 (39)	74.10 ± 0.74 (24)	74.97 ± 0.34 (71)
Prakasam	34.57 ± 0.87^{b} (56)	50.85 ± 0.90^{b} (42)	65.66 ± 0.91 ^{b} (42)	76.22 ± 0.85^{a} (34)	72.77 ± 0.91(48)	72.33 ± 0.86 (27)	75.13 ± 0.91 (69)
Krishna	34.08 ± 0.78^{b} (61)	52.51 ± 0.90^{b} (32)	62.01 ± 0.86 ^{c} (32)	72.75 ± 0.86^{b} (46)	72.87 ± 0.98 (42)	73.25 ± 0.98 (30)	72.60 ± 1.03 (64)
Nagar Kurnool	35.51 ± 0.82^{b} (51)	50.71 ± 0.64^{b} (44)	60.45 ± 0.69^{c} (48)	71.06 ± 0.46^{b} (45)	72.46 ± 0.78 (50)	72.52 ± 0.98 (34)	74.13 ± 1.31 (52)
Height at withers (cm)							
Overall	39.61 ± 0.28 **(215)**	55.90 ± 0.67 **(155)**	66.70 ± 0.33 **(156)**	73.44 ± 0.54 **(166)**	76.78 ± 0.49 **(179)**	77.56 ± 0.50 **(152)**	78.53 ± 0.58 **(256)**
Sex	**	**	**NS**	**	**	**	*
Male	40.94 ± 0.73^{a} (61)	55.66 ± 0.74^{a} (18)	68.41 ± 0.75 (13)	77.57 ± 0.86^{a} (16)	80.52 ± 0.83^{a} (13)	78.89 ± 0.93^{a} (17)	79.85 ± 1.03 ^{a} (15)
Female	38.29 ± 0.54^{b} (154)	55.99 ± 0.51^{b} (137)	64.99 ± 0.52 (143)	71.10 ± 0.46^{b} (150)	73.04 ± 0.45^{b} (166)	76.28 ± 0.49^{b} (98)	77.09 ± 0.48^{b} (241)
District	**	**	**	**	**	*	*
Guntur	42.64 ± 0.70^{a} (47)	59.35 ± 0.72^{a} (37)	68.01 ± 0.73 ^{a} (34)	71.40 ± 0.33^{a} (41)	77.84 ± 0.48^{a} (39)	77.93 ± 0.87^{ab} (24)	79.97 ± 0.40 ^{a} (71)
Prakasam	37.16 ± 1.02^{b} (56)	56.16 ± 1.06^{a} (42)	67.60 ± 1.07^{ab} (42)	72.72 ± 1.41^{a} (34)	77.80 ± 1.07^{a} (48)	80.00 ± 1.01^{a} (27)	80.40 ± 1.07^{a} (69)
Krishna	39.18 ± 0.92^{c} (61)	55.97 ± 1.01^{a} (32)	65.79 ± 1.01 ^{b} (32)	75.75 ± 1.47^{a} (46)	77.81 ± 1.16^{b} (42)	75.46 ± 1.96^{b} (30)	76.54 ± 1.21^{b} (64)
Nagar Kurnool	39.48 ± 0.97^{c} (51)	51.82 ± 0.76^{b} (44)	65.40 ± 0.82 ^{b} (48)	73.90 ± 0.77^{b} (45)	73.68 ± 0.92^{b} (50)	76.94 ± 1.15^{b} (34)	76.97 ± 1.55^{b} (52)

NS - Not significant *Significant (P<0.05) **Highly significant (P<0.01); Figures in parentheses are number of observations. Means with similar superscript within each column under each effect do not differ significantly (P≤0.05).

