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Growth performance and adaptability of Sirohi goats in arid and semi-arid regions of India

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Abstract
Sirohi goat is an important dual-purpose indigenous breed of India, native to the Sirohi district of Rajasthan and well distributed across the arid and semi-arid agro-climatic zones of Rajasthan and Gujarat. The present review compiles and critically analyses the available scientific information on growth performance and adaptability of Sirohi goats in arid and semi-arid regions of India. Birth weight ranged from 2.16 to 2.57 kg and 12-month body weight from 21.74 to 25.09 kg under diverse management conditions, with pre-weaning and post-weaning average daily gain of 87.52-113.66 g/day and 46.17-51.35 g/day respectively. Sirohi goats consistently outperformed Marwari goats of the same arid zone in pre-weaning body weights and pre-weaning ADG, confirming superior early growth efficiency driven by higher milk production capacity of Sirohi dams. Moderate heritability for birth weight (0.39±0.05) indicates good scope for within-breed genetic improvement and intensive management with concentrate supplementation significantly improved growth over extensive grazing. The breed exhibits remarkable adaptability to arid environments through maintenance of physiological parameters within near-normal range under peak summer heat stress, highest HSP70 mRNA expression among compared breeds, productivity maintenance on as low as 1.74 litres water per day and the lowest gastrointestinal parasite prevalence (10.91%) compared to Barbari (39.97%) and Jamunapari (36.93%). Systematic in-situ and ex-situ conservation and structured genetic improvement of this valuable indigenous breed is urgently needed for sustainable livestock production in the arid and semi-arid regions of India.

Keywords: Sirohi goat, growth performance, adaptability, arid region, heat tolerance, Marwari goat, India

Introduction
Sirohi goat is one of the most important dual-purpose breed in India, specifically native to the Sirohi district of Rajasthan but widely distributed across the country It has good growth performance and moderate milk production. It possesses many desirable characteristics such as disease resistance, early maturity, good adaptability to stall feeding as well as extensive grazing conditions and better survivability under harsh climatic conditions. The breed, quite important for meat and milk, is a medium to large-sized breed and is highly suited for rearing under arid and semi-arid conditions due to its compact body, strong legs and remarkable adaptability to dry and hot climates. In addition to being a good meat producer, it is also moderately prolific and serves as a dual-purpose animal under low input production systems in Rajasthan and Gujarat.

India ranks second in the world in terms of goat population with 148.88 million goats as per the 20th Livestock Census (DAHD, 2019) [15], recording an increase of 10.14% over the previous census of 2012. As per Basic Animal Husbandry Statistics 2025 (BAHS, 2025) [7], goat meat contributes 15.06% of the total meat production of the country and India is recognized as the largest exporter of sheep and goat meat in the world. Goat farming is less capital intensive and is thus suitable for a large number of rural and landless populations. Goats with their multi-facet utility for meat, milk, skin and manure contribute about 9% of livestock GDP and support the livelihoods of approximately 20 million small and marginal farmers in the country (Chakrabarti *et al*., 2014; DAHD, 2019) [11, 15].

Goat is particularly important in the arid and semi-arid regions of India, where crop production is always at risk due to erratic rainfall and drought conditions (Silanikove, 2000) [44].

Rajasthan, situated in the north-western arid and semi-arid zone of India, holds the highest goat population in the country at 20.84 million, which accounts for 16.03% of India's total goat population as per the 20th Livestock Census (DAHD, 2019) [15]. The state produced 3.10 million tonnes of goat milk and 95.23 thousand tonnes of goat meat during 2022-23, making it the leading state in goat production in the country (UPJOZ, 2024) [52]. With the increasing threat of climate change intensifying heat stress and water scarcity in arid zones, locally adapted indigenous breeds like Sirohi goat assume greater significance for sustainable livestock production (Bhateshwar *et al*., 2023) [9].

Distribution / natural habitat / population

Sirohi goat takes its name from the Sirohi district of southern Rajasthan, which is its primary area of origin and distribution (Acharya, 1982) [1]. The home tract of this breed includes the districts of Sirohi, Ajmer, Bhilwara, Tonk, Udaipur, Jaipur and Chittorgarh in Rajasthan and extends southward into the Palanpur district of Gujarat. It is also found in other parts of India due to its wide popularity and adaptability to adverse agro-climatic conditions. The breed accounts approximately 60% of Rajasthan's total goat population, underscoring its dominant role in the state's livestock economy (Animal Husbandry Dept. Rajasthan, 2019) [6]. The breed is registered as an indigenous breed of India by the ICAR- National Bureau of Animal Genetic Resources Karnal, Haryana (NBAGR, 2024) [33].

