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Synergistic Effects of Treated Wastewater Irrigation and Nutrient Management on Fodder Yield of Bajra Napier Hybrid Grass in the Cauvery Delta Zone

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ABSTRACT: The research conducted in Tamil Nadu's Cauvery Delta from 2018 to 2021 investigated the combined effects of treated wastewater irrigation and various organic and inorganic nutrient management strategies on the productivity of Bajra Napier hybrid grass (CO(BN) 5). Using a strip plot design, the study evaluated five irrigation regimes and four nutrient treatment practices to determine their impact on green and dry fodder yields. The results revealed that the combination of treated wastewater irrigation with 100% inorganic nutrients (I_5N_1) produced the highest green fodder yield of 431.1 t ha^{-1} yr^{-1} and dry fodder yield of 76.72 t ha^{-1} yr^{-1} when applied with 100% recommended nutrients. These findings have significant implications for sustainable agriculture and livestock management in regions facing water scarcity and nutrient deficiency challenges. By demonstrating the effectiveness of treated wastewater irrigation in conjunction with appropriate nutrient management, the study highlights a promising approach to enhance fodder production while conserving freshwater resources.

Keywords: Bajra Napier Hybrid, Treated wastewater irrigation, Green Fodder yield, Dry fodder Yields.

INTRODUCTION

India's livestock sector, a crucial component of the national economy contributing 5.1% to the gross value added, is grappling with severe challenges stemming from a significant green fodder shortage and water scarcity. Balasubramanya *et al.* (2022) explained that the sector can only meet 40% of the required green forage availability, highlighting a substantial gap in fodder production. This shortage is further exacerbated by the projected decrease in cultivable area due to irrigation water scarcity by 2050, as reported by the Central Water Commission (CWC, 2019). These interconnected issues pose a significant threat to the sustainability and growth of the livestock sector, potentially impacting food security and rural livelihoods (Chouhan *et al.*, 2023). In light of these challenges, innovative solutions are being explored to address both the fodder shortage and water scarcity simultaneously (Pastorelli *et al.*, 2022). Treated wastewater has emerged as a promising alternative, offering a dual benefit of water supply and nutrient provision for crop growth and development (Amerasinghe *et al.*, 2013). This approach not only helps in conserving freshwater resources but also provides a sustainable method for fodder production. By utilizing treated wastewater for irrigation, farmers can potentially increase their cultivable area and improve fodder yields, thereby addressing the green fodder deficit (Carvalho *et al.*, 2021). The integration of treated wastewater for fodder production represents a promising approach to address the interconnected challenges of water scarcity and fodder shortage in India's livestock sector (Maleko *et al.*, 2019; Manoj *et al.*, 2022). This strategy not only aligns with circular economy principles but also promotes resource efficiency, potentially enhancing the sector's resilience against environmental pressures. Bajra Napier hybrid grass, selected for this study due to its high yield potential and efficient response to irrigation and nutrients, serves as an ideal candidate for systems utilizing treated wastewater (Alkhamisi *et al.*, 2011; Ahamed *et al.*, 2022). The research delves into the complex interactions between treated wastewater and nutrient applications, with a specific focus on their impact on green and dry fodder yields. By examining these relationships, the study aims to uncover optimal conditions for maximizing fodder production while efficiently utilizing treated wastewater resources (Ahamed *et al.*, 2022). This approach not only addresses the immediate needs of the livestock sector but also contributes to the broader goal of developing sustainable agricultural practices. The findings from this research have the potential to inform policy

decisions and agricultural strategies, ultimately supporting the long-term sustainability and productivity of India's livestock industry in the face of increasing environmental challenges (Pastorelli *et al.,* 2022; Santos *et al*., 2023).

However, the long-term application of treated wastewater poses potential risks, such as the accumulation of heavy metals, pollutants, and changes in soil microbial communities, which could affect sustainability (Trotta *et al.,* 2024). While many studies confirm the yield benefits of wastewater irrigation, a significant research gap exists in understanding the long-term, multi-faceted impacts. Specifically, there is a need for comprehensive studies that assess not only yield but also the long-term effects on soil biogeochemistry, the potential uptake of emerging contaminants like pharmaceuticals into fodder, and the subsequent implications for livestock health and the food chain (Trotta *et al.,* 2024; Verma *et al.,* 2023). This study aims to address a part of this gap by examining the direct interaction effects of different treated wastewater irrigation regimes and nutrient applications on the green and dry fodder yields of Bajra Napier hybrid grass, aiming to inform sustainable agricultural practices in water-stressed regions.