age groups, except for birth and six-toothed age. The effect of district is significant on paunch girth at all age groups, except for three month and 6-toothed age groups. Previous literature revealed a significant influence of village, mandal, zone and district in North coastal sheep (Gangaraju, 2010), Nellore (Harini, 2017; Rajanna *et al.,* 2012; Rani *et al*., 2014), and Macherla sheep (Choudary, 2013). This might be due to the differences in environment and feeding conditions of animals. The body measurements of Macherla sheep is hardly variable from the North coastal sheep of Andhra Pradesh (Gangaraju, 2010; Prasanna, 2019), Deccani sheep (Rajanna *et al.,* 2012). However, Rani *et al.* (2014) reported slightly higher body lengths and heights in Nellore Jodipi sheep while Karthik *et al*. (2021) revealed lower body weights in Nellore brown sheep under farm conditions.

The least-squares means for FL, FW, EL, and TL at different ages pooled over sex of the animals and district are presented in Table 2. District has significant effect on FL and FW at all age groups except, for 3 months age. The

Table 1 (contd...): Least squares mean (±SE) of body measurements (cm) of Macherla lambs

Effects	Birth	Three months	Six months	two teeth	four tooth	six tooth	Full mouth
Chest Girth (cm)							
Overall	39.13 ± 0.37 **(215)**	60.69 ± 0.29 **(155)**	70.86 ± 0.42 **(156)**	84.72 ± 0.49 **(166)**	87.01 ± 0.52 **(179)**	87.77 ± 0.62 **(152)**	90.96 ± 0.63 **(256)**
Sex	**	**	**	**	**	**	**
Male	40.37 ± 0.75^{a} (61)	61.84 ± 0.77^{a} (18)	73.17 ± 0.78^{a} (13)	89.32 ± 0.89 ^{a}(16)	91.96 ± 0.85 ^{a}(13)	91.19 ± 0.85^{a} (17)	93.46 ± 1.06 ^{a}(15)
Female	37.90 ± 0.56^{b} (154)	59.51 ± 0.52^{b} (137)	68.56 ± 0.56^{b} (143)	79.94 ± 0.48 ^{b}(150)	82.06 ± 0.47 ^{b}(166)	85.34 ± 0.51^{b} (98)	88.41 ± 0.50 ^{b}(241)
District	NS	*	**	**	**	NS	*
Guntur	39.97 ± 0.72 (47)	59.38 ± 0.75^{a} (37)	71.74 ± 0.75^{a} (34)	83.59 ± 0.37^{a} (41)	88.71 ± 0.50^{a} (39)	86.90 ± 0.90 (24)	91.64 ± 0.41^{a} (71)
Prakasam	38.54 ± 1.06 (56)	61.20 ± 1.10^{b} (42)	74.33 ± 1.11^{b} (42)	81.22 ± 1.58^{b} (34)	88.50 ± 1.11^{a} (48)	89.41 ± 1.04 (27)	92.73 ± 1.11^{a} (69)
Krishna	38.59 ± 0.95 (61)	61.26 ± 1.04^{b} (32)	69.34 ± 1.04^{c} (32)	87.82 ± 1.56^{a} (46)	85.28 ± 1.20^{b} (42)	86.75 ± 1.20 (30)	87.13 ± 1.25^{b} (64)
Nagar Kurnool	39.44 ± 1.00 (51)	60.80 ± 0.78^{b} (44)	68.04 ± 0.85^{c} (48)	86.34 ± 0.86^{c} (45)	85.56 ± 0.95^{c} (50)	89.97 ± 1.19 (34)	92.25 ± 1.60^{ab} (52)
Paunch Girth (cm)							
Overall	35.99 ± 0.40 **(215)**	61.52 ± 0.52 **(155)**	75.55 ± 0.78 **(156)**	87.86 ± 0.62 **(166)**	87.01 ± 0.98 **(179)**	89.25 ± 0.67 **(152)**	92.38 ± 0.82 **(256)**
Sex	**	**	**	**	**NS**	**	*
Male	37.56 ± 1.08^{a} (61)	63.60 ± 1.10^{a} (18)	78.17 ± 1.11^{a} (13)	94.89 ± 1.28^{a} (16)	88.58 ± 1.28 (13)	91.29 ± 1.38^{a} (17)	94.23 ± 1.51^{a} (15)
Female	34.42 ± 0.80^{b} (154)	59.40 ± 0.75^{b} (137)	72.93 ± 0.77^{b} (143)	85.75 ± 0.68^{b} (150)	85.75 ± 0.68 (166)	87.45 ± 0.72^{b} (98)	90.46 ± 0.71^{b} (241)
District	**	NS	*	**	**	NS	*
Guntur	33.19 ± 1.04^{a} (47)	63.75 ± 1.07 (37)	74.53 ± 1.08 ^{ab} (34)	88.72 ± 0.38^{a} (41)	89.77 ± 0.71^{ab} (39)	91.03 ± 1.28 (24)	93.10 ± 0.59^{ab} (71)
Prakasam	36.71 ± 1.51^{bc} (56)	60.50 ± 1.57 (42)	80.40 ± 1.58^{a} (42)	84.72 ± 1.64^{b} (34)	90.73 ± 1.58^{a} (48)	88.79 ± 1.49 (27)	95.83 ± 1.58^{a} (69)
Krishna	36.64 ± 1.36^{c} (61)	60.82 ± 1.49 (32)	74.61 ± 1.49^{ab} (32)	86.92 ± 1.62^{b} (46)	81.84 ± 1.71^{b} (42)	89.25 ± 1.71 (30)	88.08 ± 1.79^{b} (64)
Nagar Kurnool	37.42 ± 1.43 ^{c} (51)	60.92 ± 1.12 (44)	72.65 ± 1.21^{b} (48)	91.06 ± 0.89^{c} (45)	85.72 ± 1.35^{ab} (50)	88.41 ± 1.70 (34)	92.38 ± 2.28^{b} (52)