The natural habitat of this breed is arid to semi-arid (Acharya, 1982) [1]. The average temperature in the home tract ranges from 2.3°C in winter to 42.3°C in summer and the annual rainfall of this region is approximately 660 mm (Waiz *et al.,* 2018) [54]. Systematic data on growth, reproductive and lactation traits of Sirohi goats have been generated since 2004 under the All India Coordinated Research Project (AICRP) on Sirohi Goat at the Livestock Research Station (LRS), Vallabhnagar, Udaipur, located at 582 m above mean sea level at 24°35′N latitude and 73°43′E longitude (Gautam *et al.,* 2019) [19]. The approximate population of Sirohi goat in its home tract is significant and breed dominates the goat population of Rajasthan state (DAHD, 2019) [15].

Physical Characteristics

Sirohi goat is a medium to large-sized breed having a compact body and strong legs (Acharya, 1982) [1]. The body is covered with fairly dense hair, which is short and coarse (NBAGR, 2020) [32]. The coat colour is predominantly brown and brown with light to dark brown patches (spotted brown) (Tomar *et al.,* 2001) [50]. Both brown and spotted brown types are generally available in three shades of dark, medium and light (Acharya, 1982) [1]. Very few animals are completely white and the body coat is generally shiny in nature, but some animals also possess a hairy coat (Waiz *et al*., 2018) [54]. A phenotypic characterization study conducted at farm (Chittorgarh) and field (Deogarh) conditions during 2007 to 2019 reported that the predominant coat colour was dark brown with patches (40.31%) followed by dark brown (35.20%), brown with patches (19.17%), brown (4.06%), white patches (0.72%) and complete white (0.52%), while predominant muzzle colour was dark brown (33.96%) (Shashikant and Choudhary, 2022) [43]. The typical phenotypic appearance of Sirohi doe and buck is presented in Figures 1 and 2, respectively.

Fig 1: Sirohi doe showing typical brown coat with dark patches, drooping ears and compact body

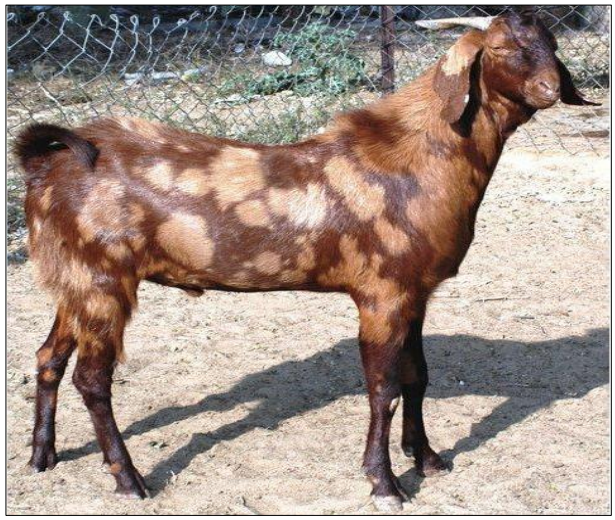

Fig 2: Sirohi buck showing upward curving horns, strong legs and compact cylindrical body.

The face of Sirohi goat is generally straight or sometimes slightly raised (Acharya, 1982) [1]. Ears are generally flat and leaf-like, medium-sized and drooping type (NBAGR, 2020) [32]. They are described as pendulous, drooping downwards, leaf-like in shape with slight curvature towards the back (Waiz *et al*., 2018) [54]. Both sexes have horns which are curved upward and backwards with a pointed tip (Tomar *et al.,* 2001) [50]. Among the total animals studied, 3.43% animals had a beard and 14.34% animals had wattles. The average horn length and ear length from 3 months to adult age were 2.37±0.30 cm to 9.02±0.22 cm and 13.93±0.52 cm to 17.74±0.18 cm, respectively (Shashikant and Choudhary, 2022) [43].