Experimental Design and Methodology. The experiment was conducted at the Veterinary College and Research Institute, Orathanadu, in the semi-arid Cauvery Delta (792 mm annual rainfall, sandy clay loam soil). A strip plot design with four replications tested five irrigation treatments: I_1 (groundwater, GW), I_2 (alternate GW and treated wastewater, TWW), I_3 (two GW + one TWW), I_4 (one GW + two TWW), and I_5 (TWW alone). Four nutrient treatments included: N_1 (100% inorganic nutrients: 75:50:40 kg NPK ha^{-1} + 25 t FYM), N_2 (100% organic nutrients: 18.75 t FYM), N_3 (50% organic + 50% inorganic), and N_4 (control). Bajra Napier CO(BN) 5 was planted on December 28, 2018, with harvests at 70 DAP (main crop) and 45-day intervals (six ratoons). Yields and proximate parameters (crude protein, crude fibre) were analyzed using ANOVA and LSD at $P<0.05$ (Gomez and Gomez 2010).

RESULTS AND DISCUSSION

A. Green fodder yield

The effect of irrigation with secondary treated sewage water, combined with manure and inorganic nutrients, on the green fodder yield of bajra napier hybrid grass was studied over a two-year period. The results, presented in Table 1, show that the main crop consistently produced higher green fodder yields compared to the six ratoon crops harvested annually. Among the irrigation management treatments, I_5 (treated sewage water alone) demonstrated the most significant impact on green fodder yield, producing 57.8 t ha^{-1}, which represents a 29.3% increase over the control (40.9 t ha^{-1}). Conversely, the lowest green fodder yield was observed when groundwater was used for irrigation (I_1). This trend persisted throughout the six ratoon harvests over the two-year study period. The total green fodder yield was highest in the I_5 treatment, reaching 383.8 t $ha^{-1}yr^{-1}$, surpassing all other treatments involving treated sewage water and the control. These findings suggest that the use of secondary treated sewage water for irrigation can significantly enhance the productivity of bajra napier hybrid grass, potentially offering a sustainable solution for increasing fodder production while utilizing treated wastewater resources.

Nutrient management treatments, encompassing both organic and inorganic nutrients, demonstrated a significant impact on the green fodder yield of bajra napier hybrid grass across multiple harvests, from the main crop to six ratoon harvests. The application of 100% recommended nutrients (N_1) proved to be the most effective treatment, resulting in the highest green fodder yield of 61.6 t ha^{-1} during the main crop harvest. This superior performance of the N_1 treatment was consistently observed in comparison to all other nutrient treatments and the control group. Conversely, the control treatment (N_4), which received no nutrient supplementation, consistently produced the lowest green fodder yield in the main crop. The trend observed in the main crop harvest persisted throughout the two-year study period, encompassing all subsequent harvests. The total green fodder yield across all harvests maintained a similar pattern, with the 100% recommended nutrient treatment (N_1) consistently outperforming other treatments. This sustained superiority of the N_1 treatment underscores the importance of optimal nutrient management in maximizing the productivity of bajra napier hybrid grass. The findings suggest that providing the recommended nutrient levels is crucial for achieving and maintaining high green fodder yields in this hybrid grass variety over multiple harvest cycles (Santos *et al.,* 2023).

Interaction between irrigation and nutrient treatments had significantly influenced the green fodder yield of bajra napier hybrid grass. Combined application of 100% recommended nutrients with treated waste water (I_5N_1) registered superior (65.5 t ha^{-1} yr^{-1}) in terms of green fodder yield in the main crop than in all other treatment combinations and also registered significantly higher total green fodder yield (431.1 t ha^{-1} yr^{-1}). The green fodder yield was on par with one irrigation with groundwater and two irrigations with treated sewage water irrigation + 100% recommended nutrients (I_4N_1). Irrigation with groundwater alone + without nutrients (I_1N_4) registered the lowest green fodder yield during all the crop harvests.

