Archives of Current Research International

Volume 24, Issue 11, Page 62-73, 2024; Article no.ACRI.124849
ISSN: 2454-7077

Genetics of Some Wool Traits in Sheep: A Review

Olympica Sarma [a*], Mubashir Ali Rather [b] and Shivangi Maurya [c]

[a] Department of Animal Genetics and Breeding, College of Veterinary and Animal Science, G B Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India.
[b] Diseases Investigation Laboratory, Nowshara, Srinagar, Kashmir, India.
[c] Department of Veterinary Public Health, College of Veterinary and Animal Science, G B Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/acri/2024/v24i11948

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/124849

Review Article

Received: 06/08/2024
Accepted: 09/10/2024
Published: 28/10/2024

ABSTRACT

Greasy fleece yield, staple length and fibre diameter are complex quantitative traits influenced by various genetic and environmental factors. Among non-genetic factors year of birth, gender of lamb, centre of rearing, parity and type of birth are known to influence wool traits in different sheep genetic resources. To develop effective breeding objectives and accurately evaluate genetic potential, more precise analysis of genetic parameters and correlations between growth traits is essential. However, inconsistent results were observed across breeds and studies, highlighting the need for breed-specific optimization strategies. Greasy fleece yield, fibre diameter and staple length are critical determinants of wool quality and quantity. Wool traits are moderately (20–50%) to highly heritable (≥50%), so improving quality and quantity of a wool clip can happen even after one

**Corresponding author: E-mail: olylucky15@gmail.com;*

Cite as: *Sarma, Olympica, Mubashir Ali Rather, and Shivangi Maurya. 2024. "Genetics of Some Wool Traits in Sheep: A Review". Archives of Current Research International 24 (11):62-73. https://doi.org/10.9734/acri/2024/v24i11948.*

generation. The significant variations observed among breeds underscore the need for breed-specific optimization strategies. By integrating genetic and environmental factors, sheep breeders and producers can develop effective breeding programs, improve wool production, and enhance profitability. Wool traits are moderately to highly heritable, however, very low and very high estimates have also been reported in different sheep genetic resources. The heritability estimates correspond to the genetic variation in a trait. Gene mapping has identified chromosomal regions influencing fibre quality and production, enabling more efficient selection of superior wool production. Recent studies have employed various techniques to investigate the impact of fibre-related genes, including the candidate gene approach, transcriptome analysis and genome-wide association studies. It is concluded that wool traits being quantitative in nature are governed by different genes and are influenced by genetic and different environmental factors.

Keywords: Wool production; sheep; parity of dam; type of birth; greasy fleece yield; fiber diameter; staple length.

1. INTRODUCTION

Wool is a versatile product in demand mainly because of its physical characteristics that directly influence wearer comfort (Hatcher et al., 2010). Key wool traits influence economic returns in sheep production include greasy fleece yield, clean wool yield, fiber diameter, staple length etc. Greasy fleece yield measures production potential and is a vital trait for evaluating clean wool yield quantity (Mahajan et al., 2018). Staple length (SL) and fiber diameter (FD) are crucial for selecting rams for breeding, as they bear a positive correlation with market prices of wool. Fiber diameter refers to the average width of a single wool fiber cross-section (Holman & Malau-Aduli, 2012). It is widely established as the most important wool trait when assessing wool quality and cost, accounting for approximately 75% of the total price of raw wool (Mortimer et al., 2010). FD value indicates the fineness with which a yarn can be spun and influences the amount of wool that can move through processing machinery at any given time. Finer wools (low FD) can be processed into yarns suited for high-value apparel textiles, producing lightweight, soft fabrics with superior handle and drape (Holman & Malau-Aduli, 2012). Conversely, coarser wools with high FD values are particularly suited for less luxurious and lower-valued uses, such as carpeting, outerwear or bedding (Poppi & McLennan, 2010). Staple length determines the end-use of wool, whether it will be used in weaving or knitting, and influences wool processing performance (Valera et al., 2009). Longer wools, generally around 51 mm and above, are processed into versatile yarns. Wool fiber staple length is becoming an increasingly important determinant of wool quality and value (Valera et al., 2009). Wools with long staple length are commercially more desirable as they tend to be easier to spin, give fewer stoppages, and ultimately can form stronger and more even yarns (Holman & Malau-Aduli, 2012).

2. GREASY FLEECE YIELD OF FIRST CLIP AND SECOND CLIP

The greasy wool yield at six months (first shearing) and 12 months (second shearing) are reliable indicators of an animal's lifetime wool production capacity. These traits are positively, significantly and highly correlated among themselves as the wool traits are influenced the same genes (Vesely et al., 1970) and any variation which may be observed in latter may be caused by environmental factors. The greasy fleece yield of different sheep breeds is reflected in Table 1. Highest and lowest greasy fleece yield of first clip of 1.08±0.119 kg and 0.43±0.032 kg is reported in Corriedale (Mir et al., 2000) and Marwari sheep (Singh et al., 1998), respectively. Similarly, highest and lowest greasy fleece yield of second clip of 1.01±0.017 kg and 0.125±0.042 kg is reported in Corriedale (Dixit et al., 2009) and Marwari sheep (Singh et al., 1998), respectively.

3. WOOL QUALITY TRAITS OF SHEEP

Wool quality is primarily determined by traits such as fibre diameter, staple length, crimp, colour and medullation percentage, which are influenced by both genetic and non-genetic factors and significantly impact wool processing performance and end-use [Valera et al., 2009; Holman & Malau-Aduli, 2012; Baba et al., 2020]. The least squares means of staple length and fibre diameter in different sheep breeds are reflected in Table 2.