Waiz *et al*. (2018) [54] recorded body measurements of adult Sirohi goats above 2 years of age and reported mean values of chest girth, body length, height at wither, paunch girth, horn length, ear length and tail length as 73.3, 63.1, 71.3, 76.2, 9.6, 15.7 and 13.7 cm respectively. The breed shows notable sexual dimorphism in body weight with adult bucks averaging around 50 kg and does averaging 23 kg, while height at withers was approximately 85 cm in bucks and 68 cm in does (NBAGR, 2020) [32]. The body length, body height and heart girth in adult males measured 80, 85 and 80

cm while corresponding values in adult females were 60, 68 and 62 cm respectively (ILRI-AGTR, 2010) [22]. In general, male Sirohi goats recorded significantly higher body measurements compared to females at all ages, a finding consistently reported across Indian goat breeds under similar agro-climatic conditions (Waiz *et al*., 2018) [54].

Sharma (2008) [60] analyzed morphometric traits of Sirohi goat kids and reported positive and high genetic and phenotypic correlations between 3 and 6 months morphometric traits, indicating that early selection at 3 or 6 months of age can reliably predict morphometric performance at later ages. The overall least squares mean for body height at birth, 3, 6, 9 and 12 months of age were 31.02±0.35, 51.53±1.19, 57.65±0.95, 61.76±2.24 and 67.09±0.95 cm respectively under AICRP field conditions (Dudhe *et al*., 2015) [17], while heart girth, height at withers and body length at 12 months of age were 63.95±0.99, 63.47±1.10 and 57.71±1.21 cm respectively (Waiz *et al*., 2018) [54]. Heritability estimates for morphometric traits were of medium to high magnitude ranging from 0.528±0.163 to 0.709±0.144 for body height, 0.408±0.159 to 0.605±0.192 for body length and 0.503±0.197 to 0.695±0.161 for body girth, indicating strong additive genetic control over these traits and considerable scope for improvement through within-breed selection (Dudhe *et al*., 2015) [17].

Husbandry Practices

Sirohi goats in their home tract are generally maintained under an extensive grazing system on community rangeland under low input and output production systems (Acharya, 1982) [1]. Goats are allowed to graze freely during daytime and during night confined to sheds and sorghum straw, tree leaves, straw of different pulses and grasses are fed to goats under farm conditions (Waiz *et al*., 2018) [54]. The flock size varies from place to place and ranges from 10 to 200 goats and most of the flocks are stationary under an extensive grazing system (ILRI-AGTR, 2010) [22]. Large-sized flocks migrate seasonally to nearby areas in search of forage and water (ILRI-AGTR, 2010) [22]. Sirohi district in Rajasthan is well known for its goat husbandry practices, where challenges such as land degradation, water scarcity and dwindling fodder resources threaten the sustainability of goat farming in the region (Akhlesh Kumar *et al.,* 2025) [4]. The grazing and browsing area in arid and semi-arid zones of Rajasthan is mainly dominated by Khejri (*Prosopis cineraria*), Ber (*Ziziphus mauritiana*), Cenchrus grass, Neem (*Azadirachta indica*) and Kheri (*Acacia senegal*) (Singh *et al.,* 2004) [45]. Farmers generally rear Sirohi goats on browsing, extensive grazing, stubble of cultivated crops and tree leaves, including khejri (*Prosopis cineraria*), which is the dominant tree species of the arid zone of Rajasthan and a major source of browse for goats during dry seasons (Singh *et al*., 2023) [46].

Under village conditions, both males and females are grazed together and natural mating is generally practiced without any controlled breeding programme (Acharya, 1982) [1]. Kids are separated from their mothers at approximately 3 months of age and provided concentrate mixture (Gowane *et al.,* 2020; Dudhe *et al*., 2015) [21, 17]. Generally, no specialized shelters are provided to goats in villages and goats are housed in small enclosures with thatched or open roofs (Acharya, 1982) [1]. In the winter season, sufficient protection from cold is ensured by taking adequate measures such as using dry grass or bhusa as bedding material (Meel *et al*., 2010) [28]. Under organized farm at LRS Vallabhnagar, animals are reared under semi-intensive feeding management with grazing supplemented with concentrate mixture of approximately 200-250 g/day/animal along with green fodder and dry roughage (Dudhe *et al*., 2015; Yadav *et al.,* 2017) [17, 57].

