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Study the Integrated Effect of Treated Wastewater, Organic and Inorganic Nutrients on Fodder Yield and Proximate Parameters of Bajra Napier Hybrid Grass in the Cauvery Delta Region of Tamil Nadu

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ABSTRACT: The current experiment was aimed to study the effect of treated municipal wastewater with manure and inorganic nutrients on the yield and quality of Bajra Napier hybrid grass. The field experiment was conducted using secondary treated wastewater, manure and inorganic nutrients in Bajra Napier hybrid grass variety CO(BN) 5 with a strip plot design and four replications. The experiment was carried out in Veterinary College and Research Institute, Orathanadu, Thanjavur, Tamil Nadu, during 2018-19. The five ratios of irrigation water were used in horizontal factor treatments and four different nutrient combination treatments were allotted in the vertical factor. The plot was divided into 27 m^2 with 2 m space between the plots. The two budded setts of bajra napier hybrid grass variety CO(BN)-5 were planted at 60 x 50 cm spacing. The irrigation and nutrients were applied as per the treatments. The use of treated wastewater for irrigation combined with manure and inorganic nutrients significantly increased the total green and dry fodder yields. Irrigation treatment with treated wastewater alone + 100% inorganic nutrients (I_5N_1) recorded significantly higher total green and dry fodder yields of 431.0 and 76.7 t ha^{-1} yr^{-1}, respectively than all other treatment combinations. Irrigated with groundwater alone (control) without nutrients (I_1N_4) recorded the lowest total green and dry fodder yields (222.5 and 47.6 t ha^{-1} yr^{-1}, respectively). The average crude protein content of all total cuttings was significantly higher (13.53%) in I_5N_1 than all other treatments. On the other hand, the average crude fibre content (28.03%) was significantly lower in the treatment I_5N_1 as compared to irrigated with groundwater without nutrients (31.18%). The perennial fodder crop Bajra Napier hybrid grass variety CO(BN) 5 cultivated under-treated wastewater combined with manure and inorganic nutrients increased the total green and dry fodder yields with beneficial proximates. The use of treated wastewater for fodder cultivation helps in conserving groundwater and utilize available nutrients in treated wastewater effectively.

Keywords: Treated wastewater irrigation, Bajra Napier hybrid grass, green fodder yield, dry fodder yield, crude protein, crude fibre.

INTRODUCTION

Agriculture and livestock production form a symbiotic relationship crucial for comprehensive food security. In India, livestock production significantly contributes to the national economy, accounting for 5.1% of the total national value added at current prices in 2018-19 (BAHS, 2019). While India leads globally in milk production, producing 198 million tonnes, the per capita output remains low due to severe feedstuff shortages (Rapiya *et al.*, 2025). This paradox highlights the pressing need for improved fodder management and production strategies. The disparity between livestock population and available resources in India is stark. Despite occupying only 2.0% of the global geographical area, India supports 15% of the world's livestock population, indicating intense pressure on the country's resources (Singh *et al.*, 2022). This imbalance is further exacerbated by the insufficient cultivation of feed crops, with only 8.4 million hectares dedicated to this purpose (Mohan *et al.*, 2017). Moreover, the available green forage meets merely 40% of the required amount. Addressing this substantial gap in fodder availability is crucial for sustaining and enhancing livestock productivity, which in turn is vital for maintaining food security and economic stability in the agricultural sector (Hasnain *et al.*, 2023).

The agricultural sector in India faces significant challenges regarding water allocation and usage. While