The bajra napier hybrid grass is a perennial fodder crop being highly productive nature might require macro and micronutrients on a continuous basis for higher yield. Application of treated sewage water produced the highest yield could be due to supply of N, P and K that distributes equally throughout the growth phases. In addition, the continuous availability of soil moisture impacted positively on green and dry fodder yields due to improved crop growth, which in turn resulted in higher biomass yield per unit area (Antonkiewicz *et al.,* 2020). Moreover, the input of N in treated sewage water causes enhanced mineralization of native humus N through a priming action and developing a more extensive root system, thereby permitting better

utilization of untagged soil N by the bajra napier grass might have higher growth parameters that are reflected in green fodder yield (Rahman *et al.*, 2020). The physiological response of plants by decreased cell division and cell elongation under nutrient deficit might have also contributed to reduced green fodder yield in groundwater irrigation. The results from the present investigation are in conformity with the findings of Mohammad and Ayadi (2004); Senthilkumar *et al.* (2021); Soni *et al.* (2016).

Table 1: Effect of treated wastewater and nutrients on the mean yield of two years in total green fodder yield (t/ha) of Bajra Napier hybrid grass.

Treatments	I_1	I_2	I_3	I_4	I_5	Mean
N_1	378.6	408.2	406.5	417	431.1	**408.3**
N_2	268.5	346.8	342	354.6	374.4	**337.2**
N_3	242.2	288.2	283.1	391.1	411.4	**323.2**
N_4	222.6	267.1	253.1	276.2	318.3	**267.5**
Mean	**278**	**327.6**	**321.2**	**359.7**	**383.8**	

	I	N	I × N	N × I
SEd	12.9	9.3	4.8	3.9
CD (p=0.05)	28	21	10.6	7.8

Horizontal factor
I_1 - Irrigation with groundwater (GW) alone
I_2 - Alternate irrigation with GW and Treated wastewater (TWW)
I_3 - Two irrigations with GW + One irrigation with TWW
I_4 - One irrigation with GW + Two irrigations with TWW
I_5 - Irrigation with TWW alone

Vertical factor
N_1 - 100% Inorganic nutrients (IN)
N_2 - 100% Organic nutrients (ON) on N basis
N_3 - 50% Organic + 50% Inorganic nutrients
N_4 - Control (without nutrients)

Ines *et al.* (2017) reported that an application of TSW irrigation in *Cenchrus ciliaries* fodder increased the plant biomass and supplies nutrients and bacteria to the soil, enhanced the quantity of soil organisms. This is in line with the findings of Sathiyabama (2017) who reported that basal application of FYM (105 t ha^{-1} yr^{-1}) on an N basis registered higher yield due to mineralization of soil N leading to buildup of higher available N through the application of organic manure. The addition of organic matter might have reduced phosphate's fixation by providing protective cover and reducing the fixation, which in turn increased the available P in soil (El-Abbas *et al.*, 2006). This result was on par with Bharadwaj and Omanwar (1994).

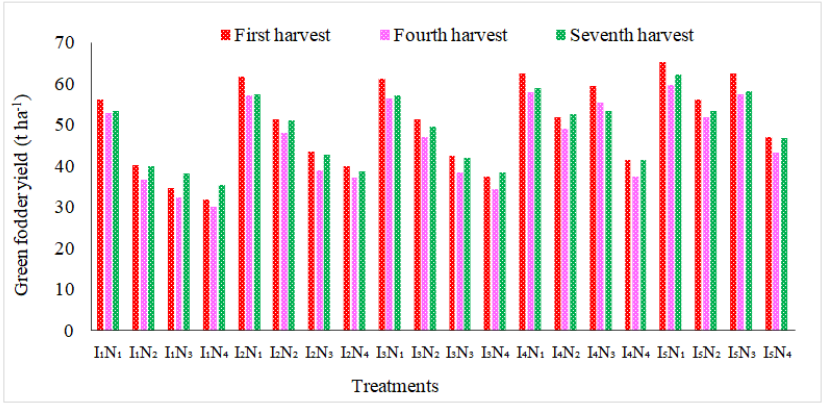

Fig. 1. Effect of treated sewage water and nutrients on total green fodder yield (t ha^{-1} yr^{-1}) of bajra napier hybrid grass at first, fourth and seventh harvests

B. Dry fodder yield

The data pertaining to the dry fodder yield of bajra napier hybrid grass showed significant differences due to secondary treated sewage water irrigation and inorganic nutrient treatments and are presented in Table 2. Dry fodder yield of bajra napier hybrid grass varied significantly due to various irrigation treatments. Similar to the green fodder yield, irrigation with secondary treated sewage water alone (I_5) produced significantly higher dry fodder yield of 9.83 t ha^{-1} in the main harvest compared to all other irrigation management treatments. The application of treated sewage water alone increased 17.8 per cent of dry fodder yield over control (8.08 t ha^{-1}). The lowest dry fodder yield was produced by the bajra napier hybrid when the groundwater alone was used as irrigation (I_1). During the rest of the seven ratoon harvests in a year for the two years, the same trend was noticed.

