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Impact of different irrigation water quality on growth attributes of forage maize under the different forage maize -based cropping system

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Abstract
The present experiment entitled was conducted during *kharif* and *rabi* season of 2021-22 and 2022-23 at horticulture field under agronomy section, College of Agriculture, Nagpur. The experimental soil was classified as Vertisols with a clay loam in texture (13.20% coarse, 8.20% sand, 22% silt and 56.60% clay), in available nitrogen (253.21kg ha^{-1}), medium in available phosphorus (21.22 kg ha^{-1}) and very high in potassium content (396.76 kg ha^{-1}). The soil was alkaline in reaction (pH 7.7). The electrical conductivity and organic carbon were 0.36 dSm^{-1} and 0.53 per cent, respectively.
The experiment was laid out in split plot design with four replications. The main plot treatments and subplot treatment applied. Main plot treatment-irrigation water quality- *viz,* W_1- Sewage water, W_2- Treated sewage water, W_3-Fresh water. Sub plot treatment- crop sequences- *viz,* S_1- Maize-Maize.S_2- Maize-Lucerne.S_3- Maize-Sorghum, S_4-Maize-Cowpea.
The pH values of all water sources remained within the safe limit of 6.5 to 8.4 (FAO 1985), with W_1 (sewage water) showing slightly lower pH values (7.1-7.3) than W_3 (freshwater: 7.4-7.6), which indicates slightly more acidic nature of sewage water. Electrical conductivity (EC) was observed to be highest in W_1 (0.59-0.61 dsm^{-1}), Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) higher in sewage water and followed in treated sewage water, (BOD: 18.36-20.21 mg L^{-1}; COD: 51.34-53.41 mg L^{-1}), exceeding the safe limits of 3.0 mg L^{-1} and 100 mg L^{-1}, respectively (WHO, 2006). Treated sewage water (W_2) showed substantial reduction in BOD (4.8-5.4 mg L^{-1}) and COD (15.32-17.35 mg L^{-1}), indicating improved quality post-treatment.
Micronutrients (Fe, Mn, Cu, Zn) Content in water Micronutrient levels in sewage water (W_1) were notably higher compared to treated sewage water (W_2) and freshwater (W_3). Fe concentrations in W_1 ranged from 5.24 to 5.64 mg L^{-1}, which slightly exceeds the safe limit of 5.0 mg L^{-1} (FAO, 1985).
Heavy metal analysis showed that lead (Pb) concentrations in W_1 ranged from 0.16 to 0.19 mg L^{-1}, well below the permissible limit (5.2 mg L^{-1}), but significantly higher than in W_2 and W_3. Cadmium (Cd), chromium (Cr), and cobalt (Co) were detected only in W_1, with Cr and Co values approaching their respective limits (0.1 and 0.05 mg L^{-1}), whereas W_2 and W_3 had negligible or non-detectable levels.
The results showed that treated sewage water (W_2) produced the highest growth performance of fodder maize during both years (2021-22 and 2022-23). It recorded maximum values for plant height (183.44 and 185.56 cm), number of functional leaves (11.70 and 12.13), leaf area (47.38 and 49.06 dm^2), stem girth (6.44 and 6.96 cm), leaf: stem ratio (0.47 and 0.49), and dry matter per plant (69.33 and 73.38 g). This treatment was statistically at par with sewage water (W_1), while fresh water (W_3) consistently produced the lowest values. Among the cropping sequences, the maize-cowpea system proved superior, recording the highest growth attributes of fodder maize at harvest. This included plant height (182.25 and 184.04 cm), number of functional leaves (11.66 and 11.42), leaf area (45.42 and 46.17 dm^2), stem girth (6.59 and 6.90 cm), leaf: stem ratio (0.46 and 0.48), and dry matter per plant (68.08 and 70.58 g) during the respective years of 2021-22 and 2022-23.
The enhanced growth under treated sewage water is attributed to improved nutrient availability, while legume-based sequences such as maize-cowpea contributed to soil fertility and nitrogen enrichment. The study concludes that using treated sewage water in combination with legume-based crop sequences is a promising strategy for sustainable forage maize production, particularly under water-limited conditions.

