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Optimizing Water Productivity through the Conjunctive Use of Borewell and Canal Water for Enhancing Sheep Productivity in Arid Climate of Western Rajasthan, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In the arid regions of Rajasthan, water scarcity poses a significant challenge to both agriculture and livestock productivity. Sustainable practices in such climates require effective management of limited water resources. This study focuses on optimizing water productivity through the conjunctive use of canal water and borewell water to address the problem of water scarcity while maximizing output per unit of water.

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The experiment involved eighteen healthy lambs of aged 2-3 months which were managed intensively and divided into three groups of six lambs each based on a randomized block design. All groups were fed *Pennisetum glaucum* (pearl millet) and *Medicago sativa* (lucerne) *ad-libitum* along with concentrates adjusted according to their body weights. The groups were offered three types of drinking water: canal water (G1), a combination of canal and borewell water (G2) and borewell water (G3) in a clean bucket twice a day. No significant effect on total feed intake and body weight of the lambs was found based on the drinking water source. However, G1 and G2 lambs, which were offered canal water, consumed significantly ($p<0.05$) less water (74.4 ± 1.84 liters) compared to the lambs in G3 (81.6 ± 1.91 liters). The virtual water requirement per kilogram of weight gain, calculated from both direct water intake and indirect intake through feed was lowest in G1 lambs (5771.34 liters) followed by G2 lambs (6129.00 liters) and G3 lambs (6312.00 liters) per kilogram of weight gain, respectively. These results indicate that water productivity was highest with canal water (G1) and lowest with borewell water (G3) per kilogram of weight gain. This study underscores the importance of efficient water management in maximizing productivity and resource use efficiency in water-limited arid regions.

Keywords: Water productivity; sheep; arid regions; conjunctive use; borewell and canal water.

1. INTRODUCTION

In Rajasthan's arid and semi-arid regions, agriculture and livestock face growing challenges due to increasing water scarcity, worsened by climate change. The state has very limited surface water resources, comprising only 1.16% of the country's total. Overuse of groundwater and reduced rainfall have led to severe water shortages and rising salinity problems in both water and soil (Singh, 2021; Coyte et al., 2019; Shah & Narain, 2019). In state, water crisis has reached a critical stage, with only 30 out of 299 blocks (12%) classified as safe (Kumar P, 2020). Therefore, emphasizing efficient water management and improving water productivity (achieving more yield with less water) is crucial, as water scarcity significantly impacts both agricultural and livestock productivity.

For poor rural families in the arid climate, small-scale livestock farming particularly of sheep and goats is a vital source of income`. Sheep were selected for this study due to their drought tolerance and adaptability to arid climates. Sheep are raised mainly for meat, milk, wool, skin, and manure. Mutton contributes 70-80% of the earnings for sheep farmers (Joshi et al.,2024). The total meat production in Rajasthan was 240.28 thousand tones in the year 2022-23 with an annual growth rate of 8.92%. The demand for animal products is increasing at a faster rate due to population growth, changing dietary habits and economic factors. Globally, agriculture and livestock products are key to food security, yet they consume over 80% of freshwater resources with about a one third going to livestock. Sheep exhibit varying water requirements and adaptability mechanisms, which influence their productivity under different water conditions. Understanding the overall water productivity of the sheep production system is essential for addressing the challenges of achieving higher productivity and resource-use efficiency in these water-scarce areas. Borewell water in Rajasthan is primarily used for drinking and cultivation and is often highly saline. The conjunctive use of borewell water and canal water offers a viable alternative for increasing productivity in agriculture-based livestock production systems. This study assesses the water productivity of canal water, borewell water and their combined use in sheep production systems. The research aims to identify the optimal water requirements for sheep production and management practices that enhance productivity under varying water availability scenarios. These insights are crucial for sustainable livestock development in arid regions.

2. MATERIALS AND METHODS

2.1 Experimental Site and Climatic Condition

The study was conducted at ICAR – CSWRI – Arid Region Campus, Bikaner (28^0 18' 0" N latitude, $73^0$30' 0" E longitude and 236 meters above sea level) in the heart of the Thar Desert. The arid climate is characterized by hot, dry conditions with irregular rainfall (annual range: 260 to 440 mm). The experimental period lasted 22 days with feeding managed on a group basis in a semi-open shed. During the study, temperatures ranged from a high of 36.1°C to a low of 25.4°C, with humidity levels varying between 76.7% and 47.3%. Wind velocity was recorded at 10 km/h. Housing space was provided according to BIS specifications at the ICAR – CSWRI Arid Region Campus, Bikaner.

2.2 Experimental Layout

Eighteen healthy lambs, both male and female, were randomly assigned to three experimental groups, each containing six lambs, following a randomized block design (RBD) with similar initial average body weights. The lambs were vaccinated according to a set schedule and all preventive and curative measures taken as needed.