it remains the largest consumer of water resources, projections indicate a 10-15% reduction in irrigation water allocation over the next two decades (CWC, 2019). This shift occurs against the backdrop of India's total utilizable water resources, estimated at 1,122 billion cubic meters per year (BCM/year), comprising 690 BCM of surface water (CGWB, 2019) and 432 BCM of groundwater (MoWS, 2017). Looking ahead to 2050, estimates suggest a total available water supply of 1,180 BCM under a high projection scenario, with irrigation still accounting for the majority (68%) of usage, followed by domestic use (9.5%), industries (7%), power development (6%), and other activities including evaporation losses, environmental needs, and navigation requirements (9.5%) (Elmahdi, 2024). The changing landscape of water demand and allocation presents both challenges and opportunities for India's water management strategies. While agricultural water use is expected to decrease by 10-12% by 2025, overall water demand is projected to increase by 22% in 2025 and 32% by 2050 (Amerasinghe *et al.*, 2013). This shift in water allocation patterns underscores the need for more efficient water use practices, particularly in the agricultural sector (Ahmad *et al.*, 2023). Additionally, the issue of water contamination remains a pressing concern, with a majority (80%) of wastewater being released into water bodies with little to no treatment. Only a small percentage of wastewater undergoes partial or complete treatment before discharge (14% in Indonesia, 10% in Philippines, 24% in India, and 4% in Vietnam), highlighting the urgent need for improved wastewater management and treatment infrastructure to address water quality issues in emerging countries like India(Rastogi *et al.*, 2024).

The increasing demand for water across various sectors, including domestic use, industrial applications, and agricultural operations, has led to a growing interest in wastewater regeneration (Denora *et al.*, 2023). This approach offers a cost-effective and attractive solution for crop irrigation, particularly in arid and semi-arid regions where maintaining productivity is challenging (Sharma *et al.*, 2014; Zahmatkesh *et al.*, 2022). Water reclamation and reuse have emerged as the most efficient methods to address both current and future water requirements. In this context, the utilization of treated wastewater for irrigating fodder crops presents a viable option in the evolving landscape of water demand management. The implicit research gap is the lack of comprehensive studies specifically evaluating the combined long-term impact of treated wastewater with integrated organic and inorganic nutrient management on both the yield and detailed proximate parameters (quality) of Bajra Napier hybrid grass in a specific agro-climatic zone like the Cauvery Delta. While individual components might have been studied, the *synergistic interaction* and its effect on both quantitative (yield) and qualitative (proximate parameters) aspects over extended periods are less explored, particularly with an emphasis on sustainable practices and resource conservation.

The study aims to fill the gap of how these specific combinations affect this particular fodder crop's yield and quality under the given regional conditions, contributing to the broader goal of conserving groundwater and utilizing available nutrients in treated wastewater effectively. The studies conducted in the Cauvery Delta region of Orathanadu, Thanjavur, Tamil Nadu, aimed to investigate the impact of secondary treated wastewater irrigation, manure, and inorganic fertilizers on the Bajra Napier hybrid grass variety CO(BN) 5. This research focused on assessing the effects of these treatments on fodder yields and proximate parameters of the grass. By examining the potential benefits of using treated wastewater for irrigation in combination with different fertilizer types, the study sought to contribute valuable insights into sustainable agricultural practices and water resource management in the region.

MATERIALS AND METHODS

A. Site description

Orathanadu is one of the leading agriculture production areas under the old Cauvery delta irrigation scheme of Thanjavur, Tamil Nadu, India. Rice, greengram, blackgram, sesame, sugarcane and coconut are the major crops and dairy, sheep and goats are central livestock units. Orathanadu belongs to town panchayat with a population of 1.60 lakhs (2011 census) and 40,383 residents consume an average of 14.2 lakh litres of water every day. The outlet wastewater from households was collected by Orathanadu town panchayat, Tamil Nadu. The secondary treated wastewater was supplied to the Veterinary College and Research Institute, Orathanadu. In this college, the secondary treated wastewater is utilized for cultivating fodder crops, especially Bajra Napier hybrid grass and multicut sorghum. This treated wastewater was utilized for irrigation purposes for the experimental study to cultivate the Bajra Napier (*Pennisetum americanum* x *P. purpureum*) hybrid grass. The study area has a semi-arid climate, with less than 792 mm of annual rainfall and summer temperatures often exceeding 40.4ºC. The soil of the experimental field is sandy clay loam in texture and coarse sand (41.63%) was the dominant constituent with an infiltration rate of 3.06 cm hr^{-1}. The experimental site's soil bulk density is 1.42 g cm^{-3} and a particle density of 2.98 g cm^{-3}.