Keywords: Irrigation water quality, forage crop sequences, growth parameters, forage maize

Introduction
Indian farming is dependent on agriculture system and livestock as our most population is dependent on it for his livelihood. Our population is (might be1400 million by year 2025) increasing continuously beside this the animal population is also increasing. The way the animal

population is increasing, demand for fodder is also coming up. Since the major dependence of livestock is on crop residues. India supports nearly 20 per cent of the world's livestock population on just 2.2 per cent of the world's geographical area. This puts a pressure to increase fodder production for a healthy livestock population. Only way to meet the fodder needs of livestock is to look for increased productivity per unit land area and also through integration of fodder crops in the cropping system. Forage cultivation, being a soil-based production system that extracts nutrients from the soil, requires efficient approaches for replenishing mined nutrients in the soil for sustaining the productivity (Palsaniya and Ahlawat, 2009) [17].

The consumption pattern for maize produced in India at present includes poultry feed 52 percent, cent, human food 24 per cent, animal feed 11 per cent and more than 22 per cent going towards industrial processing. With the growing demand of poultry feed the demand for maize is also going up in the country. It is the crop with the highest per day productivity. Some estimates indicate that India may have to produce 55 million tons of maize to meet its requirement for human consumption, poultry, piggery, pharma industry and fodder by 2030. (Maize Vision-2022 FICCI) [14].

Maize is one of the most nutritious non-legume green fodders. The high acceptability of maize as fodder can be judged from the fact that it is free from any anti-nutritional components. Maize is quick growing, yields high biomass, and is highly palatable. It contains sufficient quantities of protein and minerals and possesses high digestibility as compared to other non-legume fodders. It contains high concentrations of soluble sugars in the green stage, which makes it most fit for preservation as silage. The abundance of green fodder due to increasing cultivation of specialty corn could greatly help in boosting the prospects of dairy sector in the peri-urban regions of the country (Chaudhary *et al*. 2014) [2].

Cropping sequences is a rotation system approach in forage crop production that enabling the available natural resources to be preserved and more efficiently utilized. It is the growing of the succession of crops in time on one field in particular time With regard to plant growth and soil fertility, cropping designs containing more than one crop are normally built up by elements of crop sequences with a beneficial crop and an exploiting one Intensive land uses with continuous growing of similar crops significantly affect soil health, crop growth and has raised concerns about the potential have long term adverse effects on environmental pollution (Negash *et al*. 2017) [16]. The cropping system with forage crops provides in Soil fertility is restored by fixing atmospheric nitrogen, encouraging microbial activity, avoiding accumulation of toxin and maintaining physic-chemical properties of the soil (Kadam *et al.* 2017) [8].

India is facing a dual crisis of water scarcity and water pollution, especially in peri-urban and rural agricultural regions. Freshwater resources are depleting rapidly, with groundwater levels declining due to overextraction. Simultaneously, surface and groundwater sources are increasingly being contaminated by industrial effluents, domestic sewage, and agricultural runoff. According to the Central Pollution Control Board (CPCB, 2020) [3], more than 60% of India's rivers and surface water bodies are polluted, with high biological oxygen demand (BOD), total dissolved solids (TDS), and heavy metal content.

One major challenge in increasing fodder production is the limited availability of fresh water, especially during the dry season or in peri-urban areas. In this context, the use of non-conventional water sources, such as treated sewage water (TSW), offers an effective alternative for irrigation in fodder production. Studies by Narwal *et al*. (2016) [15] have highlighted that treated municipal wastewater, when monitored for contaminants, can safely be used for irrigating non-edible crops like fodder maize, leading to reduced pressure on freshwater and improved biomass production.

Treated sewage water, typically after secondary treatment, retains essential nutrients such as nitrogen, phosphorus, potassium, and micronutrients but with significantly reduced levels of pathogens, heavy metals, and organic pollutants. Several studies have shown that TSW irrigation can improve crop yield, reduce chemical fertilizer use, and support soil organic carbon build-up (Shende *et al.*, 2021) [26]. highlighted that peri-urban farmers using TSW observed higher biomass yield in crops like maize and sorghum without adverse effects on soil quality in the short term. However, the long-term sustainability of such practices requires careful monitoring of soil salinity, heavy metal accumulation, and crop sequence selection.

Growth parameters play a vital role in assessing the performance of forage maize under different irrigation and cropping systems. Plant population indicates successful crop establishment, while plant height reflects vegetative growth and nutrient uptake. The number of functional leaves and leaf area determine the plant's photosynthetic capacity, directly influencing biomass production. Stem girth shows the plant's structural strength and its ability to support foliage, and the leaf: stem ratio is an important indicator of fodder quality, with a higher ratio indicating more digestible leafy biomass. These parameters are influenced by water quality and crop sequence. Treated sewage water, rich in essential nutrients, can enhance crop growth when used within safe limits, while legume-based sequences improve soil fertility and promote better maize development. Evaluating these parameters helps in identifying sustainable practices for improved fodder production.