2.3 Feeding and Water Management

All groups' lambs were fed a basal diet consisting of ad libitum dry bajra fodder, concentrate, and green lucerne fodder, provided in the morning and evening based on their requirements (ICAR,2013). The drinking water provided for each group were canal water(G1), a combination of canal and borewell water(G2) and borewell water (G3) in clean buckets twice daily in morning and evening hours. Feed and water consumption were recorded separately for each group. Each lamb was provided two liters of water per day, leftover water was measured to determine individual water consumption. Likewise, leftover roughage was weighed, and feed consumption was calculated by difference. The lambs' body weights were measured weekly before feeding and watering and average daily weight gain (g/day) was calculated by difference.

2.4 Water Productivity of Fodder

To estimate the water productivity of pearl millet (*Pennisetum glaucum*) variety of Raj Bajra–1 and lucerne (*Medicago sativa*), these fodder crops were cultivated during the appropriate seasons, respectively, using a Randomized Block Design (RBD) with four replications for each treatment. Water productivity (kg/m³) was calculated by summing the rainfall received and the water applied through sprinkler irrigation during the crop growth period. The sprinkler discharge was collected in buckets for one hour, and the water discharge rate was calculated using a specific formula. The average annual rainfall during the study year was approximately 274 mm. The forage became ready for harvesting within 3-4 months. Irrigation scheduling was based on the crop's water requirements, with a total of five irrigations applied using sprinkler systems. At maturity, biomass from each plot was harvested and oven-dried at 100°C to a constant weight. Biomass yield was measured using an electronic balance, with the fresh weight recorded before drying. Water productivity was then assessed as the ratio of biomass yield (kg/ha) to the total amount of water applied (m³/ha), determining the water required to produce 1 kg fodder.

2.5 Water Productivity of Sheep Production (Per Kg Weight Gain)

To estimate water productivity per kilogram of meat produced under the experimental feeding schedule, the amount of water required to produce one kilogram of feed 1.07 kg/m³ for lucerne, 1.57 kg/m³ for bajra fodder (Raj Bajra), and 2.35 kg/m³ for barley was taken (Saini *et al*., 2024). To produce one kilogram of body weight, amount of water required was calculated by total water consumed by lambs through fodder and drinking during experimental period. Water productivity was assessed as the ratio of weight gain (kg) to the total amount of water required (liters).

2.6 Water Analysis

Water was tested for temperature, pH, and electrical conductivity (ECw, in dS/m), using the Multi-Parameter Water Analyzer-371 by Systronics.

2.7 Data Analysis

Statistical analysis was performed using appropriate methods to compare treatment effects on feed and water intake, body weight changes and water productivity. Analysis of Variance (ANOVA) was conducted to assess the significance of treatment differences by using statistical software IBM SPSS Statistics Version 20.

3. RESULTS AND DISCUSSION

3.1 Water Characteristics

The salinity levels of canal water, a canal and borewell water mix and borewell water were measured before, during, and after the feeding trial. Electrical conductivity (EC) values averaging 0.75 dS/m, 2.25 dS/m, and 4.85 dS/m, respectively, for canal, mixed, and borewell water. Borewell water was more saline than both the mixed and pure canal water. The salinity level, or concentration of dissolved solids, is

Table 1. Chemical composition of water offered to lambs

Water quality	pH	ECw (dS/m)	SAR (sodium adsorption ratio (meq/L)	Cations Na^+ (meq/L)
G1 (canal water)	7.90	0.75	4.56	2.10
G2(conjunctive water)	7.94	2.25	7.20	11.20
G3 (borewell water)	8.00	4.85	10.02	14.20

Table 2. Consumption of feed and water and estimate values of virtual water requirement per kg weight gain in lambs

Groups (n=6)	G1	G2	G3
Body weight changes			
Total Wt. gain (kg)	2.12±0.03	2.10±0.05	2.09±0.05
Average daily gain (g/d)	96.36±1.72	95.75±2.46	94.99±2.28
Avg. feed consumption (kg/d)			
Morning feed **consumption**	1.48±0.11	1.47±0.08	1.29±0.33
Evening feed **consumption**	1.68±0.62	1.77±0.64	1.78±0.61
Concentrate **consumption**	0.84±0.017	0.85±0.017	0.83±0.009
Total feed **consumption**	4.00±0.25	4.10±0.26	3.90±0.7
Avg. water consumption (l/d)			
Morning water **consumption**	5.40±0.20	5.63±0.12	5.88±0.18
Evening water **consumption** *	7.00±0.13	6.77±0.33	7.73±0.16
Total water **consumption** *	12.40±0.30	12.4±0.41	13.61±0.32
Estimated virtual water requirement for per kg gain in lambs' production			
Average water **consumption** (litre)*	74.4 ± 1.84	74.4± 2.48	81.6 ± 1.91
Average Virtual water **consumption** /kg gain	5771.34± 431.04	6129 ± 1117.37	6312± 1056.90
Average Virtual water **consumption** /kg protein	23085.36	24516.00	25248.00

