

Effect of treated wastewater irrigation combined with manures and inorganic nutrients on fodder yields and proximate parameters of Bajra Napier hybrid grass in Cauvery delta region of Tamil Nadu

ABSTRACT

Aim: The current experiment was aimed to study the effect of treated municipal wastewater with manures and inorganic nutrients on the yield and quality of Bajra Napier hybrid grass.

Study design: The field experiment was conducted using secondary treated wastewater, manures and inorganic nutrients in Bajra Napier hybrid grass variety CO(BN) 5 with a strip plot design and four replications.

Place and duration of study: The experiment was carried out in Veterinary College and Research Institute, Orathanadu, Thanjavur, Tamil Nadu, during 2018-19.

Methodology: 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 m² with 2 m space between the plot. The two budded setts were planted at 60 x 50 cm spacing. The irrigation and nutrients were applied as per the treatments.

Results: The use of treated wastewater for irrigation combined with manures and inorganic nutrients significantly increased the total green and dry fodder yields. Irrigation treatment with treated wastewater alone + 100% inorganic nutrients (I₅N₁) 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 (I₁N₄) recorded the lowest total green and dry fodder yields (222.5 and 47.6 t ha⁻¹ yr⁻¹, respectively). The average crude protein of all total cuttings content was significantly higher (13.53%) in I₅N₁ than all other treatments. On the other hand, the average crude fibre content (28.03%) was significantly lower in the treatment I₅N₁ as compared to control (31.18%) irrigated with groundwater without nutrients.

Conclusion: The perennial fodder crop Bajra Napier hybrid grass variety CO(BN) 5 cultivated under-treated wastewater combined with manures and inorganic nutrients increased the total green and dry fodder yield 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.

1. INTRODUCTION

Agriculture and livestock production are inextricably intertwined, mutually dependent and essential for total food security. In 2018-19, livestock production contributed 5.1 per cent of the total national value added at current prices, making it the backbone of Indian agriculture (1). India is the world's largest milk producer (198 million tonnes); however, per capita milk production is poor due to a massive shortage of feedstuffs. On a 2.0 per cent geographical area, the country houses 15 per cent of the world's livestock population, indicating the extent of livestock pressure on our resources compared to other countries. However, insufficient to meet the rising cattle population, only 8.4 million

hectares of cultivated feed are available (2). Also, only 40 per cent of the required green forage is available from diverse sources. Therefore, bridging this crater is a significant priority.

On the other side, the agricultural sector is the largest water user in this country and the quantity of water allocated to irrigating is expected to fall by 10-15 per cent in the next two decades (3). The estimated utilizable water resources of the country are 1,122 billion cubic metre yr^{-1} (BCM per year), out of which the share of surface water and groundwater is 690 BCM (4) and 432 BCM (5) per year, respectively. In 2050, a total of 1,180 BCM has been estimated as available water for a high projection scenario. Out of which, irrigation will be accounted for nearly 68 per cent followed by domestic use (9.5%), industries (7%), power development (6%) and other activities claimed about (9.5%), including evaporation losses, environment and navigational requirements. In India, this reduction in agriculture is predicted to be 10 - 12 per cent in 2025, whereas overall water demand is expected to increase by 22 per cent in 2025 and 32 per cent in 2050 (6). Consequently, the majority of wastewater (80%) is released into water bodies (rivers, lakes and seas) with little or no treatment and only a small percentage (14% in Indonesia, 10% in Philippines, 24% in India and 4% in Vietnam) is treated mostly or partially (7) and discharged into environmental media. Whereas, water contamination is a severe problem in emerging countries like India.

The demand for water to meet the needs of home, industrial and other farm operations necessitates the regeneration of wastewater, a cost-effective and appealing alternative to irrigating crops in arid and semi-arid places to sustain productivity (8). As a result, water reclamation and reuse are the most effective technique for fulfilling present and future water demands. Therefore, the reuse of treated wastewater in agriculture for fodder crops appears viable in this changing water demand scenario. Based on the background, the current study was carried out to determine the effect of secondary treated wastewater irrigation, manures and inorganic fertilizers on fodder yields and proximate parameters of the Bajra Napier hybrid grass variety CO(BN) 5 in the Cauvery Delta region of Orathanadu, Thanjavur of Tamil Nadu.