Materials and Methods

Field experiment was conducted at horticulture field under agronomy section, college of agriculture, Nagpur, during *kharif* and *rabi* season of 2021-22 and 2022-23. The experimental soil was classified as Vertisols with a clay loam in texture (13.20% coarse, 8.20% sand, 22% silt and 56.60% clay), in available nitrogen (253.21kg ha^{-1}), medium in available phosphorus (21.22 kg ha^{-1}) and very high in potassium content (396.76 kg ha^{-1}). The soil was alkaline in reaction (pH 7.7). The electrical conductivity and organic carbon were 0.36 dSm^{-1} and 0.53 per cent, respectively.

The experiment was laid out in split plot design with four replications. The main plot treatments and subplot treatment applied. Main plot treatment *viz*, W_1- Sewage water, W_2-Treated sewage water, W_3-Fresh water. Sub plot treatment *viz*, S_1- Maize-Maize.S_2- Maize-Lucerne.S_3- Maize-Sorghum, S_4-Maize-Cowpea.

The maize (African tall), Lucerne (Anand-2), Sorghum (FSH-3) and cowpea (Konkan Fodder Cowpea-1:) were planted using a seed rate of 40, 25-30, 40 and 25 kg ha^{-1} respectively by drilling method. Standard procedures were adopted for recording the data on various growth parameters *viz*., Plant populations (ha^{-1}), Plant height (cm), Number of functional leaves $plant^{-1}$, Leaf area $plant^{-1}$ (dm^2) (used for measuring leaf area with the help of leaf area meter) Leaf: stem ratio, Stem girth. In order to represent the plot, five plants of maize from each net plot were selected randomly, labeled properly.

Leaf Stem Ratio

Leaf stem ratio per plant was recorded from the five plants which were selected and from 500 grams green forage sample, the leaves and stem were separated from each plant and weighed separately for each plot. The leaf: stem ratio was worked out by dividing to the weight of leaves with weight of stem. The mean values were worked out for each plot.

$$\text{Leaf: stem ratio} = \frac{\text{Weight of leafy part (g)}}{\text{Total weight of sample (g)}}$$

Phytorid sewage treatment plant

Nag nalla is passing from the college farm where the continuous sewage water is flowing. For utilization of sewage water for irrigation to agricultural crops the sewage treatment plant using phytorid technology was constructed. This is wetland technology in which the treatment of sewage is possible by physical, chemical and biological way as per the technology of National Environmental Engineering Research Institute. The treatment plant of 100 M3/day capacity was designed in which inlet tank 50 m3 capacity was provided. The design has hexagonal type in which the sewage was passed through various phytorid beds and finally collected at the outlet tank. The treatment operation takes place due to gravity. The phytorid beds was about 200 M3 filled by gravel filter media in which the the aquatic plants which are helpful in dissolving oxygen in the water and also the lifter of heavy metals has been grown for obtaining the treated water. The plant species like Kena, Pothas, Typha and Bamboo were grown and established over the filter media. The sewage from the nalla was lifted in the inlet tank and the water from the outlet tank after 24 hours is used for irrigation. The treated water has no smell, no dirty colour, reduce pH and five times less BOD and COD. The total soluble salts as indicated from the EC value is also under permissible limit, i.e. 1 dS m^{-1}. It was safe for the irrigation to the plants.

Sewage water and treated water analysis. The methods for sewage water and treated water analysis have been used and reported in Table 1. given below

Results and Discussion

A) Quality parameter of irrigation water

Different quality of sewage water, treated water and fresh water indicate in table.1.

A two-year field experiment (2021-22 and 2022-23) was undertaken to evaluate the physicochemical, micronutrient, and heavy metal profile of irrigation water sources—sewage water (W_1), treated sewage water (W_2), and fresh water (W_3)—during *kharif* and *rabi* seasons. The quality of these water sources was assessed for their suitability in agricultural irrigation with reference to FAO (1985) [5] standards.