B. Experimental design

Field experiment was laid out in a strip plot design with four replications on a total of 80 plots, each of 6.0 m length and 4.5 m width. The gross plot size was 27 m_2 with 2 m space between the plots to avoid the influence of water seepage. Five ratios of irrigation water were used as horizontal factor treatments, *viz.*, I_1 - Groundwater alone (GW), 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 and I_5 - Irrigation with TWW alone and in vertical factors, nutrients *viz.*, N_1 - 100% Inorganic nutrients (IN), N_2 - 100% Organic nutrients (ON) on N basis, N_3

- 50% Organic + 50% Inorganic nutrients and N_4 - Control (without nutrients). Perennial fodder crop Bajra Napier hybrid grass variety CO(BN) 5 was cultivated for experimental purposes.

C. Cultivation practices and fertilizer application

The fodder crop Bajra Napier hybrid grass CO(BN)-5 was planted with two budded setts on 28th December 2018, with a spacing of 0.60 m between rows and 0.50 m between plants. The nutrient treatments were imposed after calculating the doses at the time of planting. Fertilizers and manure were applied through broadcasting to the individual plots and mixed manually. Nitrogen, phosphorus and potassium were applied as urea, single super phosphate and muriate of potash, respectively. In addition, organic manure in the form of farmyard manure was applied. After every harvest, the ratoon crop was applied with nitrogen as top-dressing as per the treatments. The details of the nutrient application are furnished in Table 1.

Table 1: Manure and fertilizers applied to the experimental field.

Sr. No.	Vertical factor	Basal application (ha	Top-dressing after every harvest (ha
1.	N_1	25 t of FYM Inorganic fertilizers: 75:50:40 kg NPK + 75 kg nitrogen at 30 DAP as top dressing	75 kg nitrogen after every harvest
2.	N_2	18.75 t of FYM	9.37 t of FYM
3.	N_3	12.5 t of FYM + 37.5:25:20 kg NPK	4.69 t of FYM 37.5 kg N
4.	N_4	No manure and fertilizers	No manure and fertilizers

D. Yield and proximate analysis

The main crop was harvested at 70 days after planting (DAP). The succeeding six ratoon crops were harvested at 45 days intervals. The green and dry fodder yields (t ha^{-1}) of the main crop and six ratoon crops were recorded at harvesting time and presented in total green and dry fodder yields (t ha^{-1} yr^{-1}). In addition, the plant samples from each treatment in each harvest were also collected. These samples were dried and subjected to proximate analysis *viz*., crude protein and crude fibre.

E. Statistical analysis

All the data obtained from the treatment plots and proximate parameters were analyzed in the lab and were subjected to a statistical analysis using analysis of variance (ANOVA). The least significant difference (LSD) at the probability of 5 % ($P<0.05$) was performed to compare means using SPSS for Windows (Released version 26) according to the standard methods (Gomez and Gomez 2010)

RESULTS AND DISCUSSION

A. Green and dry fodder yields

The effect of treated wastewater irrigation, manure and inorganic nutrients and thier interaction differed significantly ($P<0.05$) on green and dry fodder yields (Table 2 and 3) of Bajra Napier hybrid grass. The irrigation with treated wastewater alone (I_5) produced significantly higher total green fodder yield of 383.8 t $ha^{-1}yr^{-1}$ than all other irrigation treatments and it was on par with one irrigation with groundwater and two irrigations with treated wastewater (I_4). This might be due to the fact that, the application of treated wastewater as irrigation throughout the cropping period provides an important source of plant nutrients, especially nitrogen and mineralisation of organic matter, which can increase forage crop growth and yield. Since, Bajra Napier hybrid grass is a C_4 plant which has a higher photosynthetic nitrogen usage efficiency (NUE) than C_3 plants it can metabolise high nitrogen levels in reclaimed water (Alkhamisi *et al.*, 2011). Similar results were obtained in sorghum, bajra napier and barley crops (Galavi *et al*., 2009; Srinivas *et al*., 2014). The lowest total green fodder yield (278.0 t ha^{-1} yr^{-1}) was registered in the control (irrigation with groundwater alone - I_1).