Table 1. Least squares means of greasy fleece yield of first and second clips (kg) in different sheep breeds

Breed	Average ±S.E. (kg)		References
	GFY-1 (kg)	GFY-2(kg)	
Marwari	0.55	0.51	Sharma (1998)
Marwari	0.43±0.032	0.125±0.042	Singh et al., (1998)
Nali	0.63±0.019	0.69±0.022	Sharma (1999)
Bharat Merino	0.82±0.02	-	Tomar et al., (2000a)
Bharat Merino	0.82±0.02	-	Tomar et al., (2000b)
Chokla	0.95±0.02	-	Kumar (2000)
Corriedale	1.08±0.119	-	Mir et al., (2000)
Muzaffarnagri	0.445±0.43	-	Lal et al., (2000)
Marwari	0.577±0.005	0.57±0.005	Dass and Singh (2001)
Muzaffarnagri	0.533±0.128	0.493±0.157	Mandal et al., (2002)
Avikalin	1.06±0.02	-	Ahmad et al., (2004)
Magra	0.63±0.008	-	Dass et al., (2003)
Magra	0.93±0.003	0.795±0.005	Murdia et al., (2003)
Malpura	0.578±0.007	-	Sharma et al., (2003)
Magra	0.58±0.01	0.584±0.203	Mehta et al., (2004)
Marwari	0543±0.014	-	Nehra et al., (2005)
Jaiselmeri	0.788±0.80	-	Arora et al., (2007)
3/4th crossbred Bharat Merino	0.87±0.15	1.01±0.017	Dixit et al., (2009)
Chokla	0.95±.01	-	Kumar and Singh (2011)
Magra	0.757.82±0.11	84.30±0.09	Parihar (2012)
Marwari	0.568±4.19	0.692±5.53	Narula et al., (2011)
Marwari	0.576±0.007	0.657±0.006	Nirban (2013)
Marwari	0.564±0.078	0.494±0.022	Kannojia (2015)
Chokla	0.915 ± 0 .017	-	Yadav (2016)
Kashmir Merino	0.82±0.03	0.80±0.02	Rather et al., (2019a)
Anatolian Merino	2.97±0.19		Sertkaya et al., (2022)
Gang- Fatehpuri sheep	14.88±11.89	3.33±.23	Verma et al., (2024)

4. EFFECT OF SIRE

Research indicates that sire groups significantly impact wool traits, including greasy fleece yield, staple length and fiber diameter (Singh et al., 1998; Dixit et al., 2009; Parihar, 2012; Nirban, 2013; Rather et al., 2019; Holloway, 2017). Studies have demonstrated significant differences in greasy fleece yield of second clip due to sire groups in various breeds, including Marwari sheep (Singh et al., 1998), 3/4th crossbred Bharat Merino (Dixit et al., 2009), Magra (Parihar, 2012), Marwari (Nirban, 2013) and Kashmir Merino (Rather et al., 2019). The influence of sire groups on fiber diameter and staple length is also substantial. Random sire effects significantly influence fiber diameter in 3/4th crossbred Bharat Merino and Romney ewes (Dixit et al., 2009; Holloway, 2017). Similarly, staple length is significantly impacted by sire groups in 3/4th crossbred Bharat Merino and Romney ewes (Dixit et al., 2009; Holloway, 2017). These findings underscore the crucial role of genetics in determining wool quality and quantity. The significant influence of sire groups on wool traits has important implications for breeding programs, highlighting the need for selective breeding for superior wool traits, effective sire selection and consideration of genetic diversity to minimize inbreeding depression. By understanding the genetic basis of wool traits and leveraging genetic information, breeders can make informed decisions to enhance wool production and quality, ultimately improving the profitability and sustainability of sheep farming.

Table 2. Least squares means of staple length (SL) and fibre diameter (FD) in different sheep breeds

Breed	FD (μ)	SL (cm)	References
Bharat Merino	-	3.32±0.07	Dixit et al., (2009)
Marwari	36.15±0.27	4.69±0.05	Dass and Singh (2001)
Magra	32.41±0.28	-	Mehta et al., (2004)
Marwari	32.53±0.38	-	Nehra et al., (2005)
Corriedale	26.30±0.55	4.75±0.16	Sarkar et al., (2008)
Poll Dorset	25.18±1.28	4.04±0.51	Sarkar et al., (2008)
South Down	20.64±0.60	2.80±0.27	Sarkar et al., (2008)
Crossbred	25.21±1.16	3.65±0.21	Sarkar et al., (2008)
3/4th crossbred Bharat Merino	18.89±0.15	3.32±0.07	Dixit et al., (2009)
Kashmir Merino	20.95±0.07	5.22 ± 0.11	Das et al., (2014)
Rambouillet	21.27±0.03	5.64±0.04	Khan et al., (2015)
Harnali	25.85±0.07	5.65±0.03	Lalit et al., (2017)
Rambouillet	21.30±0.02	5.26±0.03	Mahajan et al., (2018)
Kashmir Merino	20.33±0.05	3.86±0.14	Rather et al., (2019a)
Kashmir Merino	20.88±0.07	3.47±0.10	Rather et al., (2019b)
Kashmir Merino x NARI Swarna Merino	21.10±0.13	3.39±0.19	Rather et al., (2019b)
Kashmir Merino	20.96 ± 0.002	4.05±0.01	Baba et al., (2020a)
Gurez	28.31±0.17	4.48±0.07	Ahanger et al., (2020)
Poonchi sheep	24.99±0.13	3.82±0.07	Taggar et al., (2018)
Karnah sheep	21.77±0.05	3.40±0.37	Khan et al., (2021)
Corriedale	21.20±0.05	3.88±0.05	Baba et al., (2020b)
Anatolian Merino	24.42±0.49		Sertkaya et al., (2022)
Gang- Fatehpuri sheep	14.88±11.89	47.79±1.81	Verma et al., (2024)