The quality of three irrigation water sources—sewage water (W_1), treated sewage water (W_2), and fresh water (W_3)—was evaluated over two years. Treated sewage water showed suitable pH (7.1-7.2) and EC (0.60-0.61 dS m^{-1}), along with much lower BOD (4.8-5.1 mg L^{-1}) and COD (15.3-16.4 mg L^{-1}) compared to sewage water, which recorded high BOD (19.2-21.5 mg L^{-1}) and COD (52.3-54.5 mg L^{-1}). Micronutrients in W_2 remained within FAO limits, with Fe (4.90-4.94 mg L^{-1}), Mn (0.17-0.18 mg L^{-1}), Cu (0.009-0.010 mg L^{-1}), and Zn (1.52-1.57 mg L^{-1}). Heavy metals were very low across all treatments, with Pb (0.16-0.18 mg L^{-1}), Cd (0.03-0.04 mg L^{-1}), Cr (0.05-0.07 mg L^{-1}), and Co (0.08-0.10 mg L^{-1}), remaining far below permissible limits. Overall, treated sewage water was found safe and nutrient-rich for irrigation.

B) Growth parameter of fodder Maize

Different growth parameter of forage maize *viz*, plant height, number of functional leaves, leaf area, stem girth, leaf: stem ratio and dry matter accumulation presented in below.

a) Plant height of fodder Maize

The plant height of maize indicated in table. 2. as influenced by irrigation water quality and cropping systems was recorded at three stages: 20 DAS, 40 DAS, and at harvest, over two years (2021-22 and 2022-23).

Impact of irrigation water quality

Among the water sources, the highest plant height at all stages was observed under treated sewage water (W_2) during both years. At harvest, W_2 recorded 183.44 cm (2021-22) and 185.56 cm (2022-23), followed by sewage water (W_1) and fresh water (W_3). The lowest plant height was observed under W_3, with values of 177.81 cm and 178.78 cm, respectively. Treated sewage water provides a balanced nutrient supply without the toxic effects associated with untreated sewage water. These findings align with those of Singh *et al.* (2019) [27],

Impact of cropping system

Among the cropping systems, the maize-cowpea (S_4) sequence recorded the tallest plants at all stages across both years, with final plant heights of 182.25 cm (2021-22) and 184.04 cm (2022-23). This was followed closely by maize-lucerne (S_2) and maize-sorghum (S_3). The lowest height was seen in the maize-maize (S_1) sequence.

The increased plant height in maize-cowpea systems may be attributed to the residual nitrogen fixation and organic matter contribution by cowpea, a leguminous crop. Kharche *et al.* (2015) [10]

Interaction Effects

The interaction between irrigation water quality and crop sequences was non-significant,

b) Number of functional leaves per plant^{-1} of fodder maize

Table.3 explained the number of functional leaves per plant increased progressively from 20 DAS to harvest in both years of experimentation, indicating steady vegetative growth.

Impact of irrigation water quality

Among the irrigation water treatments, W_2 - Sewage treated water recorded the highest number of functional leaves per plant at all growth stages across both years. At harvest, W_2 reported 11.07 and 12.13 functional leaves per plant during 2021-22 and 2022-23 respectively, followed by W_1 - Sewage water (10.13 and 11.13), while W_3 - Fresh water consistently recorded the lowest leaf count (8.68 and 9.01). The pooled mean also confirmed this trend (W_2: 11.60, W_1: 10.63, W_3: 8.85).

Treated sewage water also improves soil microbial biomass and stimulates plant hormone activity, which collectively enhance photosynthetic area and thus leaf formation. This aligns with the findings of Rani *et al.* (2021) [21],

Impact of cropping system

The crop sequences significantly influenced the number of functional leaves per plant. Among the sub-treatments, S_4 - Maize-Cowpea recorded the highest number of functional leaves per plant across all stages and both years, with values of 10.66 and 11.42 at harvest during 2021-22 and 2022-23 respectively. This was followed by S_2 - Maize-Lucerne (9.85 and 10.93), and

S_3 - Maize-Sorghum (9.32 and 10.42), while S_1 - Maize-Maize consistently recorded the lowest leaf numbers (10.01 and 10.26 at harvest).
The superiority of S_4 - Maize-Cowpea can be attributed to the biological nitrogen fixation by cowpea, which improved the residual soil nitrogen available for the subsequent maize crop. These findings corroborate the work of Kumar *et al.* (2018) [11]

Interaction Effects
The interaction between irrigation water quality and crop sequences was non-significant

c) Leaf Area (dm²)
presented in Table 4.

Impact of irrigation water quality
Significant differences were observed among the main plot treatments. Among the irrigation sources, W_2 (sewage treated water) recorded the highest leaf area across all stages in both years. Specifically, at harvest, W_2 recorded 47.38 dm² (2021-22) and 49.06 dm² (2022-23).
In contrast, the lowest leaf area was recorded in W_3 (fresh water), with 39.69 dm² (2021-22) and 40.81 dm² (2022-23) at harvest. The limited nutrient content in freshwater compared to sewage or treated water may have restricted vegetative growth. However, W_1 (raw sewage water) also showed moderately high values, i.e., 44.69 dm² (2021-22) and 46.19 dm² (2022-23), indicating the potential benefit of organic matter and nutrients, although concerns over contamination and salinity may limit its effectiveness.