NS - Not significant * Significant (P<0.05) **Highly significant (P<0.01); Figures in parentheses are number of observations. Means with similar superscript within each column under each effect do not differ significantly (P≤0.05).

influence of district was found for EL and TL at all ages except for full mouth age for EL and at six-toothed and full mouth age for TL. Sex of the sheep exerted significant (P<0.05) influence on face length at below one year age (P<0.01) and have non-significant effect on adult age groups. Sex of the sheep exerted highly significant (P<0.01) influence for EL at birth, three months, four-toothed age. Sex of the sheep exerted significant (P<0.05) influence on tail length only at six months age group.

Body weights

The body weights of Macherla sheep at all ages recorded in the present study (table 3) was similar to those presented by Choudary (2013). Nevertheless, relatively lower values were reported in Nellore Jodipi sheep (Rani *et al.,* 2014), Nellore Brown (Karthik *et al*., 2021; Reddy, 2015), Nellore Palla (Harini, 2017), and North coastal sheep (Gangaraju, 2010; Prasanna, 2019) of Andhra Pradesh and other Indian Sheep breeds. The influence of district on body weight

Table 2: Least-squares mean (±SE) of body measurements (cm) of Macherla sheep

Effects	Birth	Three months	Six months	two teeth	four tooth	six tooth	Full mouth
Face width (cm)							
Overall	6.49 ± 0.08 **(215)**	9.36 ± .19 **(155)**	9.63 ± 0.12 **(156)**	9.17 ± 0.23 **(166)**	9.93 ± 0.12 **(179)**	10.16 ± 0.13 **(152)**	10.48 ± 0.14 **(256)**
Sex	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	*
Male	6.60 ± 0.20 (61)	9.26 ± 0.20 (18)	10.17 ± 0.20 (13)	10.82 ± 0.23 (16)	9.94 ± 0.22 (13)	10.34 ± 0.25 (17)	10.80 ± 0.28^{a} (15)
Female	6.38 ± 0.15 (154)	9.43 ± 0.14 (137)	9.08 ± 0.14 (143)	9.74 ± 0.12 (150)	9.92 ± 0.12 (166)	9.95 ± 0.13 (98)	10.08 ± 0.13^{b} (241)
District	**	**	**	**	*	**	NS
Guntur	7.94 ± 0.19^{a} (47)	11.26 ± 0.20^{a} (37)	10.20 ± 0.20^{a} (34)	8.66 ± 0.14^{a} (41)	9.43 ± 0.13^{a} (39)	9.90 ± 0.24^{a} (24)	10.31 ± 0.11 (71)