5. EFFECT OF PERIOD OR YEAR OF BIRTH

Management and grazing quality/quantity influence wool production across different periods. Studies demonstrate significant effects of period of birth on greasy fleece yield in Magra (Murdia et al., 2003; Mehta et al., 2004), Nali and Marwari (Sharma, 1998), Malpura (Gowane & Arora, 2010), and Marwari (Kannojia, 2015). Additionally, significant effects of year of birth on fiber diameter have been reported in Magra (Gajbhiye & Johar, 1983), Nali (Malik et al., 1990), Xinjiang (Wang et al., 1994), Afrino (Snyman et al., 1995), crossbred, Poonchi and Rambouillet (Qureshi et al., 2013), and Rambouillet (Khan et al., 2015; Mahajan et al., 2018). Period of birth also significantly impacts staple length in Nali (Malik et al., 1990), crossbred, Poonchi and Rambouillet (Qureshi et al., 2013) and Rambouillet (Khan et al., 2015; Mahajan et al., 2018). However, non-significant effects have been reported for year of birth on fiber diameter in Merino and Deccani half-bred sheep (Kulkarni & Deshpande, 1990) and Magra (Mehta et al., 2004). Similarly, period of birth has no significant effect on staple length in Kashmir Merino (Das et al., 2014; Rather et al., 2019) and Harnali sheep (Lalit et al., 2016). Understanding these temporal variations is crucial for optimizing wool production. By recognizing the impact of period / year of birth, breeders can make informed decisions regarding importance of management and nutrition in wool production traits.

6. EFFECT OF GENDER OF LAMB

Researchers have extensively investigated the impact of lamb gender on wool production and quality traits. The significant effects of lamb gender on greasy fleece yield of the first clip in Marwari and Magra, respectively was reported by Dass & Singh (2001); Murdia et al (2003). Similarly, (Mehta et al., 2004; Narula et al., 2011; Parihar, 2012) observed significant effects on greasy fleece yield of the second clip in Magra. However, (Dixit et al., 2009) found non-significant effects on greasy fleece yield of the second clip in 3/4th crossbred Bharat Merino. Lamb gender also significantly impacts fiber diameter. The significant effects in Corriedale and Russian Merino were reported by Malik et al., (1990), while (Dixit et al., 2009) observed significant effects in 3/4th crossbred Bharat Merino. Conversely, (Mehta et al., 2004) found non-significant effects in Magra, and (Qureshi et al., 2013; Khan et al., 2015; Mahajan et al., 2018) reported non-significant effects in crossbred, Poonchi, and Rambouillet. Regarding staple length, significant effects of lamb gender have been reported by Vesely et al., (1970) in Rambouillet, (Malik et al., 1990) in Corriedale and Russian Merino and (Dixit et al., 2009) in 3/4th crossbred Bharat Merino. However, (Qureshi et al., 2013; Khan et al., 2015; Mahajan et al., 2018) found non-significant effects in crossbred and Rambouillet. Rather et al., (2019) in Kashmir Merino sheep reported non-significant effect of gender on greasy fleece yield and significant effect on fiber diameter and staple length.

7. EFFECT OF FARM/ STATION

Studies have shown that the centre of rearing significantly affects greasy fleece yield. The significant effect in Magra sheep's first clip was reported by Murdia et al., (2003). Similarly, (Gupta, 2000) observed a significant impact of farm on Rambouillet, Merino, Gaddi and their crosses. The place of birth also influences wool traits. The significant effect on greasy fleece yield was reported by Qureshi et al., (2013). The highly significant effect of farm on fibre diameter in Rambouillet, Merino, Gaddi and their crosses was reported by Gupta, (2000). However, (Rather et al., 2019) reported significant effects of farm on greasy fleece yield in Kashmir Merino sheep but no significant impact on fibre diameter and staple length. The non-significant effect of farm on FD and SL was reported by (Baba et al., 2020).

8. EFFECT OF TYPE OF BIRTH

Research on Baluchi (Yazdi et al., 1997) and 3/4th crossbred Bharat Merino sheep (Dixit et al., 2009) reveals significant effects of type of birth

Table 3. Effect of genetic and non-genetic factors on greasy fleece yield of first clip in different sheep genetic resources

Breed/Genetic group	Genetic and non-genetic factors						References
	N	Sire	Period	Gender	Type of birth	Parity	
Bharat Merino	556	*	*	*	NS	-	Singh and Kushwaha, (1995)
Baluchi	-	-	*	*	*	*	Yazdi et al., (1997)
Nali	-	-	**	NS		-	Shanna et al., (1999)
Corriedale	-	NS	**	NS	NS	-	Mir et al., (2000)
Bharat Merino	-	-	**	NS		-	Tomar et al., (2000a)
Cholka	-	-	**	**	-	-	Kumar (2000)
Marwari	1132	-	**	**	-	-	Dass and Singh (2001)
Muzaffarnagri	-	-	-	-	-	NS	Mandal et al., (2002)
Magra	4107	**	**	**	-	-	Murdia et al., (2003)
Malpura	-	-	**	**	-	-	Sharma et al., (2003)
Magra	352	-	NS	NS	-	-	Dass et al., (2003)
Marwari	-	-	*	*	-	-	Nehra et al., (2005)
Jaisalmeri		-	-	**	-	-	Arora et al., (2007)
3/4th crossbred Bharat Merino	2425	**	-	**	**	-	Dixit et al., (2009)
Kajli	-	-	**	**	NS	-	Qureshi et al., (2010)
Magra	-	**	NS	**	-	NS	Chander (2012)
Magra	-	**	*	**		-	Parihar (2012)
Marwari	-	**	**	**	-	**	Nirban (2013)
Chokla sheep	-	**	**	NS	-	-	Kumar et al., (2013)
Corriedale			**	NS			Baba et al., (2020b)