2. MATERIALS AND METHODS

2.1. 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's with a population of 1.60 lakhs (2011 census) and 40,383 residencies consume an averagely 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*). The study area has a semi-arid climate, with less than 792 mm of annual rainfall and summer temperatures often exceeding

40.4⁰ C. The soil of the experimental field is sandy clay loam texture and coarse sand (41.63%) was the dominant constituent with an infiltration rate of 3.06 cm hr⁻³. The experimental site's soil bulk density is 1.42 g cm⁻³ and a particle density of 2.98 g cm⁻³.

2.2 Experimental design

The field experiments was laid out in a strip plot design with four replications on a total of 80 plots, each of 4.5 m width and 6.0 m length. The gross plot size was 27 m² with 2 m space between the plots to avoid the influence of water seepage. The five ratios of irrigation water were used as horizontal factor treatments, namely I₁ - Groundwater alone (GW), I₂ - Alternate irrigation with GW and treated wastewater (TWW), I₃ - Two irrigations with GW + one irrigation with TWW, I₄ - One irrigation with GW + two irrigations with TWW and I₅ - Irrigation with TWW alone and in vertical factors, nutrients namely N₁ - 100% Inorganic nutrients (IN), N₂ - 100% Organic nutrients (ON) on N basis, N₃ - 50% Organic + 50% Inorganic nutrients and N₄ - Control (without nutrients). Perennial fodder crop Bajra Napier variety CO(BN) 5 was cultivated for experimental purposes.

2.3 Planting and fertilizer application

The fodder crop Bajra Napier variety 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

S. No.	Vertical factor	Basal application (ha ⁻¹)	Top-dressing after every harvest (ha ⁻¹)
1.	N ₁ – 100% Inorganic nutrients	25 t of FYM Inorganic fertilizer: 75:50:40 kg NPK + 75 kg nitrogen at 30 DAP as top dressing	75 kg nitrogen after every harvest
2.	N ₂ – 100% Organic nutrients on N basis	18.75 t of FYM (based on nitrogen content of 0.8 %)	9.37 t of FYM (on 0.8 % N basis)
3.	N ₃ – 50% Organic + 50% Inorganic nutrients	12.5 t of FYM + 37.5:25:20 kg NPK + 37.5 kg nitrogen at 30 DAP as topdressing	4.69 t of FYM (on 0.8 % of N basis) + 37.5 kg N
4.	N ₄ – Control	No manures and fertilizers	No manures and fertilizers

2.4 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 ($\text{t ha}^{-1} \text{yr}^{-1}$). In addition, the plant samples from each treatment in each plot were also collected. These samples were dried and subjected to proximate analysis like crude protein and crude fibre.

2.5 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 (9).

3. RESULTS AND DISCUSSION

3.1. Green and dry fodder yield

The effect of treated wastewater irrigation, manure and inorganic nutrients and their interaction differed significantly ($P < 0.05$) on green and dry fodder yields (Table 2) of Bajra Napier hybrid grass. The irrigation with treated wastewater alone (I_5) produced significantly higher total green fodder yield of $383.8 \text{ t ha}^{-1} \text{yr}^{-1}$ than all other irrigation treatments and it was on par with one irrigation with groundwater and two irrigation with treated wastewater irrigations (I_4). This might be due to, 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 grass is a C_4 plant has a higher photosynthetic nitrogen usage efficiency (NUE) than C_3 plants and can metabolise high nitrogen levels in reclaimed water (10). The lowest total green fodder yield ($278.0 \text{ t ha}^{-1} \text{yr}^{-1}$) was registered in the control (irrigation with groundwater alone - I_1). Similar results were obtained in sorghum, bajra napier and barley crops (11,12,13, 14).