Prakasam	5.96 ± 0.28^{b} (56)	8.56 ± 0.29^{b} (42)	10.13 ± 0.29^{a} (42)	9.22 ± 0.61^{ab} (34)	10.10 ± 0.29^{b} (48)	9.85 ± 0.27^{b} (27)	10.10 ± 0.29 (69)
Krishna	5.89 ± 0.25^{b} (61)	8.59 ± 0.27^{b} (32)	9.00 ± 0.27^{b} (32)	8.02 ± 0.67^{b} (46)	10.12 ± 0.32^{b} (42)	9.75 ± 0.32^{abc} (30)	10.55 ± 0.33 (64)
Nagar Kurnool	6.17 ± 0.26^{b} (51)	$8,97 \pm 0.20^{b}$ (44)	9.18 ± 0.22^{b} (48)	10.84 ± 0.32^{c} (45)	10.06 ± 0.25^{b} (50)	11.08 ± 0.31^{c} (34)	10.80 ± 0.42 (52)
Ear length Length (cm)							
Overall	9.43 ± 0.27 **(215)**	14.98 ± 0.26 **(155)**	15.19 ± 0.26 **(156)**	14.82 ± 0.37 **(166)**	15.72 ± 0.14 **(179)**	15.80 ± 0.15 **(152)**	16.60 ± 0.85 **(256)**
Sex	**	**	**NS**	**NS**	**	**NS**	**NS**
Male	9.81 ± 0.61^{a} (61)	15.64 ± 0.62^{a} (18)	15.57 ± 0.63 (13)	15.32 ± 0.72 (16)	16.15 ± 0.69^{a} (13)	15.77 ± 0.78 (17)	17.02 ± 0.86 (15)
Female	9.05 ± 0.46^{b} (154)	14.28 ± 0.42^{b} (137)	14.80 ± 0.44 (143)	15.17 ± 0.39 (150)	15.29 ± 0.38^{b} (166)	15.83 ± 0.41 (98)	16.08 ± 0.40 (241)
District	**	**	**	NS	NS	NS	NS
Guntur	11.50 ± 0.59^{a} (47)	15.99 ± 0.61^{a} (37)	16.60 ± 0.61^{a} (34)	14.09 ± 0.22 (41)	15.86 ± 0.40 (39)	16.13 ± 0.73 (24)	17.78 ± 0.33 (71)
Prakasam	8.84 ± 0.86^{b} (56)	14.66 ± 0.89^{b} (42)	14.33 ± 0.90^{b} (42)	14.85 ± 0.97 (34)	15.90 ± 0.90 (48)	16.19 ± 0.85 (27)	16.43 ± 0.90 (69)
Krishna	9.10 ± 0.77^{b} (61)	14.48 ± 0.85^{b} (32)	14.59 ± 0.85^{b} (32)	15.10 ± 0.94 (46)	15.53 ± 0.97 (42)	15.46 ± 0.97 (30)	15.80 ± 1.01 (64)
Nagar Kurnool	8.28 ± 0.81^{c} (51)	14.71 ± 0.63^{b} (44)	15.23 ± 0.69^{b} (48)	15.25 ± 0.53 (45)	15.60 ± 0.77 (50)	15.41 ± 0.97 (34)	16.19 ± 1.30 (52)

NS - Not significant * Significant (P<0.05) **Highly significant (P<0.01); Figures in parentheses are number of observations. Means with similar superscript within each column under each effect do not differ significantly (P≤0.05).

of Macherla sheep are found to be significant at all ages studied except for two-toothed and six-toothed ages. The mean body weights are highest in Guntur district at birth, three months, six months, two-toothed age, four-toothed, six-toothed, and full mouth age (50.36 kg).