*NS indicates non-significant; * indicates significant at 5% level; ** indicates significant at 1% level; N indicates no. of observations* on greasy fleece yield of the first clip (Table 3). However, (Dixit et al., 2009) found non-significant impact on greasy fleece yield of the second clip. Type of birth significantly influences staple length and fibre diameter in 3/4th crossbred Bharat Merino, as reported by Dixit et al., (2009). Conversely, (Rather et al., 2019) found non-significant effect of type of birth on staple length, fibre diameter or greasy fleece yield of either clip (Ahanger, et al. 2013; Singh, et al. 2008.)

9. EFFECT OF PARITY OF DAM

In Baluchi sheep (Yazdi et al., 1997) and in Magra sheep (Chander, 2012) reported that parity of dam had a significant effect on greasy fleece yield of first clip. However, (Mandal et al., 2002) in Muzaffarnagri sheep reported a non-significant effect of parity on the trait. The effect of parity of dam on the greasy fleece yield of first clip (GFY-1) have been reviewed and summarized in Table 3. The information regarding effect of parity of dam on greasy fleece yield of second clip was very scanty in print and electronic media. In Muzaffarnagri (Mandal et al., 2002) and (Chander, 2012) in Magra sheep reported that parity of dam had significant effect on greasy fleece yield of second clip. The information regarding effect of parity of dam on greasy fleece yield of second clip was very scanty in print and electronic media. In Muzaffarnagri sheep (Mandal et al., 2002) and in Magra sheep (Chander, 2012) different researchers have reported that parity of dam which showed significant effect on greasy fleece yield of second clip. The non-significant effect of parity of dam on staple length, fibre diameter or greasy fleece yield of either clip (Rather et al., 2019).

10. HERITABILITY

Wool traits exhibit moderate (25-50%) to high (≥50%) heritability, indicating that genetic factors significantly influence trait variation. This suggests that genomic selection can substantially enhance wool production progress (Bromley et al., 2000). However, despite these promising heritability estimates, few genetic markers have been validated for use in genomic breeding strategies specifically targeting wool traits (Becker et al., 2023). The heritability estimates for greasy fleece yield (GFY-1 and GFY-2) and wool quality traits (FD and SL) have been reviewed and summarized in the Table 4. Wool yield traits are moderately (20–50%) to highly heritable. However, low (<0.25) heritability estimates have been reported by (Mandal et al., 2002; Sheikh & Dhillon, 1992; Tomar et al., 2000; Kumar, 2000; Nehra & Singh, 2006) in Kashmir Merino, Bharat Merino, Muzaffarnagari, Cholka and Marwari sheep genetic resources, respectively whereas very high heritability estimate of 0.98 ±0.090 was reported in Marwari sheep by Nirban (2013). Moderate heritability estimates were observed by (Mandal et al., 2002; Dixit et al., 2009; Nirban, 2013) whereas (Rather et al., 2019) in Kashmir Merino observed a high heritability estimate. (Nehra & Singh, 2006; Rather et al., 2019) in Marwari and Kashmir Merino, respectively observed a low heritability estimate for FD. The moderate heritability estimates for FD and SL in Harnali sheep was reported by Lalit et al., (2017). The high and low heritability estimates for FD and SL was reported in Rambouillet sheep, respectively (Khan et al., 2015).

11. GENOMIC SELECTION AND ITS IMPACT ON WOOL TRAITS

Gene mapping has identified chromosomal regions influencing fibre quality and production, enabling more efficient selection of superior wool-producing animals (Hamadani et al., 2023). Recent studies have employed various techniques to investigate the impact of fibre-related genes, including the candidate gene approach, transcriptome analysis (Yunxia et al., 2021; Liu et al., 2023), and genome-wide association studies (Zhao et al., 2021). Differential and relative expression-based studies (Ma et al., 2023) have facilitated the identification of genes controlling hair and fibre traits, revealing unique expression patterns. Over the past few decades, DNA-based marker technology has enabled the identification of genomic regions, or quantitative trait loci (QTLs), underlying complex traits such as fibre diameter and crimp frequency (Xiao et al., 2023). Wool yield traits are known to be influenced by Leptin, PIT1 also IGF1 genes. The nine significant SNPs for fibre diameter, distributed across seven autosomes was discovered by Wang et al., (1994). Additional SNP markers have been reported on chromosomes OAR1, OAR5, OAR6, OAR13, and OAR25. KRTAP28-1 Variants. Six variants (A-F) of the KRTAP28-1 gene, containing eight SNPs was identified, and detected TG dinucleotide repeat polymorphism (Bai et al., 2019). Research has identified QTLs associated with staple length. Seven QTLs were detected on chromosomes 3, 7, 14, 15, 18, and 25 (Itenge, 2021). Three QTLs on chromosomes 3, 7, and

25 were linked to staple length. Four putative QTLs were identified on chromosomes 14, 15, 18, and 25. Furthermore, (Li et al., 2017) demonstrated that CRISPR/Cas9-mediated disruption of FGF5 activity can promote wool growth, increasing wool length and yield. An overview of the important genes governing wool traits and their importance was published by Hamadani et al., (2023).