Among the nutrient management, 100% inorganic nutrients (N_1) observed a higher total green fodder yield of 408.3 t ha^{-1} yr^{-1} than other treatments and control (267.5 t ha^{-1} yr^{-1}). The favourable growth parameters might be attributed to the increase in green fodder production under recommended doses of manure and inorganic fertilizers application (Bhardwaj *et al*., 2021). Presence of nitrogen might have promoted cell division and as a result, internode elongation and in turn, overall growth parameters (Sharma *et al*., 2022). The results were in accordance with other researchers (Gori *et al.*, 2004; Kaur *et al*., 2017; Keshav Prasad Kurmi *et al*., 2023).

The interaction effect of secondary treated wastewater irrigation and inorganic nutrient treatments revealed that, the treated wastewater alone and 100% inorganic nutrients (I5N1) recorded significantly more total green fodder yield (431.1 t ha^{-1} yr^{-1}) than irrigation with GW alone without nutrients (222.6 t $ha^{-1}yr^{-1}$). The amount of N, P and K deposited in the soil was proportional to the amount of wastewater used in irrigation and the quantity of inorganic nutrients applied. As a result, it promoted more extensive crop growth and increased forage yield. The wastewater contains essential nutrients for plant growth, such as N, P and K, as well as micronutrients like iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu) as well as a significant amount of organic matter (Senthilkumar *et al.*, 2021). Furthermore, N is an essential constituent of amino acids and chloroplasts, which directly influence plant

leaf area, growth and development through greater photosynthates, resulting in higher green fodder yield, which may be attributed to the addition of irrigation at optimum soil moisture and nutrients. These findings align with what has previously been published by Nogueira *et al.* (2013); Alghobar and Suresha (2016); Ghassemisahebi *et al.* (2020).

Table 2: Effect of treated wastewater and nutrients on total green fodder yield (*t ha^{-1}yr^{-1}*) 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	417.0	431.1	408.3
N_2	268.5	346.8	342.0	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	278.0	327.6	321.2	359.7	383.8	
	I	N	I x N	N x I		
SEd	12.9	9.3	4.8	3.9		
CD (P=0.05)	28.0	21.00	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)

A similar trend was seen in dry fodder yield also. The total dry fodder yields (total of all crop harvests from main and six ratoons) expressed significant ($P<0.05$) differences by using treated wastewater for irrigation along with manure and inorganic nutrients (Table 3). Among the different irrigation treatments, irrigation with treated wastewater alone (I5) produced significantly higher total dry fodder yield of 69.12 t ha^{-1} yr^{-1} and the lowest total dry fodder yield was registered in control (I1) which irrigated with groundwater alone (54.62 t ha^{-1} yr^{-1}). The optimal soil-water, macro and micronutrient availability increases nutrient uptake resulting in increased growth parameters that influence dry fodder output. The results were on par with previous research works (Santos *et al.*, 2014; Nogueria *et al.*, 2013).

In the manure and inorganic nutrient treatments, the plot applied with 100% inorganic nutrients (N1) showed significantly higher total dry fodder yield (72.45 t ha^{-1} yr^{-1}) compared to all other nutrient treatments. Applying inorganic nutrients, especially nitrogen, increases the plant's leaf area. Under optimum nutrient level, with adequate sunlight, increased leaf area would increase the photosynthates and finally produces more dry fodder yield of the bajra napier hybrid grass. The application of manure that releases more nutrients slowly throughout the crop growth period also improves the higher dry fodder yield. Similar research findings were also reported earlier (Bandeswaran *et al.*, 2013; Khadijah, 2016; Utamy *et al.*, 2018).

Table 3: Effect of treated wastewater and nutrients on 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	53.30	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	60.30	66.01	69.12	
	I	**N**	**I × N**	**N × I**		
SEd	0.31	0.35	0.20	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

On interaction effect, treatment with treated wastewater alone and 100% inorganic nutrients (I5N1) recorded significantly were total dry fodder yield (76.72 t ha^{-1} yr^{-1}) compared with all other treatment combinations and control (47.68 t ha^{-1} yr^{-1}). The increase might be due to nutrients available in TWW, the decomposition of organic manure being accompanied by a release of appreciable quantities of nutrients and higher mineralisation of full dose of fertilizers, which contribute to higher total dry fodder yield. The results of green fodder yield reflected in dry fodder yield too. Therefore, dry fodder yields under-treated wastewater with manure and fertilizer matches the previous results (Bharadwaj *et al.,* 1994; Larson, 2010; Raveena *et al.,* 2021).