Among the nutrient management, 100% inorganic nutrients (N_1) observed a higher total green fodder yield of $408.3 \text{ t ha}^{-1} \text{yr}^{-1}$ than other treatments and control ($267.5 \text{ t ha}^{-1} \text{yr}^{-1}$). The favourable growth parameters might be attributed to the increase in green fodder production under recommended doses of manure and inorganic fertilizers application. Presence of nitrogen might have promoted cell division and as a result, internode elongation and in turn, overall growth parameters. The results were in accordance with other researchers (16,17).

The interaction effect of secondary treated wastewater irrigation and inorganic nutrient treatments, the treated wastewater alone and 100% inorganic nutrients (I_5N_1) recorded significantly more total green fodder yield ($431.1 \text{ t ha}^{-1} \text{yr}^{-1}$) than irrigation with GW alone without nutrients ($222.6 \text{ t ha}^{-1} \text{yr}^{-1}$). 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 (17). 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 (18,19,20).

Table 2: Effect of treated wastewater and nutrients on total green fodder yield ($\text{t ha}^{-1}\text{yr}^{-1}$) 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				Vertical factor		
I ₁ – Irrigation with groundwater (GW) alone				N ₁ – 100% Inorganic nutrients (IN)		
I ₂ - Alternate irrigation with GW and Treated wastewater (TWW)				N ₂ – 100% Organic nutrients (ON) on N basis		
I ₃ - Two irrigations with GW + One irrigation with TWW				N ₃ – 50% Organic + 50% Inorganic nutrients		
I ₄ - One irrigation with GW + Two irrigations with TWW				N ₄ – Control (without nutrients)		
I ₅ - Irrigation with TWW alone						

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 $69.12 \text{ t ha}^{-1} \text{ yr}^{-1}$ and the lowest total dry fodder yield was registered in control (I₁) which irrigated with groundwater alone ($54.62 \text{ t ha}^{-1} \text{ yr}^{-1}$). 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 (18,21,22,23)

In the manure and inorganic nutrient treatments, the treatment applied with 100% inorganic nutrients (N₁) showed significantly higher total dry fodder yield ($72.45 \text{ t ha}^{-1} \text{ yr}^{-1}$) compared to all other nutrient treatments. Applying inorganic nutrients, especially nitrogen, increases the plant's leaf area. Under optimum nutrient level, favourable 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 (24,25,26).

Table 3: Effect of treated wastewater and nutrients on total dry fodder yield ($\text{t ha}^{-1} \text{ year}^{-1}$) of Bajra Napier hybrid grass

Treatments	I ₁	I ₂	I ₃	I ₄	I ₅	Mean
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N₁	67.88	71.53	71.09	75.01	76.72	72.45
N₂	53.30	62.98	61.74	64.65	66.38	61.81
N₃	49.63	58.52	57.08	68.67	73.53	61.49
N₄	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 x N	N x I		
SEd	0.31	0.35	0.20	0.19		
CD(P=0.05)	0.68	0.79	0.45	0.38		
Horizontal factor			Vertical factor			
I ₁ – Irrigation with groundwater (GW) alone			N ₁ – 100% Inorganic nutrients (IN)			
I ₂ - Alternate irrigation with GW and Treated wastewater (TWW)			N ₂ – 100% Organic nutrients (ON) on N basis			
I ₃ - Two irrigations with GW + One irrigation with TWW			N ₃ – 50% Organic + 50% Inorganic nutrients			
I ₄ - One irrigation with GW + Two irrigations with TWW			N ₄ – Control (without nutrients)			
I ₅ - Irrigation with TWW alone						

On interaction effect, treatment with treated wastewater alone and 100% inorganic nutrients (I₅N₁) recorded the highest 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 quantity of nutrients and higher mineralization of full dose of fertilizers, which contributes to higher total dry fodder yield. The results of green fodder yield also reflected in dry fodder yield too. Therefore, finding dry fodder yields under-treated wastewater with manure and fertilizer matches the previous results (27,28,29).

3.2. Fodder quality parameters

The plant samples were collected during the harvest of 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 presented in the average content of all harvest.

3.2.1. 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 (P<0.05) increased 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 (I₅) significantly influenced the higher average crude protein content (12.64%) than all other treatments. Control (irrigated with groundwater alone - I₁) registered the lowest crude protein content (10.70 %). It might be because the treated wastewater partially supplies the nitrogen throughout the lifecycle of forage crop growth and increases the crude protein content. The rise in crude protein content in corn fodder could be linked to sufficient nitrogen in wastewater (30). 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 (31,32,33).