12. FUTURE RESEARCH IN WOOL

As currently wool has lost market to synthetic fibre. Therefore, to increase the market value of wool and counter the dominance of synthetic fibers, research should focus on its potential in emerging markets. Investigations should aim to identify and validate novel genetic markers associated with desirable wool traits.

Table 4. Heritability estimates for greasy fleece yield of first and second clips in different sheep breeds

Breed	GYF-1	GYF-2	FD	SL	References
Soviet Merino	0.55±0.23	-			Kaul and Tomar (1983)
Russian Merino	0.67±0.21	-			Singh et al., (1984)
Merino	0.67±0.21	-			Mehta (1986)
Rambouillet	0.57±0.64	-			Mehta (1986)
Kashmir Merino	0.19±0.08	-			Sheikh and Dhillon (1992)
Avivastra	0.44±0.09	-			Kushwaha et al., (1995)
Bharat Merino	0.519±0.145	-			Singh and Kushwaha (1995)
Marwari	0.35 ± 0.084	0.31± 0.097			Sharma (1998)
Marwari	0.51 ± 0.058	0.03±0.031			Singh et al., (1998)
Nali	0.57 ± 0.286	0.023±0.144			Sharma et al., (1999)
Bharat Merino	0.02±0.06	-			Tomar et al., (2000a)
Bharat Merino	0.49±0.09	-			Tomar et al., (2000b)
Cholka	0.11±0.06	-			Kumar (2000)
Muzaffarnagari	0.23±0.05	0.38±0.06			Mandal et al., (2002)
Avikalin	0.41	-			Ahmad et al., (2004)
Marwari	0.162±0.117	-	0.216±0.123	-	Nehra et al., (2006)
3/4th crossbred Bharat Merino	0.54±0.013	0.31±0.09	0.46±0.13	0.76±0.15	Dixit et al., (2009)
Marwari	0.98 ±0.090	0.37±0.065			Nirban et al., (2013)
Rambouillet			0.55±0.09	0.15±0.05	Khan et al., (2015)
Synthetic sheep	0.25±0.05	-	0.52±0.12	0.45±0.11	Sehrawat (2016)
Harnali			0.45±0.06	0.38±0.05	Lalit et al., (2017)
Kashmir Merino	0.61 ± 0.08	0.52 ± 0.04	0.23 ± 0.04	0.66±0.10	Rather et al., (2019c)

13. CONCLUSION

Greasy fleece yield, fibre diameter and staple length are critical determinants of wool quality and quantity. The significant variations observed among breeds underscore the need for breed-specific optimization strategies. By integrating genetic and environmental factors, sheep breeders and producers can develop effective breeding programs, improve wool production and enhance profitability. Furthermore, understanding wool traits can inform decisions on nutrition, health and management practices, ultimately contributing to sustainable and resilient sheep production systems. Future research should focus on exploring innovative breeding technologies and management strategies to optimize wool trait expression and drive economic growth in the sheep industry. Research should be focused to increase the market value of wool and counter the dominance of synthetic fibers.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of this manuscript. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below:

1. Meta AI

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Ahanger, S. A., Sofi, A. H., Paul, M. A., Khalil, M., Hamadani, A., Khan, N. N., Baba, M. A., Shah, M. M., Baba, J. A., Kuthu, B. A., & Rather, M. A. (2013). Wool characteristics of Figurez sheep. *Sciences*, 1, 20-25.

Ahmad, M., Singh, C. V., Sharma, R. K., Kumar, S., & Arora, A. L. (2004). Genetic estimates of growth and wool yield in Avikalin sheep. *The Indian Journal of Small Ruminants*, 10(2), 156-158.

Arora, A. L., Prince, L. L., & Mishra, A. K. (2007). Performance evaluation of Jaisalmeri sheep in farmers' flocks. *The Indian Journal of Animal Sciences*, 77(8), 759-762.

Baba, J. A., Hamadani, A., Shanaz, S., & Rather, M. A. (2020b). Factors affecting wool characteristics of Corriedale sheep in temperate region of Jammu and Kashmir. *Indian Journal of Small Ruminants*, 26(2), 173-177.

Baba, M. A., Ahanger, S. A., Hamadani, A., & Rather, M. A. (2020). Factors affecting wool characteristics of sheep reared in Kashmir. *Tropical Animal Health and Production*, 20, 1-5.

Bai, L., Wang, J., Zhou, H., & Gong, H. (2019). Identification of ovine KRTAP28-1 and its association with wool weight and mean fibre diameter-associated traits. *Animals*, 9(4), 142.

Becker, G. M., Woods, J. L., Schauer, C. S., Stewart, W. C., & Murdoch, B. M. (2023). Genetic association of wool quality characteristics in United States Rambouillet sheep. *Frontiers in Genetics*, 13, 1081175.

Bromley, C. M., Snowder, G. D., & Van Vleck, L. D. (2000). Genetic parameters among weight, prolificacy and wool traits of Columbia, Polypay, Rambouillet and Targhee sheep. *Journal of Animal Science*, 78, 846-858.

Chander, S. (2012). Genetic evaluation of growth, wool and reproduction traits of Magra sheep (Doctoral dissertation, Rajasthan University of Veterinary and Animal Sciences, Bikaner-334001).

Das, A. K., Chakraborty, D., Kumar, N., Gupta, P., Khan, N. N., & Bukhari, S. (2014). Effects of non-genetic factors on performance traits of Kashmir Merino sheep. *Indian Journal of Animal Research*, 48(2), 106-108.