As concerned with nutrient treatments (organic and inorganic nutrients), there was a significant variation in dry fodder yield of both main and six ratoon harvests. Application of full dose inorganic fertilized plot (N_1) produced more dry fodder yield (10.28 t ha^{-1}) of bajra napier hybrid grass in the main crop than other nutrient combined treatments (N_2 and N_3) and control. As expected, bajra napier hybrid grass not received any fertilizers, recorded the minimum dry fodder yield in the main crop. The dry fodder yield in all six ratoon crops was also in a similar pattern.

Table 2: Effect of treated wastewater and nutrients on the mean yield of two years in total dry fodder yield (t ha^{-1}year^{-1}) of Bajra Napier hybrid grass.

Treatments	I_1	I_2	I_3	I_4	I_5	Mean
N_1	67.88	71.53	71.09	75.01	76.72	**72.45**
N_2	53.3	62.98	61.74	64.65	66.38	**61.81**
N_3	49.63	58.52	57.08	68.67	73.53	**61.49**
N_4	47.68	53.72	51.27	55.71	59.86	**53.65**
Mean	**54.62**	**61.69**	**60.3**	**66.01**	**69.12**	

	I	N	I x N	N x I
SEd	0.31	0.35	0.2	0.19
CD (p=0.05)	0.68	0.79	0.45	0.38

Horizontal factor
I_1 - Irrigation with groundwater (GW) alone
I_2 - Alternate irrigation with GW and Treated wastewater (TWW)
I_3 - Two irrigations with GW + One irrigation with TWW
I_4 - One irrigation with GW + Two irrigations with TWW
I_5 - Irrigation with TWW alone

Vertical factor
N_1 - 100% Inorganic nutrients (IN)
N_2 - 100% Organic nutrients (ON) on N basis
N_3 - 50% Organic + 50% Inorganic nutrients
N_4 - Control (without nutrients)

The interaction effect between irrigation water and nutrient treatments on dry fodder yield was significant in the main and subsequent ratoons of bajra napier. Combined use of 100% recommended nutrients and treated sewage water irrigation (I_5N_1) significantly increased dry fodder yield (10.83 t ha^{-1}) in the main crop than all other treatment combinations. The treatment I_1N_4 (without fertilization and groundwater alone) produced the least dry fodder weight in the main crop. The results were replicated in other ratoon harvests as well. The increase in dry fodder yield due to the application of inorganic nutrients could be attributed to the positive effect of nitrogen on all the growth parameters, resulted in increased dry forage yield (Bhatt *et al.,* 2021). Previous studies by Pathan *et al*. (2012) reported an increase in dry fodder yield with increasing nitrogen rates of 150-225 kg N ha^{-1} in the Bajra Napier hybrid. Srivani *et al.* (2023); Srinivas *et al*. (2014) recorded the highest dry fodder yield with 100% NPK application.

CONCLUSIONS

The green and dry fodder yields of Bajra Napier hybrid grass were significantly and positively influenced by the application of secondary treated sewage water and nutrient management. The irrigation treatment using treated sewage water alone (I_5) produced a higher quantity of green and dry fodder across all cuttings compared to other irrigation strategies. Among nutrient treatments, the application of 100% recommended nutrients (N_1) resulted in higher yields. The synergistic use of 100% recommended nutrients with treated sewage water irrigation (I_5N_1) yielded the best results, leading to a 48.4% increase in total green fodder yield and a 37.9% increase in total dry fodder yield over two years. This study confirms that integrating treated wastewater for irrigation is a viable strategy to boost fodder production and address water scarcity in agriculture.

Future research could explore the long-term impacts of treated wastewater irrigation on soil physicochemical properties and the accumulation of heavy metals or other contaminants in Bajra Napier hybrid grass, ensuring fodder safety for livestock and human health. Further investigation into the economic viability and farmer adoption rates of these integrated water and nutrient management practices would also be beneficial. Additionally, studies could evaluate the effects of such practices on crude protein content, digestibility, and overall nutritional quality of the fodder, providing a more comprehensive assessment for livestock feeding. Exploring different wastewater treatment levels and their specific effects on crop performance and soil health could also yield valuable insights.

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Conflict of Interest. None.

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