Production Characteristics

Birth Weight

Birth weight of Sirohi goat kids has been reported by various workers under different management conditions. Misra *et al.* (1980) [30] reported birth weights of 2.96 and 1.51 kg in male and female kids, respectively under farm conditions. Sharma and Pathodiya (2007) [41] reported 2.16±0.05 kg under field conditions, while Gautam *et al*. (2019) [19] reported 2.34±0.03 kg based on 6,772 growth records at AICRP, LRS Vallabhnagar. Waiz *et al.* (2018) [54] and Ahari and Waiz (2024) [2] reported 2.50±0.39 and 2.57±0.036 kg, respectively with male and single-born kids significantly heavier than females and twins in both studies. Sex, type of birth and season significantly influenced birth weight across all studies (Banerjee and Jana, 2010; Dudhe *et al.,* 2015) [8, 17]. In comparison, Marwari goats of the same arid agro-climatic zone of Rajasthan recorded birth weights of 2.24 kg (Kumar and Rohilla, 2003) [24], 3.05±0.05 kg (Rai *et al.,* 2004) [35] and 2.47±0.01 kg (Sharma *et al.,* 2022) [40] under different management conditions. Both breeds showed broadly similar birth weight ranges under arid conditions. Sirohi birth weights were more consistent across diverse environments, including farm, field, semi-intensive and even hot-humid conditions outside its home tract, reflecting superior phenotypic stability and adaptability of the breed (Waiz *et al.,* 2018; Gautam *et al.,* 2019) [54, 19].

Pre-weaning Body Weight: Pre-weaning body weight at 3 months of age reflects the dam's milk production ability and the kid's early growth efficiency. Misra *et al.* (1980) [30] reported 3-month weights of 9.59 and 9.12 kg in male and female Sirohi kids, respectively under farm conditions. Sharma and Pathodiya (2007) [41] reported 10.84±0.23 kg under field conditions, while Waiz *et al.* (2018) [54] reported 11.21±0.36 kg under farm and field conditions in southern Rajasthan. Gautam *et al.,* (2019) [19] reported the highest value of 12.44±0.19 kg based on 6,772 growth records at AICRP, LRS Vallabhnagar, with the variation across studies largely attributed to differences in dam's milk production, feeding levels and management system. In comparison, Marwari goats of the same arid zone recorded 3-month weights of 8.79 kg (Kumar and Rohilla, 2003) [24], 11.35±0.17 kg (Rai *et al.,* 2004) [35] and 8.03±0.03 kg (Sharma *et al.,* 2022) [40] under different conditions. Sirohi goats (10.84-12.44 kg) consistently recorded higher pre-weaning weights than Marwari goats (8.03-11.35 kg) across comparable management conditions, primarily attributed to the higher milk production capacity of Sirohi dams during the suckling period (Waiz *et al.,* 2018; Gautam *et al*., 2019) [54, 19].

Post-weaning Body Weight: Post-weaning body weights at 6, 9 and 12 months of age are important indicators of growth efficiency and meat production potential. Misra *et al.* (1980) [30] reported 6 and 12-month weights of 16.74 and 23.92 kg in males and 14.81 and 22.49 kg in females under organized farm. Sharma and Pathodiya (2007) [41] and Waiz *et al.*

(2018) [54] reported comparable values of 15.24±0.28, 18.33±0.40, 21.74±0.35 kg and 15.29±0.41, 18.00±0.57, 21.86±0.77 kg at 6, 9 and 12 months respectively under field conditions. Gautam *et al.* (2019) [19] reported the highest values of 16.31±0.22, 20.08±0.47 and 25.09±0.40 kg at 6, 9 and 12 months based on 6,772 growth records at AICRP, LRS Vallabhnagar. Waiz *et al.* (2019) [55] further reported that selection at 6-9 months of body weight can reliably predict 12-month performance in Sirohi goats. In comparison, Marwari goats of the same arid zone recorded 6 and 12-month weights of 13.02 and 18.50 kg (Kumar and Rohilla, 2003) [24], 14.94±0.21 and 23.19±0.18 kg (Rai *et al.,* 2004) [35] under comparable conditions. Sirohi goats (15.24-16.31 kg at 6 months; 21.74-25.09 kg at 12 months) consistently outperformed Marwari goats (13.02-14.94 kg at 6 months; 18.50-23.19 kg at 12 months), confirming their greater production efficiency for commercial meat production in arid and semi-arid regions of Rajasthan (Gowane *et al*., 2011) [20]. The body weights of Sirohi goats at different ages, as reported by various workers under different management conditions, are summarised in Table 1.