B. Fodder quality parameters

The plant samples were collected during the harvest of the main and six ratoon crops and from all the treatment plots and used for proximate compound analysis. The important fodder quality parameters *viz.*, crude protein and crude fibre contents, were analyzed and the average content of all harvests were presented.

C. Crude protein content

The protein content of forage crops is an important quality factor from the animal nutrition point of view. The crude protein content is directly related to the nitrogen percentage of the plant tissue. Adopting irrigation with treated wastewater combined with organic and inorganic nutrients have shown significantly increase on the crude protein content of Bajra Napier hybrid grass (Table 4) and it's ranged from 9.58-13.53 per cent. Among the treatments, irrigation with treated wastewater alone (I_5) registered significantly higher average crude protein content (12.64%) than all other treatments. Control (irrigated with groundwater alone - I_1) registered the lowest crude protein content (10.70 %). The increased crude protein content with treated wastewater might be due to the partial supply of nitrogen throughout the lifecycle of forage crop growth. The rise in crude protein content in corn fodder could be linked to sufficient nitrogen in wastewater (Tavassoli *et al.,* 2010). Several studies have reported a significant increase in crude protein content of sorghum, maize and tomatoes through the application of treated wastewater as irrigation source (Ghanbari *et al.,* 2007; Galavi *et al.,* 2010; Orlofsky *et al.,* 2016).

Table 4: Effect of treated wastewater and nutrients on mean crude protein (%) of Bajra Napier hybrid grass.

Treatments	I_1	I_2	I_3	I_4	I_5	Mean
N_1	12.78	13.02	12.99	13.46	13.53	13.16
N_2	10.50	11.70	11.58	12.15	12.38	11.66
N_3	9.92	11.17	11.02	12.82	13.33	11.65
N_4	9.58	10.49	10.24	10.82	11.31	10.49
Mean	10.70	11.59	11.46	12.31	12.64	

	I	N	I x N	N x I
SEd	0.04	0.03	0.02	0.02
CD(P=0.05)	0.09	0.08	0.05	0.04

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)

Mean data (Table 4) of all seven crop harvests (from the main crop to sixth ratoon harvest) in a year influenced by manure and inorganic nutrient application significantly. The treatment applied with 100% inorganic nutrients (N_1) registered significantly greater crude protein content (13.16%) than all other treatments and the control. This could be due to adequate nitrogen application through manure and inorganic nutrients increased the vegetative growth, N concentration, amino acids and protein content in forage, ultimately increased the total crude protein yield. In addition, the slow release of nitrogen in organic manure had an added advantage to uptake and increased the crude protein content in the bajra napier forage crop. The findings corroborate with the earlier findings (Vennila and Anathi 2019; Sheta *et al.,* 2010), that reported increasing the crude protein content with the application of manure and inorganic nutrients.

Among irrigation and inorganic nutrients combinations, treatment imposed with treated wastewater alone and 100% inorganic nutrients (I_5N_1) recorded significantly higher crude protein content (13.53%) than all other treatments. It could be because of the presence of numerous nutrients, particularly nitrogen, in treated wastewater which are required for the growth of bajra napier hybrid grass (Fig. 1). The availability of sufficient moisture and adequate nutrients favoured early canopy development, resulting in greater nutrient uptake, which promoted the synthesis of more metabolites and paved the way for higher crude protein yield. Also, higher use of solar radiation due to increased leaf N concentrations resulting from high N availability in the soil after adopting treated wastewater irrigation. As a result, the crude protein content reflected the nutrient concentration, particularly nitrogen. These findings were on par with other researchers (Mojid *et al.,* 2012; Senthilkumar *et al.,* 2021).