Impact of cropping system
The sub-plot treatments also showed significant variation in leaf area. Across the years, S_4 (Maize-Cowpea) recorded the highest leaf area, with 44.42 dm² (2021-22) and 46.17 dm² (2022-23) at harvest.
The lowest leaf area was noted under S_2 (Maize-Lucerne) at 43.92 dm² (2021-22) and 45.17 dm² (2022-23), which was statistically at par with S_1 (Maize-Maize) and S_3 (Maize-Sorghum). The higher values in S_4 also reflect the positive impact of residue quality from cowpea, which decomposes faster and releases nutrients beneficial to the following maize crop.

Interaction Effect
statistically non-significant at all stages

d) Stem Girth (cm)
The data on table. 5 stem girth of fodder maize recorded at different growth stages (20 DAS, 40 DAS, and at harvest) during 2021-22 and 2022-23,

Impact of irrigation water quality
A perusal of the data reveals that stem girth was significantly influenced by irrigation water quality during both years and at all growth stages, except at 20 DAS. Among the treatments, W_2 (sewage treated water) recorded the highest stem girth across all stages during both years — 2.27, 5.50, and 6.48 cm during 2021-22 and 2.61, 5.83, and 6.96 cm during 2022-23 at 20 DAS, 40 DAS, and harvest respectively. It was significantly superior over W_3 (fresh water), which recorded the lowest stem girth (2.12, 4.25, and 5.23 cm in 2021-22 and 2.23, 4.66, and 5.41 cm in 2022-23). The values under W_1 (sewage water) remained at par with W_2 at most stages but were slightly lower than W_2 (e.g., 6.13 and 6.90 cm at harvest during 2021-22 and 2022-23, respectively). Similar result found (Hussain *et al.*, 2010) [7].

Impact of cropping system
The stem girth was also significantly influenced by different fodder crop sequences. The maximum stem girth was recorded under S_4 (Maize-Cowpea), with values of 2.35, 5.34, and 6.36 cm in 2021-22 and 2.72, 5.82, and 6.51 cm in 2022-23, respectively, at 20 DAS, 40 DAS, and harvest. This was followed closely by S_2 (Maize-Lucerne) and S_3 (Maize-Sorghum). The lowest stem girth values were observed under S_1 (Maize-Maize) across all growth stages in both years (1.85, 5.11, and 5.44 cm in 2021-22 and 1.83, 5.42, and 6.29 cm in 2022-23).
The superior performance of the Maize-Cowpea (S_4) system can be attributed to the biological nitrogen fixation by the legume crop cowpea during the previous season, which might have contributed to enhanced soil nitrogen status for the succeeding maize crop. Similar findings were reported by Ghosh *et al.* (2007) [6], Patil *et al.*, 2013) [19].

Interaction Effects
Non-significant at all stages during both years

e) Leaf: Stem Ratio of Fodder Maize
Impact of irrigation water quality
Presented in Table 6.
The highest leaf: stem ratio was observed under W_2 - Treated sewage water (0.84, 0.81, and 0.47 at 20 DAS, 40 DAS, and harvest respectively in 2021-22 and 0.90, 0.87, and 0.49 in 2022-23).This was closely followed by W_1 - Sewage water, while W_3 - Fresh water consistently recorded the lowest leaf: stem ratio (e.g., 0.79, 0.77, 0.37 in 2021-22 and 0.88, 0.79, 0.38 in 2022-23).
These nutrients promote vegetative growth, especially leaf development, which ultimately leads to a higher leaf component relative to stem biomass. This was in line with the findings of Kumar *et al.* (2020) [13],

Impact of cropping system
The effect of crop sequences on leaf: stem ratio was significant at harvest in both years. Among the crop sequences. The highest leaf: stem ratio was recorded under S_4 - Maize-Cowpea (0.45 and 0.46 at harvest in 2021-22 and 2022-23, respectively), followed by S_2 - Maize-Lucerne and S_3 - Maize-Sorghum. The lowest ratio was observed in S_1 - Maize-Maize (0.43 in 2021-22 and 0.43 in 2022-23).
The Maize-Cowpea (S_4) rotation likely improved the leaf: stem ratio due to the beneficial residual effect of the legume (cowpea), which improves soil nitrogen status through biological nitrogen fixation. as similar reported by Patel *et al.* (2021) [18] and Reddy *et al.* (2019**)** [22].