Among sexes, males recorded higher (P<0.01) body weights than females, at all ages studied. Similar effect of sex on body weights also reported by Choudary (2013) in Macherla sheep, Gangaraju (2010) and Prasanna (2019) in North coastal sheep of Andhra Pradesh, Karthik *et al*. (2021) in Nellore Brown, Rani *et al*. (2014) in Nellore Jodipi, and Harini (2017) in Nellore Palla sheep of Andhra Pradesh.

The variation of body weights between different age

Table 2 (Contd): Least-squares mean (±SE) of body measurements (cm) of Macherla sheep

Effects	Birth	Three months	Six months	two teeth	four tooth	six tooth	Full mouth
Tail length (cm)							
Overall	6.83 ± 0.18 **(215)**	9.12 ± 0.19 **(155)**	10.35 ± 0.14 **(156)**	11.33 ± 0.26 **(166)**	9.76 ± 0.19 **(179)**	10.15 ± 0.17 **(152)**	10.32 ± 0.32 **(256)**
Sex	**NS**	**NS**	*	**NS**	**NS**	**NS**	**NS**
Male	6.98 ± 0.30 (61)	9.45 ± 0.30 (18)	10.66 ± 0.31^{a} (13)	10.97 ± 0.35 (16)	9.47 ± 0.34 (13)	10.47 ± 0.38 (17)	10.68 ± 0.42 (15)
Female	6.67 ± 0.22 (154)	8.77 ± 0.21 (137)	10.03 ± 0.21^{b} (143)	10.69 ± 0.19 (150)	10.05 ± 0.18 (166)	9.82 ± 0.20 (98)	9.95 ± 0.20 (241)
District	**	NS	**	**	NS	**	*
Guntur	8.00 ± 0.29^{a} (47)	9.51 ± 0.30 (37)	11.34 ± 0.30^{a} (34)	10.25 ± 0.16^{a} (41)	9.30 ± 0.20 (39)	9.38 ± 0.36^{a} (24)	9.33 ± 0.16^{a} (71)
Prakasam	6.48 ± 0.92^{bc} (56)	8.40 ± 0.43 (42)	9.93 ± 0.44^{b} (42)	12.47 ± 0.68^{a} (34)	9.76 ± 0.44 (48)	10.15 ± 0.41^{a} (27)	10.36 ± 0.44^{bc} (69)
Krishna	6.66 ± 0.38^{b} (61)	9.10 ± 0.41 (32)	9.60 ± 0.41^{b} (32)	11.50 ± 0.67^{a} (46)	10.34 ± 0.47 (42)	9.90 ± 0.47^{a} (30)	11.00 ± 0.50^{c} (64)
Nagar Kurnool	6.17 ± 0.40^{c} (51)	9.44 ± 0.30 (44)	10.52 ± 0.33^{b} (48)	11.12 ± 0.37^{a} (45)	9.64 ± 0.37 (50)	11.16 ± 0.47^{a} (34)	10.58 ± 0.63^{c} (52)
Face Length (cm)							
Overall	11.21 ± 0.11 **(215)**	15.94 ± 0.16 **(155)**	19.29 ± 0.29 **(156)**	25.53 ± 0.32 **(166)**	25.17 ± 0.25 **(179)**	26.63 ± 0.34 **(152)**	27.57 ± 0.28 **(256)**
Sex	*	*	*	**NS**	**NS**	**NS**	**NS**
Male	11.46 ± 0.3^{a} (61)	16.25 ± 0.3^{a} (18)	20.03 ± 0.3^{a} (13)	24.49 ± 0.43 (16)	26.10 ± 0.41 (13)	27.22 ± 0.47 (17)	27.53 ± 0.52 (15)
Female	10.96 ± 0.2^{b} (154)	15.59 ± 0.2^{b} (137)	18.56 ± 0.2^{b} (143)	24.64 ± 0.23 (150)	24.43 ± 0.23 (166)	26.01 ± 0.25 (98)	27.42 ± 0.24 (241)
District	**	NS	**	**	**	*	*
Guntur	11.86 ± 3.5^{a} (47)	16.42 ± 0.36 (37)	21.43 ± 0.3^{a} (34)	28.17 ± 0.20^{a} (41)	27.73 ± 0.24^{a} (39)	27.81 ± 0.44^{a} (24)	27.16 ± 0.20^{a} (71)
Prakasam	10.40 ± 0.5^{b} (56)	15.62 ± 0.53 (42)	20.13 ± 0.5^{b} (42)	24.72 ± 0.85^{a} (34)	26.86 ± 0.54^{b} (48)	27.19 ± 0.51^{a} (27)	28.96 ± 0.54^{b} (69)
Krishna	11.23 ± 0.4^{c} (61)	15.72 ± 0.51 (32)	17.58 ± 0.5^{cd} (32)	26.92 ± 0.87^{a} (46)	25.22 ± 0.58^{c} (42)	26.62 ± 0.58^{b} (30)	27.04 ± 0.61^{c} (64)
Nagar Kurnool	11.35 ± 0.4^{c} (51)	15.92 ± 0.38 (44)	18.03 ± 0.4^{d} (48)	22.31 ± 0.46^{b} (45)	20.86 ± 0.46^{d} (50)	24.85 ± 0.58^{b} (34)	26.75 ± 0.78^{c} (52)