Table 1: Body weights of Sirohi goats at different ages reported by different workers

Birth Wt (kg)	3-month (kg)	6-month (kg)	9-month (kg)	12-month (kg)	Condition	References
2.96 (M) 1.51 (F)	9.59 (M) 9.12 (F)	16.74 (M) 14.81 (F)	—	23.92 (M) 22.49 (F)	Farm	Misra *et al.,* (1980) [30]
2.16±0.05	10.84±0.23	15.24±0.28	18.33±0.40	21.74±0.35	Field	Sharma and Pathodiya (2007) [41]
2.50±0.39	11.21±0.36	15.29±0.41	18.00±0.57	21.86±0.77	Farm+Field	Waiz *et al.,* (2018) [54]
2.34±0.03	12.44±0.19	16.31±0.22	20.08±0.47	25.09±0.40	AICRP Field	Gautam *et al.,* (2019) [19]
2.57±0.036	—	—	—	—	Semi-arid	Ahari and Waiz (2024) [2]

M = Male; F = Female; AICRP = All India Coordinated Research Project; LRS = Livestock Research Station, Vallabhnagar, Udaipur

Effect of Non-Genetic Factors on Body Weight: Various non-genetic factors have been reported to significantly influence the body weights of Sirohi goats at different ages. Banerjee and Jana (2010) [8] reported that birth weight in Sirohi goats is significantly influenced by year, season, type of birth and dam's weight, with male kids recording higher birth weights than females across all types of birth — single, twins and triplets. Ahari and Waiz (2024) [2] reported an overall mean birth weight of 2.57±0.036 kg in Sirohi kids under semi-arid conditions, with male kids (2.67±0.051 kg) significantly heavier than females (2.46±0.041 kg), single-born kids (2.66±0.051 kg) significantly heavier than twin-born kids (2.30±0.052 kg) and winter-born kids (2.60±0.052 kg) recording slightly higher birth weight than autumn-born kids (2.53±0.051 kg). Dudhe *et al.* (2015) [17] reported that the effects of sire, cluster, year of birth and sex was highly significant (p<0.01) on all three morphometric traits in Sirohi goats under AICRP field conditions. Gautam *et al.* (2019) [19] reported that cluster and period of birth had a significant effect on all body weight traits and summer-born kids recorded higher body weight and pre- and post-weaning gains than winter and rainy season-born kids. Male animals showed significantly higher body weights than females at all ages, which is a consistent finding across Indian goat breeds (Dudhe *et al*., 2015; Waiz *et al.,* 2018) [17, 54].

Average Daily Gain (ADG)

Pre-weaning body weight gain (g/d): Pre-weaning ADG reflects the dam's milk production ability and the kid's early growth efficiency. Tomar *et al.* (2004) [51] reported 87.52±3.16 g/day, Sharma and Pathodiya (2007) [41] reported approximately 95-100 g/day and Gautam *et al.* (2019) [19] reported the highest value of 113.66±2.15 g/day based on 6,772 growth records at AICRP, LRS Vallabhnagar, with summer-born kids recording higher gains than other seasons. In comparison, Marwari goats of the same arid zone recorded pre-weaning ADG of 82.05±0.74 g/day (Verma *et al.,* 2020) [53] with a significant effect of season and sex on early gains (Rai *et al.,* 2004) [35]. Sirohi goats (87.52-113.66 g/day) consistently recorded higher pre-weaning ADG than Marwari goats (82.05 g/day) under comparable arid conditions, confirming superior early growth efficiency largely driven by the higher milk production capacity of Sirohi dams (Gowane *et al.,* 2011) [20].

Post-weaning body weight gain (g/d): Post-weaning ADG reflects the breed's inherent growth potential independent of the dam's milk. Tomar *et al.* (2004) [51] reported 51.35±3.01 g/day and Gautam *et al.* (2019) [19] reported 46.17±0.94 g/day in Sirohi goats under farm and AICRP field conditions, respectively, with season having a highly significant (p<0.01) effect on ADG in all post-weaning stages (Waiz *et al.,* 2024) [56]. In comparison, Marwari goats recorded post-weaning ADG of 49.18±0.76 g/day from 3 to 6 months (Verma *et al*., 2020) [53] with males recording 22% higher gains than females (Rai *et al.,* 2004) [35]. Although post-weaning ADG of Sirohi (46.17-51.35 g/day) and Marwari (49.18 g/day) was broadly comparable, Sirohi demonstrated overall superior growth efficiency owing to its significantly higher pre-weaning ADG and consistent performance across diverse management conditions of arid Rajasthan (Tomar *et al*., 2004; Gautam *et al.,* 2019) [51, 19]. A comparative summary of growth performance between Sirohi and Marwari goats under the arid and semi-arid conditions of Rajasthan is presented in Table 2.