Dass, G., & Singh, V. K. (2001). Relative wool production and quality performance of elite flock of Marwari sheep. *The Indian Journal of Small Ruminants*, 7(1), 1-4.

Dass, G., Singh, V. K., Chopra, S. K., & Ayub, M. (2003). Wool production and quality of Magra sheep under hot arid zone of Rajasthan. *The Indian Journal of Small Ruminants*, 9(1), 10-12.

Dixit, S. P., Singh, G., Kant, N., & Dhillon, J. S. (2009). Contribution of genetic and phenotypic parameters affecting fleece traits in 3/4th bred Bharat Merino sheep. *Indian Journal of Animal Research*, 43(1), 1-6.

Gajbhiye, P. U., & Johar, K. S. (1983). Effect of some non-genetic factors on birth weight and fleece weight in Magra sheep [India]. *Indian Veterinary Journal*, 60(10), 831-838.

Gowane, G. R., & Arora, A. L. (2010). Performance evaluation of sheep in farmer's flock of eastern semi-arid region of Rajasthan. *The Indian Journal of Small Ruminants*, 16(1), 87-91.

Gupta, N. (2000). Genetic evaluations of exotic fine wool breeds (Rambouillet & Merino) and other crosses with indigenous sheep breeds of Northwestern Himalayan region (Doctoral dissertation, CSKHPKV, Palampur).

Hamadani, A., Ganai, N. A., Rather, M. A., & Bashir, I. (2023). Important genes affecting fibre production in animals: A review. *Indian Journal of Animal Sciences*, 93(10), 939–945.

Hatcher, S., Atkins, K. D., & Safari, E. (2010). Lamb survival in Australian Merino sheep: A genetic analysis. *Journal of Animal Science*, *88*(10), 3198-205.

Holloway, H. J. (2017). Analysis of the effects of sire and age on wool quality traits in Romney ewes (Doctoral dissertation, Lincoln University).

Holman, B., & Malau-Aduli, A. E. (2012). A review of sheep wool quality traits. *Annual Review and Research in Biology*, *2*(1), 1-14.

Itenge, O. T. (2021). Application of PCR technique to detect polymorphism of the KRTAP1.1 gene in three sheep breeds: A review. *Analytical Chemistry-Advancement, Perspectives and Applications*. DOI: 10.5772/intechopen.96941.

Kannojia, K. (2015). Selection strategies for genetic improvement of Marwari sheep (MV Sc. Thesis, Rajasthan University of Veterinary and Animal Sciences, Bikaner).

Kaul, K. L., & Tomar, N. S. (1983). Genetic studies on Russian Merino and Stavropol sheep in India. *Indian Veterinary Journal*, 60, 42-45.

Khan, N. N., Kumar, N., Das, A. K., Chakraborty, D., Taggar, R. K., & Gupta, P. (2015). Genetic studies on wool production traits in Rambouillet crossbred sheep in J & K State, India. *Indian Journal of Animal Research*, *49*(1), 40-43.

Khan, N. N., Rather, M. A., Hamadani, A., Bukhari, S., & Shah, R. (2021). Wool quality traits of sheep reared in Karnah tehsil of J&K. *The Indian Journal of Small Ruminants*, 9(2), 255-257.

Kulkarni, A. P., & Deshpande, K. S. (1990). Birth weight in Deccani sheep and its crosses with exotic breeds. *Indian Veterinary Journal*, 68(1), 33-35.

Kumar, R. (2000). Genetic analysis of body weight and wool yield traits in Chokla sheep (Doctoral dissertation, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar).

Kumar, R., & Singh, C. V. (2011). Effect of genetic and non-genetic factors on growth and wool yield traits in Chokla sheep. *Indian Journal of Small Ruminants*, 17(1), 95-98.

Kumar, R., Singh, C. V., & Barwal, R. S. (2013). Estimation of genetic parameters and evaluation of sires for growth and fleece yield traits using animal model in Chokla sheep. *Animal Molecular Breeding*, 2, 4-15.

Kushwaha, B. P., Jain, A., & Singh, G. (1995). Estimates of genetic and phenotypic parameters of body weights and fleece weight in Avivastra sheep. *Indian Journal of Animal Sciences*, 65(7), 812-813.

Lal, N., Misra, B. S., Singh, P. K., & Shukla, S. N. (2000). Growth rate and wool production in Muzaffarnagri sheep and its exotic grades. *The Indian Journal of Small Ruminants*, 6(2), 68-72.

Lalit, Malik, Z. S., Dalal, D. S., Dahiya, S. P., Magotra, A., & Patil, C. S. (2016). Genetics of growth traits in sheep: A review. *International Journal of Recent Research in Life Sciences*, *3*(2), 12-18.

Lalit, Malik, Z. S., Dalal, D. S., Patil, C. S., & Dahiya, S. P. (2017). Genetic studies on growth, reproduction and wool production traits in Harnali sheep. *Indian Journal of Animal Research*, 51(5), 813-816.

Li, W. R., Liu, C. X., Zhang, X. M., Chen, L., Peng, X. R., He, S. G., Lin, J. P., Han, B., Wang, L. Q., Huang, J. C., & Liu, M. J. (2017). CRISPR/Cas9-mediated loss of FGF5 function increases wool staple length in sheep. *The FEBS Journal*, 284(17), 2764-2773.