Interaction Effects (W × S)
The interaction between irrigation water quality and crop sequence was non-significant across all stages in both years.

f) Dry Matter Accumulation (g plant^{-1})
Presented in Table 7.

Impact of Irrigation water quality
Among the treatments, treated sewage water (W_2) recorded the highest dry matter accumulation at harvest (69.33 g in 2021-22 and 73.38 g in 2022-23), which was at par with sewage water (W_1) but significantly superior.to fresh water (W_3), which

recorded the lowest values (59.38 g and 60.13 g, respectively). A similar trend was observed at 40 DAS, while the differences at 20 DAS were non-significant

Impact of cropping system
Regarding crop sequences, maize under maize-cowpea (S_4) produced the maximum dry matter accumulation per plant at harvest (68.08 g and 70.58 g), which was at par with S_2 and was significant superior over rest of the treatment. At 40 DAS, S_4 remained significant superior and at par with S_2 during both the years.

Interaction Effect
The interaction between irrigation water quality and crop sequence was non-significant across all stages in both years.

Table 1: Quality parameter of Irrigation Water

Table 1.1: PH, EC, BOD and COD content in irrigation water

Treatments	PH				EC				BOD (mgL^{-1})				COD (mgL^{-1})			
	2021-22		2022-23		2021-22		2022-23		2021-22		2022-23		2021-22		2022-23	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
W_1 - Sewage water	7.2	7.3	7.1	7.2	0.61	0.60	0.60	0.59	19.18	20.12	21.56	18.36	52.36.	53.41	54.25	51.34
W_2- Treated sewage water	7.1	7.2	7.1	7.1	0.34	0.33	0.32	0.35	5.2	5.4	4.8	5.1	15.11	15.32	16.42	17.35
W_3 -Fresh water	7.5	7.6	7.6	7.5	0.42	0.43	0.44	0.45	1.2	1.66	1.68	2.67	5.6	5.8	5.4	5.2
Safe limit -	8.4				3.0				250				100			

Table 1.2: Fe, Mn, Cu and Zn content in irrigation water.

Treatments	Micronutrients (mg. L^{-1})															
	Fe				Mn				Cu				Zn			
	2021-22		2022-23		2021-22		2022-23		2021-22		2022-23		2021-22	2022-23	2021-22	2022-23
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Rabi*	*Kharif*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
W_1 - Sewage water	5.35	5.64	5.63	5.24	0.95	0.97	0.96	0.94	1.13	1.10	1.11	1.12	1.67	1.68	1.63	1.64
W_2- -Treated sewage water	5.12	5.10	5.19	5.14	0.35	0.36	0.36	0.34	1.14	1.13	1.12	1.13	1.56	1.52	1.53	1.57
W_3 -Fresh water	0.03	0.03	0.04	0.02	0.10	0.09	0.11	0.12	0.008	0.009	0.009	0.008	0.20	0.21	0.22	0.21
Safe limit	5.0				0.20				0.2				2.0			

Treatments	Heavy Metal (mg. L^{-1})															
	Pb				Cd				Cr				Co			
	2021-22		2022-23		2021-22		2022-23		2021-22		2022-23		2021-22	2022-23	2021-22	2022-23
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Rabi*	*Kharif*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
W_1 - Sewage water	0.19	0.17	0.18	0.16	0.08	0.07	0.09	0.08	0.65	0.63	0.63	0.64	0.06	0.05	0.07	0.08
W_2- Treated sewage water	0.002	0.001	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W_3 -Fresh water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Safe limit -	5.2				0.01				0.1				0.05			

Table 2: Impact of irrigation water quality and cropping systems on Plant height of Maize

Treatment	Plant height (cm)					
	2021-22			2022-23		
	20 DAS	40 DAS	At harvest	20 DAS	40 DAS	At harvest
Main treatment (Irrigation water quality)						
W_1 - Sewage water	31.30	87.53	180.75	32.76	89.39	182.46
W_2 - Sewage treated water	32.94	90.39	183.44	33.87	92.40	185.56
W_3 - Fresh water	31.81	84.64	177.81	32.74	85.06	178.78
SE (m) ±	0.32	0.97	1.05	0.25	0.89	0.99
CD at 5%	NS	3.36	3.63	NS	3.08	3.43
Sub treatment (cropping system)						
S_1 - Maize-Maize	32.12	87.38	179.58	32.26	88.18	180.99
S_2 - Maize-Lucerne	31.44	87.23	180.92	33.18	89.33	182.13
S_3 - Maize-Sorghum	32.04	87.06	179.92	33.25	88.45	181.92
S_4 - Maize-Cowpea	32.46	88.41	182.25	33.80	89.85	184.04
SE (m) ±	0.40	0.70	0.59	0.35	0.55	0.65
CD at 5%	NS	2.02	1.70	NS	1.59	1.89
Interaction						
S.E.(m) ±	0.70	1.21	1.01	0.60	0.95	0.93
C. D. at 5%	NS	NS	NS	NS	NS	NS
GM	32.02	87.52	180.67	33.13	88.95	182.27