Level of significance $p < 0.05$

crucial in determining water suitability and palatability for livestock. Studies suggest that while low salinity levels may enhance animal performance, higher salinity tends to have the opposite effect (Costa et al., 2013). Goats and sheep, however, show greater tolerance to saline water than other ruminants, with an optimal electrical conductivity (EC) range for goats between 8.0-11.0 dS/m.

3.2 Body Weight (kg)

The mean initial body weights of the lambs were 17.31 ± 1.60 kg, 17.00 ± 1.30 kg, and 17.83 ± 0.30 kg for groups G1, G2, and G3, respectively. By the end of the study, the final body weights were 19.43 ± 1.60 kg, 19.10 ± 1.28 kg, and 19.85 ± 0.40 kg for G1, G2, and G3, respectively. The influence of water sources did not have a significant effect on weight gain in any of the groups. The total weight gain (2.12 ± 0.03 kg) and average daily gain (96.36 ± 1.72 g) were observed highest in G1 lambs which was offered canal water while the lowest weight gain was reported in G3, which consumed borewell water. In study, no reduction in dry matter intake (DMI) among lambs provided with various water could explain the non-significant differences in body weight gain across the groups. These results align with previous studies, which also found no significant effect of drinking water salinity on average daily gain in kids (Harini et al., 2022; El-Gawad, 1997).

3.3 Feed Intake (kg/day)

Total feed intake was not significantly affected by the different drinking water sources across the groups. However, the lambs in group 3, which were offered borewell water, consumed comparatively less feed (3.90 ± 0.7 kg/day) compared to the other groups. Lambs in groups 1 and 2, which were provided canal water and a mix of canal and borewell water, had similar feed consumption (4.0 ± 0.26 kg/day).

3.4 Water Intake (lit./day)

In contrast to feed, total water consumption was significantly influenced by the different drinking water regimes among the groups. The results indicated that the lambs in group 3, which were provided borewell water, had significantly higher average water consumption in the evening compared to the lambs in groups 1 and 2, which were offered canal water and conjunctive water, respectively. The total water consumption (liters/day) was similar for groups 1 and 2 (12.40 ± 0.82 liters) and was significantly lower than the 13.61 ± 0.64 liters observed in group 3. These findings demonstrate that lambs provided with saline borewell water had consumed more water due to physiological mechanism that allows the animals to manage salt intake by excreting excess salt through urine.

3.5 Water Requirement of Per Kg Gain

The overall average direct water consumption during the experimental period was significantly different between groups. Groups 1 and 2, which were offered canal and mixed drinking water, consumed significantly ($p<0.05$) less water (74.4 ± 1.84 liters) compared to group 3 (81.6 ± 1.91 liters). The total virtual water consumption, including both feed and drinking water during the trial period, is summarized in Table 2. The estimated virtual water requirement per kilogram of weight gain was lowest in group 1 lambs (5771.34 liters), followed by group 2 (6129.00 liters) and group 3 (6312.00 liters), respectively. These results indicate the highest water productivity in lambs offered canal water, while borewell water demonstrated the lowest productivity. The findings of significantly lower water consumption and higher weight gain in lambs drinking canal water highlight its exceptional water use efficiency and suitability for arid and semi-arid regions. Furthermore, blending canal and borewell water enhanced water productivity compared to using saline groundwater for sheep farming.

From a practical standpoint, these results underscore the importance of utilizing canal and mixed water sources in sheep farming, particularly in Rajasthan's arid regions. By prioritizing canal water use, farmers can enhance livestock productivity while optimizing water resources, ultimately leading to more sustainable agricultural practices in water-scarce environments. This approach not only supports the economic viability of sheep farming but also contributes to improved food security and resource management in the region.

4. CONCLUSION

The study's findings indicate that canal water offers higher water productivity, as its use led to greater body weight gain while reducing water needs per kilogram of meat production. Although borewell water showed lower productivity, blending it with canal water can improved water productivity compared to using saline borewell water alone, which is the primary drinking water source for sheep farming in Rajasthan’s arid regions. Future research is needed to evaluate the effects of different salinity levels and mineral compositions in water on various livestock species. Such insights will be crucial in maximizing production performance under varying water conditions, supporting sustainable livestock development in arid regions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT. etc) and text-to -image generators have been used during writing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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