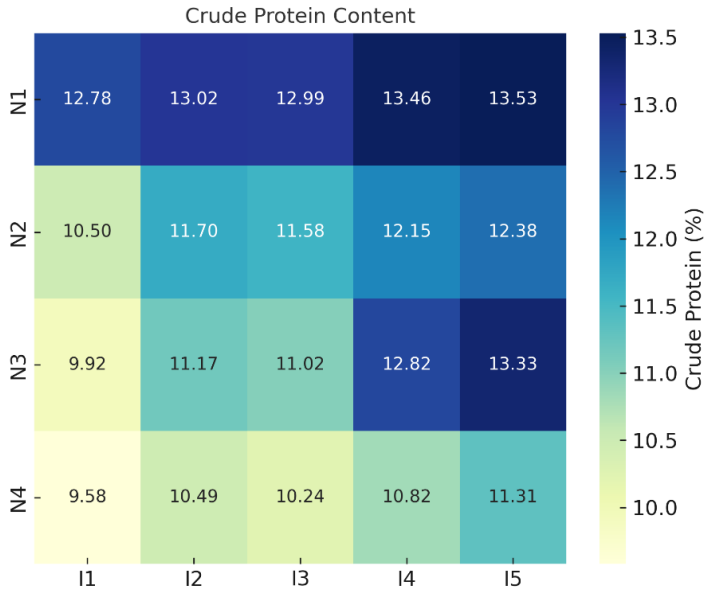

Fig. 1. Effect of treated sewage water and nutrients on crude protein (%) of bajra napier hybrid grass.

D. Crude fibre content

The total crude fibre content of the Bajra Napier hybrid grass is significantly affected by the use of treated wastewater for irrigation, manure and inorganic nutrients (Table 5). Among different irrigation treatments, significantly lower crude fibre (28.80%) was seen in irrigation with treated wastewater alone (I_5) than other treatments. The highest crude fibre content (30.36%) was recorded in control (I_1 - irrigated with groundwater alone). This might be due to partial supplement of nitrogen in treated wastewater increased the photosynthates which reduce in turn the accumulation of cellulolytic components in plants and decreased the crude fibre content. On the other hand, there is no nutritive value in groundwater that induces lignin accumulation in the plant cell. These results were supported by other research findings (Raveena *et al.*, 2021).

Table 5: Effect of treated wastewater and nutrients on mean crude fibre *(%)* of Bajra Napier hybrid grass.

Treatments	I_1	I_2	I_3	I_4	I_5	Mean
N_1	28.92	28.57	28.65	28.18	28.03	28.47
N_2	30.43	29.35	29.56	29.20	29.05	29.52
N_3	30.92	30.02	30.16	28.89	28.36	29.67
N_4	31.18	30.51	30.78	30.31	29.78	30.51
Mean	30.36	29.61	29.79	29.15	28.80	
	I	N	I × N	N × I		
SEd	0.14	0.09	0.06	0.05		
CD(P=0.05)	0.30	0.20	0.13	0.10		

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)

Among the nutrient treatments, the plots received 100% organic nutrients (N1) received treatment registered significantly lower average crude fibre content (28.47%) compared to the control (30.51%) and other treatments. The value of crude fibre is an indirect indication of the digestibility of the forage. It is known that higher crude fibre content lowers the digestibility and vice-versa. The availability of nitrogen fraction in the soil through manure and inorganic nutrients might improve the carbohydrates and reduce the formation of lignin, cellulose and hemicellulose material, which are responsible for increasing the crude fibre content. The decrease in nitrogen content increases the crude fibre in observed by other scientific workers in bajra napier (Bandeswaran *et al.*, 2013; Khadijah, 2016). In interaction effects of irrigation and inorganic nutrients, combination of treated wastewater along with 100% inorganic nutrients (I_5N_1) recorded significantly lower crude fibre content (28.03%) than all other treatment combinations (Fig. 2). Lower fibre content in treated wastewater and inorganic nutrition applied treatment compared to the control could be due to the supply of sufficient essential nutrients and better decomposition of organic matter improved the availability of nutrients resulting in high succulent biomass formation and yield. The same results were reported earlier (Galavi *et al.*, 2009; Raveena *et al.*, 2021; Malarvizhi *et al.*, 2001).