Table 3: Impact of irrigation water quality and cropping systems on number of functional leaves of fodder maize

Treatment	Number of functional leaves plant^{-1}					
	2021-22			2022-23		
	20 DAS	40 DAS	At harvest	20 DAS	40 DAS	At harvest
Main treatment (Irrigation water quality)						
W_1 - Sewage water	3.48	6.57	10.13	3.73	7.03	11.13
W_2 - Sewage treated water	3.72	7.84	11.07	4.03	8.09	12.13
W_3 - Fresh water	3.51	5.98	8.68	3.85	6.21	9.01
SE (m) ±	0.04	0.23	0.41	0.07	0.31	0.57
CD at 5%	NS	0.79	1.43	NS	1.06	1.97
Sub treatment (cropping system)						
S_1 - Maize-Maize	3.49	6.45	10.01	3.73	6.67	10.26
S_2 - Maize-Lucerne	3.67	6.70	9.85	3.92	7.03	10.93
S_3 - Maize-Sorghum	3.39	6.44	9.32	3.65	6.72	10.42
S_4 - Maize-Cowpea	3.72	7.60	10.66	4.19	8.02	11.42
SE (m) ±	0.06	0.31	0.36	0.21	0.44	0.46
CD at 5%	NS	NS	NS	NS	1.38	1.54
Interaction						
S.E.(m) ±	0.10	0.54	0.62	0.36	0.76	0.80
C. D. at 5%	NS	NS	NS	NS	NS	NS
GM	3.57	6.80	9.96	3.87	7.11	10.76

Table 4: Impact of irrigation water quality and cropping systems on leaf area of fodder Maize

Treatment	Leaf area plant^{-1} (dm^2)					
	2021-22			2022-23		
	20 DAS	40 DAS	At harvest	20 DAS	40 DAS	At harvest
Main treatment (Irrigation water quality)						
W_1 - Sewage water	6.13	22.40	44.69	6.46	24.31	46.19
W_2 - Sewage treated water	6.81	25.06	47.38	6.98	27.56	49.06
W_3 - Fresh water	6.23	20.58	39.69	6.34	21.89	40.81
SE (m) ±	0.12	0.93	0.87	0.14	1.29	0.90
CD at 5%	0.41	3.21	3.00	0.48	4.47	3.10
Sub treatment (cropping system)						
S_1 - Maize-Maize	6.39	22.17	43.83	6.63	23.92	45.08
S_2 - Maize-Lucerne	6.22	22.97	43.92	6.46	24.52	45.17
S_3 - Maize-Sorghum	6.25	21.92	43.50	6.31	24.33	45.00
S_4 - Maize-Cowpea	6.69	23.67	44.42	6.96	25.58	46.17
SE (m) ±	0.10	0.79	0.69	0.12	0.76	0.78
CD at 5%	NS	2.29	2.01	NS	2.21	2.26
Interaction						
S.E.(m) ±	0.34	1.37	1.20	0.27	1.77	1.35
C. D. at 5%	NS	NS	NS	NS	NS	NS
GM	6.39	22.68	43.92	6.59	24.59	45.35

Table 5: Impact of irrigation water quality and cropping systems on stem girth of fodder Maize