Table 2: Comparison of growth performance between Sirohi and Marwari goats under arid and semi-arid conditions of Rajasthan

Parameter	Sirohi	Reference	Marwari	Reference
Birth weight (kg)	2.16-2.57	Gautam *et al.,* 2019; Waiz *et al.,* 2018 [19, 54]	2.24-3.05	Kumar & Rohilla, 2003; Rai *et al.,* 2004 [24, 35]
3-month weight (kg)	10.84-12.44	Gautam *et al.,* 2019; Waiz *et al.,* 2018 [19, 54]	8.03-11.35	Kumar & Rohilla, 2003; Rai *et al.,* 2004 [24, 35]
6-month weight (kg)	15.24-16.31	Gautam *et al.,* 2019; Waiz *et al.,* 2018 [19, 54]	13.02-14.94	Kumar & Rohilla, 2003; Rai *et al.,* 2004 [24, 35]
9-month weight (kg)	18.00-20.08	Gautam *et al.,* 2019; Waiz *et al.,* 2018 [19, 54]	15.76-18.28	Kumar & Rohilla, 2003; Rai *et al.,* 2004 [24, 35]
12-month weight (kg)	21.74-25.09	Gautam *et al.,* 2019; Waiz *et al.,* 2018 [19, 54]	18.50-23.19	Kumar & Rohilla, 2003; Rai *et al.,* 2004 [24, 35]
Pre-weaning ADG (g/day)	87.52-113.66	Tomar *et al.,* 2004; Gautam *et al.,* 2019 [51, 19]	82.05	Verma *et al.,* 2020 [53]
Post-weaning ADG (g/day)	46.17-51.35	Tomar *et al.,* 2004; Gautam *et al.,* 2019 [51, 19]	49.18	Verma *et al.,* 2020 [53]
Dressing percentage (%)	45.53-56.07	Rajkumar *et al.,* 2010; Sureshkumar *et al.,* 2010 [36, 47]	47.3-48.16	Acharya, 1982 [1]

ADG = Average Daily Gain; Sirohi data from AICRP field conditions, LRS Vallabhnagar, Udaipur; Marwari data from AICRP field conditions

Genetic Parameters for Growth Traits

Knowledge of genetic parameters is essential for designing effective selection and breeding programmes for genetic improvement of any livestock breed. Data collected over a period of 21 years (1988-2008) at CSWRI Avikanagar, Rajasthan, were used to estimate heritability for birth weight (BWT), weaning weight (WWT), 6-month weight (6WT), 9-month weight (9WT) and 12-month weight (12WT). Heritability estimates for BWT, WWT, 6WT, 9WT, 12WT, ADG1, ADG2 and ADG3 were 0.39±0.05, 0.09±0.03, 0.06±0.02, 0.09±0.03, 0.11±0.03, 0.10±0.03, 0.04±0.02 and 0.01±0.01, respectively (Gowane *et al.,* 2011) [20]. The moderate to high heritability for birth weight (0.39) indicates good scope for improvement through selection, while the low heritability estimates for post-weaning weights suggest greater influence of environmental factors on these traits and the need for improved management practices rather than selection alone. The growth curve parameters using the Brody function showed that the least-squares mean for asymptotic weight (A), folding point (B) and maturity rate (K) were 26.18±3.11 kg, 0.88±0.00 and 0.16±0.00 days, respectively (Waiz *et al.,* 2019) [55], indicating that the breed reaches mature body weight at a relatively early age which is economically favourable for meat production in arid zone farming systems.