Liu, Z., Sun, Z., Ke, H., Chen, B., Gu, Q., Zhang, M., Wu, N., Chen, L., Li, Y., Meng, C., Wang, G., Wu, L., Zhang, G., Ma, Z., Zhang, Y., & Wang, X. (2023). Transcriptome, ectopic expression and genetic population analysis identify candidate genes for fiber quality improvement in cotton. *International Journal of Molecular Sciences*, *24*(9), 8293.

Ma, S., Long, L., Huang, X., Tian, K., Tian, Y., Wu, C., & Zhao, Z. (2023). Transcriptome analysis reveals genes associated with wool fineness in Merinos. *PeerJ*, 11, e15327.

Mahajan, V., Das, A. K., Taggar, R. K., Kumar, D., Khan, N., Sharma, R., & Shanti, V. R. (2018). Non-genetic factors influencing the wool traits of Rambouillet sheep in Jammu. *International Journal of Current Microbiology and Applied Sciences*, *7*, 3966-3973.

Malik, B. S., Singh, B., & Sangwan, M. L. (1990). Studies on fleece production in Nali and its crosses. *Indian Journal of Animal Research*, 24(2), 82-84.

Mandal, A., Rout, P. K., Pant, K. P., & Roy, R. (2002). Genetic studies on fleece weights of Muzaffarnagri sheep. *The Indian Journal of Small Ruminants*, 8(2), 92-96.

Mehta, B. S. (1986). Discrimination among exotic fine wool breeds (Rambouillet and Russian Merino), native superior carpet wool breeds (Chokla and Nali) and their crosses on the basis of fleece characteristics (Doctoral dissertation, Kolkata).

Mehta, S. C., Chopra, S. K., Singh, V. K., Ayub, M., & Mahrotra, V. (2004). Production and quality of wool in Magra breed of sheep. *The Indian Journal of Animal Sciences*, 74(7), 792-794.

Mir, M. Y., Risam, K. S., Kiramani, M. A., & Gani, T. A. (2000). Genetic and environmental factors influencing greasy fleece yield in a closed flock of Corriedale sheep. *The Indian Journal of Animal Sciences*, *70*(5), 540-542.

Mortimer, S. I., Atkins, K. D., Semple, S. J., & Fogarty, N. M. (2010). Predicted responses in Merino sheep from selection combining visually assessed and measured traits. *Animal Production Science*, *50*(10), 976-82.

Murdia, C. K., Saharan, R., Joshi, R. K., Ramnani, K., & Yadav, S. B. (2003). Genetic improvement in greasy fleece yield of Magra sheep under field conditions. *The Indian Journal of Small Ruminants*, 9(1), 35-38.

Narula, H. K., Dass, G., Kumar, A., & Sharma, P. R. (2011). Wool yield and quality of Magra sheep under arid conditions. *Indian Veterinary Journal*, *88*(5), 53.

Nehra, K. S., & Singh, V. K. (2006). Genetic evaluation of Marwari sheep in arid zone: Growth. *The Indian Journal of Small Ruminants*, 12(1), 91-94.

Nirban, L. (2013). Genetic and phenotypic trends of growth and wool traits in Marwari sheep (Doctoral dissertation, Rajasthan University of Veterinary and Animal Sciences, Bikaner-334001).

Parihar, K. (2012). Studies of genetic and phenotypic trends of growth and wool traits in Magra sheep (Doctoral dissertation, Rajasthan University Veterinary and Animal Sciences, Bikaner-334001).

Poppi, D. P., & McLennan, S. R. (2010). Nutritional research to meet future challenges. *Animal Production Science*, *50*(6), 329-38.

Qureshi, M. A., Babar, M. E., & Ali, A. (2010). Environmental and genetic factors influencing performance traits of Kajli sheep in Pakistan. *Pak. J. Zool.*, 42(3), 339-343.

Qureshi, M. A., Khan, S. A., Shafique, M., Sabir, N., & Ahmed, G. (2013). Influence of genetic and non-genetic factors on quantity and quality of wool from sheep reared at Rawalakot Azad Jammu and Kashmir. *Journal of Animal and Plant Sciences*, 23, 20-25.

Rather, M. A., Magray, S., Ahanger, S. A., Baba, M. A., Shah, M. M., Rather, T. A., Farooq, Y., & Abbas, Q. (2019a). Effect of some non-genetic factors and Fec-B gene introgression on performance traits of Kashmir Merino sheep. *International Journal of Current Microbiology and Applied Sciences*, *8*(8), 444-9.

Rather, M. A., Shanaz, S., Ganai, N. A., Baba, M. A., Hamadani, A., Ahmad, M. S., & Ahmad, T. (2019b). Genetic, phenotypic and environmental trends for production and reproduction traits in Kashmir Merino sheep. *International Journal of Livestock Research*, *9*(12), 73-78.

Rather, M. A., Shanaz, S., Ganai, N. A., Bukhari, S., Hamadani, A., Khan, N. N., Yousuf, S., Baba, A., Raja, T. A., & Khan, H. M. (2019c). Genetic evaluation of wool traits of Kashmir Merino sheep in organized farms. *Small Ruminant Research*, 177, 14-17.

Sehrawat, V. (2016). Experimental study of genetic architecture of sheep population. *International Journal of All Research Education and Scientific Methods*, *4*(3), 76–82.

Sertkaya, Ş., & Öztrürk, A. (2022). Fleece yield and some characteristics of wool in Anatolian Merino sheep. *Selcuk Journal of Agriculture and Food Sciences*, *36*(1), 8-12.

Shanna, P. R., Beniwal, B. K., Singh, V. K., Dass, G., & Sharma, B. S. (1999). Wool production of Nali sheep in hot arid region of Rajasthan. *The Indian Journal of Small Ruminants*, 5(1), 9-13.