NS - Not significant * Significant (P<0.05) **Highly significant (P<0.01); Figures in parentheses are number of observations. Means with similar superscript within each column under each effect do not differ significantly (P≤0.05).

groups and sexes might be due to the linearly increased body weight with the advancement of age consequently increasing the metabolic activity, muscular and skeletal growth, reproductive organs' growth etc. The ideal birth weight had influence on the weaning weight to desirable as 17.80 kg. Heavier weaning weight indicates good mothering ability of the ewes and the growth potential of ram lambs. The mean adult body weight of Macherla sheep was 47.85 kg reflecting the breed's massiveness with an ideal body frame work.

Reproductive Performance

The reproductive performance of Macherla ewes from the farmers' flocks (Table 4) were within the normal range of species. The age at first mating was about 1 year (357 days in males, 354 days in females). The first lamb crop was

Table 3: Least-squares mean (±SE) of body weights (kg) of Macherla sheep

Effects	Birth	Three months	Six months	two teeth	four tooth	six tooth	Full mouth
Body weight (Kg)							
Overall	4.41±0.70 **(215)**	17.80±0.24 **(155)**	28.41±0.37 **(156)**	39.04±0.38 **(166)**	42.46±0.38 **(179)**	43.09±0.52 **(152)**	47.85±0.81 **(256)**
Sex	**	**	**	**	**	**	**
Male	4.84±0.70[a] (61)	19.49±0.71[a] (18)	31.06±0.72[a] (13)	43.30±0.83[a] (16)	48.97±0.79[a] (13)	47.74±0.89[a] (17)	53.25±0.98[a] (15)
Female	3.99±0.52[b] (154)	16.21±0.49[b] (137)	26.17±0.50[b] (143)	35.37±0.44[b] (150)	36.71±0.43[b] (166)	39.93±0.47[b] (98)	43.14±0.46[b] (241)
District	**	**	**	NS	*	NS	*
Guntur	4.78±0.67[a] (47)	19.21±0.69[a] (37)	30.24±0.60[a] (34)	39.96±0.26 (41)	43.68±0.63[ac] (39)	43.71±0.87 (24)	50.36±0.57[a] (71)
Prakasam	4.16±0.96[b] (56)	17.59±1.00[ab] (42)	29.42±0.78[a] (42)	39.71±0.67 (34)	42.36±0.76[ac] (48)	43.25±1.01 (27)	48.83±1.54[ab] (69)
Krishna	4.28±0.87[b] (61)	17.16±0.95[b] (32)	27.64±0.78[b] (32)	38.70±0.50 (46)	42.15±0.83[b] (42)	43.00±1.15 (30)	45.28±1.67[b] (64)
Nagar Kurnool	4.43±0.92[b] (51)	17.24±0.70[b] (44)	26.35±0.63[b] (48)	37.83±0.57 (45)	41.68±0.65[c] (50)	42.41±1.15 (34)	46.94±2.23[b] (52)