Effect of feeding on growth performance

Feeding and nutrition play a key role in realizing the full genetic potential of Sirohi goats for growth under arid and semi-arid conditions. Jat *et al.* (2020) [23] reported that weaned Sirohi kids fed 100-200 g concentrate per day recorded maximum total weight gain of 7.72 kg compared to 5.52 kg in the control group fed only 50 g concentrate per day, with a significant difference (P≤0.05) between treatments. Chaudhary *et al.* (2015) [12] reported that concentrate supplementation significantly improved growth performance, carcass traits and meat composition of Sirohi kids under field conditions in their native tract. Nagda *et al.,* (2023) [31] reported that concentrate fed three times per day recorded higher final body weight (17.22±0.06 kg) and ADG (43.68 g/day) compared to once-daily feeding (16.18 kg; 32.30 g/day). Sharma *et al.* (2021) [39] reported that feeding green Azolla (*Azolla pinnata*) significantly improved growth performance in Sirohi male kids with better feed conversion efficiency compared to the control group. Chouhan *et al.* (2018) [14] reported that replacement of concentrate with *Moringa oleifera* leaves at 25% level had no adverse effects on growth performance, feed utilization and blood biochemical parameters in Sirohi kids, making it a cost-effective alternative feed material for arid zone farmers. A recent study by Alok Kumar *et al.* (2025) [5] from Madhav University, Sirohi, Rajasthan, reported that locally available fruit plant leaves, including tamarind, mango, guava and neem, possess valuable nutrients, including proteins, vitamins, minerals and fibre and serve as cost-effective supplementary fodder for goat farmers in Sirohi district, where access to quality fodder is limited.

Effect of management on growth performance

Management system, including housing and grazing conditions, significantly influences the growth performance of Sirohi goats in arid and semi-arid regions. Chopdar *et al.* (2022) [13] reported that body weight gain under extensive, semi-intensive and intensive management systems was 2964 g, 3638 g and 4780 g, respectively with the intensive system recording significantly (p<0.01) higher growth than the extensive system. Rajkumar *et al.* (2010) [36] reported that Sirohi kids under intensive management attained 28.47 kg slaughter weight, which was 16.11% more than 24.52 kg under the semi-intensive system at 9 months of age. Sharma *et al.* (2024) [42] reported that a loose housing system positively influenced body length, height at withers and heart circumference in Sirohi kids compared to a conventional housing system at RAJUVAS, Udaipur. Waiz *et al.* (2018) [54] reported that cluster effects reflecting differences in grazing resource availability were highly significant on body weights at all ages in Sirohi goats under field conditions in southern Rajasthan.

Adaptability

Heat Tolerance

Physiological parameters such as respiratory rate (RR), pulse rate (PR) and rectal temperature (RT) are important indicators of an animal's ability to maintain homeothermy under heat stress. The normal resting ranges in healthy adult goats are respiratory rate 16-34 breaths per minute, pulse rate 70-80 beats per minute and rectal temperature 38.5-40.0°C, and any significant elevation above these values during peak summer reflects the degree of thermal stress experienced by the animal (Swenson and Reece, 2006) [48]. Phulia *et al*. (2010) [34] reported morning rectal temperature of 38.97°C and respiratory rate of 43.66 breaths per minute in Sirohi goats during summer, which increased to 39.35°C and higher RR at 3.00 PM, while rectal temperature ranging from 37.63±0.08 to 38.97±0.15°C and heart rate of 111.33±5.38 beats per minute were recorded under controlled heat stress conditions, indicating that Sirohi goats maintain physiological parameters within near-normal range even under peak summer heat. Bhattacharya *et al*. (1995) [10] reported that increase in afternoon RT, RR and PR over morning values was higher in black-coated followed by dark brown, light brown and white Sirohi goats in descending order, confirming that lighter coat colour confers greater heat tolerance in this breed. Sharma *et al*. (2024) [42] further reported that Sirohi kids under loose housing exhibited significantly lower RT and RR compared to conventional housing at RAJUVAS, Udaipur.