Sharma, M. K. (1998). Comparative study of Nali and Marwari breeds of sheep in arid zone of Rajasthan (Doctoral dissertation, Rajasthan University of Veterinary and Animal Sciences, Bikaner).

Sharma, P. R., Beniwal, B. K., Singh, V. K., Dass, G., & Sharma, B. S. (1999). Wool production of Nali sheep in arid zone of Rajasthan. *Indian Journal of Small Ruminants*, 5(1), 9-13.

Sharma, R. C., Arora, A. L., Mishra, A. K., & Kumar, S. (2003). Production performance of Malpura sheep in an organised farm in Rajasthan. *The Indian Journal of Small Ruminants*, 9(2), 119-121.

Sheikh, N. A., & Dhillon, J. S. (1992). Genetic studies on quantitative wool traits in Kashmir Merino sheep. *Wool and Woollen of India*, 29(1), 21-23.

Singh, B., Chopra, S. C., & Arora, C. L. (1984). Genetic analysis of some economic traits in Russian Merino sheep. *Indian Veterinary Journal*, 61, 886-870.

Singh, G., & Kushwaha, B. P. (1995). Estimates of genetic and phenotypic parameters of body weights and greasy fleece weights of Bharat Merino sheep. *The Indian Journal of Small Ruminants*, 1(2), 5-11.

Singh, P. K., Banik, S., Ganai, T. A., & Sarkar, T. K. (2008). Comparative performance of different breeds of sheep on wool production and quality traits in Kashmir valley. *Indian Journal of Animal Research*, 42(1), 63-65.

Singh, V. K., Dass, G., Mehta, S. C., & Sharma, P. R. (1998). Selection in Marwari sheep: 1. Performance of selection line. *The Indian Journal of Small Ruminants*, 4(1), 1-4.

Snyman, M. A., Erasmus, G. J., & Wyk, J. B. (1995). Non-genetic factors influencing growth and fleece traits in Afrino sheep. *South African Journal of Animal Science*, 25(3), 70-74.

Taggar, R. K., Chakraborty, D., Kumar, D., Vohra, V., Tantia, M. S., & Sharma, A. (2018). Wool characteristics of Poonchi sheep. *International Journal of Fauna and Biological Studies*, 5(2), 133-135.

Tomar, A. K., Mehta, B. S., & Singh, G. (2000b). Genetic and non-genetic factors affecting growth in Bharat Merino sheep. *The Indian Journal of Animal Sciences*, 70(6), 647-648.

Tomar, A. K., Mehta, B. S., Jaishankar, J., & Singh, G. (2000). Genetic studies on growth and greasy fleece yield in Bharat Merino sheep. *The Indian Journal of Animal Sciences*, 70(5), 537-539.

Valera, M., Arrebola, F., Juarez, M., & Molina, A. (2009). Genetic improvement of wool production in Spanish Merino sheep: Genetic parameters and simulation of selection strategies. *Animal Production Science*, 49(1), 43-47.

Verma, M. K., Singh, V. K., Verma, A. K., Singh, J., Gautam, S., Pal, V. K., & Verma, H. C. (2024). Quantification of reproductive traits and wool characteristics of lesser-known Gang-Fatehpuri sheep of Uttar Pradesh. *Environment and Ecology*, 42(2), 533–536.

Vesely, J. A., Peters, H. F., Slen, S. B., & Robison, O. W. (1970). Heritabilities and genetic correlations in growth and wool traits of Rambouillet and Romnelet sheep. *Journal of Animal Science*, *30*(2), 174-81.

Wang, X. L., Saremu, L. W., & Andrews, R. N. (1994). Wool characteristics of fine wool sheep in Xinjiang Autonomous Region, China. *Proceedings of the New Zealand Society of Animal Production*, 54, 167.

Xiao, X., Liu, R., Gong, J., Li, P., Li, Z., Gong, W., Liu, A., Ge, Q., Deng, X., Li, S., Chen, Q., Zhang, H., Peng, R., Peng, Y., Shang, H., Pan, J., Shi, Y., Lu, Q., & Yuan, Y. (2023). Fine mapping and candidate gene analysis of qFL-A12-5: A fiber length-related QTL introgressed from *Gossypium barbadense* into *Gossypium hirsutum*. *Theoretical and Applied Genetics*, 136(3).

Yadav, S. B. S. (2016). Selection strategies for genetic improvement of Chokla sheep (Doctoral dissertation, Rajasthan University of Veterinary and Animal Sciences, Bikaner-334001).

Yazdi, M. H., Engström, G., Näsholm, A., Johansson, K., Jorjani, H., & Liljedah, L. E. (1997). Genetic parameters for lamb weight at different ages and wool production in Baluchi sheep. *Animal Science*, 65(2), 247-255.

Yunxia, Q., Shaoyin, F., Xiaolong, H., Biao, W., Lai, D., Rigele, T., Ma, Y., Sun, S., Wenguang, Z., & Yongbin, L. (2021). Preliminary comparison of skin transcriptome from sheep with different wool fibre diameters. *Animal Production Science*, 61, 708–714.

Zhao, H., Guo, T., Lu, Z., Zhu, S., Qiao, G., Han, M., Yuan, C., Wang, T., Li, F., Zhang, Y., Hou, F., Yue, Y., & Yang, B. (2021). Genome-wide association studies detect candidate genes for wool traits by re-sequencing in Chinese fine-wool sheep. *BMC Genomics*, 22, 127.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of the publisher and/or the editor(s). This publisher and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.

© Copyright (2024): Author(s). The licensee is the journal publisher. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/124849