Treatment	Stem girth (cm)					
	2021-22			2022-23		
	20 DAS	40 DAS	At harvest	20 DAS	40 DAS	At harvest
Main treatment (Irrigation water quality)						
W_1 - Sewage water	2.24	5.44	6.13	2.44	5.71	6.90
W_2 - Sewage treated water	2.27	5.50	6.48	2.61	5.83	6.96
W_3 - Fresh water	2.12	4.25	5.23	2.23	4.66	5.41
SE (m) ±	0.17	0.34	0.22	0.24	0.42	0.54
CD at 5%	NS	1.16	0.76	NS	1.47	1.87
Sub treatment (cropping system)						
S_1 - Maize-Maize	1.85	5.11	5.44	1.83	5.42	6.29
S_2 - Maize-Lucerne	2.29	5.00	5.98	2.55	5.39	6.52
S_3 - Maize-Sorghum	2.35	4.79	6.01	2.61	4.96	6.38
S_4 - Maize-Cowpea	2.35	5.34	6.36	2.72	5.82	6.51
SE (m) ±	0.13	0.19	0.15	0.13	0.12	0.15
CD at 5%	NS	NS	0.44	NS	0.36	0.46
Interaction						
S.E.(m) ±	0.22	0.33	0.26	0.23	0.21	0.26
C. D. at 5%	NS	NS	NS	NS	NS	NS
GM	2.21	5.06	5.95	2.43	5.40	6.43

Table 6: Impact of irrigation water quality and cropping systems on leaf: stem ratio of fodder Maize

Treatment	Leaf: stem ratio					
	2021-22			2022-23		
	20 DAS	40 DAS	At harvest	20 DAS	40 DAS	At harvest
Main treatment (Irrigation water quality)						
W_1 - Sewage water	0.83	0.80	0.46	0.91	0.86	0.48
W_2 - Sewage treated water	0.84	0.81	0.47	0.90	0.87	0.49
W_3 - Fresh water	0.79	0.77	0.37	0.88	0.79	0.38
SE (m) ±	0.01	0.01	0.01	0.01	0.02	0.01
CD at 5%	NS	0.03	0.04	0.02	0.07	0.02
Sub treatment (cropping system)						
S_1 - Maize-Maize	0.83	0.80	0.43	0.82	0.87	0.43
S_2 - Maize-Lucerne	0.80	0.79	0.42	0.89	0.83	0.45
S_3 - Maize-Sorghum	0.80	0.79	0.43	0.89	0.79	0.45
S_4 - Maize-Cowpea	0.84	0.78	0.45	0.90	0.86	0.46
SE (m) ±	0.02	0.03	0.01	0.001	0.02	0.01
CD at 5%	NS	NS	0.03	NS	0.06	0.03
Interaction						
S.E.(m) ±	0.03	0.05	0.02	0.01	0.03	0.01
C. D. at 5%	NS	NS	NS	NS	NS	NS
GM	0.82	0.80	0.43	0.90	0.84	0.45

Table 7: Impact of irrigation water quality and cropping systems on dry matter accumulation plant of fodder Maize

Treatment	Dry matter plant^{-1} (g)					
	2021-22			2022-23		
	20 DAS	40 DAS	At harvest	20 DAS	40 DAS	At harvest
Main treatment (Irrigation water quality)						
W_1 - Sewage water	3.26	24.81	67.44	3.48	25.88	68.88
W_2 - Treated sewage water	3.54	26.13	69.33	3.86	28.19	73.38
W_3 - Fresh water	3.04	21.40	59.38	3.18	22.19	60.13
SE (m) ±	0.02	0.71	0.89	0.19	1.02	0.95
CD at 5%	NS	2.45	3.08	NS	3.53	3.29
Sub treatment (cropping system)						
S_1 - Maize-Maize	3.06	22.83	63.77	3.18	23.92	65.92
S_2 - Maize-Lucerne	3.27	24.75	66.25	3.44	26.25	68.42
S_3 - Maize-Sorghum	3.19	22.83	63.42	3.44	23.83	64.92
S_4 - Maize-Cowpea	3.61	26.03	68.08	3.95	27.67	70.58
SE (m) ±	0.05	0.65	0.77	0.11	0.98	0.79
CD at 5%	NS	1.89	2.23	NS	2.84	2.29
Interaction						
S.E.(m) ±	0.09	1.38	1.11	0.37	1.91	2.74
C. D. at 5%	NS	NS	NS	NS	NS	NS
GM	3.28	24.11	65.38	3.50	25.42	67.46

Conclusion

Treated sewage water (W_2) was found to be safe, nutrient-rich, and the most suitable for irrigation, as it m*et al*l quality standards while maintaining low organic load and acceptable micronutrient and heavy-metal levels.

Application of treated sewage water (W_2) with maize-cowpea system (S_4) recorded highest plant height, number of functional leaves plant^{-1}, leaf area plant^{-1}, stem girth, leaf: stem ratio and dry matter accumulation plant^{-1} of fodder maize in both years. Which comparable with sewage water, due to residual nitrogen contribution, enhanced microbial activity and better soil physical conditions created by the preceding legume crop.

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