NS - Not significant * Significant (P<0.05) **Highly significant (P<0.01); Figures in parentheses are number of observations.

Table 4: Least-squares means (±SE) of reproductive performance (days) of Macherla adults

Effects	N	AFM (Males)	AFM (Females)	AFE	AFL	LI	LS
District							
Guntur	27	357.96 ±12.60	354.41±6.22	323.60 ±4.33	548.53±13.61	287.30±4.27	1.24±0.03
Prakasam	24	371.13±12.60	365.23±12.46	331.33±11.33	553.76±14.25	292.96±7.68	1.22±0.04
Krishna	22	357.20±13.41	351.11`±6.89	325.60±13.45	539.37±16.64	298.27±5.05	1.20±0.03
Nagar Kurnool	19	352.46±15.49	366.86±9.97	332.80±10.88	566.40±14..30	290.16±9.64	1.16±0.05
Overall	**92**	**361.68 ± 6.3**	**356.41 ±7.77**	**322.04±5.54**	**552.15±7.27**	**292.47±3.49**	**1.20±0.03**

N= number of flocks studied, Age at first mating in males (AFM), Age at first mating in females (AFM), Age at first estrous (AFE), Age at first lambing (AFL), Lambing interval (LI) and Litter size (LS).

obtained at about 1.5 years (548 days) within the species specificities mentioned earlier. It can be inferred that the life time lamb crop production would be maximum due to its potential reproductive traits of early age of first service/ mating. Adequate feeding resources, ideal management practices and production system might have attributed for the ideal reproductive traits (Karthik *et al*., 2021). The reproductive traits of local Macherla sheep ewes showed that the breed was capable of producing lambing crop at an early age with high prolificacy and short lambing interval provided all input resources are optimized.

The reproductive trait values are comparable and marginally lower than North coastal sheep of Andhra Pradesh (Gangaraju, 2010 and Anandarao, 2010) and other Indian sheep breeds and significantly lower than Nellore sheep (Rani *et al.,* 2014, Karthik *et al*., 2021; Reddy *et al.,* 2018b, Harini, 2017). The lambing Per centage observed in Macherla sheep (97.4 per cent) was higher than the other hairy sheep of south India such as Mandya, Nellore (Acharya, 1982).

Correlation between body weights and linear body measurements

The phenotypic correlation between body weight and linear body measurements pooled over the various ages and sexes was presented in Table 5. Present study revealed that positive, strong and significant associations were found between body weight and other linear body measurements. The associations are body length ($r = 0.92$), height at withers ($r = 0.92$), chest girth ($r = 0.96$), paunch girth ($r = 0.92$), face length ($r = 0.85$), face width ($r = 0.48$), ear length ($r = 0.29$), and tail length ($r = 0.45$). Among the body measurements, chest girth was the most strongly correlated trait with body weight ($r = 0.96$) than other body measurements facilitating the accurate estimation of body weight using chest girth. This highest association of chest girth with body weight was in agreement with the reports of Belete *et al*. (2017), Abera (2014), and Mesfin (2015) in indigenous sheep of Ethiopia. The ear length was less correlated to the body weight and other body measurements. Further, body weight was moderately correlated with face width and tail length.