Table 4: Effect of treated wastewater and nutrients on average 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			Vertical factor			
I ₁ – Irrigation with groundwater (GW) alone			N ₁ – 100% Inorganic nutrients (IN)			
I ₂ - Alternate irrigation with GW and Treated wastewater (TWW)			N ₂ – 100% Organic nutrients (ON) on N basis			
I ₃ - Two irrigations with GW + One irrigation with TWW			N ₃ – 50% Organic + 50% Inorganic nutrients			
I ₄ - One irrigation with GW + Two irrigations with TWW			N ₄ – Control (without nutrients)			
I ₅ - Irrigation with TWW alone						

Mean data (Table 4) of all seven crop harvests (from the main crop to sixth ratoon harvest) in a year showed that total crude protein yield was significantly ($P < 0.05$) influenced by manures and inorganic nutrient application. The treatment, 100% inorganic nutrients (N₁) 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 increase the vegetative growth, N concentration, amino acids and protein content in forage, ultimately increasing 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 (34,35), who reported increasing the crude protein content in the application of manure and inorganic nutrients.

Among irrigation and inorganic nutrients combination, treatment imposed with treated wastewater alone and 100% inorganic nutrients (I₅N₁) recorded a significantly higher crude protein content (13.53%) than all other treatments. It could be because numerous nutrients, particularly nitrogen, are present in treated wastewater which are required for bajra napier hybrid grass. 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 increase leaf N concentrations resulting from high N availability in the soil after treated wastewater irrigation. As a result, the crude protein content reflects the nutrient concentration, particularly nitrogen. These findings were on par with other researchers (22,30,36).

3.2.2. Crude fibre content

The total crude fibre content of the Bajra Napier hybrid grass is significantly affected ($P < 0.05$) by the use of treated wastewater as irrigation, manures 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 all 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 increases photosynthates to reduce the accumulation of cellulolytic components in plants, decrease 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 (12, 29)

Among nutrient treatments, 100% organic nutrients (N_1) received treatment registered significantly lower on average crude fibre content (28.47%) as 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 is responsible for increasing the crude fibre content. The decrease in nitrogen content increases the crude fibre also observed by other scientific workers in bajra napier (15,16,24,25).

Table 5: Effect of treated wastewater and nutrients on average 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 x N	
SEd	0.14		0.09		0.06	
CD(P=0.05)	0.30		0.20		0.13	
Horizontal factor				Vertical factor		
I ₁ – Irrigation with groundwater (GW) alone				N ₁ – 100% Inorganic nutrients (IN)		
I ₂ - Alternate irrigation with GW and Treated wastewater (TWW)				N ₂ – 100% Organic nutrients (ON) on N basis		
I ₃ - Two irrigations with GW + One irrigation with TWW				N ₃ – 50% Organic + 50% Inorganic nutrients		
I ₄ - One irrigation with GW + Two irrigations with TWW				N ₄ – Control (without nutrients)		
I ₅ - Irrigation with TWW alone						

In interaction effects of irrigation and inorganic nutrients, combination of treated wastewater alone with 100% inorganic nutrients (I_5N_1) recorded significantly lower crude fibre content (28.03%) than all other treatment combinations. 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 (11,29,37).

4. CONCLUSIONS

The effect of treated wastewater irrigation combined with inorganic nutrients on Bajra Napier hybrid grass showed a significant difference in total green and dry fodder yields. The imposed treatments influenced crude protein and crude fibre in the proximate analysis. The treatment received irrigation with treated wastewater combined with organic and inorganic nutrients registered the highest total green and dry fodder yields and had the positive response in proximate compounds. Based on the study results, it can be concluded that treated wastewater irrigation with the recommended dose of organic and inorganic nutrients is a viable option to increase fodder productivity. It will help to utilize nutrients available in treated wastewater effectively, reduce the water demand for fodder cultivation and conserve the groundwater in the future.

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