Climate Resilience

Heat shock proteins (HSPs) serve as important molecular biomarkers of climate resilience in livestock and HSP70 is considered the most common genetic biomarker of thermotolerance in goats (Tijjani *et al*., 2022) [49]. Dangi *et al*. (2016) [16] reported that Sirohi exhibited the highest mRNA expression levels of HSP70 gene compared to Jamunapari, Barbari and Jakhrana goats at CIRG Makhdoom, indicating better heat stress regulation in the breed. Sajjanar *et al.* (2013) [38] further reported significant variation (P<0.01) in HSP70 gene expression between seasons in heat-adapted Sirohi and Barbari and cold-adapted Gaddi and Chegu goats, with higher expression during summer. Kumar *et al*. (2018) [25] reported that while respiratory rate increased significantly (p<0.01) during summer in Sirohi, Barbari and Jhakrana, rectal temperature did not change significantly (p>0.05) across seasons in Sirohi goats alone, confirming superior thermoregulatory efficiency over other breeds. Kumar *et al*. (2014) [26] further confirmed that Sirohi and Barbari showed significantly

(p<0.01) lower RT, RR and PR compared to cold-adapted Gaddi and Chegu across all seasons. In addition to thermal resilience, Sirohi goats consumed only 1.74±1.07 and 1.68±0.76 litres of water per day in arid and semi-arid zones respectively while maintaining milk production, with water conservation regulated by elevated levels of ADH, aldosterone and angiotensin II (Femi Francis *et al.,* 2023; Silanikove, 2000) [18, 44].

Disease Resistance

Disease resistance and survivability are critical components of adaptability in low-input extensive production systems of arid and semi-arid regions. Sirohi goat has proved to be an excellent breed with respect to disease resistance, adaptability to dry and hot climate and production performance under poor quality range conditions (Meel *et al.,* 2010; Shashikant and Choudhary, 2022) [28, 43]. The cumulative pre-weaning mortality rate in Sirohi goats was reported as 5.69% in the first 3 months of age with adult mortality of only 2.56%, which is significantly lower than mortality rates reported in other Indian goat breeds under similar semi-arid field conditions (Gowane *et al.,* 2024) [58]. A study on gastrointestinal parasite infections in goats in semi-arid rural ecosystems of India showed that Sirohi recorded the lowest prevalence of gastrointestinal parasites (10.91%) compared to Barbari (39.97%) and Jamunapari (36.93%), with Jamunapari goats showing significantly higher intensity of *Haemonchus contortus* infection than Sirohi goats, confirming superior natural parasite resistance of the breed (Yadav *et al.,* 2013) [59].

Conservation status and breed improvement

The Sirohi goat faces serious threats of genetic dilution due to indiscriminate crossbreeding, early castration of elite males and shrinking grazing resources in its home tract. A serious challenge to goat breed dilution is the lack of high-potential and true-to-breed bucks and in Indian conditions, crossbreeding of local goats with exotic breeds is not suitable **(**Rout *et al*., 2024) [37]. Production-oriented propagation through crossbreeding and upgrading did not work in the long term and is eroding the existing genetic architecture of indigenous goat germplasm and steps have been initiated by Central and State Government agencies and NGOs through ICAR-NBAGR, ICAR-CIRG and ICAR-CSWRI for in-situ and ex-situ conservation (Mandal *et al.,* 2014) [27]. Cryogenic storage of DNA of different goat breeds, including Sirohi has been undertaken at NBAGR, Karnal as an alternative approach for ex-situ conservation (Mandal *et al*., 2014) [27]. The AICRP leads conservation efforts on Goat Improvement initiated by ICAR in 1971 and the farm-based units of Jamunapari, Barbari and Sirohi are working as the best models for in-situ and ex-situ conservation with semen of different goat breeds preserved for conservation (AICRP-CIRG, 2022) [3]. The AICRP on Goat Improvement explores genetic variation through superior animal identification, pedigree and individual performance recording and selecting high genetic potential animals for breeding in their respective home tracts (AICRP-CIRG, 2022) [3]. The Sirohi AICRP unit at LRS Vallabhnagar has supplied 1279 improved animals to State Governments, NGOs and farmers for breed improvement, serving as a model for in-situ and ex-situ conservation (Dudhe *et al.,* 2015) [17].

Conclusion

The Sirohi goat is one of the most important dual-purpose indigenous goat breeds of India, well adapted to the arid and semi-arid agro-climatic conditions of Rajasthan and Gujarat, with good growth performance and consistent carcass quality under diverse management systems. The breed exhibits remarkable adaptability to harsh arid environments through efficient thermoregulation, HSP70 gene expression and superior water conservation ability, confirming its distinct advantage over other breeds of the same region. As the population of this breed is under threat from indiscriminate crossbreeding and shrinking grazing resources, there is an urgent need for systematic conservation and genetic improvement of this valuable indigenous breed.

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