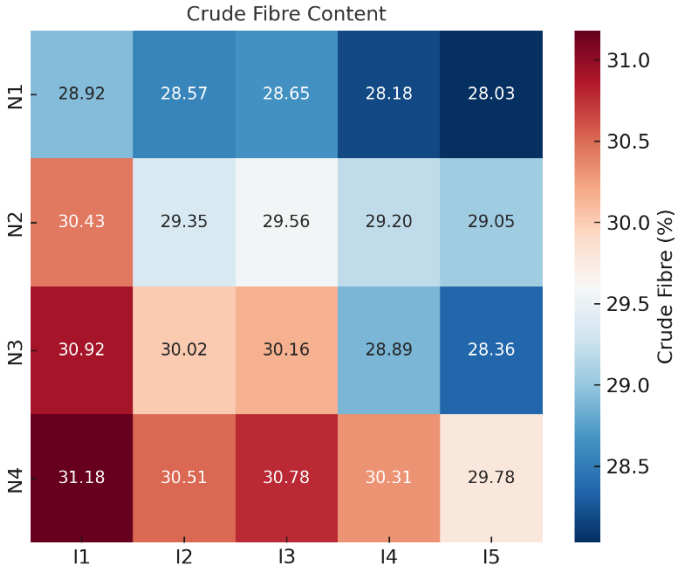

Fig. 2. Effect of treated sewage water and nutrients on crude fibre (%) of bajra napier hybrid grass.

CONCLUSIONS

This study comprehensively investigated the integrated effects of treated wastewater irrigation combined with manure and inorganic nutrients on the fodder yield and proximate parameters of Bajra Napier hybrid grass in the Cauvery Delta region of Tamil Nadu. The findings unequivocally demonstrate a significant positive impact of the imposed treatments on total green and dry fodder yields, as well as on the crude protein and crude fibre content. Specifically, the irrigation treatment utilizing treated wastewater alone in combination with 100% inorganic nutrients (I_5N_1) consistently recorded the highest total green (431.0 t ha^{-1} yr^{-1}) and dry (76.7 t ha^{-1} yr^{-1}) fodder yields. This particular combination also yielded the highest average crude protein content (13.53%) and the lowest average crude fibre content (28.03%), indicating a superior nutritional quality of the fodder. The beneficial response in both quantitative and qualitative parameters highlights the efficacy of using treated wastewater as a valuable resource, not only for irrigation but also for its inherent nutrient content. This integrated approach offers a viable and sustainable option to enhance fodder productivity, effectively utilize available nutrients in treated wastewater, reduce dependence on freshwater sources, and conserve groundwater resources in water-stressed agricultural regions.

FUTURE SCOPE

Building upon these findings, future research should delve deeper into several critical areas to further enhance the sustainability and long-term viability of using treated wastewater for fodder production:

- ***Long-Term Environmental Monitoring:*** Conduct multi-year studies to assess the long-term impact of treated wastewater irrigation on soil health, including potential accumulation of heavy metals, emerging contaminants (e.g., pharmaceuticals, microplastics), and their effects on soil microbial communities and biodiversity.
- ***Fodder Safety and Livestock Health:*** Evaluate the uptake of potential contaminants from treated wastewater into the Bajra Napier hybrid grass and its subsequent transfer to livestock. This should involve feeding trials to determine any effects on animal health, productivity, and the safety of animal products (e.g., milk, meat).
- ***Optimizing Nutrient Recycling*:** Further investigate the precise nutrient contributions from different types of treated wastewater and organic manures to optimize inorganic fertilizer application rates, promoting greater nutrient use efficiency and reducing external inputs.
- ***Water Quality and Treatment Levels:*** Explore the impact of different levels of wastewater treatment (e.g., primary, secondary, tertiary) on fodder yield, quality, and environmental safety to identify the most cost-effective and environmentally sound treatment standards for agricultural reuse.

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Conflict of Interest. None.

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