Regression analysis

Regression analysis is commonly used in animal research to describe quantitative relationships between response variable and one or more explanatory variables such as body weight and linear body measurements (body length, chest girth, height at wither etc.), especially during the lack of access to weighing equipment (Cankaya, 2008). In the present study, all age groups and sexes were polled for increasing accuracy of results and are presented in table 6. The results showed that the chest girth (CG) alone had highest R^2 (0.92) compared with other body measurements.

Table 5: Correlation coefficients among body measurements and body weight of Macherla sheep

	BW	BL	HW	CG	PG	FL	FW	EL	TL
BW	1	0.920**	0.916**	0.958**	0.921**	0.857**	0.480**	0.287**	0.449**
BL		1	0.910**	0.934**	0.922**	0.865**	0.489**	0.270**	0.538**
HW			1	0.932**	0.886**	0.859**	0.468**	0.272**	0.459**
CG				1	0.947**	0.883**	0.475**	0.281**	0.446**
PG					1	0.849**	0.493**	0.268**	0.458**
FL						1	0.339**	0.253**	0.400**
FW							1	0.223**	0.408**
EL								1	0.142**
TL									1

**Highly significant (P<0.01); Body weight (BW), Body length (BL), Height at withers (HW), Chest girth (CG), Paunch girth (PG), Face length (FL), Face width (FW), Ear length (EL), Tail length (TL).

Table 6: Multiple linear regression analysis of live body weight on different LBMs for Macherla sheep

Model	Intercept	b1	b2	b3	b4	b5	b6	b7	b8	R^2
BL	-34.034	0.920								0.847
HW	-35.988	0.916								0.839
CG	-29.66	0.958								0.919
BL + HW	-38.213	0.506	0.456							0.883
BL + HW + CG	-33.364	0.161	0.123	0.694						0.926
BL + HW + CG + PG	-32.986	0.136	0.128	0.638	0.078					0.926
BL + HW + CG + PG + FL	-33.002	0.137	0.128	0.639	0.078	-0.002				0.926
BL + HW + CG + PG + FL + FW	-33.580	0.131	0.125	0.638	0.072	0.006	0.016			0.926
BL + HW + CG + PG + FL + FW + EL	-33.679	0.131	0.124	0.635	0.073	0.005	0.015	0.015		0.926
BL + HW + CG + PG + FL + FW + EL +TL	-33.433	0.139	0.124	0.632	0.072	0.005	0.016	0.015	-0.008	0.926

It indicated that Chest girth was more reliable in predicting body weight than other linear body measurements at field level. The better association of body weight with chest girth was possible due to relatively larger contribution to body weight by chest girth consisting bones, muscles, and viscera (Thiruvenkadan, 2005). Regression analysis revealed that the combination of chest girth with height at withers and body length (BL + HT + HG) has equal R^2 (0.93) value compared with the other equations involving all body measurements (BL + HT + CG + PG + FL + FW + EL + TL). The scenario indicates that due to the difficulty in restraining animals under field conditions, the combination of chest girth with body length and height will be best suited for predicting body weight. Similar results were reported by Vani *et al*. (2018) in Nellore sheep and Michel *et al*. (2016) and Belete *et al*. (2017) in Ethiopian indigenous sheep.

CONCLUSION

The Macherla sheep are comparable and differentiated from the established sheep breeds of India because of the distinct phenotypic pattern and good productive and reproductive performances. The local Macherla sheep can be characterized by its strong and heavy body size, attractive coat color, high lambing percentage, and good adoptability to local climatic conditions. The observed growth and reproductive performances of Macherla sheep were optimum under Indian conditions. The influence of district on morphological and productive parameters indicates the variation in terms of resources and management. Regression analysis revealed that the measurement of chest girth alone or a combination of chest girth, height at withers and body length are best suited for predicting body weights under field conditions. The study also concluded that the selective breeding and optimizing the managemental techniques might cause further improvement in Macherla sheep.

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